Bridging and Breakdowns
- Using computational artifacts across social worlds

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Contents

0.1 Preface

The work presented in this thesis was conducted at four institutions and under four main graduate supervisors from different fields. Even though the supervision periods were non-overlapping, in some sense, the thesis topic on multidisciplinary collaboration was created in a multidisciplinary environment itself.

A significant part of the quantitative data collection and analysis was conducted under supervision of Professor Toru Ishida, Social Informatics, Graduate School of Informatics, Kyoto University (ICE case in Section 4.3), and Professor Kumiyo Nakakoji, Knowledge Interaction Design Lab, The University of Tokyo (Software design case in Section 4.1), and Koichi Hori, AI Lab, The University of Tokyo. As a visiting scholar in the winter 2004 and 2005 at the Human-Computer Interaction Institute, Carnegie Mellon University, Professor Sara Kiesler and her group gave me a fruitful experience on designing and conducting experiments and statistical analysis. On the other hand, a large part of my ethnomethodological investigations were conducted in IT University of Copenhagen, Denmark and analyzed under the supervision of Professor Kjeld Schmidt, Copenhagen Business School (CBS), with the help of Professor Kristian Kleiner also at CBS. Finally and most importantly, the overall theoretical foundation as well as the aggregated analysis of the five case studies clearly owe to intense and insightful discussions with my PhD supervisor, Kjeld Schmidt.

The research reported in the thesis rests on a number of earlier publications. Some findings of the software design case were presented in [Yasuoka et al., 2004, Yasuoka, 2006, Nakakoji et al., 2004]. The Carlsberg case (in Section 4.2) and the renovation case (in Section 4.4) were presented as a comparative case study in [Yasuoka, 2007]. A detailed description and analysis of the ICE experiments can be be found in various papers and reports [Nomura et al., 2003b, Nomura et al., 2003a, Yasuoka et al., 2003, Yasuoka, 2003]. In addition, I would like to mention my project on digital cities at Kyoto University under supervision of Professor Toru Ishida [Ishida et al., 2004, Yasuoka et al., 2005, Yasuoka et al., 2010] which is not included in this thesis, but has had a significant impact on the work by giving me a fundamental understanding of collaboration in heterogeneous virtual communities and community awareness.

0.2 Abstract

Collaboration is a social activity because it occurs through interaction among people. Collaboration is also a process of collaborative design since collaborators create new forms of such as new ideas and new meanings through collective processes of a project. Moreover, collaboration, especially among professionals with different knowledge backgrounds, is a process of intercultural collaboration because professionals who engage in collaborative design are rooted in their own ethnic culture and work culture and need to go beyond such cultural knowledge boundaries to work together.

Intercultural collaboration among professionals is a social process often facilitated by artifacts. Artifacts are central to the collaborative process because they give physical presence to tacit knowledge. Artifacts reify intangible nebula and concepts to visible and tangible representations. Reification is particularly important because professionals in collaborative work have their own unique knowledge defined by object-worlds, mental models, and work processes fostered in professional education and experience. It is even often the case that they have different classification schemes, norms, beliefs, and professional language. In order to collaborate, they must overcome each others' differences.

Using statistical conversation analysis and empirical techniques such as observation and interviewing, we study the communication process of several intercultural collaborations from the software design domain as well as the architecture and product design domains. We consider *project jargon* the basis for collaboration and aim at understanding how collaborators develop and create project jargon from *collaborative design processes*. Previous work has pointed to *ontological drift* as one of the collaboration challenges among professionals, and shown that unique project oriented words, expressions or, in other words, jargon can make the collaborative design move. However, it has not been sufficiently investigated how ontological drift relate to such unique language and how such language is created and developed.

In order to understand intercultural collaboration, this thesis presents several intercultural collaborative cases including two cases not facilitated by computational artifacts. For the following three reasons, we in particular pay attention to computational artifacts as facilitators for the creation of unique local language. First, computational artifacts have become and will continue to be a dominant carrier of complexes of communication modalities in collaborative work due to technical developments and globalization. Second, computational artifacts in nature have far more descriptive abilities than any previous artifacts for communication. All in all, computers can support visible, audible and tangible representations more than any earlier media. Finally, related to the second point, computers are compound artifacts which can deal with several communication modalities at the same time including retentive, graphical, and portable.

We consider *common ground* and *the practice of sign systems* in computational artifacts to be two theoretical constructs that are useful for understanding collaboration as a social and collaborative design process in a computer mediated setting among professionals. Common ground as the base of collaboration and its development process is investigated through communication. With the concept of boundary objects, we introduce a view of

computational artifacts as boundary objects and describe the collaborative process as a creative process of unique local language (*project jargon*) in the development process of common ground. The practice of sign systems in computational artifacts will provide a complementary explanation for this view of common ground. We show that semiotics in computational artifacts can explain the importance of signs to reify professionals' tacit knowledge in computer mediated collaborations. Furthermore, we try to show how the practice of sign systems contributes the development process of common ground in intercultural collaboration.

The collaboration we consider can be understood as a combination of creative process and cooperative practice. In this thesis, however, we focus on creative processes rather than cooperative practice which has been a central investigation target in Computer Supported Cooperative Work (CSCW). To this end, we investigate the early stage of collaboration where the differences of stakeholders are wider than in later stages. Compared to a highly established routine work where one culture is dominant, the amount of scientific work focusing on the early stage of intercultural collaboration in which professionals with different knowledge background go beyond their cultural boundaries is very limited.

Our analysis of five different intercultural collaborations is based on statistical analysis and empirical investigations and it allows us to outline some salient features of intercultural collaboration and its communication. Our observation of the intercultural collaboration process suggest that when professionals with different knowledge background collaborate for collective concern in the early design period, their collaboration style is characterized by creating *local and temporal alignment of practices* facilitated by complexes of interrelated communication modalities carried by artifacts.

Our study of how computational artifacts are used as boundary objects and how *project jargon* is created and used in work situations facilitated by computational artifacts has deepened our understanding of collaboration among professionals with different knowledge background. In this way, the thesis provides insight on collaboration in situations where professionals with unique abilities and knowledge work together to solve complex objectives. Since the thesis deals with phenomena for which little prior work exist, it has been necessary to take a somewhat exploratory approach. The thesis, however, still aims at clarifying the main components of this kind of collaboration and making a foundation for further studies.

Chapter 1

Introduction

1.1 Background: Collaboration Support

Over time, humans have extended their senses and body functions by using sophisticated tools. For examples, a hammer can be seen as an extension of patting objects by hands. Likewise, a phone can be understood as an extension of distant hearing and, a car extends walking and running abilities, which enlarge peoples physical access to activities. Similarly, in the beginning of the computer age, computers could be described as an extension of human arithmetic ability. These observations suggest that it is a natural human desire to try to invent tools that support or strengthen complex activities. In the current global era, where people work together beyond time and space barriers, collaborators have been seeking for tools that can facilitate their collaboration.

In this thesis, we investigate the communication process of five collaboration cases from the software design domain as well as the architecture and product design domains, using statistical conversation analysis and empirical techniques such as observation and interviewing. Three among the five cases are facilitated by computational artifacts, and together with the two remaining cases, we try to understand the nature of the collaboration process among professionals with ethnic cultural and work cultural knowledge backgrounds. The introduced five cases are varied in many aspects, however, we believe such variation is of importance for understanding the nature of collaboration in abstract level that we are aiming at.

Research on collaboration and computer systems supporting collaborative activity emerged in the 80's as interdisciplinary field between computer science, informatics, Human Computer Interaction (HCI, or Computer Human Interaction, CHI), psychology and sociology. Because of the interdisciplinary characteristics of this research on collaboration and computer systems supporting collaborative activities, the taken approaches often vary. One approach rooted in computer science tends to give a system solution for future computational artifacts, while another approach rooted in the social science tradition tends to provide deeper understanding of existing work practice and processes by taking an ethnographic approach (e.g., [Schmidt, 1991, Schmidt and Bannon, 1992]). However, not many

	Distributed	Co-sited
Synchronous	ShrEdit, GROVE	EVIDII, KNC
Asynchronous	gIBIS	Answer Garden, EGRET

Figure 1.1: Matrix and examples of collaboration support systems.

findings in empirical work have been reflected in designing systems for a long time. The gap between these approaches is called the *great divide* [Bowker et al., 1997] and it has been argued that the two approaches must be bridged. Even after more than a decade, though, this bridge between understanding work processes and designing support systems is still regarded as missing [Bardram, 1998].

Historically, in the computer science and informatics, experimental computational artifacts have been created that focus mainly on supporting collaboration in distributed environments. In 1968, Doug Engelbart gave a demonstration of a distance collaboration support system called the oNLine System (NLS) [Engelbart and et al., 1968]. The demonstration introduced several novel concepts such as a remote meeting system, collaborative writing and shared hypertext. Doug Engelbart regarded computer systems as supportive means for intelligent production at work and his work had a strong impact on the research community. Later studies aimed at creating a shared work place where collaborators write or draw in distributed environments. The sociological approach which is often taken within Computer Supported Cooperative Work (CSCW), has focused on understanding complicated work processes in practice and articulation work by taking an ethnographical approach. (as for CSCW, more details will be discussed in Section 2.2.2).

Research in the field has typically been framed in the synchronous versus asynchronous (time dispersion) and co-sited versus distributed (geographic dispersion) dichotomies shown in Figure 1.1, inspired by Johansen's work originally applied on groupware [Johansen, 1988]. A wide variety of systems such as the ones shown in Figure 1.1 have been developed within the frame. For example, shared display (e.g., [Ishii, 1990, Ishii and Miyake, 1991]), shared whiteboard facilities (e.g., Tivoli [Pedersen et al., 1993], NoteLook [Chiu et al., 1999]) and video conferencing systems (e.g., [Isaacs et al., 1994, Fish et al., 1990, Sellen, 1992]) aim at supporting synchronous collaboration who are geographically distributed. Collaborative writing system such as ShrEdit [McGuffin and Olson, 1992] and GROVE [Ellis et al., 1991] make it possible for multiple users located in distance to contribute simultaneously to a shared document. Several systems such as EVIDII [Ohira, 2003] and Knowledge Nebula Crystallizer (KNC) [Amitani, 2005] are introduced in synchronous and co-sited collaborative settings, with which stakeholders establish shared understanding as well as creative ideas through interaction with other stakeholders and their knowledge. On the other hand, collaboration support systems, such as gIBIS [Conklin and Begeman, 1988], Answer Garden [Ackerman and Malone, 1990], EGRET [Johnson, 1992] are categorized as asynchronous organizational activity supports. gIBIS supports design rationale among people who are involved in software development projects no matter where they are located, Answer Garden offers a function to circulate professional knowledge within an organization, and EGRET supports exploratory group work within organization by offering graphical task structures. Such systems have often been discussed in relation to their ability of tracing organizational memory which is stored in a series of documents and artifacts created in the organization.

Later, increasing attention has been paid to cultural issues in work situations and other collaborative settings from a social activity perspective instead of conventional subjects such as work processes and business processes (e.g., [Suchman, 1987, Branne and Salk, 2000, Krishna et al., 2004, Bjørn, 2006, Vatrapu and Suthers, 2009]). One of the main reasons for this is an increasing number of collaborations beyond organizational as well as national boundaries due to technical as well as social reasons. Emerging collaborative systems, technology development such as network infrastructure and its stability, and globalization lead organizations to go beyond organizational as well as ethnic boundaries. At the same time, with the advent of new international economic players such as China and India, offshore projects managed by American, European and Asian mega companies have increased. In such projects, distributed teams from all over the world are formed and company branches situated in different continents gather virtually to create a single team. In this current era, collaborators in these teams tend to engage in short term projects rather than static inter-organizational projects that are run for a couple of years or more [Friedman, 2005]. Moreover, the collaborators typically come from different professional domains or from different ethnic areas to form work groups aiming at solving emerging complex and specialized tasks. Before the collaborators get accustomed to their work environment of the project, they disperse to attain to new projects. In such intercultural collaborative environments, ethnic as well as work culture differences have emerged as a critical issue to be supported (As for *intercultural collaboration*, we define more precisely in Section 2.1). Furthermore, as we describe below, such collaborations often face new challenges not covered by the conventional matrix shown in Figure 1.1.

1.2 Emerging Communication Issues

When regarding collaboration as a social activity among professionals with different knowledge backgrounds, a major challenge is to overcome different perspectives and languages well enough to collaborate and fulfill project objectives. This challenge is hard because, as is briefly mentioned in 1.1, collaborative activities in current practice are often carried out by a wide variety of members from different work and ethnic cultures. With respect to work culture differences, they have their own professional knowledge and norms, and each has his or her own object-world and mental models fostered through professional education and experience.

Wenger calls a cluster of people sharing culture *communities of practice* [Wenger, 1999]. When professionals in collaboration bring together several communities of practice with collective concerns, *communities of interests* [Fischer, 2004] are formed. In contrast to communities of practice, professionals in communities of interests tend to have different preferences [Rönkkö et al., 2004], culture, sense of values and terminology [Bødker and Pedersen, 1991].

Thus communication in such collaboration means more than just translating language of one culture to another at a symbolic level [Ostwald, 1996], because it is often the case that different work cultures have different semantics for identical symbols and representations. This *ontological drift*, "arising out of the different practices of the group and the essential incommensurability of their world views and language" [Robinson and Bannon, 1991] often occurs unconsciously in collaborative settings among different professionals. Only when a breakdown [Schegloff, 1991] occurs, often caused by interaction through external representations, the collaborators are forced to face such ontological drift. In many collaboration cases, this ontological drift causes problems and thus is regarded as a challenge to be addressed.

For a long time, this kind of intercultural collaboration has been an issue only for limited groups of people such as scientists [Star, 1995] and software engineers who have to collaborate with people from different professional domains. For example, in the software engineering domain, a wide variety of in-depth knowledge has been required in order to design software for different domains. Today, due to specialized and distributed knowledge, not only the software engineering domain but also architecture, transportation, medical domains and so on are obliged to face the same intercultural collaboration issues.

In order to deal with this problem using computational support, several approaches such as supporting shared understanding and mutual understanding, specifying work cultural background (e.g., [Ostwald, 1996, Olson and Olson, 2000, Ohira, 2001, Ohira, 2003]), and enrich awareness (e.g., general awareness [Dourish and Bly, 1992, Dourish and Bellotti, 1992, Heath et al., 1995], and community awareness shown in a series of Digital City projects such as [Ishida, 2002, Ishida et al., 2004, Yasuoka et al., 2005, Yasuoka et al., 2010]) have been suggested. Some of them have approached the issue from social aspects (e.g., [Strauss, 1985, Gerson and Star, 1986, Strauss, 1988]) while other work have focused on designing and building computational systems based on design ideas generated from ethnographical approaches [Bardram, 1998, Amitani, 2005].

Currently, however, the detailed collaboration processes including how collaborators realize and react to ontological drift, build common ground and solve their collective concerns beyond differences in the collaboration and computer systems supporting collaborative activity have not been fully investigated except a few [Yasuoka et al., 2003, Yasuoka et al., 2004, Nakakoji et al., 2004, Yasuoka, 2006]. Even though community of practice [Wenger, 1999] give us a deeper understanding of the process of learning in a cohesive group of people, it does not cover community of interests [Fischer, 2000]. At the same time, even though the importance of shared understanding and awareness is acknowledged, we know only a little about how they exist and how they are created in community of interests. Without understanding such detailed collaboration processes among people with different knowledge backgrounds, systems designed based on empirical work can not support important aspects of collaboration.

1.3 Research Questions, Approach and Structure

This thesis considers *common ground* the base of collaboration and investigates its development process through communication. It examines in detail the process of ontological drift as well as the development and creation of common ground (Collaboration). The investigations will focus on external representations especially the role of computational artifacts and the modalities of communication that such external representations mediate (Communication). The Target of investigation is *intercultural collaboration* (Settings). By intercultural collaboration we mean work situations where professionals with different ethnic as well as work cultural knowledge background gather in short term projects as typically seen in global collaboration nowadays. To re-iterate,

1. Settings: This thesis targets collaboration among professionals in the following design domains: software design, information design, and architectural design. Today, the design domain is highly specialized and technical so that, in many cases, professionals with different knowledge background are obliged to gather and disperse in short term projects. They do not share social context in nature especially in the early stages of collaboration, and consequently they tend to face collaboration challenges such as ontological drift.

2. Collaboration: The thesis studies the detailed process of how professionals develop and create the base of collaboration, common ground, over time. It examines how ontological drift occurs, externalizes and breaks down. In other words, this thesis investigates how professionals in a group with limited social contexts establish common ground in short term collaborations in order to solve their collective concerns.

3. Communication: The thesis mainly utilizes external representations to observe interactive environments. Some external representations are tangible such as written documents, figures on white boards, signs on maps, and drawing printouts of computational artifacts. Others are intangible such as oral expressions, gestures and drawing of computational artifacts. We are particularly interested in the role of computational artifacts, but we also cover conventional non-computational artifacts that play a substantial role in collaboration. Computational artifacts can mediate unique interactive characteristics with rich communication modalities in which artifacts themselves can change their interaction depending on the users behavior toward the system.

In sum, this thesis investigates and analyzes collaboration and its associated communication among design professionals with different knowledge background, taking interaction with other design professionals, artifacts and even physical space into consideration. Given these positions of the thesis, our objective is to achieve a deeper understanding of collaboration and its communication process among people with different knowledge background. Thus, the ultimate objective is to collect knowledge and insights that can provide design

	Case 1	Case 2	Case 3	Case 4	Case 5
Case Name	Software Design	Carlsberg	ICE	Renovation	Svane
Domain	Software Engineering	Architectural Design	Software Engineering	Architecture Design	Illumination Design
Collaborative facilitation	Conventional Collaboration	Conventional Collaboration	Computational Artifacts	Computational Artifacts	Computational Artifacts

Figure 1.2: Chapter organization.

implications for efficient computational artifacts for collaboration that can bridge the *great divide*.

Thus, the research questions of the thesis are formulated as follows:

- How can design professionals with different knowledge cultural background develop and create a base for collaboration?, and
- What kind of computational artifacts could be offered to support its process?

The reminder of this thesis is organized as follows. Chapter 2 describes especially theories of intercultural collaboration, and chapter 3 introduces background theories. Next, Chapter 4 introduce five empirical observations on intercultural collaboration. Case 1 (*Analysis software design*) and Case 3 (*Intercultural collaboration experiment (ICE)*) are on collaborative process among professionals in the software design. Case 2 (*Carlsberg landscape design*), 4 (*Copenhagen building renovation*) and 5 (*Svane illuminated sign*) deal with design-professionals in architectural and illumination design. First and second case are conventional collaboration cases with no facilitation systems while the others are facilitated by computational artifacts.

The main focus of our empirical investigation is to understand the collaboration process of development, reification, and especially creation of common ground for collaboration among professionals with different knowledge backgrounds. First, we examine how ontological drift and breakdowns, if any, occur, and how a base of collaboration, common ground is created. In addition, we investigate what kind of inventions professionals make in order to achieve such development and creation of common ground.

In Chapter 5 analyzes and discuss five empirical investigation cases based on our research questions. Finally, the last chapter concludes the thesis and discusses directions for future work.

1.4 Contribution

This thesis aims at understanding the communication processes of emerging collaboration styles. We focus on ontological drift and its related processes in computer supported intercultural collaboration. Ontological drift appears to be a critical collaboration issue as it is one of the causalities of mismatch between demands and deliverables. For example, this mismatch was often seen in software development. A client might complain because a delivered system design does not fulfill his demand. In construction industry, an architect might complain because his design is not realized in the finished building

The research presents the following through a detailed investigation of the communication processes of five case studies. First, our investigations show that ontological drift is an unavoidable integral aspect of intercultural collaboration while mutual understanding and shared understanding in intercultural collaboration might not necessarily be integral aspects. Second, the creation process complimenting ontological drift is also an unavoidable integral aspects. Third, communication facilitated by computational artifacts requires a deeper understanding of not only oral means but also the practice of sign systems.

To this end, the thesis contributes, first a deeper understanding of computer supported intercultural collaboration by clarifying communication characteristics of such collaboration through communication modality and its complexes. Especially, the thesis describes the detailed communication process in the early stage of collaboration based on extensive empirical investigations supported by extensive quantitative investigations. This microscopic step-by-step analysis of communication processes focusing on ontological drift has not been made before. Even though some previous work on collaboration and computer systems supporting collaborative activity have mentioned collaboration among people with different ethnic or work cultural background, a cohesive approach from cultural diversities has not been thoroughly reported to out knowledge. We believe that this approach and its findings also give some additional insights to CSCW community as well. Second, it contributes a clarification of the creation process in such communication through not only empirical but also statistical and visual analysis. To our knowledge, it is the first time to show such creation characteristics of communication process in a graphical structure. Since only a few prior investigations exist, the thesis can not avoid taking a pragmatic approach in understanding the communication of collaboration it target. However, we believe that the contributions mentioned above could promote and accelerate further understanding of the emerging new collaboration style among professionals with different knowledge background.

Chapter 2

Theory and Related Research

This chapter describes the theoretical foundation of intercultural collaboration used in the thesis. Section 2.2 overviews selected academic approaches to intercultural collaboration. They include information science communication models, the notion of cooperative work within CSCW, and collaborative design. Section 2.3 describes several concepts used in the thesis to establish our view of collaborative work, such as *boundary objects*, *external representations*, *common ground* and *interactivities*. Finally, Section 2.4 describes related work on intercultural collaboration.

2.1 What is Intercultural Collaboration?

The word, *culture*, covers a wide range of meanings. According to the Oxford Dictionary [Wehmeier, 2000], they include:

1. The customs and beliefs, art, way of life and social organization of a particular country or group. European/Islamic culture, working – class culture.

2. A country, group, etc. with its own beliefs, etc.

3. Art, music, literature, etc., thought of as a group.

4. The beliefs and attitudes about *s*th that people in a particular group or organization share.

Although in daily life we often regard the notion of culture to describe ethnic forms such as nationality and mother tongue differences, the definition of culture above tells us that culture has a broader meaning. Culture is formed in a social class, in a work environment, a hobby group, in which ethnic cultures are not necessarily involved. On the other hand, studies in collaboration cover both ethnic and work cultural aspects at the same time. However, such studies appear to have focused mainly on work culture such as organizational differences and knowledge based on profession. Even when natural language differences may be a critical parameter in collaboration, this tendency to emphasis work culture has often continued. In short, what happen within the form of community of practice [Wenger, 1999] is often the main issue.

In the emerging domain of computer supported intercultural collaboration, Vatrapu and Suthers in several studies define culture as patterns or schemes of an individual's social interactions [Vatrapu and Suthers, 2007, Vatrapu, 2008, Vatrapu and Suthers, 2009]. In another study by Lederach that also defines *intercultural collaboration*, culture is "the shared knowledge and schemes created by a set of people for perceiving, interpreting, expressing, and responding to the social realities around them" [Lederach, 1995]. Lederach also refers to Damen's definition of culture as "learned and shard human patterns or models for living; day-to-day living patterns". According to Damen, "these patterns and models pervade all aspects of human social interaction. Culture is mankind's primary adaptive mechanism" [Damen, 1987]. Although these definitions are mainly used in collaborative learning settings, they are general enough to scale to other domains.

In accordance with the definitions above, culture can be interpreted as the shared knowledge fostered through social interaction in both ethnic and work communities. As a consequence, intercultural collaboration in this thesis applies the following definition;

> *Collaboration between professionals across community boundaries not only with ethnic culture differences but also professional work culture differences.*

Despite that it seems to be common to distinguish between ethnic (such as nationality or native languages) and work culture (such as profession and education), this thesis does not make such a division, but treat them under the common term *intercultural collaboration* or *collaboration between professionals with different knowledge background*. In particular, we assume that both ethnic and work cultural difference similarly create barriers for collaboration. At the same time and more importantly, it is not an objective of the thesis to investigate what culture is, nor compare ethnic cultural differences with work cultural differences in collaborative settings. Rather, the thesis aims at investigating both ethnic and work cultural differences under the same label, intercultural collaboration. By doing so, we believe, we can focus on collaboration issues among people with differences in a more general sense.

2.2 Theories related to Intercultural Collaboration

A wide variety of work from different domains have studied collaboration in order to support professionals with different knowledge background. In this section, we overview the following academic approaches toward intercultural collaboration; information science especially related to communication models, cooperative work in CSCW, and collaborative design.

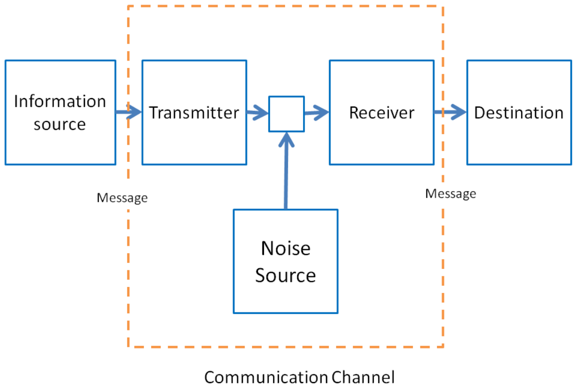

Figure 2.1: Shannon and Weaver's communication model. Reproduced from [Shannon, 1948]

2.2.1 Linear Communication

Information science describes communication using models of human communication processes that focus on how people process information. In earlier models, communication was explained as an encode, transmit and decode process. The famous model of Shannon and Weaver [Shannon, 1948] in Figure 2.1 is one of the most influential communication models. It describes communication as a linear transmission of information from a source to a destination. Communication is viewed as a one way transmission process where messages are sent and received as signals and may be interrupted by noise. Later Katz and Lazarsfeld [Katz and Lazarsfeld, 1955] showed a different type of linear communication model that describes how messages are distributed to a wider audience. Because of its characteristics, it is mainly applied to mass communication. Even though the message transmission is still considered linear in their model, it is unique in the way that a message is sent indirectly through another representation. Later, non-linear models were also suggested. For example, Schramm [Schramm et al., 1966] introduced circular communication models, in which a sender is also a receiver because communication is an endless process where participants swap roles. By applying bidirectional and circular models to describe communication, information science has shown that communication is not a simple encode, transmit and decode process, but also an interaction and interpretation of messages.

It should not be neglected that the models from information science are made to fit the design of computer systems. It is clear that they are not strong enough to explain the complexity of interaction in collaborative environments nor in dealing with ontological drift problems caused by knowledge differences among collaborators.

2.2.2 Collaboration and Cooperative Work

Cooperative work has been investigated in CSCW mainly to gain knowledge about supportive computer systems. Research in CSCW often deals with designing computer systems to facilitate a wide variety of cooperative activities including articulation work, classification and coordination in organizations. In the early period of CSCW, it was defined as "an identifiable research field focused on the role of computers in group work" [Greif, 1988]. Later, Schmidt and Bannon extended the scope of CSCW, by focusing on support requirements of cooperative work arrangements, but not on "computer support for groups". According to Schmidt and Bannon "CSCW should be conceived as an endeavour to understand the nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies" [Schmidt and Bannon, 1992]. Consequently, the following are general research interests of the field.

1. What characterizes cooperative work?
2. How can cooperative work be modeled?
3. What kind of computational facilities and computer systems should be provided to support cooperative work?

A core concept of cooperative work is interdependence in work. The typical target domain has been routine work in daily work environments. Schmidt [Schmidt, 1991] defines cooperative work as follows,

> Cooperative work occurs when multiple actors are required to do the work and therefore are mutually dependent in their work and must coordinate and integrate their individual activities to get the work done.

As described above, CSCW has a cooperative work perspective that often argues in relation to process control in production and development of factories and offices. The main objective of cooperative work is to coordinate activities such as planning and re-planning. Since planning in practice has become increasingly complicated, design requirements of computer systems aim at facilitating cooperative work by handling task dependency as well as offering a common information space [Carstensen, 1996].

Largely two different approaches have been proposed within CSCW to tackle this challenge. One approach taken from the engineering tradition is to design computer systems that support acquiring and maintaining design rationale, and establishing organizational memory (Detailed examples of such systems are shown in Figure 1.1 and explained in Figure 1.1). Some of the work go beyond designing computer systems and consider designing the media environment itself by integrating advanced audio, video and network technology. Many of the computer systems offering shared work space are designed under the WYSIWIS concepts (What You See Is What I See [Stefik et al., 1987]) and aim at creating virtual collaboration space via a data network.

Another approach is taken from a more social perspective: conceptual frameworks of cooperative work has been developed using social approaches which often apply an archaeological perspective of fieldwork [Latour, 1993]. The critical importance of cooperative work in practice has been widely recognized and a large number investigations in CSCW have been carried out. Some studies have introduced frameworks such as the coordination mechanism [Carstensen, 1996, Schmidt and Simone, 1996] and classifications [Bowker and Star, 1999], while others have elaborated and addressed unique aspects of cooperative work. For example, coordination mechanisms show that the means to control task dependency is coordinative protocols supported by artifacts that facilitate complex cooperative work. Coordination is not static but evolves to adapt to the changing situation. Thus, according to Carstensen and his colleagues, systems should be equipped with functions to control coordination locally and learn new environments tentatively.

Cooperative work involves secondary activities of mediating and controlling cooperative relations, apart from their core work. Actors in cooperative work are mutually interdependent on each other and individuals cannot accomplish the collaborative task alone. Any work targeted in cooperative work should ensemble in order to fulfill the objective so that to articulate (allocate, coordinate, integrate, interrelate, mesh etc.) their distributed but yet individual activities is critical [Strauss, 1985, Strauss, 1988, Gerson and Star, 1986]. Such articulation work creates division of labor, which make it possible for a large number of participants to work in cooperative way.

Later, Schmidt [Schmidt and Wagner, 2004] has shown that such coordinative work is carried out using complexes of interrelated coordinative practice and artifacts including time schedules, meeting memos, and so forth. Such *ordering systems* are the key for the success to "interact in the highly distributed and mediated cooperative work without succumbing to disorder and utter chaos" [Schmidt and Wagner, 2004].

In addition to coordination and articulation work, several concepts have been suggested to provide better understanding of cooperative work. The concept of *awareness* emphasize that supporting the senses among collaborators about each others activities contributes to the collaboration process (e.g., [Dourish and Bly, 1992, Dourish and Bellotti, 1992, Heath et al., 1995, Ishii, 1990, Nardi et al., 2000]). For that purpose, developing mutual awareness is suggested as one of the important keys to facilitate intercultural collaboration.

The unique characteristics of stigmergy can be seen in collaboration among professionals such as architects [Christensen, 2007, Christensen, 2008]. Stigmergy is defined as the phenomenon that "actors coordinate and integrate their cooperative efforts by acting directly on the physical traces of work previously accomplished by themselves or others" [Christensen, 2007](p.17). Thus, "signs left or modifications made by individuals on artifacts may, given an appropriate context of practice, become meaningful to these individuals themselves or to others and in turn inspire new actions on artifacts" [Christensen, 2008](p.563). In contrast to coordinative work which needs strong coordination and high-cost-work, stigmergy is an autonomous collaboration style which has minimal overhead for cooperation.

These conceptual frameworks suggests that groups engaging in complex work situations have a system or order for cooperative work in order to fulfill group objectives. They contribute to understand how people act in complex work situations in normative daily work situation and its processes. Since the main target of CSCW research is often such highly complex and conventional daily work process, there has been less focus on emerging collaboration styles which may happen in early design and highly specialized and short-term projects based on collaboration among professionals with different knowledge backgrounds. In such emerging collaborative situations, collaborators lack the shared classifications and fixed work processes that are implicitly regarded as prerequisites of targeted groups in mainstream CSCW research. In order to coordinate a newly formed group of people where people from different communities of practice work together, classification and orders have to be created in the beginning of the collaboration. So, how does it happen? How do people with different knowledge background acquire coordination mechanisms? If each of them brings different classification schemes in the beginning of collaboration, what then happens to these schemes? Do they merge, learn from each other, or do new classifications emerge?

Existing coordination mechanisms, classifications and ordering systems in collaboration are often mentioned, but it is rarely discussed in detail how these processes are created or merged. This, however, is not a novel topic and has been raised by several people (e.g. [Bowker and Star, 1999, Trigg and Bodker, 1994]). For example, in the book *Sorting Things Out* [Bowker and Star, 1999], Bowker and Star explain this missing link to some extent in relation to their concept of classification.

First, they suggest that classification can bridge several cultures since "classification as technologies are powerful artifacts that may link thousands of communities and span highly complex boundaries [Bowker and Star, 1999](p.287)". Furthermore, they explain how one classification merge with other classification such as local classification by "accommodations, work-around, and in some sense, a higher level of artful integration"[Id.]. However, they do not elaborate it further by mentioning, "Too often, this sort of work remains invisible to traditional science and technology, or to rational analysis of process" [Bowker and Star, 1999](p.292). Still, for such "re-representation" in their term, they suggest to answer the following questions [Bowker and Star, 1999](p.293), which appears as if they acknowledge the issues that we proposed above.

1. How can objects inhabit multiple contexts at once, and have both local and shared meaning?

2. How may people, who live in one community and draw their meanings from people and objects situated there, communicate with those inhabiting another.

3. How can relationships form between (1) and (2) above - how can we model the information ecology of people and things across multiple communities?

4. What range of solutions to these three questions is possible and what moral and political consequences attend each of them?

They did not reach to the point to suggest any solutions toward these questions. In reality, as Bowker and Star argue, the additional hardship to overcome differences in work culture will not be carried out unless it is of critical necessity.

> In our interviews of public health officials, nurses, or scientists, we have found that they recognize this about their own classification systems. At the same time, there is little inducement to share problems across domains. Because of the invisible work involved in local struggles with formal classification systems and standards, a great deal of what sociologists would call 'pluralistic ignorance' obtains [Bowker and Star, 1999](p.320).

We learn from Bowker and Star's analysis of classification that classifications are useful for understanding routine tasks, but they do not shed much light on intercultural collaboration because professionals in these settings do not share the same classification scheme.

As we can see, the target of this thesis - intercultural collaboration as collaboration among professionals with different knowledge background - and the traditional focus of CSCW have a lot in common when considering social aspects such as social context and social interaction in situations. Collaboration is essentially social and mutually dependent and in need of cooperative work in nature. Moreover, ordering systems are crucial for understanding collaboration and give a solid foundation for understanding collaborative practices among professionals with different knowledge background. Conceptual frameworks of cooperative work, however, become problematic when the concept is applied to the intercultural setting we are targeted at. Typically, the targeted group of cooperative work is limited to "across functions and professional boundaries within an organization or within a network of organizations" [Schmidt, 1994]. Traditionally, organizational culture differences, in spite of shared nationality, have been pointed out as a critical collaboration barrier (e.g., [Fischer, 2000]) in CSCW. However surprisingly, prior research in CSCW has not adequately addressed issues from an intercultural collaboration perspective, not to mention differences in ethnic culture and language.

Looking back to the middle 90's, Schmidt [Schmidt, 1994] did mention different requirements in the course of the emergent nature of cooperative work that clearly covered the limited capacity of each individual to multiple specialities in the collaboration settings. For example, by *augmentation of capacity*, he showed that human individuals have limited mechanical and information processing capacities such that cooperation enables collaborators to accomplish tasks that otherwise would be infeasible for a single person. Also by *differentiation and combination of specialities*, he suggested that multiple technique-based specialities are combined in order to accomplish a task. However, although Schmidt could see the emerging nature of multiple aspects in cooperative work, his studies focus mainly on cooperative work itself and do not extend to intercultural collaboration.

This thesis, as previously mentioned, focuses on short term projects rather than daily routine work. In our case sudies, professionals with different knowledge background rather than ordinary workers work together, not just to get the work done but to solve complex issues which none of them can handle individually. Such short term projects seems to be emerging arrangements in response to the global economy and the border-less society.

Lastly, let us emphasize that the above aspects of intercultural collaboration have been considered in cooperative work from time to time. But they have not been thoroughly investigated as a central topic, which is what we would like to call attention to. In addition, in order to focus on different emerging work aspects, we use the term *collaboration* which has a different connotation of work style than cooperative work. There is no doubt that cooperative work provides us with a good foundation and initiation for studying intercultural collaboration. But to understand and clarify the nature of intercultural collaboration, we believe that it is necessary to go beyond the current focus of CSCW.

2.2.3 Collaboration in Collaborative Design

Designs of complex contemporary artifacts and information technology is often defined through interaction and collaboration of numerous professionals with wide varieties of skills and views. Theory and practice of such *collaborative design* have been rooted in two different traditions [Johansson, 2005]. The first is from the Scandinavian equality movement in the 80's, which is often characterized as Scandinavian ideology of democracy in design [Kensing and Blomberg, 1998]. The other has a more pragmatic viewpoint of design, where design processes are considered collaborative in nature. Conventional thinking towards design focuses on professionals' individual skills and rely on an unidentified nature of creative thoughts from a "mysterious world". In contrast to this, the latest studies have provided ample evidence that multiple expertise and social interaction between people with different expertise is important for creating new ideas, and deal with the size and complexity of modern design tasks [Nakakoji, 2006, Page, 2007, Sawyer, 2007]. Consider recent and complex design artifacts such as very large buildings, information systems, and route planning in international logistics companies. They would be impossible to realize without expertise from many different domains.

In the collaborative design research community, communication among the different stakeholders has been regarded as one of the most important challenges. Johansson [Johansson, 2005] mentioned this challenge as "communication is essential for all collaborative work, and when the participants in the design project have different backgrounds and come from different professional contexts, it is necessary to develop ways to communicate". Thus, communication with other collaborators is key in collaborative design.

The heart of such communication resides in interaction with human and artifacts with which collaboration moves. Professional work settings which were regarded as solitary work as if playing mono-drama are now understood as collaborative orchestras where *symmetry of ignorance* or *asymmetry of knowledge* [Fischer, 2000] [1] exists among the ensembled members. Software programmers have to communicate with peer developers using multiple communication modalities such as face-to-face, email and chat [Nakakoji, 2006] to design, program and ultimately accomplish their tasks. Architects often make phone calls,

[1] We will describe this term in more detail in Section 2.3.5. For the time being, note that this symmetry of ignorance characterizes the current collaborative environment where no single professional has coherent or comprehensive knowledge, but the group as a whole has collective knowledge for fulfilling the task at hand.

exchange drawings, and build models in addition to face-to-face meetings [Yasuoka, 2007]. Quite a few investigations show that when designers communicate with and through sketches it contributes to the design process. Designers conduct back-talk with his or her artifacts by engaging in conversation in situ in design [Schön, 1983]. Information architects crystallize design ideas in the early design process through communication with freehand sketches [Suwa and Tversky, 1997], and designers communicate with observers through drawings in which visual sketches and textual descriptions are combined [Alistair McGowna and Rodgersb, 1998]. "The sketches mediate the design work, and the participants depend on the sketches for their collaboration" [Alistair McGowna and Rodgersb, 1998]. Communication with stakeholders using artifacts is what collaboration in collaborative design is all about.

To understand the characteristics of communication in collaborative design *the language game* which is a philosophical concept developed by Ludwig Wittgenstein, offers valuable insight. Wittgenstein shows that the meaning of language is determined in its use, where actions are interwoven and the roles are different from one instance to the next; the rules depend on the context. The following is a classical example of the language game, the so-called "builder's language'; shown in his seminal book *Philosophical Investigations* [Wittgenstein, 1953]. Communication is determined by the context and integrates the activities among two (or more) agents.

> The language is meant to serve for communication between a builder A and an assistant B. A is building with building-stones: there are blocks, pillars, slabs and beams. B has to pass the stones, in the order in which A needs them. For this purpose they use a language consisting of the words 'block', 'pillar' 'slab', 'beam'. A calls them out; B brings the stone which he has learned to bring at such-and-such a call [Wittgenstein, 1953](PI 2).

Inspired by Wittgenstein's language game, several methods of collaborative design have been suggested. One of them is the *Design game* [Ehn, 1988] which aims at supporting design as action during its early stages of collaboration. Originally, the design game was implemented in designing detailed technical systems in shop floor, involving manual workers. Gradually, design games have been used under user-centered design concepts, and applied to industrial design, landscape design and so forth. For example, Buur, Binder and Brandt (e.g., [Binder, 1999, Buur et al., 2000, Brandt and Messeter, 2004]) applied design game in designing future office, haring aids, mobile technology devices and so on. In this way, they extended the reach of design games by creating multiple scenario based platforms and initiate the use of short video clips within the same design game concept. According to them, design is a social enterprise - like a game. Both in a society adn in a game, each stakeholder has a role, different knowledge, competence, responsibilities and interest in joining the development of products. Both in the real and game world, stakeholders negotiate and compromise when making decisions.

In addition to the design game approach based on Wittgenstein's notion, the use of mock-ups and scenarios [Buchenau and F., 2000, Burns et al., 1991, Howard et al., 2002, Iacucci and Kuuti, 2002, Oulasvirta and E. Kurvinen, 2003] have also been widely accepted in collaborative design settings. Briefly explained, scenarios can be applied to the design context flexibly and let stakeholders immerse in interaction by offering a shared context. Similar to design games, the collaborative design methods mentioned above promote and facilitate collaboration in design by affirmative intervention.

Collaborative design is often applied in the early design phase when creative and innovative discussions are critical. For that reason, collaborative design is also seen as an ill-defined activity [Winograd and Flores, 1986, Simon, 1969] or even as wicked problems [Buckingham Shum, 1997, Rittel and Webber, 1984] which create further collaborative barriers. The ill-defined or wicked problems are considered to have the following four characteristics. First, collaborators do not have a clear understanding of who each other are, and only a vague vision in mind about how to collaborate in the beginning of the task. Thus, second, there are no clear orders or classification schemes that every participant can follow. Naive participants often use terms, expressions and procedures that are not clear to others. Under such circumstances, third, one ultimate best collaborative design does not exist. And lastly, since differences resides deep in collaborator himself, solutions found for better collaboration turn out to be not-valid in the next moment, thus, eternally evolving.

From the above characteristics, we can see commonalities between collaborative design and intercultural collaboration. We target at investigating these in a pragmatic way. In spite of the differences among these two schools – collaborative design focuses on design activities among design professionals while intercultural collaboration focuses on collaborative activity among professionals with different knowledge backgrounds –, they still have rich similarities. Both aims at building, generating and creating design artifacts, and such artifacts are made through communicative interaction with humans and artifacts. By regarding collaboration among professionals with different knowledge background as a collaborative design activity, we can approach intercultural collaboration from a different angle. In short, we can investigate how design professionals would communicate with each other in order to design artifacts collaboratively. By doing so, intercultural collaboration can focus on communicative activities between professionals designing new artifacts (such as new buildings, new software, and new information boards) rather than targeting at general and overall collaboration activities which have vague connotation and broad aspects. For all events, the communication process of developing and creating a base for collaboration is what intercultural collaboration is about in this thesis. Collaborative design can offer an adaptable framework for the social interaction of intercultural collaboration in which the establishment of a design vocabulary for fruitful idea generation and design discussions is brought forward to the discussion table of intercultural collaboration.

The next section overviews several important concepts for intercultural collaboration from a collaborative design perspective.

2.3 Key Concept

The concepts described in this section are all related to each other and form the theoretical basis for our study of intercultural collaboration from a collaborative design point of view. This section is neither a summery of any existing collaboration theory nor a comprehensive overview of collaborative design. It is rather an introduction of a certain view of intercultural collaboration aimed at building the foundation for our approach toward collaborative design in intercultural collaboration. Unmentioned concepts may be useful for other approaches, but the selected set is intentionally small and cohesive so that our approach is easier to understand.

To date, vast scholarly theorizing in collaborative design have been carried out and several important concepts have been defined and discussed. In the earlier history of collaboration research, a fundamental question was how two people can understand each other in a pragmatic sense, and how mainly oral language is used in communication. The studies were often based on a speech act perspective [Austin, 1962, Searle, 1969, Searle, 1979]. Later researchers also paid attention to external representations such as written expressions, unique expressions in certain communities (common language [Bjørn, 2006], interface language or work language from semiotic perspective [Andersen, 1990, de Souza, 2004]), tangible artifacts, and even the interactive physical environment itself such as room layout [Watanabe, 2001].

In collaboration in general, it is normally thought that *common ground* such as a certain level of information or social context is required. From that perspective, it is simply understandable that intercultural collaboration is difficult because stakeholders do not share common ground because they often have different ethnic cultural backgrounds or different professional knowledge. Such different ethnic and world culture have different semantics for identical symbols and representations. Thus, *ontological drift* arise. In a process of collaboration across cultures, *boundary objects* have attracted attention as something facilitating collaboration without the need of common ground. Boundary objects are defined as tangible artifacts with which people from different communities manage to work together in spite of different languages. However, can we argue that low-level common ground such as being human would be found even in intercultural collaboration? At the same time stakeholders in collaboration *interact* with a whole collaborative environment such as themselves, other stakeholders, artifacts and physical space and externalize their thoughts. Such *external representation* (such as speech, gestures, models and drawings) as reflections of ones thoughts and tacit knowledge, can have a high ability to facilitate intercultural collaboration because external representations make tacit thoughts or knowledge (which might be rooted in ethnic or work cultural differences) visible (or audible). Sometimes boundary objects are formed based on such tangible external representation (like models and drawings).

How can we explain the relation between such concepts seen in collaboration settings? How are external representations and boundary objects as well as common ground and boundary objects related? In the next sections, we describe the topics listed below in order to clarify these concepts to give profound understanding of computer supported intercultural collaboration:

- Ontological drift.
- Common ground.

- Boundary objects.
- External representations.
- Interactivity.

2.3.1 Ontological drift

Professionals with different ethnic and work cultural backgrounds often have different *ontology*, that is a different set of concepts relationships between them as well as world views and languages. Thus, they often have different semantics for identical symbols and representations. When such professionals work together, misinterpretations of the original meaning, or *drift of meaning* can easily occur.

This phenomenon is called ontological drift [Robinson and Bannon, 1991] and was originally acknowledged in the software engineering domain. Ontological drift cause the original meaning of a term or relations with other terms to collapse, and subsequently the results, for example software requirements in software engineering, do not meet the original requirements. Due to this, ontological drift, arising out of the different practices of the group and the essential incommensurability of their world views and language, could be a critical challenge for collaboration across community boundaries [Robinson and Bannon, 1991].

In the thesis, this ontological drift is considered a central collaboration challenge that intercultural collaboration faces.

2.3.2 Common Ground

In order to collaborate, a certain level of information sharing and social context is required among people engaged in the collaborative activity. Such information and social context can be comprised of language, beliefs, sense of values, terminologies or embedded procedures which are socially constructed in both ethnic and work communities and collaborative settings. Moreover, such information and social context are explained by referring to the current location (The place where they communicate. For example, class room, bar, train and so forth), the current situation (We are here to learn fundamental English as second language), shared friends (Both of us know Mr. Smith), shared hobby (Both of us like classical music) and so forth. Such information and social context that participants are aware that they have in common is called *common ground* by Clark and Brennan [Clark and Brennan, 1991, Clark, 1996].

In collaboration among professionals with different knowledge background as well as collaboration mediated by computational artifacts especially in on-line collaboration, this common ground is usually missing to a higher degree. Common ground has originally been discussed in face-to-face conversational context. Thus, it was thought to be important to meet several conditions related to face-to-face conversation[2] in order to achieve

[2]Such conditions are 1. face-to-face conversation, 2. same physical environment, 3. visibility of each other, 4. speech usage, and 5. simultaneous communication.

common ground. However, later many attempts to investigate establishment, development and maintenance of common ground in collaborative settings through artifacts [Lee, 2004, Lee, 2005, Lee, 2007] including computational artifacts such as distance collaboration technologies [Olson and Olson, 2000, Bjørn, 2006] have been conducted. Such investigations showed that to establish common ground is particularly critical in distributed collaboration environment as well as in computer mediated collaboration. It is generally understood that it is possible but very challenging to establish common ground. The thesis which investigates computer supported collaboration process among professionals with different knowledge background has to face such issues.

Previous studies show that it is relatively easy for a co-located team to establish common ground. They share not only local social context, but also micro context such as who is doing what. Such awareness [Dourish and Bly, 1992, Dourish and Bellotti, 1992, Heath et al., 1995] makes communication easier and thus facilitates establishment, development and maintenance of common ground. It is also easy to establish common ground if the collaborators from different domain have established common ground beforehand. For example, people working in the same company for a long time have common ground based on the company culture even when collaborators have been allocated to totally different projects and never have collaborated before. Based on these findings, it is not surprising that intercultural collaborative work in distributed environments often is successful when the team members belong to the same professional domain such as computer engineering [Yasuoka et al., 2003] or architecture [Yasuoka, 2007]. The reason is that they have some degree of common ground for exmaple from their computer science education and architect education respectively which they can base additional common ground upon. Based on this, it seems that the importance of common ground is not whether people have or not, but to which degree they share common ground and can use pre-acquired common ground to enrich their common ground further. As a consequence, people who have established a high degrees of common ground can collaborate with less distortion generated from differences in spite of other devastating collaboration conditions such as distance [Bjørn, 2006] or linguistic background differences [Olson and Olson, 2000].

One critical discussion in current understanding of common ground is in relation to establishing, developing and maintaining common ground. It is generally agreed that establishing, developing and maintaining common ground through grounding processes is crucial for collaboration, but it is still not so clear, how common ground evolves in collaborations. In fact, a key question is *how common ground can emerge when it is missing at the beginning of the collaboration*. Researchers by and large agree that common ground is established often accompanied by interactive processes through conversation or other types of communication. For example, Clark and Brennan [Clark and Brennan, 1991] show that there often is a collaborative process in which people mutually establishes common ground. Olson [Olson and Olson, 2000] also points out that common ground is made through interactive joint construction. Olson describes its characteristics by mentioning that common ground emerges “not necessarily based on preexisting categories”[Olson and Olson, 2000] (p.158). This indicates an essential point about how common ground is created. However, there still is a critical lack of detailed understanding of the emergence of common ground and its processes.

In relation to common ground and its grounding, *indexicality* introduced by Garfinkel [Garfinkel and Sacks, 1970] is often taken as one of the relevant concepts because of its striking similarity with Clark's work on common ground. Briefly explained, indexicality is defined as "local, time-bound and situational aspects of action". It shows that meanings of speech and action are socially and iteratively defined. Indexicality creates social reality, which in turn adds up social reality. However, Garfinkel presupposes not collaborative setting where people work together for a certain period of time, but relatively short term communicative acts such as one ask and the other reply. Indexicality can not explain some of the characteristics of common ground that contribute to collaborative work. For example, indexicality can not explain common profession based knowledge which play a facilitating role in the complete collaborative period.

On the other hand, *community language* [Wenger, 1999] and *work language* [Andersen, 1990] which are unique shared expressions that function as common ground in collaborations, are good examples of related concepts in collaborative settings. However, the associated theories are not able to explain the grounding process of such languages when there is no shared culture or when the setting is short term project based collaboration (i.e., intercultural collaboration).

How such languages emerge, develop and settle in intercultural collaboration has not been explicitly mentioned or investigated before. A similar question toward such community language or work language, was stated by Lee [Lee, 2004, Lee, 2005, Lee, 2007] who coined the term *boundary negotiating artifacts* and investigated the creation process of boundary objects as objects comprised of the iterative use of interwoven sets of boundary negotiation practices and boundary negotiating artifacts. Lee shows that boundary negotiation artifacts are created through the collaboration process and used as a common base in collaborative settings.

2.3.3 Boundary Objects

In CSCW the concept of boundary objects has been considered a useful theoretical construct to understand the facilitating role of artifacts in collaborations. As a key concept for collaboration, Star and Griesemer [Star and Griesemer, 1988], who originally introduced the term, show that boundary objects play an important role in collaboration among professionals from different communities.

In *Sorting Things Out*, Bowker and Star [Bowker and Star, 1999] explain the concept as;

> Boundary objects are those objects that both inhabit several communities of practice and satisfy the information requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual-site use. These objects may be abstract or

> concrete. Star and Griesemer (1989) first noticed the phenomenon in studying a museum, where the specimens of dead birds had very different meaning to amateur bird watchers and professional biologist, but 'the same' bird was used by each group. Such objects have different meaning in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary object is a key process in developing and maintaining coherence across intersecting communities. [Bowker and Star, 1999]

According to Star's classification [Star and Griesemer, 1988], there are four types of boundary objects. "They are *repositories* such as piles of objects that are indexed in a standardized fashion e.g. in libraries and museums, *ideal types* which are vague and therefore adaptable such as diagrams and atlas", *coincident boundaries* which have identical boundaries but different internal contents such as the state of California, and *standardized forms* which are standardized indexes that serve as methods of common communication such as forms. Later, Carlile [Carlile, 2002] suggested three types based on Star's four classifications, *repositories*, *standardized forms and methods*, and *objects, models and maps*.

The concept of boundary objects has kept attracting a great deal of attention. Widely varied boundary objects have kept being reported with supposedly overlooked or additional roles and characteristics. To give an overview of them, we will briefly list what has been discussed.

One of the most outstanding and accepted characteristics of boundary objects is that they *enable joint activity* by acting as *common information spaces* since they "inhabit several intersecting social worlds" [Lutters and Ackerman, 2002, Lee, 2004]. Due to this, they have *translation capability*. According to Lutters, since boundary objects have different meaning in different social worlds and work as a translation medium, they can *translate meanings* from one group to another [Lutters and Ackerman, 2002]. In this way, boundary objects allow *multiple perspectives of a single information artifact* [Lutters and Ackerman, 2002] and *interpretative flexibility* [Bijkerand et al., 1987, Carlile, 2002]. Their interpretative flexibility was also originally mentioned by Star: "[boundary objects] have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation" [Star and Griesemer, 1988]. In addition, *the flexibility of shapes* of boundary artifacts has also been observed. According to Lutters, boundary objects are not static, but exist within an information flow [Lutters and Ackerman, 2002] and are continually reinterpreted. Further more, boundary objects do not require *consensus or a shared goal*. Even without consensus or shared goals, boundary objects enable interaction and coordination [Bartel and Garud, 2003]. Considering collaborative settings in practice, the objective of each stakeholder can vary, but still is is an advantage for them to work together. Related to this point of view, boundary objects are often discussed in the context of negotiation and creation [Bechky, 1998, Lee, 2004, Lutters and Ackerman, 2002, Henderson, 1998], which may explain the previous characteristics *the flexibility of shapes* as those changing its shape iteratively through negotiation and creation. Lee [Lee, 2004] differentiates between such boundary objects used for negotiation and general boundary objects, and coined a concept called *boundary negotiating artifacts* to indicate the latter. Lastly, and more importantly to understand our work, compound characteristics of boundary objects have also been reported. As implied by Star's classifications, the range of boundary objects can be extended to compound objects such as folders circulated with enclosed papers and documents. According to this point of view, information systems such as collaboration support systems, CAD systems and ERP information systems can also be regarded as boundary objects [Pawlowski et al., 2000]. They offer documents, drawings and sounds in aggregate tangible form in the shape of data.

In addition to the characteristics mentioned above, we also have to mention a controversial characteristic. This is the idea that boundary objects can be *concrete as well as abstract*. From an early point, it has been argued that boundary objects can be concrete and abstract, and also weakly structured in common use and strongly structured in individual use at the same time [Bowker and Star, 1999]. Wenger [Wenger, 1999] also supports this idea to include abstract objects within the boundary object category, by explicitly mentioning that boundary objects are "artifacts, documents, terms, concepts, and other forms of reification around which communities of practice can organize their interconnections". In addition, intangible practice itself, or social manifestations such as conferences and workshops, furthermore narratives are also suggested as boundary objects. Due to their capacity to preserve the complexity, ambiguity and dynamism of particular set of events, boundary objects enable knowledge exchange and generation [Bartel and Garud, 2003].

Despite such advocates of the presence of intangible boundary objects, it is also argued that there are several advantages of tangible boundary objects. Tangible boundary objects "help coordinate distributed cognition since they allow for the manipulations of tacit knowledge between individuals" [Henderson, 1998]. Carlile [Carlile, 2002] also points to boundary object as "the collection of artifacts that individuals work with - the numbers, blueprints, faxes, parts, tools, and machines that individuals create, measure, or manipulate", and explicitly insists of the importance of tangibility. For him, "the tangibility of physical parts allows for an ease in specifying differences and dependencies; their value becomes clear as they anchor the 'scenarios' told by individuals about possible trade-offs to pursue". The importance of the tangibility of boundary artifacts is in their ability to make tacit knowledge visible. Bechky mentions the advantage of tangible objects from another angle.

> Such objects provide *tangible definitions* - or physical touchstones- that help create the common ground for communication and through which local understandings can be re-contextualized- creating the transformation of understanding needed to enable knowledge to be shared. [Bechky, 1998]

As indicated by the long description of boundary object characteristics, the usage of boundary objects has sprawled in all directions and is often incompatible and sometimes conflicting. Due to this, the concept of boundary objects often incur disputes. As Schmidt [Schmidt and Wagner, 2004] has already warned, current conceptual frameworks introduced in CSCW including boundary objects "do not tell the whole story" and they are "incomplete" and "rather patchy and incoherent'. Later, a growing number of researchers have expressed their concern including Lee [Lee, 2004, Lee, 2005, Lee, 2007] who also questioned this tendency "that all objects that move between communities of practice are boundary objects". In her work [Lee, 2007], she argues;

> The tendency of researchers to label every artifact that 'lives' in that space a boundary object is troubling because it forces us to deny what we observe, to ignore the finer points of the boundary object definition, or to awkwardly wrap new theories around the box. It's time to stop these gymnastics. The role of material artifacts in practice is incredibly important to collaborative work and is far too complex to be defined by a single concept, however, compelling.

Based on her empirical work, as we have mentioned previously, she coined *boundary negotiative artifacts* as a term for physical artifacts that facilitate collaboration, rather than calling such artifacts boundary objects. By doing so, she introduced a special kind of artifacts facilitating collaboration arising from a process of iterative use of interwoven sets of negotiation of practice and artifacts and at the same time restricted the use of boundary objects only to physical, material and tangible entities.

The concept of boundary objects seems in need of amendment. However, the need of amendment is not to neglect all work related to boundary objects. Rather, it aims at avoiding creating further unproductive discussions. No one involving in these disputes on boundary objects deny that there exists something that could bridge over differences and facilitate collaboration by satisfying the informational requirement of people with different background-knowledge, which we currently know as boundary object, boundary negotiating artifacts [Lee, 2004], prototypes [Subrahmanian et al., 2003], or intermediary objects [Boujut and Blanco, 2003]. That disputes have erupted does not mean that the concept is incorrect, but rather that it is incomplete. At the same time, we believe that the chaotic usage of the concept mainly is due to its usefulness and intuitive appealing power.

2.3.4 External Representation

While scholars in the early days tried to understand collaboration from a communication aspect focusing on oral conversation [Clark, 1996], some have recognized that also written expressions, gestures, artifacts at interaction time and even the interaction environment itself such as the layout of the discussion room [Watanabe, 2001] have significant roles in communication. Since expressions such as intangible oral expressions and artifacts often reflect the cognitive processes of individuals, investigating such external representations is one way of understanding collaboration.

According to Zhang [Zhang, 1997], external representations can be,

> [...] defined as the knowledge and structure in the environment, as physical symbols, objects, or dimensions (e.g. written symbols, beads of abacuses,

dimensions of a graph, etc.) and as external rules, constrains, or relations embedded in physical configurations (e.g. spatial relations of written digits, visual and spatial layouts of diagrams, physical constraints in abacuses, etc.).

External representations have drawn attention because of their ability to act as memory aids by extending working memory. In addition, Zhang argues for the importance of external representations as "not simply inputs and stimuli to the internal mind; rather they are so intrinsic to many cognitive tasks that they guide, constrain, and even determine cognitive behavior". External representations are "the form of a representation that determines what information can be perceived, what process can be activated, and what structures can be discovered from the specific representation". For Zhang, the importance of external representations is summarized by its ability (1) to provide information that can be directly perceived and used without being interpreted and formulated explicitly, (2) to anchor cognitive behavior, and (3) to change the nature of tasks by showing completely different tasks from a task performer's point of view.

Later, Fischer [Fischer, 2000] elaborates on the importance of external representation:

1. Externalization causes us to move from vague mental conceptualizations of an idea to a more concrete representation of it.

2. Externalization provides a means for others to interact with, react to, negotiate around, and build upon.

3. Externalization provides an opportunity to create a common language of understanding.

In this way, external representations can be facilitators for collaborative work, sometimes taking the role of boundary objects.

Based on these concepts, many investigations in collaboration have been made in relation to the external representations. Related to the third point stated by Fischer, quite a few insightful findings are reported. For example, people in the same community of practice often use the same expressions or *community language* [Wenger, 1999]. Another study shows that certain keywords thrown into a diverged discussion may cause the conversation to converge [Isaacs et al., 1994, Roschelle, 1992]. Externalized expressions can create a common language. Such interface language and work language (see Section 2.3.1) at interaction time in the intercultural collaboration project can act as a facilitator. In this way, the cognitive as well as social character of language [Clark, 1996] has been shown to facilitate collaborative processes in several studies based on external representations.

In our collaborative settings, we stress the importance of external representations as representations externalized in the cognitive processes of collaborators. Not always but often they facilitate collaboration. In spite of the knowledge differences of collaborators, externalized expressions can often easily relate to each representation world. As discussed above, so far, the main analytical target of external representation in collaborative work has been in conversation and oral interaction. The importance of other external representations and their interactions has gradually been recognized. But the topic has not been investigated sufficiently yet. Understanding how written expressions, artifacts such as drawings and sketches, the interactive environment itself and signs can facilitate the collaboration processes can contribute to understanding communication in collaboration. We discuss this further under the role of writings in Section 2.5.

2.3.5 Interactivity

In the context of human and computer interaction, *interactivity* have mainly been discussed in relation to the computer. As suggested by the name, Human Computer Interaction (HCI) put interaction in the center of research interests where the human *interacts* with the computer. In HCI interactivity is originally defined as "the set of processes, dialogs, and actions through which a human user employs and interacts with a computer" [Baecker and Buxton, 1987](p.40). In *Understanding Interactivity* [Svaneas, 2000], Svanaes extends the range of interactivity to artifacts by denoting the interactive aspects of artifacts. Still, he sees interactivity in similarity between designing graphics for computer displays and other visual media, and does not discuss beyond that range. Needless to say, the importance of such view of interaction should never be underestimated, but something is missing in the discussion of interactivity for our purpose.

The essence of interactivity in groups that we are investigating is not limited to human-computer-interaction, but interaction between people, tools, artifacts, and external representations. Since when it comes to human group activities in relation to computational artifacts usage, interaction outside the realm of HCI also influences computer usage. In contrast to conventional communication theory that deals with linear sender-receiver relations, research shows that humans communicate by utilizing a wider surrounding world beyond the original scope of HCI. Considering architects, they use pen and paper and filing systems as well as Computer Aided Design (CAD) systems for coordination [Schmidt and Wagner, 2004, Yasuoka, 2006, Yasuoka, 2007]. Aircraft pilots use a pile of paper, and physical location of tangible artifacts at the cockpit in addition to computational systems [Hutchins, 2001, Nomura et al., 2006]. In these studies, interaction not only between human and computer, but also interactivity with the environment such as papers and furniture settings play an important role just as shown by the importance of situatedness of human activity [Suchman, 1987]. This thesis which try to understand computer supported collaboration among professionals also needs to take this position, going beyond traditional HCI and covering a whole interactive environment.

Apart from what HCI covers, another important aspect of interactivity in collaborative settings relates to the *symmetry of ignorance* or *asymmetry of knowledge* of groups. Fischer [Fischer, 2000] introduced this concept of symmetry of ignorance, suggesting that complex collaborative work today requires more knowledge than can be handled by a single professional. When designing complex systems, the participants teach and instruct each other [Greenbaum and Kyng, 1991]. As current projects become increasingly interdisciplinary, more professionals with different knowledge backgrounds are needed for a single project. Fischer [Fischer, 2000] comments on this issue by note that:

> Complex design problems requires more knowledge than any other single person can process, and the knowledge relevant to a problem is often distributed and controversial.
>
> When a domain reaches a point where the knowledge for skillful professional practice cannot be acquired in a decade, specialization will increase, collaboration will become a necessity, and practitioners will make increasing use of reference aids, such as printed and computational media supporting external cognition.

This symmetry of ignorance characterizes the current collaborative environment where no single professional has coherent or comprehensive knowledge, but such group as a whole has collective knowledge for fulfilling the task at hand. Due to this, it is important for professionals in intercultural collaboration to interact with each other, artifacts and other environment in order to externalize their thoughs and knowledge. Without externalization through interaction, tacit knowledge remain invisible and ontological drift remain unsolved.

This section has introduced several key concepts that we consider important for collaboration among professionals. Since such professionals gather with different knowledge backgrounds, boundary objects (Section 2.3.3) often play important roles to facilitate their collective activities. Professionals interact with collaborative environments, such as other professionals and external representations (Section 2.3.4) as reifications of their tacit knowledge. Further more by utilizing common ground (Section 2.3.2), they collaborate to get their work done. However, as this section conclude, current theory can not explain some critical relations between common ground and boundary objects.

Does no common ground exist when people use boundary objects or does common ground exists to some extent? If both common ground and boundary objects co-exist in intercultural collaboration, what is the relation of the two?

We cannot answer such questions straight away. However, by investigating the nature of intercultural collaboration in such pragmatic way as this thesis does, we expect these questions to be clarified to some extent.

2.4 Various Approaches to Support Intercultural Collaboration

Recall that intercultural collaboration in this thesis refer to the early design period in highly specialized and short-term project based collaborations among professionals with different knowledge backgrounds. With these preconditions, this section discusses approaches with special focus on the problem of ontological drift (see Section 2.3.1), relating to the key concepts mentioned in the preceeding sections. Recall that ontological drift is the shift in meaning from one practice to another caused by the essential incommensurability of their world view and language. Different work cultures often have different semantics for identical symbols and representations. Thus, this ontological drift is often unavoidable in intercultural collaborative settings. This thesis regards such ontological drift as a challenge to be solved. The approaches introduced in this section are *building shared and mutual understanding*, *grounding support*, and *creative support*.

2.4.1 Approaches for Building Shared and Mutual Understanding

Ontological drift occurs in the intersection of practices, thus building shared and mutual understanding seems to be one of the straightforward approaches in such groups with different world view and languages. The importance of shared and mutual understanding in collaborative settings has been discussed in CSCW (e.g., [Bødker and Pedersen, 1991, Pawlowski et al., 2000]), HCI (e.g., [Roschelle, 1992]), collaboration studies (e.g., [Ohira, 2003]) and related domains (e.g., [Clark and Brennan, 1991, Schegloff, 1991]).

A wide variety of approaches have been suggested to support the establishment of shared and mutual understanding. Some have tried to establish shared and mutual understanding in a indirect manner, for example by visually externalizing stakeholders background with large displayes [Ishii, 1990, Ishii and Miyake, 1991, Ishii and Ullmer, 1997] or in an online community [Ishida, 2002, Ishida, 2005, Ishida et al., 2004, Yasuoka et al., 2005, Yasuoka et al., 2010], while others have developed means to enhance background senses utilizing concepts such as awareness [Dourish and Bly, 1992, Dourish and Bellotti, 1992, Heath et al., 1995].

In spite of the importance of shared and mutual understanding, it has not been clearly argued whether supporting means to *build* shared and mutual understanding is a reasonably valid approach in order to facilitate intercultural collaboration. For example, in Ohira's approach [Ohira, 2003], construction of shared understandings is achieved by utilizing visualization system called EVIDII. EVIDII displays association differences of each stakeholders' impressions toward a set of pictures and key words. By doing so, EVIDII aims at deliberately letting breakdowns occur among the stakeholders' minds. The system aims at promoting mutual understanding among stakeholders by letting them notice differences. However, there are at least two arguments in his approach. First, even if Ohira's approach would be valid, and stakeholders manage to find differences by referring to other's associations, whether breakdown happens and consequently mutual understanding is established is left in the hand of the EVIDII system users. Second and more important, we are still not confident that shared and mutual understanding can be established or needed to the extent to promote intercultural collaboration. As Rochelle [Roschelle, 1992] argues, if shared understanding and mutual understanding is constructed from connecting or transformating existing knowledge, how can people ever achieve the *same* meaning for a particular symbol, word or expression? This is a theoretically important and difficult issue. At the same time the view point that "mutual understanding is desired but not really required" [Ehn, 1988] has been widely accepted in the collaborative design community, which as we mentioned earlier has a lot in common with our intercultural collaboration setting.

As shown by Fischer's theory of symmetry of ignorance [Fischer, 2000], collaborative work environments often gather a wide variety of professionals. No professionals have identical knowledge in these collaborative settings since their typical role is to complement each other. The knowledge gap between professionals is vast especially in the early stages of a project. In our case of intercultural collaboration, such knowledge gap is unavoidable and happens as long as symmetry of ignorance is a prerequisite condition for tackling the project challenges. Many approaches who tackle establishing shared or mutual understanding assume that mutual understanding is needed or practically possible to promote collaboration. It can be imagined that collaboration works smoothly if the stakeholders have the same knowledge as is the case in a collaboration in a community of practice. Taking the position that collaborative design can be fulfilled without mutual understanding, it is not clear whether shared understanding and mutual understanding is needed or possible in intercultural collaboration.

2.4.2 Approaches for Grounding Support

An approach for supporting grounding processes has been suggested in the participatory and collaborative design domain introduced in Section 2.2.3. Grounding support in these domains often consists of utilizing several devices, scenario and tangible artifacts such as mock-ups, prototypes, paper, and artifacts on *design move*. [3]

In design games which are one form of participatory design, tangible artifacts such as a set of cards (e.g., the Layout Kit or Organizational Kit [Ehn and Sjogren, 1991]) have been introduced. Each card represents a function or artifact in the work place. Games that utilize devices [Iacucci and Kuuti, 2002], wearable computing art device [Garabet et al., 2002] and conduct scenario sessions with focus-groups have been suggested. By using scenarios, stakeholders can concentrate on the game and immerse themself into the game which generates further shared context among them. A scenario can also be more flexible than a prototype. By using tangible artifacts called *game pieces*, stakeholders accelerate design moves, and help participants to focus on collaboartion. The main advantage of game pieces is their ability to create common ground in the process of the design work. Secondly, game pieces can support different understandings and interests despite ambiguity. Participants with different knowledge backgrounds such as different believes and common sense can still play in the same game. Third, game pieces have an ability of promote creativity [Finke et al., 1992]. Finke explains this aspects as "heavily restrictions on idea generation activities actually can improve the outcome". All in all, games make it possible to promote smooth collaboration in the design process.

In the collaborative design domain, the grounding process, which is critical for intercultural collaboration, is promoted through design games, tangible artifacts, scenarios etc. The main objective of devices used in collaborative design is not to support intercultural collaboration, but rather to support and understand the design activity. However, due to the similarities between collaborative design and intercultural collaboration, we believe that we can utilize several approaches and concepts applied to the collaborative design domain.

[3] Schön [Schön, 1983] explains a design move as a re-creation of the current situaion with new insights.

2.4.3 Approaches for Creativity Support

It has been argued that creativity is often observed at the borders of cultures. Recent research in creativity support indicates that background differences between stakeholders that were considered a negative element could be a source of creativity. The tendency to regard *differences* as potentially negative is quite strong especially in the software development domain where intercultural collaboration challenges emerged earlier than in other domains. However, according to Finke [Finke et al., 1992] and other followers, new paradigmes emerge at the border of domains. Since iterative circles of divergent and convergent thinking generate creativity, breakdowns that often occur between domains can contribute as a trigger for divergent thinking. For this reason, many computer systems developed to provide creativity support [Hori, 1994, Hori, 1996, Amitani, 2005] offer visualizations that let the breakdowns happen consciously by showing unexpected images to users.

It is not a completely bizarre approach to account for intercultural collaborative work from a creativity perspective. The relation between collaborative work and creativity has not been fully investigated yet, but similarities between them has been pointed out recently [Page, 2007, Sawyer, 2007]. For example, the collaborative settings often lead to divergent thinking through interaction with the environment. Thus, creation of new ideas can happen in the intercultural collaborative work process, or in the early stages of collaborative work. It is a salient attribute of collaborative work between professionals from different domains.

Divergent and convergent thinking is often difficult to observe because it is often tacit activities in the mind. However, it could be externalized in different forms; from language use to drawings or to tangible objects. Some interaction analysis of collaboration show a transition process of language use and creation of expressions during the collaboration process. The shared expressions become increasingly sophisticated, transformed, and often in the end unique to the project group and forms a basis for intercultural collaborative work. For instance, Yasuoka's work [Nakakoji et al., 2004, Yasuoka, 2006] indicates that intercultural collaboration can create unique expressions among stakeholders.

The above examples indicate a framework where collective creation guides to build community oriented language in the interaction process of collaboration. Such frameworks are relevant for this thesis. What is missing in the creative support domain in order to deploy ideas to intercultural collaboration is a detailed understanding of creative processes in community oriented languages that are key to intercultural collaboration as well as creative support.

2.5 Computer Supported Communication

> *Without writing, the logical analytical, rational, and scientific mode of modern thought was impossible. Writing made available certain knowledge, skills, and procedures essential for the rational mode of thoughts, such as organizing, manipulating, elaborating, and reflecting upon logical relations in the analytic form*

of linear sequences. Speech, which is the external representation of language in spoken form, is constrained by the transient and dynamic nature of utterance and the limited capacity of work memory [Zhang, 1997].

How do people collaborate? To answer this question, for many decades, investigations have been made mainly through the analysis of oral conversation [Sacks et al., 1974, Sacks, 1995, Schegloff, 1991]. However, recent work shows that people collaborate through multiple modes of communication with a wide variety of external representations (see Shapter 2.3.5). It has become clear that it is almost impossible to capture the essence of collaboration only by analyzing oral conversation. Especially nowadays, collaboration is carried out, often facilitated by computational artifacts, where written signs are as important as speech. Meanings of signs and thus, meanings of lines and notations are necessary to understand.

As for writing, Goody [Goody, 1977], Ong [Ong, 1982] and others have argued early for the impact of writing on cognition. They essentially consider writing as a written form of speech. Later, several investigations have emphasized the importance of signs as external representations in collaborative settings. Some have investigated sign systems to be independent entities from speech, which is different from the conventional view of writing. Others have investigated signs in user interfaces of computer systems and have tried to show how computer systems can facilitate collaborative work. Collaboration facilitated by computational artifacts is more frequently carried out via signs on computer screens than face-to-face conversation. Although in face-to-face conversation, signs such as gestures and facial expressions have an important role, written signs on computer screens play a critical role because of the limited communicative modalities such collaborative settings can offer.

Harris [Harris, 1986] is one of the earliest scholars who pointed out the importance of writing. He analyzes writing systems and gives a detailed characteristic of writing and its independency from speech, differing from Goody or Ong. Some linguists such as Andersen [Andersen, 1990] and de Souza [de Souza, 2004] have introduced semiotics to the field of computer systems and stress the importance of designing signs as things that "can trigger converging semiosis around its implemented meaning" [de Souza, 2004] (p.87).

There are three important aspects of sign usage in relation to collaboration. First, written signs as well as oral conversation convey messages and each form a communication modality [Harris, 1986, Harris, 1995]. Second, since communication is socially situated, the meaning of signs is not static but evolves through interaction during the process of collaboration [Harris, 1986, de Souza, 2004, Andersen, 1990]. Lastly, third, written signs can sometimes express more than oral conversation [Harris, 1986, Harris, 1995, Harris, 1998]. Because written signs can create concepts equivalent to phonetical expressions, written signs provide a richer communication modality than ordinary oral communication does.

This section covers basic theories for understanding intercultural collaboration, more precisely understanding communication in computer supported intercultural collaboration settings. Theories introduced here form a base for analyzing and discussing the five cases studies described in Chapter 4. Our interest is computational artifacts and their use, however, we first need to understand the essence of signs, before considering signs on computer screens. we do this below and after that, we overview signs in computational artifacts using the semiotics introduced by Andersen [Andersen, 1990] and de Souza [de Souza, 2004].

2.5.1 What are Signs?

Sign systems have communication purpose. Scholar Roy Harris [Harris, 1986], who studied writing systems, shows that writing is a mode of communication with unique characteristics. According to Harris, a writing system is "a system of signs; and all systems of signs presuppose communicational purposes for which they are used" [Harris, 1986](p.127). Writing systems have the following characteristics.

1. Written signs are independent from oral communication.
2. Some written signs can even be independent of verbal communication.
3. A written sign without a name can supply new vocabulary to deal with it.

With respect to the first point, the most prevailed notion is that written signs such as alphabetic signs make a permanent verbal record for human use. It dispenses the presence of a speaker and the need of face-to-face conversation. Written signs make "verbal communication independent of the individual communicator, by providing an autonomous text which can survive transmission over time and distance" [Harris, 1986](p.24). Secondly, scriptorial signs or graphical signs such as musical notation and mathematical notation do not demand oral or verbal communication. Instead they require to *read*. They have no linguistic basis and are essentially independent even of verbal communication.

> A musical notation, for instance, does not need the backing of a musical metalanguage if the musicians can 'read' its signs directly in terms of fingering techniques, strategy of breath control, and other playing skills which can in principle be learned directly by imitation from a teacher rather than by oral explanation [Harris, 1986](p.150).

The last characteristic is explained in relation to creation. For instance, in mathematical notation, the concept of the mathematical operation for $\sqrt{}$ came before the word 'square root of':

> More generally, mathematics offers a paradigm case of conceptual development which would be 'unthinkable' without the availability of a graphic notation in which to 'do the thinking' involved. [...] It suffices to think about the problem of representing the square root of minus one on an abacus to convince oneself that for certain purposes there is no substitute for writing. But once the exploitation of a certain graphic system has lead to new conceptual developments, it is no major problem to supply any associated verbal system with a new vocabulary to deal with it [Harris, 1986](p.151).

The above shows that in spite of the conventional view that written signs substitute oral and verbal communication, written signs go beyond that. Written signs have unique characteristics that can be communicated only by signs. This fact has often been neglected because of the outstanding character of oral conversation. Nevertheless, the importance of written signs is increasing. One of the reasons is the advent of computer mediated communication. Collaboration through computational artifacts has increased and is sometimes not facilitated by speach at all. Instead, collaborators communicate with each other using signs carried by computational artifacts.

> [...] the question could not be posed clearly until writing itself had dwindled to microchip dimensions. Only with this latest of the communications revolutions did it become obvious that the origin of writing must be linked to the future of writing in ways which bypass speech altogether [Harris, 1986](Epilogue p.158).

Integrationalist perspective

Harris' position toward communication is called the integrational approach. The conventional notion of communication assumes that the system of communication is independent of its users and the context. Those who communicate are expected to know a particular system of signs and a breakdown occurs if they misapply the system. In this context, individuals are requested to deploy the correct rules, which is a pre-determined static mode. In contrast to this conventional view, integrationalism insists that there is no context free signs. Communication is socially situated, open ended and evolve eternally. Thus, communication could be explained as an essentially dynamic and iterative creative process.

> [C]ommunication, in other words, is not a closed process of automatic 'transmission' of given signs or messages from one person's mind to another's, but of setting up conditions which allow all parties involved the free construction of possible interpretations, depending on the context [Harris, 1998].

From Harris' point of view *temporality* and *space* are two essential aspects of written communication. In this perspective, three parameters are identified to be relevant: biomechanical, macrosocial, and circumstantial. The biomechanical parameter relates to physical and mental capacities of individuals, the macrosocial parameter relates to practices established in community, while the circumstantial parameter relates to the particular communication situation.

Temporality and space

According to Harris' integrationalism, time is the key for human communication because all communication is time bound. "There is implicit an integration of past, present and possible future activities". He explains the importance of time in writing as:

> No message is timeless. But certain forms of communication, of which writing is one, are distinguished by the way they allow certain time-gaps to be bridged [Harris, 1998].

The essence of writing has been thought to reside in being mnemonic. In ancient time, Plato viewed writing as an essentially mnemonic device, since those who use writing do it to keep what they might forget otherwise. This is true. However, new technologies such as voice recording and video recording offer other possibilities of memory aid. Another essential feature of writing is its enduring existence. Goody [Goody, 1977] views writing as a visible form of audible speech which offers a potential durability.

> [W]hen an utterance is put in writing it can be inspected in much greater detail, in its parts as well as its whole, backwards as well as forwards, out of context as well as in its setting: in other words, it can be subjected to a quite different type of scrutiny and critique than is possible with purely verbal communications [Goody, 1977] (p.44).

This is also true. However again, modern technologies have weakened the previous close relation between writing and speech and with that definitions based on it. To define writing solely from a visible or static perspective is not precise enough any more. When arguing for his temporality point of view, Harris reveals several characteristics of writing which often are neglected. By reviewing conventional comparison between writing form and kinetic from a temporal perspective, this becomes more clear. For example, gestures and speech as intrinsically kinetic are not static but processing.

> This is communication in which there are no second chances, no physiological possibility of checking or re-examining the message. It is communication in which, without access to a repetition of the signal, all subsequent assessment is memory-dependent [Harris, 1998] (p43).

Writing is a static visual form that people can examine in details, re-examine and re-process during the duration of the written matter. Duration in writing is not eternal but also not kinetic so that in writing, duration is sufficiently long, and communication is sufficiently slow. In such written communication, a message can be checked and reexamined to the readers' content. At the same time, in the form of writing, durability in visual modality can also vary. Writing on sand has less durability than writing on paper.

> [writing can] be processed and reprocessed as often as may be, and by as many people as have access to it, within the temporal limits determined by its own duration [Harris, 1998](p.43).

Another important aspect of temporality is “the interdependence of our concept of communication and self”. In contrast to the conventional view that “communication is essentially a process linking two or more individuals” [Harris, 1998](p.38), Harris claims that communication with oneself shows some part of what writing is. For example, keeping a diary makes a person write and offer her or him the possibility of re-reading and reflecting on what was written. This possibility to examine beyond time-gaps is what writing can offer, but which is problematic in the case of speech.

> What makes the notion of 'communication with oneself' viable in the case of writing but problematic in the case of speech (before the advent of sound recording) is the common temporal scheme into which we fit both our understanding of the activity of communication and our understanding of the continuity of the self. [...] Integrating knowledge of an earlier self with knowledge of a later self become a semiological process subject to conscious control and evaluation [Harris, 1998].

The second key technology in writing is the use of space. Although space is used in speech and oral conversation, space in writing has more varieties and complex features. Space in writing is used in alphabetic writing, graphics and drawings, which involves *surface*, *graphical space* and *direction*. By deploying space, writing offers richer communication.

> It is the availability of space for the deployment of written forms which gives the syntagmatics of writing far greater variety and complexity than the syntagmatics of speech could ever have. [...] There simply is no counterpart in speech to the use of a surface, which is the commonest way in writing of articulating spatial relations [Harris, 1998].

Harris argues that it is more important to grasp *graphical space* than graphic units such as symbols or icons, and pictorial or scriptrial to understand writing.

Graphical space of writing shows writing can offer compound communication characteristics significantly and vividly which graphic units can not show. Consider Harris' examples where both drawing and writing are used such as in book illustration, captions of photographs and captions of figures. Each form of communication (illustration and text, photographs and caption, and figures and caption) overlaps. At the same time they exist independently and require different visual and mental processing. But still they are not dividable. In these examples, understanding communication in *graphical space* is equal to understanding a several forms of communication combined. Harris insists that communication should be analyzed as combined forms of communication, since in modern communication multiple modes are intermeshed.

Direction is also a key concept in addition to surface and graphic space. Briefly explained, even though the contemporary linguistic tradition tends to think that all glottic writing is linear just like speech, the graphic space has, as a matter of fact, "more than one dimension and thus permits a variety of possible forming and processing procedures" [Harris, 1998](p.128). The linear characteristics of writing is not the essence, but *graphic space* is. From this point of view, written forms are just arranged in a particular way in order to be read. It is incorrect to see writing as a linear form, or something to be read from left to right or from top to bottom. The essential quality of writing resides in direction rather than which kind of direction.

Mode of communication

As we have seen, writing provides a wider variety of communication modalities than oral conversation which is traditionally in the centre of communication theories. Harris gives detailed definitions of these written modes of communication in his integrational based typology. From an integrational point of view, signs that conventionally may be regarded as having uniform features can be quite different semiotically due to differences in form, processing and interpretation. This may consequently result in different impact on communication.

Consider the two representations for calculating numbers shown below.

$$24 + 12 = 36$$

$$\begin{array}{r} 24 \\ \underline{+12} \\ 36 \end{array}$$

The latter representation visualizes the cognitive problem solving process more than the former. According to Harris' integrational approach, it is important to understand how to write signs and how they are visually processed as this can show the context of the writing and the cognitive process of the mind clearer. Thus, his integrational approach focuses on the utilization of the space and its implications for cognitive processes rather than interpreting writing based on conventional theory which tends to focus on distinguishing whether writing is ideographic or phonetic.

> Taking an integrational approach, thus opens up the possibility of a typology of writing systems which cuts across the traditional division between glottic and non-glottic writing altogether and focuses instead on similarities and differences between the ways in which various kinds of writing utilize the graphic space available. The theoretical justification for this change of emphasis is that the utilization of graphic space, and its implications for processing the text, may be factors common to many forms of writing irrespective of whether the signs are to be interpreted phonetically, logographically, musically, etc [Harris, 1998].

Next, we review key modes of communication introduced by Harris including *glottic writing, scripts, charts, notations and mixed systems.* They provide us a tool toward what we need to pay attention in understanding writing, consequently communication in computer supported intercultural collaboration. Reviewed previously, conventional study in communication often focus on oral conversation, and such approach captures only a limited part of the nature of communication. In this thesis, especially we focus on collaboration often facilitated by computational artifacts, where written signs are as important as speeh.

Glottic and non-glottic writing

Glottic writing defines a form of writing related closely to spoken language. In comparison to non-glottic writing, glottic writing presupposes knowledge of a particular language in order to form and interpret texts [Harris, 1998](p.95). On the other hand, the potential range of non-glottic writing is infinite because forming, processing and interpreting is unlimited through the use of written signs. Mathematics is a collection of non-glottic writings such as math formulas and tables. Tabular - "the modern layout of the simple sum of addition has the Arabic figures arranged in columns. [...] the activity to be integrated is not simply reading the text but mental calculation based on the role of memorization of tables of equivalences" [Harris, 1998]. In contrast to charts where the whole graphic space is semantically mapped in advance in a uniform way, tabular writing forms meanings depending on syntagmatic relations between co-occurring graphic forms.

Scripts and charts

Both scripts and charts are modes of graphic communication. Still they are different in the forming, processing and required interpretation. Charts require the exercise of spatial skills and associated mapping procedures which are not demanded at all in setting down a string of characters. On the other hand, scripts which is a sequence of letters require mastery of the formative features of a whole set of differentiated marks. When it comes to reading a chart, once a message is misread, all the remaining messages may be misread consequentially and systematically. On the other hand, when it comes to reading scripts, there is no possibility of a consequential misreading. Charts are systems which make semiological use of absolute locations in a given graphic space, while scripts are systems based on the recognition and relative sequencing of the members of an inventory of characters, such as letters, numerals, syllabaries, differentiated by their form.

Let's refer Harris's example [Harris, 1995]. T1, T2 and T3 shown in 2.2 , T1 shows a phone number in Arabic numerals, T2 is translated form of T1 in alphabetic letters, and T3 is also the same phone number but displayed in ten-by-ten grid. T1 and T2 are script while T3 are chart. By referring three styles of writings indicating the same phone number, we can understand they are different in the forming, processing and required interpretation.

Notations

Notations are representations used to articulate writing systems. The alphabet and Arabic numerals are given as examples in Harris' book. There are two unique features of notations when compared to other modes of communication. The first is that a notation is a mode of graphic communication, which involves visual processing and interpretation and requires no 'reading' in the everyday sense. The secondary is that a notation has its own structure,

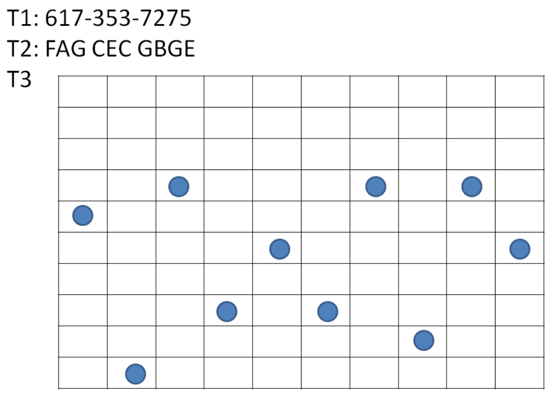

Figure 2.2: T1 and T2 are script while T3 is chart. Reproduced based on [Harris, 1998]

and can develop independent form from scripts (as shown in the French example below) and other associated writing systems. For example, alphabetical order has nothing to do with the writing system. It is forming, processing and interpreting without understanding the language written. Those who cannot understand French can copy a French sentence with no problem [Harris, 1998](Chapter 15).

Mixed systems

'Mixed' systems as shown by its name combine several modes of communication. Frequent examples of mixed systems by Harris apart from examples of captions are bar-codes in supermarkets and modern musical score 2.3 for which both scripts and charts are used. In the former, the script is the numeral sequence under the bar-code and the chart is the bar-code itself. They are processed by human eyes and by laser and provide different messages. In the latter, the general sequence of notes is a script while the five line stave function as a chart. In order to read music, two different processing techniques must be used.

2.5.2 Signs in Computational Artifacts

In this subsection, we review semiotics introduced to the field of computer systems. Computer semiotics introduced by de Souza [de Souza, 2004] and Andersen [Andersen, 1990] stress the importance of designing signs in computer systems, which give us a fruitful foundation in understanding communication facilitated by computer systems.

De Souza's interface language

De Souza coined the term *semiotic engineering* and approaches HCI from a semiotic point of view. Her main message in semiotic engineering is to regard HCI as computer mediated communication between designers and users.

Figure 2.3: Examples of the mixed system: bar-codes and music score

> [...] the essence of semiotic engineering is the communication between designers and users at interaction time to tell users how to use the signs that make up a system or program [de Souza, 2004](introduction).
>
> The goals of semiotic engineering as a theory of HCI are to present an extensive and distinctive characterization to HCI, to provide a consistent ontology from which frameworks and models of particular aspect of HCI can be derived, and to spell out epistemological and methodological constraints and conditions applicable to the spectrum of research that the theory can be expected to support. [de Souza, 2004](p.83).

The communication does not need to be verbal but can be non-verbal. In other words, the communication is carried out through the *interface language* that can be explained from a semantics perspective.

> Verbal communication is of course a prime means for expressing the variety of representations contained in computer programs. And the more users know about such variety, the greater the scope of possibilities for them to innovate and evolve. But verbal communication may step back and make way for other types of communication, whose limitations may be an important part of the designer's message. [de Souza, 2004](p.255)

Designers of computer systems send *one-shot messages*, which are "a complete and immutable content encoded in and made available by the system's interface" [de Souza, 2004](p.84). The interpretation and understanding of interface language is made by users. In addition, in computer mediated communication, tangible signified representations in the system interface is the target of interpretation and understanding of users, no matter what kind of intention the senders have.

> The actual meaning designers assign to a system they may have designed is much richer than what is encoded and will evolve over time. So will the user's meaning. The computationally encoded portion of the designer's meaning constitutes and defines the one-shot metacommunication message sent to users. It can be generated and interpreted by computational procedures that will manipulate all and only the signs that have been implemented as symbols in the system's interface language.

De Souza mainly explains signs in computer systems from an HCI perspective. However, her theory is very insightful to the computer mediated communication too, thus to our purpose. First, de Souza expresses the particular interpretations of the computer as a medium [McLuhan, 1964] in which De Souza extends the concept of a computer to a medium for communicative exchanges. For her a computer is;

> a medium for communication and metacommunication, but programs in the computer determine the codes, the channels, the messages, the context, and even the degree of freedom of interlocutors [de Souza, 2004](p.89).

This point of view makes it possible for her to include computer mediated communication (CMC) in the semiotic characteristics of HCI. For example, users communicate with other users through the program on which signs are carried. The communication model (see Figure 2.4) that de Souza developed based on the Jakobson's communication model [Jakobson, 1960] explains the CMC aspect in semiotic engineering.

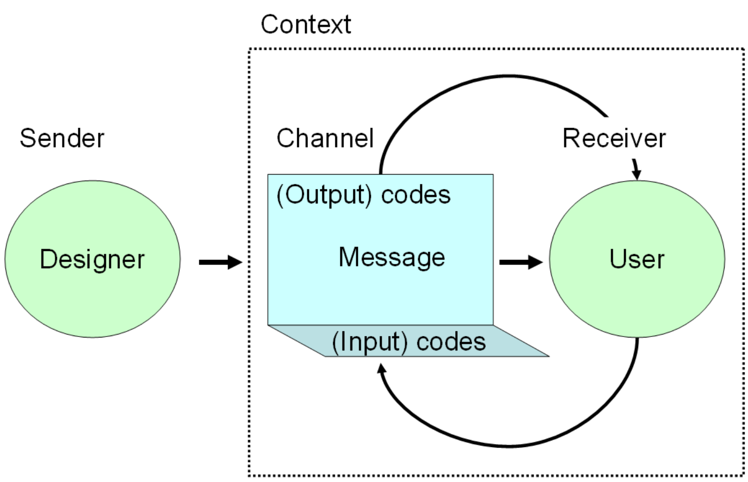

Figure 2.4: The HCI design space in semiotic engineering [de Souza, 2004](p.88).

The second reason that de Souza's theory is relevant for this thesis is that the interactivity between designers and users is explained within her semiotic theoretical frame. In her theory, the process of communication is a continuous meaning generation process since users interpret and understand iteractively at interaction time. Since meanings are created continuously, communication can be successful without sharing a complete coherent objective world between designers and users. Her explanation is relevant to Ehn's message [Ehn, 1988], in which Ehn questions the necessity of mutual understanding among stakeholders in collaboartive design.

> [...] so long as users generate meanings that are compatible with the designer's meanings encoded in their message, user-system communication is successful even if users don't interpret technology in the same way as designers do [de Souza, 2004](p.84).
>
> The success of HCI design can be measured not only by the user's complete acceptance of the designer's message as such, but also by the user's interventions to adapt and repurpose the message for unanticipated goals and contexts [de Souza, 2004](p.254).

De Souza regards a computer as the designer's deputy for communication between designers and users. Moreover, communication is a signification process that involves signs and semiotics. According to the semiotic approach the programs, codes, channels, messages and contexts are interpreted and understood by users during interaction time. Semiotic engineering does not use the traditional user-centred design perspective of HCI which need to know the users, but require instead representations to be self-evident.

The design intention of the designers should be shown in signs on software artifacts as another type of communication. De Souza explains that "human meanings cannot be fully known, and consequently not be completely (or adequately) encoded in computer systems" [de Souza, 2004](p.258). That is why, it is unavoidable that "users meaning is an evolving unlimited process of interpretation, halted and resumed for contingent reasons, and shaped by unpredictable factors that emerge during the process itself" [de Souza, 2004]. From her semiotic engineering point of view, interaction in computer mediated communication is understood as an infinitely evolving process through the interface language reified as signs. For that reason, it seems more critical to support the iterative interactive processes among stakeholders by utilizing signs and symbols than to support building mutual understandings.

Andersen's work language

Similar to de Souza, Andersen interprets computer systems from a semiotic point of view. He claims that it is critical to understand, choose and utilize signs carefully when designing computer systems even though the symbolic nature of computer systems has only attracted serious attention in recent years. There are several reasons for this. First, from being a tool for computer professionals, computer systems have been integrated in the work situation of non-computer professionals such as architects and designers. Second, computers have become "a communication media with functions similar to text books, telephones [...] where the importance of sign concept and semiotics is well established" [Andersen, 1990], Lastly, computers have become equipped with further functions such as pictures, sound and movies. Signs on computers today are used for communication for collective purposes rather than individual usage.

> the interface can no longer be viewed as a component of the system, but must be seen as a relation between system processes and users' interpretation, and input and output viewed as data types must be replaced by the communicative functions they perform [Andersen, 1990] (p.171).

We believe this to be no less important for the particular setting of our intercultural collaborative work.

In Andersen's theory of computer semiotics, the most noticeable and relevant point to our work is the importance of *work language*, which conceptually is somewhat similar to de Souza's interface language. In his terms, language includes all communicative means with signification in the situation. [4] For the central communicative means – language – it is important to differentiate a *register* from national language. National language is based on a certain country while a register is based on collaborative work or collaborative action.

> A register is the language used in a particular type of situation with the purpose of supporting or changing its activities [Andersen, 1990](p.54).

The concept of *work language* that Andersen introduces is the register that changes or supports organizational activities in certain collaborative work situations. According to him, computer systems are symbolic tools that generate new concepts, vanishes old concepts, and re-interpret existing concepts. In other words, work language is a changeable entity along with the change of the situation and is used for communication purposes. [5]

> We need to develop concepts for understanding why and how language changes. The reason is that designing computer systems implies changing the language of users to a greater or lesser extent, since they must learn new terminology and often also learn to look at and describe their work differently from how they are used to. Successful systems development presupposes that the users are able to adopt and use the new concepts in their daily life [...]. I assume that language change is connected to the register and caused by changes in its associated situation type [Andersen, 1990](p.43).

From his computer semiotics point of view, interaction in collaborative work is understood as the process of establishing a work language facilitated by signs. Thus, in order to

[4] Andersen uses language in the broad sense in his theory. "I have already mentioned gestures and facial expression, but clothes, pictures, hairstyles, and computer systems in so far they are interpreted by users, belong here. All these phenomena are therefore languages in the broad sense. It is the broad sense of language that makes it feasible at all to transfer linguistic and semiotic concepts to computers" [Andersen, 1990](p.42).

[5] Note that in Andersen's theory, language is not analyzed in the same way as Saussure (e.g., [de Saussure, 1983]) and Hjelmslev(e.g.,[Hjelmslev, 1953]), where language is separated from situation and understood in itself.

understand collaborative work, he insists that it is critical to take signs, their signification and their use in the collaborative environment into account.

Both interface language and work language introduced by de Souza and Andersen have been developed in HCI and CMC communities. For them, the focus on signs in understanding collaborative processes is more rational because oral conversation in computer mediated work environments hardly has taken a significant role. In collaboration environments facilitated by computers, signs have become an increaingly powerful facilitator, in contrast to conventional oral means. In the computer age, communication via computational artifacts has becomes the centre of the collaborative process. In such environments, semiotics mediated by information media take a significantly important role and should not be neglected.

It is important to note that signs as well as language are social means [Harris, 1998, Eco, 1976]. Since they are social, signs can be different from culture to culture. Hence, via computational artifacts intercultural collaboration also happens. As a consequence, signs on computational artifacts should be observed carefully in order to understand intercultural collaborative work facilitated by computational artifacts.

Chapter 3

Approach and Setting

This chapter describes the research approaches used in the thesis. Section 3.1 describes the *mixed method* in general as well as our position toward mixed method. Section 3.2 describes our mixed method approach where ethnographical inquiry is used as qualitative approach and statistics is used to analyze conversational data. Since the five cases introduced in this thesis are quite different, we postpone further details about our approach to later chapters. Finally, in Section 3.3, we reflect on the validity of our approach as well as its scalability.

3.1 Mixing Qualitative and Quantitative Methods

We apply a *mixed approach* that combines qualitative and quantitative methods to observe, investigate and analyze collaboration among professionals with different knowledge background. Individually, qualitative and quantitative methods have their limitations and advantages. Thus, each approach has domains for which it is particularly suited, and there has been a long tradition for one over the other in certain domains. Some even say they belong to different paradigms [Sale et al., 2002]. For example in computer science, the validity of system behavior is often examined using statistical analysis, while in CSCW, elaborated ethnographical inquiry is often applied to understand daily routines in work settings. Although it is true that a solid approach brings solid validity to data results, the opportunity to get further insights, for example by supporting data with statistical means in an ethnomethodological investigation or to draw insights from observations in a qualitative research is often underestimated or neglected deliberately. Because of its ability to investigate one event from multiple angles, such mixed approaches have evoked skepticism, and their validity have been discussed and challenged by situationalists and pragmatists (e.g., [Cook and Campbell, 1979, Greene et al., 1989]).

3.1.1 Mixed Method Evaluation Design

Mixed methods have mainly been applied in the domain of educational and social program evaluation. Since the 1960s both qualitative and quantitative methods have been employed for improving quality and providing comprehensive understanding of the observed target [Greene et al., 1989, Sale et al., 2002]. Greene [Greene et al., 1989] has defined mixed methods "as those that include at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words), where neither type of method is inherently linked to any particular inquiry paradigm or philosophy" [Greene et al., 1989].

The validity and methodological design of mixed methods have been a point of argument, flourishing in 70s and 80s. From the purists point of view, a mixed-method approach cannot be valid as a research method because it is based on different paradigms. The quantitative paradigm is based on positivism in which there is only one truth - an objective reality. In contrast, the qualitative paradigm is based on interpretivism and constructivism in which reality is socially constructed and constantly changing. The "qualitative paradigm is based on a worldview not represented by the quantitative paradigm" [Sale et al., 2002].

In contrast, the advocates of mixed approaches such as Greene, Cook [Cook and Campbell, 1979], Miles and Huberman [Miles and Hubermanm, 1984] and Trochim [Trochim and J.P.Donnelly, 2006] argue for the importance of being practical rather than keeping epistemological purity in a research approach.

> [...] the practical demands of the problem are primary; inquirer flexibility and adaptiveness are needed to determine what will work best for a given problem. Or, in the pragmatic view [...], epistemological purity does not get research done. [Greene et al., 1989]

Greene and collaborators [Greene et al., 1989] have identified five attributes of mixed method evaluation that may enhance analysis:

- Triangulation. Triangulation seeks convergence, corroboration, and correspondence of results from the different methods. It increases the validity of constructs and inquiry results by counteraction or maximizing the heterogeneity of irrelevant sources of variance attributable especially to inherent method bias but also to inquirer bias, bias of substantive theory, and biases of inquiry context.

- Complementarity. Complementarity seeks elaboration, enhancement, illustration, clarification of the results from one method with the results from the other methods. It increases the interpretability, meaningfulness, and validity of constructs and inquiry results by both capitalizing on inherent method strengths and counteracting inherent biases in methods and other sources.

- Development. Development seeks to use the results from one method to help develop or inform the other method, where development is broadly construed to include sampling and implementations, as well as measurement decisions. It increases the validity of constructs and inquiry results by capitalizing on inherent method strength.

- Initiation. Initiation seeks the discovery of paradox and contradiction, new perspectives of frameworks, the recasting of questions or results from one method with questions or results from the other method. It increases the breadth and depth of inquiry results and interpretations by analyzing them from different perspectives of different methods and paradigms.

- Expansion. Expansion seeks to extend the breadth and range of inquiry by using different methods for different inquiry components. It increases the scope of inquiry by selecting the methods most appropriate for multiple inquiry components.

Later, Sale [Sale et al., 2002] who recently reviewed the above arguments thoroughly, concluded that the approaches in mixed methods reside in different paradigms and cannot be combined for cross-validation or triangulation purposes. They can, however, be combined for complementary purposes. Because "The fact that the approaches are incommensurate does not mean that multiple methods cannot be combined in a single study if it is done for complementary purposes" [Sale et al., 2002](p.50). Based on Sale's arguments, the advantages of using mixed methods are to increase quality of final results, to provide a more comprehensive understanding of analyzed phenomena by offering complimentary analytical results [Greene and Caracelli, 1997, Caracelli and Greene, 1997].

As previously mentioned, mixed methods have mainly been applied to educational and social program evaluation such as in Lee's work [Lee and Greene, 2007]. Lee uses mixed methods for investigating the correlation between academic performance and English-language competence by applying data collection through interview or questionnaire and grade points. Later, mixed methods have been applied in several domains including medicine (e.g., [Westhues et al., 2008]) and cross-cultural studies (e.g., [Fry et al., 1981]). These studies show that the advantages of applying mixed methods reside not only in giving higher validity to the analysis results to the complex phenomena, but also in solving evolving issues that have emerged along with the increasing number of multidimensional projects. These projects are large, multifaceted, and complex in particular because the stakeholders of the projects in collaborative work as well as research teams have become multidisciplinary.

3.1.2 The Use of Mixed Methods in This Thesis

This thesis uses a mixed method with ethnographical inquiry and statistical analysis of conversation data as complementary bases. Thus, a basic stance of our mixed method is to put positivistic inquiry into constructivistic phenomena. As we have seen in the preceding section, mixed methods can be very controversial since they mix two or more methodological paradigms together. In this thesis, however, we believe they are very beneficial to apply for pragmatic reasons.

As already mentioned, this thesis takes the position of "the importance of being practical rather than keeping epistemological purity in a research approach". As formulated in its research questions, this thesis aims at understanding how design professionals with different knowledge backgrounds develop and create a base for collaboration from communication perspectives and what kind of computational artifacts should be offered to support this process. For pursuing these challenges, not only oral conversation which conventional investigations have targeted at, but also artifacts and other types of external representations around them will be target for investigations. As shown by other advocates of mixed methods, statistical approaches are unable to cover the whole communicative activity which we consider critical in order to grasp collaboration. Thus, empirical investigations are necessary. Thus, our methodological standpoint cannot help being pragmatic in nature. In short, this thesis tries to understand what conventional methods are unable to disclose sufficiently.

Statistical approaches are strong in internal validity and show solid results once parameters are selected. The results, however, may be too narrow to describe the social phenomena that this thesis investigates. Activities and behavior may be the result of combined effects of social situation and social interaction of complex intercultural collaborations, which are difficult, even if not impossible, to grasp in a parametrized statistical model. In addition, in contrast to, for example, analysis of computer architectures for which statistical approaches may sometimes be suitable, it is a question whether statistical approaches alone provide the necessary means for the kind of analysis we target. Intercultural collaboration facilitated by computational artifacts resides in communication as well as interaction with human and computational artifacts in social settings. To analyze relations between humans as social entities - mediated by computational artifacts, statistical approaches have limitations in explaining what happens in the social interaction, even when the analysis try to understand a whole environment of human and computer interaction.

At the same time, it is argued that empirical approaches are rather subjective and that the results are difficult to interpret and give clear validity. It may therefore be hard to bridge the empirical investigation results and the design implications of collaborative support systems if the results are too situation oriented. Thus, the long lasting issue in CSCW, called the *great divide* [Bowker et al., 1997] (see Section 1.3) remains unresolved. The purpose of applying mixed methods in this thesis is "adding qualitative flesh to the quantitative bones" as Trochim mentioned [Trochim, 1997], which seems like a good strategy to overcome some of these challenges.

Consider the five purposes of using mix methods that Greene et. al. [Greene et al., 1989] propose. The main purpose of using mixed methods in this thesis is *development*; using the results from one method to help develop or to inform the other method. The results from qualitative and quantitative analysis will also be *complementary* to each other. In our research design, statistical conversation analysis takes a supportive role to further understand the analysis results of our empirical observations.

3.2 Qualitative and Quantitative Inquiry

In this section, we first introduce the ethnographical inquiry as the qualitative approach we take in this thesis. Secondly, the statistical approach to analyze conversational data is described.

3.2.1 Ethnographical Inquiry

Qualitative investigation is central in our mixed method approach. Briefly described, our ethnographical inquiry method consists of observing, recording, analyzing, and interpreting collaboration among professionals with different knowledge backgrounds. The detailed methods will be elaborated for each case study in the each case chapter.

The first question that may come to mind when hearing the name *ethnographical inquiry* might be what is *ethnographical inquiry*? According to the Oxford English Dictionary, ethnography is "the scientific description of nations and races of men, their customs, habits and differences". In social science, ethnography is employed in not only traditional anthropological field work but also in a wider variety of fields such as marketing, business, daily life and work settings. Ethnography has been explained as the description of human activities and culture [Pettinari and Heath, 1998] and an investigation process to find something unexpected [Levis, 2003]. [1]

> Ethnography allows us to being to retrieve these ordinary competences by examining in detail how others accomplish their activities and coordinate them with colleagues, friends and the like. It helps us "make visible" the practices and procedures, assumptions and understandings that we rely on, in accomplishing our ordinary, but routine, activities [Pettinari and Heath, 1998].

Ethnography is often used when investigating, analyzing and understanding human behavior and social processes in groups [Spradley, 1979]. The purpose of observation is to describe the social life to those who are not there through the observers immersive experience in the group.

> The ultimate goal is to produce a coherent, focused analysis of some aspect of the social life that has been observed and recorded, an analysis that is comprehensible to readers who are not directly acquainted with the social world at issue [Emerson et al., 1995].

Thus, ethnographical inquiry enables us to understand how computational artifacts are embedded and support human activities and how they are interwoven as social-technical systems. It may even give implications on design of computational artifacts and how they might be improved.

Ethnography covers a range of different analytical approaches which rely on a method or set of methods of investigation, including field observation, in-depth interview, the use of video, and other data collection strategies. They target social activities that are difficult to observe in statistical manners. Largely speaking, there are historically two analytical standpoints. The first is *symbolic interactionism* and the second is *ethnomethodology* [Garfinkel, 1991] and *conversation analysis*. Symbolic interactionism is concerned with

[1] Precisely speaking, Lewis' definition is for the term, *qualitative analysis*. "The term 'ethnography' is often used interchangeably to refer to one of the several qualitative approaches to social research, and/or a method or set of methods of investigation, namely fieldwork, such as participating in and observing activities" [Pettinari and Heath, 1998]. This thesis applies Lewis definition to ethnography.

how individuals establish a "world in common" by describing the routines, the informal or tacit practice and fundamental changes in which they rely on. Ethnomethodology treats social actions and activities, facts and findings, objects and the environment. Conversation analysis focus on actions and activities produced through talk or oral conversation. In addition to these two major analytical standpoints, other ethnographic settings also exist such as *comparisons* and *case studies*. In comparisons, the difference between an experimental group and a control group is analyzed, while in case studies, a single target is observed and analyzed from different perspectives. None of these settings is dominating. Each has its own role and may therefore be the most suitable for a different as well as particular research purpose.

A large part of our ethnographical inquiry research uses case studies to understand social phenomena in collaboration. In the rest of this section, we briefly overview the basic ideas of field observation and in-depth interviews used in the thesis.

Field observation and its conduct

When conducting ethnographic studies, the most important attitude toward a domain is to keep a clear mind when entering the domain and immerse oneself in it. It is less important to be experienced and knowledgeable in the domain in advance. It is of key importance to be able to wonder and be puzzled by the observed behavior without taking things for granted because "unfamiliarity keeps [observers] away from taking things for granted. It makes them sensitive to things that have become so commonplace to informants that they ignore them" [Spradley, 1979] (p.50). During and soon after the observations, ethnographers write field notes, while a vivid impression is still floating around inside the observer [Emerson et al., 1995].

Several observational roles are suggested for field observations. Pettinari and Heath [Pettinari and Heath, 1998] suggest four categories such as *passive presence*, *limited interaction*, *active control* and *full participation*. In the same manner, Gold [Gold, 1958] applies four models of observation which elaborates the patterns of researcher-subject relationship based on Junker's four field observer roles [Junker, 1952]. They are *the complete participant*, *the participating observer* (originally the participant-as-observer), *the observing participant* (the observer-as-participant), and the *complete observer*. We use Gold's four categories as they reflect our attitude to field observation in a pragmatic sense. Golds four categories are;

1. The complete participant. A participant who pretends a role of participation. "The true identity and purpose of the complete participant in field research are not known to those whom he observes".

2. The participating observer. A participant who takes an observer role in the field. Both field worker and informant are aware that their relation is limited to the field. The participating observer role is used often in community and collaboration studies where observers spend more time and energy on participation than in observation.

3. The observing participant. Those who do not participate in activities or intervene in discussions but attends meetings as a pure observer. "It calls for relatively more formal observation than either informal observation or participation of any kind". This role is easier to take than the previous two roles with respect to the responsibility of participation. The observer can balance a participating role and research.

4. The complete observer. Those who are entirely away from interacting with informants engaged in a field work. "A field worker attempts to observe people in ways which make it unnecessary for them to take him into account, for they do not know he is observing them or that, in some sense, they are serving as his informants".

The models of observation taken in the emprical observations of our research are either "The participating observer" or "the observing participant". This is largely because of the restrictions in the offered settings. Four out of five field cases in this thesis are real business situations that have time and resource constraints.

In ethnographical studies, recommended observation targets are for example, physical setting, type and characteristics of activities, artifacts and equipments, key events, and patterns of interaction. As described in Chapter 2, especially the role of external representations such as conversations and written signs will be the targets of observations in this thesis. In other words, by analysing communication, the thesis aims at investigating how tools and artifacts are collaboratively used and shared and what kind of problems appear in usage and how they facilitate social interactions.

In-depth interview

Some ethnographic studies use in-depth interviews alone or in connection with other methods. The method is often called *a conversation with purpose*. The core idea of an in-depth interview is to construct an interview to fulfill the research objectives. It is often an unstructured interview, but that does not mean that the interviewer can do whatever he or she likes.

Originally, there is two ways to conduct an in-depth interview. The first is to pull out the interviewees thoughts, and the second is to create facts collaboratively through interaction between interviewee and interviewer. The former is the approach taken in traditional science, while the latter is the emerging way of thinking. In either case, an interview is a *collaborative construct of conversation*. For example, Pettinari and Heath [Pettinari and Heath, 1998] comment that a good qualitative interview is complex and a creative piece of work. A shared view by both is that basically no matter which approach is taken, the most important skills in in-depth interviews are summed up as follows [Legard et al., 2003]: [2]

1. To listen to what the interviewee says,

2. To organize the answers logically and construct the next questions,

[2]They might also be taken as a common sense for conventional daily life conversation.

3. To remember interviewees previous comments.

The ultimate purpose of the in-depth interview is to cover wide and profound topics, by utilizing two question techniques; *content-mapping* questions and *content mining* questions. Content-mapping questions are a group of questions that narrow down themes. There are general *ground mapping* questions which are overall questions suitable to starting the conversation, *dimension mapping* questions that narrow down the direction of further questions, and *perspective-widening* questions that approach the theme from different perspectives. Content-mining questions are a group of questions for understanding the theme more profound. They consist of *amplificatory probes*, *exploratory probes*, *explanatory probes*, and, *clarificatory probes*. Usually, content mapping question and content mining question techniques are used in combination.

All in all, an in-depth interview can only provide what the interviewee has thought and created through the process of interacting with the interviewer. Thus, what interviewers get through an interview is not just a description of a phenomenon, but a secondary processed description. It is important to note what interviewees mention or do not mention in order to keep internal consistency of his or her previous comments, and all the more, memories can change unintentionally as time passes.

Our in-depth interviews are conducted based on the frame mentioned above - collaborative construct of conversation. We value improvised dialogue with interviewees and try to avoid predefined script thinking. In addition, we offered a document to interviewees to give a fundamental background for conducting interviews instead of preparing a list of questions. Our interviews are used as a supplemental component to ethnographical investigations.

3.2.2 Statistical Conversation Analysis

In addition to the ethnographical inqury approach introduced in the preceeding section, quantitative approaches are used in this thesis mainly to support the results of the qualitative analysis. As we discussed in Section 3.1, we consider our mixed method valid because we believe no single method can disclose the complete nature of collaboration in our case. Since the detailed method will be elaborated in next chapters, we only give a brief description here.

Our quantitative approach is used for recording and transcribing conversation data in collaboration projects among professionals with different knowledge background. Transcribed data is processed, analyzed using statistical methods and visualzied for further analysis. The conversation processes between professionals is clarified along time-lines and step-by-step transition. Changes in the relation of each professional's utterance is visually demonstrated. Through a visualization of a conversation over time, the statistical analysis aims at showing how each professional recognizes the collaborative situation. In this section, we describe the statistical approach and visualization techniques developed for cases such as the one describe in Section 4.1.

As mentioned, the goal of this statistical analysis is to show the correlation of participants' utterances visually in order to understand and clarify the process of collaboration among professionals with different knowledge background. All external representations used in such intercultural collaborative activities (including oral conversation, signs, writings, mockups, models, papers and so forth) are the target for our empirical analysis. However, in this statistical investigation, conversation is the only as well as possible target for analysis. The statistical analysis does not aim at testing a hypothesis as is often the case in quantitative research. Instead, it aims at supporting the findings based on the empirical investigation and pop out such findings vividly by showing a different angle of one facet of a multidimensional phenomenon, which may otherwise be overseen and unidentified.

The overall process is to process transcribed conversation data with a document analysis method and visualize temporal correlations between expressions. The statistical analysis takes several steps. First, transcribed conversation data taken from an empirical investigation is analyzed morphologically. After that, the temporal occurrence relation of expressions is calculated, and finally these relations are visualized. Several statistical tools for conversation analysis including *Chasen* [3] for Japanese morphological analysis [Matsumoto, 2003], *popout prism* for visualization developed by PARC [PARC, 2002], and *Polaris* [Okazaki and Ohsawa, 2003] for occurrence relations are used together with the original analysis system. Finally, we developed the *KEV system* for further visualization. We will explain more details about the KEV system in the subsequent section.

Pre-processing

Before applying the statistical conversation analysis system, the following four pre-processing steps are taken.

1. Raw conversation protocol data and recorded and video-taped conversation protocols are transcribed.

2. Transcribed conversation protocols are analyzed by a language parser and categorized morphologically.

3. Among morphologically categorized protocols, verbs, nouns, and adjectives are filtered out.

4. Among filtered expressions, the 20 most frequently used expressions in the meeting, *key expressions*, are statistically calculated.

The morphological analysis in step two above for Japanese conversation uses Chasen version 2.3.3 [Matsumoto, 2003], which is a morphological parser. Chasen categorizes each morpheme, among which verbs, nouns and adjectives are filtered for analysis purposes. Next, the 20 most frequently used expressions in the meeting, so called key expressions, are statistically calculated and selected.

[3] Nara Institute of Science and Technology

After these four steps, the key expressions are analyzed using two different visualization methods in order to give higher validity.

The first visualization method

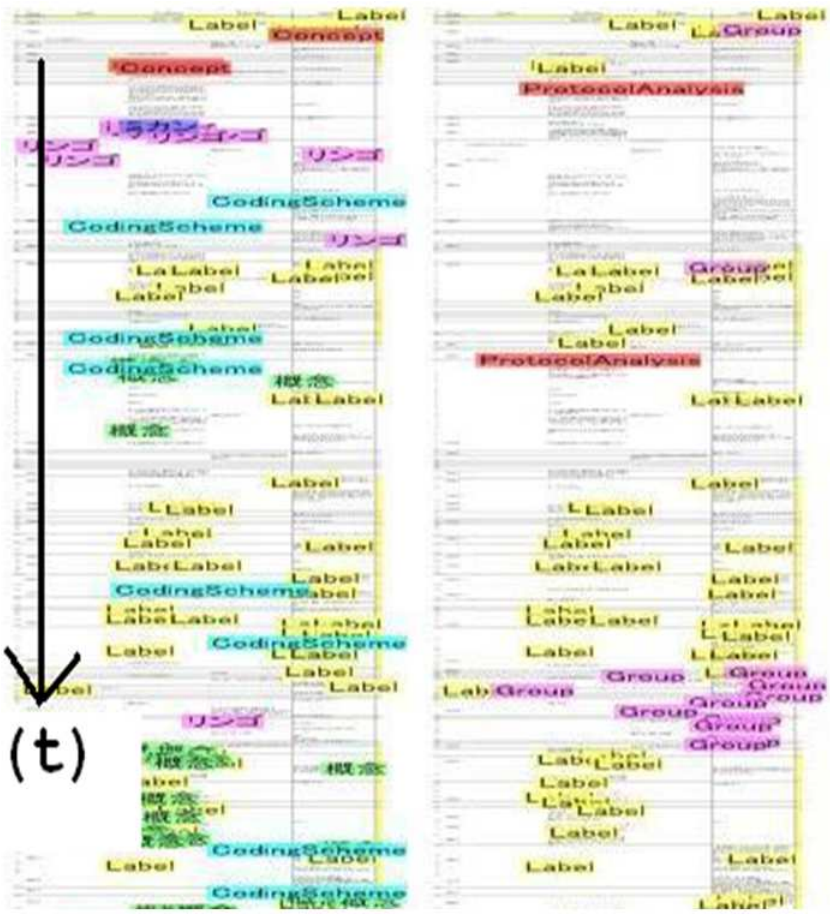

Figure 3.1: An example of a Popout Prism visualization showing the relation of a key expression *Label* with other key expressions. Different colors are used over time. Notice that time (t) runs from top to bottom.

The transition of the relations of each key expression is analyzed and visualized with different colors in the visualization system *Popout Prism*. Popout Prism [PARC, 2002] is originally developed to highlight key words in the document or the web, which help users smooth transition from overview to detail. Popout Prism offers functions which make user-selected key words popout in the documents or the web visually with multiple color. Figure 3.1 shows a transition of the key expression *Label* in relation to other key expressions. By visualizing the usage transition of key expressions with different colors, the relation among key expressions over time is roughly clarified.

The second visualization method

The Key Expression Visualization system (The KEV system) which incorporates a morphological parser and a visualization tool, has been developed and implemented specifically for our research.

In contrast to the Popout Prism system, which just visualizes the key expressions, the KEV system visualizes relations of key expressions based on the co-occurrence relations among key expressions as well as the temporal transition of these key expression relations. For analytical purposes, text data is first pre-processed and formatted to adapt to the need of our statistical analysis tool. The interface of the KEV system is shown in figure 3.2 which shows the KEV control side bar to the left and the KEV visualization window to the right.

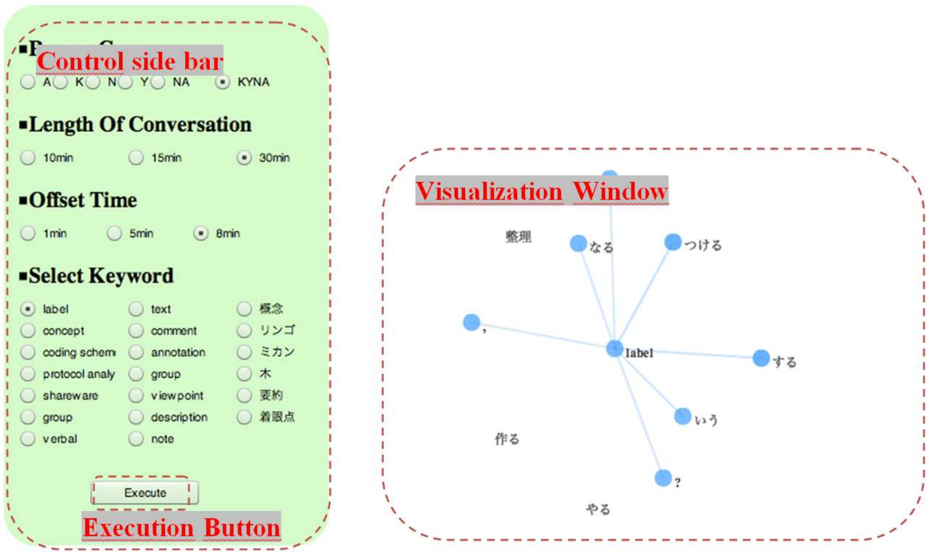

Figure 3.2: Examples of the KEV control side bar (left) and visualization window (right).

The KEV system takes pre-processed conversation data as input that is recorded or video-taped, transcribed and finally formatted as conversation protocols that stakeholders externalize as illocutionary acts in the collaborative work. First, KEV produces the structure of conversation files shown in Figure 3.3. Conversation files of each stakeholder are created with 10, 15 and 30 minutes separation using 1, 5 and 8 minutes offset-time. By conduction this preprocess, it becomes possible to display key expression relations at a designated fix time.

Next, the KEV system executes the following five steps to visualize data.

1. Calculate the co-occurrence rate between key expressions with *Polaris*.

2. Visualize the co-occurrence relations between key expressions in a graph structure.

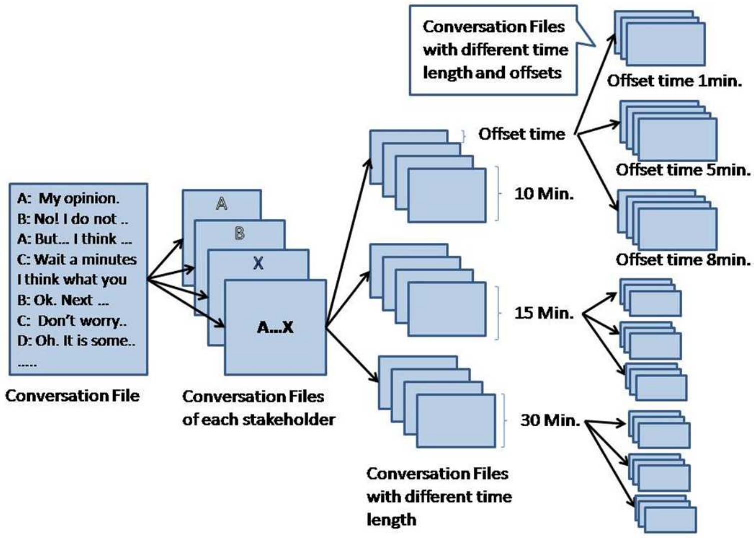

Figure 3.3: Conversation files of the KEV system.

3. Assemble all XML graph data (figure 3.4).

4. Load and read XML files, and map key expressions in order to display previously shown nodes at fixed coordinates.

5. Visualize transitions of the co-occurrence relations as output.

The KEV system incorporates a morphological parser, Chasen version 2.3.3, which is mainly used for Japanese language analysis, and a co-occurrence visualization function of Polaris 0.18 alpha [Okazaki and Ohsawa, 2003]. These visualization functions calculate the co-occurrence of key expressions at each time point for each participant. Two key expressions co-occur if they both are mentioned in a sentence. We use the *Jaccard coefficient* [Jaccard, 1901, Tan et al., 2005] to meassure co-occurence. Let $\mathit{Freq}(X)$ and $\mathit{Freq}(Y)$ denote the number of times that key expression X and Y appear in a document. Further, let $\mathit{Match}(X, Y)$ denote the number of times that X and Y co-occur in the document. We then have

$$\mathit{Jaccard} = \frac{\mathit{Match}(X, Y)}{\mathit{Freq}(X) + \mathit{Freq}(Y) - \mathit{Match}(X, Y)}.$$

Thus, basically the co-occurence of X and Y is the fraction of sentences in a document where both X and Y are mentioned.

In the last step, the KEV system visually shows the transition of co-occurrence relations among key expressions in a graph structure. In this graph, each vertex represents a key expression while an edge represents co-occurance between two key expressions. An example of a co-occurrence graph for a single participant at a particular point in time is shown in Figure 3.5. The Kev systems allows many ways to draw the graph. In the Figure, black

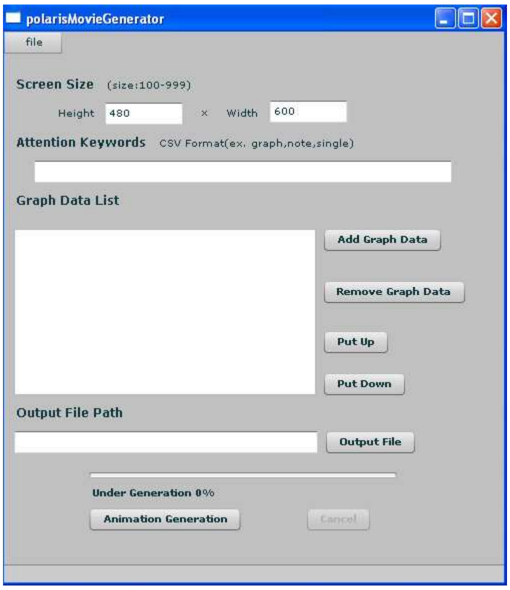

Figure 3.4: Input data interface of the KEV system.

vertices represents frequent words while red vertices represent less frequent words. The co-occurrence graph will be elaborated in the next chapter together with ethnographical analysis.

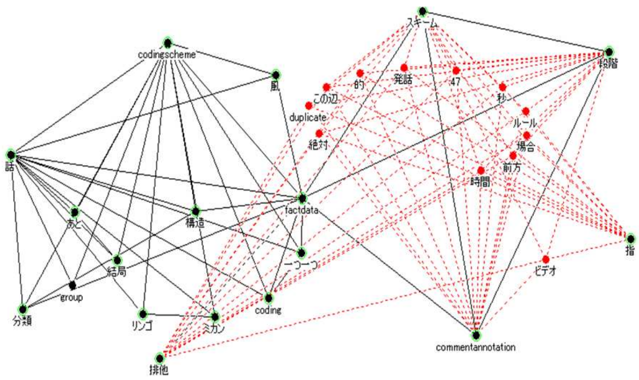

Figure 3.5: An example of a co-occurrence graph of the KEV system for a single participant at a particular point in time.

Analytical issues of the KEV system

There are several issues to consider when formatting conversation files and calculating co-occurrences in the KEV system. In particular

1. How is a conversation file defined?

2. Is the Jaccard coefficient an appropriate data mining method for conversation?

Conversation has unique characteristics such as *redundancy* and *repair* [Schegloff, 1991]. Thus, conversation analysis is different from conventional documents analysis for which co-occurrence data analysis is applied. In occurrence analysis of documents, the documents are often divided statistically mainly based on the topics [Akaishi et al., 2006] and the distance between the documents is then calculated. Conversation data on the other hand, is often divided into segments through qualitative analysis [Matsumura et al., 2003] and statistical methods are rarely applied. Osawa [Ohsawa et al., 1999] suggests to define a conversation file as a single sentence with punctuation. This, however, makes it difficult to calculate co-occurrence since sentences often are too short to identify a co-occurrence rate. As a solution for this, first we can imagine using a concept dictionary which transforms, for example, both CAT and DOG to ANIMAL, but this will generate critical issues in which the ability to distinguish ontology differences can be lost. Another possibility is to use a whole utterance of a person A as one sentence, but unfortunately this means that the whole utterance of A implicitly is regarded as correlated. Currently, there is no ideal method to segregate conversation data through quantitative analysis. For that reason, as a pragmatic solution, the KEV system is able to choose division units of conversation data arbitrary (in Figure 3.2, users can manipulate segments in the control bar). The reason for this function is to improve validity of the analysis results by making it possible to try out different data sets with different data segments.

Regarding the second issue, there are several ways to calculate the coefficient. To name a few, match coefficient, dice coefficient, overlap coefficient, cosine coefficient, and dependent coefficient [Tan et al., 2005]. Match coefficient is very convenient, since it is based in the inner product of the expression vector. However, it will not show the occurence rate. Moreover, the match coefficient will not have a limited codomain which is hard for users to comprehend. Other coefficients including the Jaccard coefficient, limits its codomain to $[0, 1]$. Besides, the Jaccard coefficient is the fraction of sentences containing both key expressions among sentences containing either key expression, which is a quite suitable meassure of correlation in conversation.

To fulfill our analysis objective, it is reasonable to investigate several of the calculation methods mentioned above.

Lastely, it may be important to mention. The objective of this analysis is neither to define general key expressions nor to design a visualization system for conventional use, but instead to shed light on how people discuss, negotiate and agree by investigating usages of key expressions as a suppliment to the findings of empirical investigations. As a part of our mixed method, conversation protocols are investigated statistically. Clearly, the intention of this is not to limit the range of our targeted external investigation only to conversation protocol data. On the contrary, other kinds of multimodal representations such as figures drawn on white boards, distributed documents, models, and repeatedly used body language are also key external representations and can be targets for empirical analysis.

3.3 Reflections on Mixed Methods

This chapter has described our mixed method approach. First, a general concept of mixed methods was introduced, and then our stance on mixed methods and further details of the qualitative investigation and quantitative approach, we take in the thesis, were explained. In spite of the critique of mixing several different paradigms of methods, we deploy mixed methods mainly for pragmatic reasons. We consider this legitimate due to the clear advantages for what this thesis aims at investigating. In this section, we reflect on our chosen methodology.

Ethnomethodological inquiry in our qualitative investigation enables us to grasp a complete collaborative environment where professionals interact, while statistical conversation analysis can support one part of the ethnomethodological observations with quantitative inductions. In short, by utilizing this mixed method, we manage to illustrate enough verification of communicative processes in collaboration, showing how language is used, how words and expressions interplay in each professionals utterance, and how microscopic conversational interaction proceed.

We have found that it has been advantageous and fruitful to apply a mixed method in our field cases. It has shed light on more aspects of collaboration and areas of communication than we believe any single method could do.

For example, quite a few ethnomethodological approaches have shown convergence of words, expressions and concepts in communication (e.g., [Roschelle, 1992]). However, such findings of convergence of words and reification of expressions in a group have been supported only by qualitative investigations, and no quantitative data have been used to indicate such convergence of words. All the more, combined evidence of statistical and empirical data has to our knowledge not been reported. We argue that single evidence from either empirical investigation or statistical analysis is too weak to achieve the results and discussions that we do in subsequent chapters, which we consider a strength of our mixed method.

However, there are also potentially negative effects of applying our mixed method. One worry is the shortage of work applying mixed methods. In spite of its advantages, its negative connotation has caused it only to be applied in a limited number of cases including educational and social program evaluation, medicin, and cross-cultural studies. The number of applications is not large enough to have absolute validity and form a method to tolerate various conditions. Thus, it is not difficult to anticipate there is still much room left to argue, modify and improve its methodological frame, development of approach, and so forth.

Our contribution to mixed methods is to show that some areas and purposes of investigation such as our cases can benefit from the approach. This is definitely crucial for the practice of using the method. However, it is too early and not necessarily true to conclude that mixed methods fit to a wide variety of cases. Some might need profound affirmation of the diverse influences of qualitative and quantitative parameters before applying a mixed method especially if the mixed method is intended to treat qualitative and quantitative approaches evenly.

Chapter 4

Five Case Studies

The five cases introduced in this chapter appears to be varied in settings, styles, taken methodologies and challenges at the first sight. However, our view is different. They are similar in a way they engage in early design, highly specialized and short-term projects with either ethnic or work cultural differences. Also, they are similar in a way that they suffer ontological drift in collaboration. We admit the five cases have variant challenges. In spite of that, by viewing communication in collaboration from one identical ontological drift perspective, the different five cases can spell out core aspects of collaboration among professionals, thus provide us not only profound but also enough abstract understanding to grasp a holistic view of certain kind of collaboration.

We present our five case studies (see Figure 1.2). The first case *Analysis software design* [Yasuoka et al., 2004, Nakakoji et al., 2004, Yasuoka, 2006] and third case *Intercultural collaboration experiment (ICE)* [Nomura et al., 2003b, Nomura et al., 2003a, Yasuoka et al., 2003, Yasuoka, 2003] case study consider software development by professionals in software design domains. The second case study *Carlsberg landscape design*, the forth case study *Copenhagen building renovation* [Yasuoka, 2007] and the fifth case study *Svane illuminated sign* deal with collaborative design processes in landscape design, architecture design, and illumination design, respectively.

The software design case and the Carlsberg case are conventional collaborative design cases with only a little computational support, while the others are facilitated by computational artifacts through the whole collaboration period. The focus in these five empirical investigations are on their communication process focusing on ontological drift, utilizing external representations to observe interactive environments.

When conducting our empirical observations, we usually placed a chair in the corner of the meeting room or next to the target collaborator's desk. In the empirical observations, we took either *participating observer* or *observing participant* as the model of observation [Gold, 1958]. During observations, memo and photos were taken and artifacts that participants would use during the collaboration were collected. For several cases, only when it was approved by the attending stakeholders, conversation protocols during the collaborative meeting were recorded and video-taped. They were used in statistical conversation analysis to complement the qualitative investigations. In the software design case, we had full access to detailed conversation data, so the mixed method approach that applies empirical and statistical conversation analysis was introduced in a complementary purpose. Questionnaires and interviews were also used in the software design case, the renovation case, and the Svane case.

4.1 Case 1: Analysis Software Design

4.1.1 Background

One of the five empirical investigation cases deals with the initial phase of a collaborative software design process. Professionals with different work knowledge backgrounds discussed what software design to choose in order to deliver a computational analysis tool for academic researchers.

Participants

The stakeholders were four in total. There was no change of members during the whole collaboration period. The members were two professional programmers, one interaction designer and one client. The two programmers worked as software designers in the same software company. One of them (Asada) had six years experience, while the other (Nishimoto) had 15 years experience in the software design field. Asada had little experience in joining projects outside his company, while Nishimoto had several experiences with internal as well as external projects with other companies. Nishimoto also had led several previous projects as a project manager. The interaction designer (Yasu) had a computer science background and profound software design knowledge. Yasu worked as interaction designer for two years. So, although his job title was software interaction designer, a large part of his knowledge was those of a computer scientist. The client (Kurakawa) was a software architect researcher. His research was about software design. Thus he had fundamental knowledge about software architecture. Still, his practical software design as well as programming knowledge was limited compared with the other three professional practitioners. All of them knew each other since they had already worked together for the same client's project for a different system one year earlier. Japanese was used as a common language since their shared mother tongue was Japanese.

Project background

The system to develop was a computational tool for statistical protocol analysis for academic researchers. The dialog started when Kurakawa asked a company to design and build a computational tool to minimize his work load on statistical protocol analysis.

Kurakawa is a researcher working at a Japanese university. He analyzes video material as a part of his research. He records video for the targeted activity, transcribes data and analyzes it. First he transcribes the targeted activities in digital files (Excel files), while watching video. Then, he conventionally analyzes his *protocol data* manually using separate software and systems. In the analysis phase, he first adds tags to protocol data that he has transcribed to excel files by hand. He calls these tags *comment annotation*. After having a set of data with comment annotation, he analyzes the data statistically using a software tool. In this statistical analysis, he uses a *coding scheme* created based on the comment annotation.

His request to the programmers was to build a support system for his statistical protocol analysis incorporated with functions that met his needs, such as a function to add comment annotation while editing data and to generate a coding scheme semi-automatically based on the comment annotation he had added. There exists software tools for statistical analysis. Their provided functions, however, were insufficient for Kurakawa's research purposes. The main problem was that since conventional statistical analysis tools only had functions for statistical analysis, Kurakawa had to move from one software system to another during the data analysis, which disturbed his analysis process. What he expected from the new analysis software tool was a coherent frame for several analysis processes. Thus, the new system should have functions for both protocol analysis and conventional statistical analysis.

4.1.2 Analysis Method

We deployed the mixed method described in Chapter 3. It consists of a combination of field observation as ethnographical inquiry (see Section 3.2.1) and statistical conversation analysis (see Section 3.2.2). Statistical conversation analysis is used as a complement to the qualitative investigation. Several statistical analysis tools were used for the statistical conversation analysis: Chasen [Matsumoto, 2003] is used for Japanese morphological analysis, popout prism developed by PARC [PARC, 2002] is used for conversation visualization, Polaris [Okazaki and Ohsawa, 2003] is used for occurrence relations of conversation, and the KEV system is used to visualize occurrence relations of conversations over time.

In our empirical approach, four meetings out of five were covered and the collaborative process was investigated from a practice and social process point of view. Their collaboration falls in the category of early design and design development process. After the design development process, the programmers worked separately which was not covered empirically by our study. The model of observation taken is *observing participant* [Gold, 1958] where the observer is not participating in activities or intervening in discussions but attends meetings as a pure observer. A single observer occupied one corner at the discussion room so that all conversations and movements were covered. Gestures, activities and artifacts on the table were observed without disturbing participants' activities. Video-taping, voice-recording were also conducted and five photos in total were taken in order to record drawings on the whiteboard made during the meeting (e.g., see Figure 4.4 and 4.1.3). In addition, notes were taken during the meeting for recording significant events. Soon after the meeting, the notes were translated and transcribed. In addition, 12 hours conversation was transcribed for analysis purpose.

In the statistical conversation analysis see in Section 3.2.2, the 20 most frequently used expressions were extracted from the conversation protocols as external representations and their transition was visualized among the whole group and each participant. These 20 *key expressions* were: label, concept, coding scheme, protocol analysis, segment table, group, verbal, comment, annotation, viewpoint, description, note, fact data, tree, semantics, concept (Gainen in Japanese, as from here, J), Apple (Ringo, J), Orange (Mikan, J), Tree (Ki, J), Abstract (Gaiyou, J), Point of View (Shiten, J).

First the 12 hours of transcribed conversation was analyzed with the morphological parser for the Japanese language, Chasen [Matsumoto, 2003], that categorized each morpheme. The output from Chasen was filtered and separated into nouns, verbs, adjectives and other expressions that were omitted from the expression list. After that, the frequency of each expression was calculated both for the total conversation and for each participant. Next, the transition of the number of usages of each key expressions was analyzed and visualized with colors using Popout Prism [PARC, 2002] (see Figure 4.1).

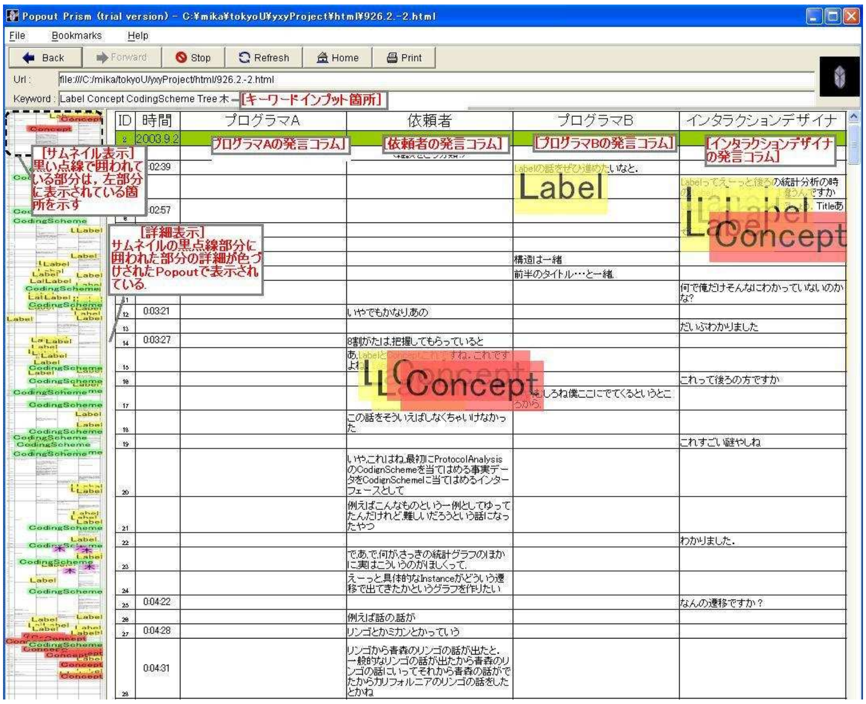

Figure 4.1: Example of Popout Prism result on the conversation data.

Different key expressions are emphasized with different colors in Figure 4.1. In this example, the key expressions *label* and *concept* are shown in popout style colored yellow and red, respectively. In the left column, the whole view of the conversation at a certain time is displayed.

Co-occurrence relations among key expressions over time were also calculated and visualized in a graph structure based on the co-occurrence calculation results (see Figure 4.2), using Polaris [Okazaki and Ohsawa, 2003] and our original analysis system, the KEV system (More details about the KEV system, see 3.2.2).

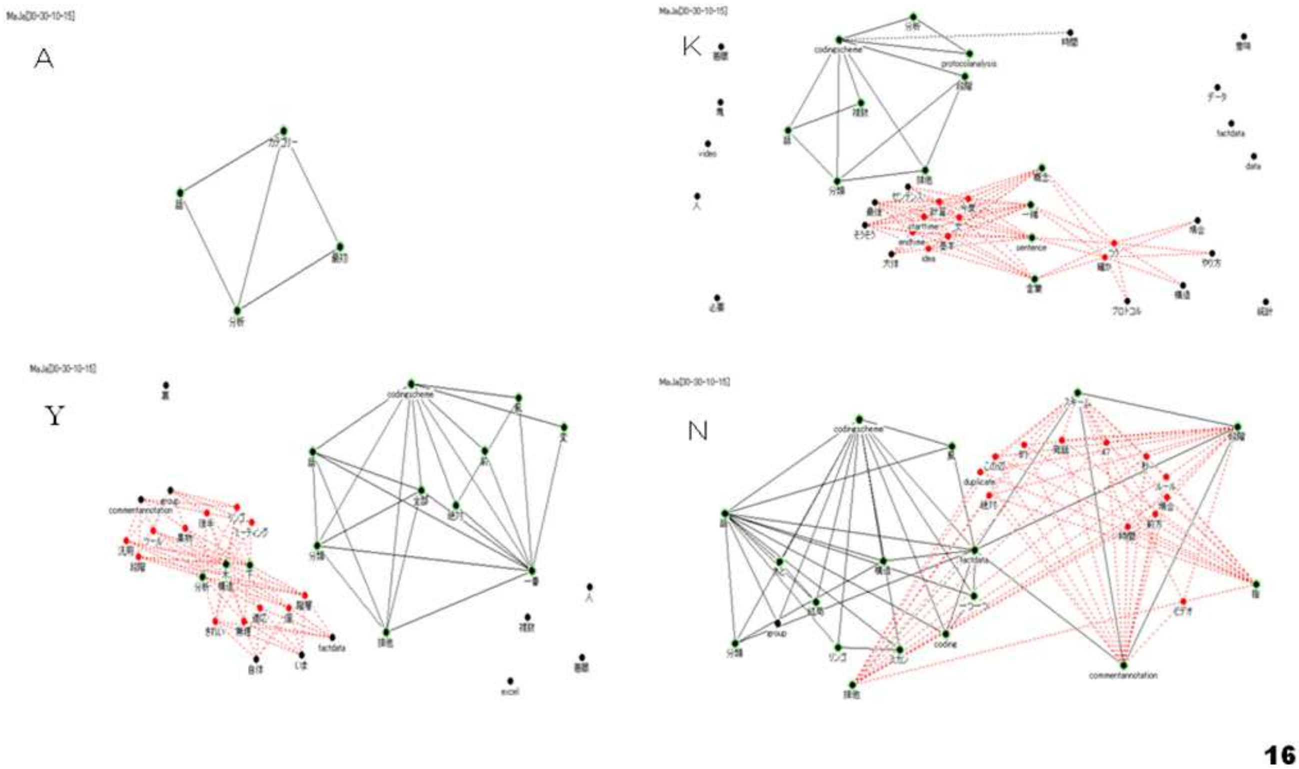

Figure 4.2: Visualized keywords relation.

4.1.3 Case Details - Observation

Four collective general meetings were made from the middle of October 2003 to November 2003. The first two meeting were held in the interaction designer's office in Tokyo. These meetings were half-day meetings each and there were a few days between them. The other two meetings were held at the clients office in Nara. These two meetings were held in a row taking a full day each. The purpose of the first meeting was to outline the requirements of the client. Based on the first meeting, designers and programmers asked questions in the second meeting and tried to confirm their understanding of the requirements. In the last two meetings, the functions of a demo system were shown to the client based on the programmers' understanding of the task from the previous meetings. The programmers redesigned the demo during meeting breaks and presented their new demo versions. After these four meetings, no further collective meetings were held. The requirement discussion and the interactive collaborative meetings were over. After that each professional, worked independently. The system was delivered to the client a month after the last meeting.

The first meeting

The first meeting was held on the 26th of September. All four members attended the meeting. This was the second meeting for them since they had already had their first meeting before the observations started. In the first meeting, they agreed to actually develop a system. Since they knew each other from a previous project, they did not have to introduce themselves. They knew who each other were and, roughly what each participant's background was. Each member brought his computer, pens and notebooks to the meeting. There was a whiteboard at one corner of the room that they could draw on using four color markers. They were seated around one table. The table was large enough for everyone to have a seat. Each had enough space for his computer, pens and paper. At the same time, the table was small enough for all to see the whiteboard clearly and for members to look at any computer screen from their own seat.

Collaboration flow

First, Kurakawa explained the protocol analysis process, using his previous research data. He explained in details about his method for depicting and describing protocols and the analysis of his video data. Kurakawa started his explanation by describing, how he would analyze and understand his video data. His first step was to edit comment annotations while watching video, and make a coding scheme based on the comment annotations. Since the other members looked confused, Kurakawa explained how to make coding schemes by using a metaphor based on the fruits apple and orange.

When Kurakawa explained the coding scheme using this metaphor, Yasu who looked puzzled questioned the definition of coding scheme (1-1). After a short discussion, Kurakawa explained that "a coding scheme remains unchanged while analyzing data". Then, Yasu stopped questioning. Kurakawa kept explaining what a coding schemes was by showing Excel files. He explained by relating a coding scheme to fact data. "Fact data could be transcribed in excel files and these data would be related to a coding scheme". Yasu and Asada "understood how difficult it could be".

Kurakawa also mentioned that a coding scheme was applied to a chunk of conversation, or category. According his explanation, the minimal unit for a coding scheme was a sentence. Then, Yasu questioned again, how data could be separated. They discussed this topic for a while since from the programmers' point of view, "data should be exclusive" (1-2). They discussed whether a coding scheme could be drawn as a tree structure. Kurakawa thought it was a difficult question because it was a matter of what a coding scheme really was. Then, they started to discuss a little about semantics, the meaning behind the expressions (1-3). They took a break after that.

After a short break, Kurakawa explained his analysis process again. First, he transcribed protocols from video data. While transcribing protocol data, he would add comment annotations that interpret the data (e.g., what it really means and what really happens). After editing comment annotations, coding schemes were created (1-4). Yasu questioned how the data was divided (1-5) and Kurakawa explained the classification methodology of protocol analysis (1-6). Kurakawa continued to explain the process of his analysis, showing how data in Excel files converted to graphs (1-7). Then they took another break.

After a second short break, they dicussed two different concepts, label and group. They were keywords according to Kurakawa because he would like to check how each instance would transit over time. Then, again, Yasu questioned how he would like to classify the data and what the relation were between the coding scheme and the concepts label and group (1-8). Kurakawa defined the meaning of label and explained "we apply a coding scheme and put a label to understand the meaning behind the expressions" and "by analyzing, I would like to clarify how the meaning behind the expressions would transit". Then, Kurakawa ended his explanation of the analysis process.

Next, Kurakawa explained his system design image and described which functions the system should provide. In reaction to his suggestions, the programmers mainly questioned details, or gave their opinions. He expressed his wishes like "When the user adds transition data, the system should change colors and sort data". Then, Nishinaka asked what kind of configuration would be needed. After a while, they again were back to the discussion of the analysis process. They discussed the definition of expressions expressed iteratively in conversations such as concept, meta-concept and label (1-9).

Kurakawa explained the process again. "Comment annotations are described from fact data, and comment annotations are used for making a coding scheme". In spite of Kurakawa's repeated explanation, Yasu still had trouble understanding the concept. Yasu questioned the process again, trying to relate frequently used-expression such as comment annotation, coding scheme and so forth as if he clarified each analysis step (1-10).

They discussed how to use and apply a label to data. Kurakawa explained that a label would be used to understand fact data. "This is one of the processes the system should support". Since Yasu did not understand what Kurakawa wanted, Yasu started to explain why he did not understand it using his own words. From his point of view, "If the number of attributes increases, the number of coding schemes would also increase" (so that what Kurakawa said was impossible). However, this time, Kurakawa did not understand Yasu. For him, "it is important not to need to apply a label without a coding scheme. A coding scheme should be generated before applying a label to data" (1-11).

Since their conversation did not reach an agreement, they switched topic back to design. They started to discuss interface design. However, Asada and Nishinaka suggested stopping the meeting since "it was very difficult for them to imagine how the design should be in the latter half of the analysis process if they did not understand how each function was related". Yasu agreed that the "computer system design was largely influenced by the programmers' point of view" (so, without the programmers' understanding, the usability of the system would not be appropriate). They agreed to have the next meeting three days later and they decided that next discussion theme should be *design*.

How they collaborated

The meeting had clear structure. The discussion was mainly made using explanation, question and answer where the explanations and answers came from the client, while questions came from the interaction designer and the programmers. Kurakawa prepared material on his laptop and often initiated the discussion. He explained his research process, the protocol analysis process, and his needs. He suggested his ideas about how the computer system could be designed.

A typical pattern of conversation was that Kurakawa first explained a part of his work process (analysis process) to the others. Yasu often intervened into Kurakawa's explanation and asked questions. Asada and Nishinaka often jointed the discussion by commenting, agreeing, refuting or stating their opinion and understandings. Many questions made by Yasu were constructed with the purpose of repetition and confirmation of what Kurakawa had explained in Yasu's own terms and expressions.

In this meeting, the main external representation used for collaboration was oral conversation although Kurakawa explained his work using derivertives of computational artifacts such as his video data, transcribed raw data and Excel data shown on the computer display. While the four professionals were discussing what kind of data should be input and what kind of interface design should be applied, they drew data structures and rough designs of the system architecture. However, the use of non-conversational external representations was very limited.

The second meeting

The second meeting was made in the same room on the 29th of September. All four members attended. They did not bring anything special except their computers, pens and papers. There were whiteboards and color markers to write with as at the previous meeting.

The programmers and the interaction designer had digested their understanding of the system and brought their own ideas based on the explanations and suggestions made by the client at the previous meeting. At the second meeting, the programmers and the interaction designer led the meeting and asked questions to the client in return. The client answered how he expected the design should be, and agreed on listed requirements for the software architecture. They also negotiated the meaning of expressions consciously including expressions they had difficulties understanding at the previous meeting.

Collaboration flow

First, the professionals reviewed the discussion of the previous meeting. During this review, one of the key expressions, *coding scheme* triggered a concentrated discussion. They initiated the first discussion for the purpose of defining the usage of coding schemes. They agreed that it should be possible to edit coding schemes and create new coding scheme even after analysis. Thus, the edit function for coding schemes should be turned on almost all the time in the interface (2-1). The next discussion during the review was about the definition of fact data. One challenge they had was to answer whether fact data would be fixed, and if so, when (2-2). After that, they discussed template layout led by Yasu. These discussions did not end in disputes and after summing up the review they had a break.

After the break, they moved to discuss a function called *notes*. They confirmed the role of notes, and its possible design layouts. During the discussion, Asada commented that the terms used in their discussion seemed to be incoherent (2-3). For that reason, after summing up the current discussion, they started to define terms that confused them, such as *group, category, label, coding scheme, syntax*, and *design, concept*.

How they collaborated

This meeting had also clear structure. The discussion was mainly made with questions and answers; questions from the design and program perspective and answers from the client side. All members joined in question-answer dialogs. When one person made a questioned, the client answered. The others also often stated their opinion or mentioned another point of view. Each participant clearly had his own angle to the meeting. Kurakawa answered questions from his analyst point of view, while Yasu, Asada and Nishinaka tried to grasp an overview of designing the system.

In the first meeting and the first half of the second meeting, many discussions about definitions were observed. However, they were spontaneous and unstructured. The discussion about definitions started in the middle of the question-answer dialogs. As a consequence, the discussion about definitions tended to have no clear agreement and ending. They often moved back to the original topic when they felt that a solution had been found. This is understandable since many questions toward definitions were triggered by other issues. To clarify a definition was not the only point when questions forced them to be discussed. However, in the latter half of the second meeting, although it was not a long period (about 30 minutes), participants consciously decided to discuss the definition of each key word.

In this meeting, participants discussed semantic matters in addition to design suggestions which was the core topic of the second meeting. Their tool for collaboration was mainly oral, using Japanese language. Even though they had many confusing discussions, they did not make any drawings or any other supportive representations other than oral expressions. There was no clear attempt to try to externalize concepts into tangible materials at this stage.

The third meeting

The third meeting was held at Kurakawa's office on the 20th of October. The previous two meetings were held at the interaction designer's office, while the remaining two meetings were held at Kurakawa, the client's office. The meeting room had changed but the office design was not that different from the previous meeting room. There was a table and chairs, and participants had a seat around the table. This time the programmers prepared a presentation in order to show their suggestions. There was a projector in the room in addition to their conventional tools: computers, pens, papers and whiteboard with markers. To explain functions that the programmer had designed, projectors and connected computers were used. The screen was placed in one corner of the room where every body could see the projected pictures without problems. The whiteboard was placed just next to the screen so that professionals could see both the whiteboard and the screen at the same time.

In this meeting, participants started to review the previous meetings and each reported their own activities and progress for the project. The main topic of this meeting was to present a demo that the programmers had prepared. The programmers explained the functions using the projector and their computers. Then, the client asked for more functions to be adding by specifying the requirements in detail. They discussed which additional functions they should add, and confirmed their suggestions.

Collaboration flow

First, the participants reviewed the discussions of the previous meetings. Then, each member reported their own activities and progress for the project. Next, the programmers explained their design rationale for the demo. They explained the framework of the demo system structure. The programmers showed the demo and its behaviors in general. Each implemented function was explained, following Kurakawa's analysis process. They also mentioned possible manipulations of each function, which could be implemented if needed by the client. Either Asada or Nishinaka explained the functions while the other operated the demo system. Kurakawa sometimes intervened in their explanations and asked questions. Asada and Nishinaka often confirmed the functions to each other in order not to skip introducing any of the functions they had created.

After a while, during a discussion about *notes*, Asada asked Kurakawa.

Asada	:How do you want to use *notes*?
Nishinaka	:Aren't they used in the final stage of analysis? Do you have any requests on how *notes* should be?
Asada	:Why don't we name (the function) *notes*?
(Conversation 3-1)	

They discussed a specific function called *notes*, however, they sometimes got confused about what they were talking about. One reason was that notes also could be a general term. After a while, they agreed it was important to differentiate between the function *notes* and the activity of making notes.

Related to the discussion on *notes*, a conversation about *concept transition* was observed. Kurakawa used terms such as *concept transition*, *transit a concept*, *concept will shift* while showing visual figures on the display. The other participants sometimes got confused about whether he talked about figures or the state of a concept. At one point, Asada suggested to call the visual figures that show how a concept transition for *concept transition* figures (Conversation 3-2). After that they used this term. It also became a name of a function that would pop up in the display after analysis.

When they discussed an additional function for showing video files , Kurakawa asked, Kurakawa : Is it possible to show video files while I am working on *comment annotations*? I mean can the display I see on my computer be incorporated as a function in the system or not?

(Nishinaka Instead of answering, Nishinaka searched the website and showed a screen-shot on the projector screen connected to his computer.)

Nishinaka : Is your image like this?

(Nishinaka Nishinaka showed the function he imagined it would be from Kurakawa's explanation by using a web resource.)

(Conversation 3-3)

Kurakawa could not express the detailed functions to Nishinaka. However, Nishinaka could search his almost exact image of functions from the Web. Nishinaka knew the keywords to search for them and could show the functions graphically without using oral expressions of programmers such that Kurakawa could understand him. Nishinaka and Asada discussed possible ways to realize the function. After that, they decided to have a short break.

After the break, the programmers continued to explain the functions in detail. The programmers explained the flexibility of the interface that made it possible for the user to decide which pictures could be shown. Then, Kurakawa asked whether it could be shown as a tree structure. Kurakawa explained how he wanted the interface to be. In return, Asada and Nishinaka described the possibilities by showing mockups on the projected screen,

Kurakawa : Could it be shown like a tree structure?

Nishinaka : Is your image like this?

(Conversation 3-4)

They kept discussing how to show the data as a tree structure for a while. Next, Kurakawa suggested one additional function. Then, Nishinaka asked,

Nishinaka : What was the name (of such s function) again? Was it *graph*? Was it *notes*?

Kurakawa : It could be called *concept*.

Asada : It should be *note*, shouldn't it? Aren't we talking about one *note*?

(Conversation 3-5)

The definition of *notes* was supposedly confirmed earlier. However, the same kind of discussion were made in relation to another conceptual function,*concept*. When Kurakawa suggested another function, Nishinaka together with Asada expressed their disagreement as they did not understand why the client needed the function. Kurakawa tried to explain, but neither Nishinaka nor Asada could get the point. After a long discussion, Asada said,

Asada : I thought each note would be used only one by one. (I did not think several notes could be used at one time).

Nishinaka : We need to define concepts and name functions, otherwise we cannot move forward.

(Conversation 3-6)

They discussed the concept that each function was associated with and named these functions as well.

Nishinaka	: What do you think about *Temporal Distribution Map, TDM*? Since we want to see the temporal distribution not the spatial one.
Asada	: It should be little more precise because there are semantic differences in one word. We need to differentiate it from other functions.
Nishinaka	: So, *Note Temporal Distribution Map, NTDM.*
Kurakawa	: Yes, *Note distribution map* could be fine.

(Conversation 3-7)

They continued discussing several vague expressions. In some cases, their dispute could not reach agreement and terminated.

Asada	: I think *category* should have hierarchical structure.
Kurakawa	: There is no hierarchical structure, but it has *view point.*
Nishinaka	: I think it is just a matter of expression.

(Conversation 3-8)

Even after a long discussion on the definition of terms, the participants could easily get confused about how to use them. They decided to take a break. During the break, the programmers started to repair and develop new functions. As the programmers decided to continue development of new functions, the meeting of the day ended.

After the meeting, Asada made a note and distributed it to the other members on the same day of the meeting. Asada's note described each module of the system. Each module had the names of its functions and a description of how each function would work. In addition, there was a list of questions and a to-do list for each member.

How they collaborated

The structure of the meeting was as follows. The meeting was preceded by, first, an explanation of the function of the proposed software system. The client intervened into the programmers' explanation and questioned several functionalities. Second, in the middle of the explanation, the members started to discuss the definition and names of functions. This activity to give functions names was a new approach for the members. In this meeting, they clarified definitions of the terms they had used both consciously and unconsciously in the previous meetings. In addition, they discussed functions and gave them names and reflected on their behavior. Since they intentionally named functions, they could refer to names of functions rather than referring to the behavior of the functions, and they often did.

The role of each participant was very clear. The programmer Nishinaka and the interaction designer Yasu often played the role of interpreters when the client questioned or explained a new idea, or when Asada, the other programmer tried to explain a function they had developed. The client Kurakawa kept suggesting new functions as a user without considering any technical limits. On the other hand, the programmers proposed possible approaches grounded on their computational knowledge.

In this meeting, the collaboration of the participants was often facilitated by computational artifacts including computer and projector screen. Everyone watched the activity shown on the screen while the programmers explained functionality and the client asked questions. Their collaboration tools were mainly oral conversation, and peripherally the demo and pictures shown on the display. Participants sometimes stood up and approached the display and pointed to the screen with reference terms (such as *this, that.*) when they discussed functions. The ability to point something out was very functional for them because sometimes it was hard to name the functions of the system. As previously mentioned, the names of the functions that they intentionally had created were utilized most frequently while discussing.

One of the outstanding challenges of this collaboration was conceptual ideas and their realization in system functions. The reason for this was that some of the functions that the programmers had developed and some of the activities the client would describe had no clear identifiable names. For that reason, they were often forced to use reference terms (e.g., this or that) when they talked about ambiguous functions and concepts. They endured this situation for a while. However, in the middle of the meeting, they began to create their own unique terms consciously. They explicitly mentioned that they needed names for each function as well as concepts, suggested candidate names, and gave a name to each function. There was a tendency that the clearer a function was defined, the more the function needed a name. However, until the end of the meeting, conscious as well as unconscious discussions of namings were continuously carried out.

The forth meeting

The forth meeting was held in Kurakawa's office the next day on the 21st of October. The meeting room was equipped as the previous day. As in the last meeting, they often used the projector while explaining and discussing.

Collaboration flow

The programmers brought a rebuilt demo system to the meeting based on the refinement suggestions made the previous day. The professionals continued the discussions from the previous day mainly about what kind of functions could be added and how current functions could be designed better. The programmers worked over night and managed to show rough refined ideas of what had been suggested the previous day.

First, the programmers showed the newly added functions. However, before explaining any details about the new functions, they decided to go back to the point where the last meeting ended. They started to discuss what kind of functions could be added or refined. In the discussion, Kurakawa suggested to use a special icon for the tree structured index and add space to write definitions of them. They discussed for a while how to realize the function. While discussing functions and names, the definition of *label* was brought to the discussion table again. Even after several discussions and the supposedly settled definition of *label*, it still could be a problematic expression.

Kurakawa : This *label* should be...
Nishinaka : In my understanding, this couldn't be *label*.
Kurakawa : But in relation to this (point out drawing), it is *label*.
Asada : What? This has no relation to *label*
Nishinaka : Yes! It is an important point.
(Conversation 4-1)

After discussing for a while, Nishinaka suggested to give a name to a particular concept.

Asada : This name, why don't we change it to *grounding table*?
Kurakawa : Well.
Asada : How about *coding category table*?
Kurakawa : I think *coding category table* sounds a little weird. They are called *segments* instead of *categories*.
Nishnaka : Ok, let's call it *segment table*.
(Conversation 4-2)

This kind of naming activity of a concept continuously occurred. By this time, when they created a new function equivalent to a particular concept, they also created a new name to the function with a clear intention.

The participants often discussed details about each function in this fourth meeting. When they discussed about the structure of a *segment table*, which had a quite complicated structure, Nishinaka started to draw on the whiteboard. Nishinaka talked while drawing.

Nishinaka : Is this function like this?
Kurakawa : Yeah, it might be so.
Nishinaka : I think you want to proceed like this when you add data, but you want to see it like this when you analyze.
(Conversation 4-3)

Drawing on the whiteboard happened occasionally but not often. While using whiteboard, they used reference terms (*this, that*) by pointing the whiteboard. After several discussions about functions, they reviewed the system by following the analytical process. Participants discussed concepts such as *fact data, coding scheme, view point, segment, coding category*, and functions such as *coding scheme editor*. During the discussion, there was no clear breakdowns due to ontological drift among the participants.

After taking a short break, Asada drew a pie graph on the whiteboard (shown in Figure 4.4) and explained how he understood *segments* since this was a concept he still was puzzled about how to implement. The two programmers, Asada and Nishinaka, mainly discussed structure using the whiteboard (shown in Figure 4.1.3), and Kurakawa sometimes intervened and commented. Although Kurakawa commented sometimes, he kept silence while Asada, Nishinaka and Yasu discussed together. One reason was that their discussion became very technical and detailed so that it was hard for Kurakawa to join it.

After a while it seemed like they had discussed almost everything they wanted. The programmers explained what they could do with the current technology and their skills, while the client suggested what he could imagine. After this, they ended the final meeting.

How they collaborated

The meeting had less structure than the previous day. Largely speaking, they expressed their opinions spontaneously when they got an idea rather than carrying out an organized discussion. They reviewed functions and concepts they confused about earlier together. The confusion over expressions happened less in the fourth meeting than in any of the previous meetings. Rather, the participants seemed to use expressions quite carefully, explaining them by relating to functions and other concepts.

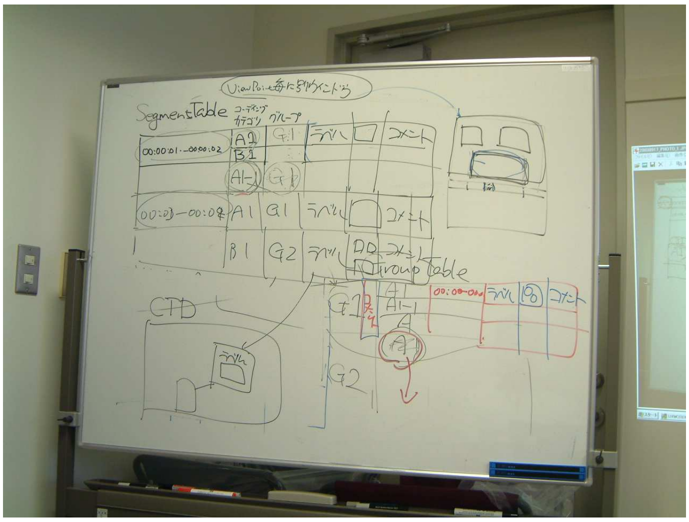

Figure 4.3: Design idea of one function *segment table*.

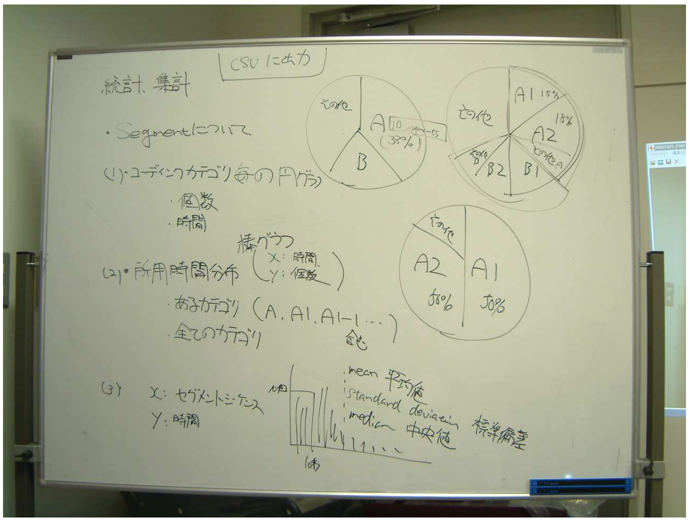

Figure 4.4: Pie chart explaining segment.

The whiteboard was also used to describe the programmers' understanding and support their discussions. One drawing was the structure of a *segment table* which showed which functions could be called when the *segment table* was open (see Figure 4.1.3). The other drawing showed the participants' discussion about how statistical analysis was made based on the segment that users would make (see Figure 4.4).

The drawings were used for discussions between the programmers, and they were difficult to understand for the client. However, the client sometimes asked questions about the structures while they were drawn on the whiteboard. Putting it another way, even though the written language that was used on the whiteboard was only partially understood by the client, the client could join the discussion by pointing at expressions on their drawings.

In this fourth meeting, participants collaborated occasionally facilitated by computational artifacts including computer and projector display. They often discussed together, watching the screen of the projector. There were not many new concepts they had to define, since what they needed to fix in this meeting were small details of functionalities.

4.1.4 Analysis of the Collaboration

In this Section we analyze the collaboration process of the case study. The analysis focuses on communication aspects based on the mixed method utilizing ethnographical investigation (see Section 3.2.1) and statistical conversation analysis (see Section 3.2.2). In the statistical conversation analysis, the KEV system, which was developed specially for our work, was deployed. We briefly review several analytical aspects *including distortions, communication modality, strategies for handling breakdowns, and creation of words, expressions and sentences*, related to the problem of ontological drift (see Section 2.3.1) and its handling.

How did they collaborate?

This empirical investigation case has covered from the beginning of the software design phase to the design development phase just before the implementation of the system. Through the whole period, the participants worked intensively and collaboratively in a co-located setting. They dispersed after the fifth meeting and developed functions of the software separately in a distributed manner. This latter part of the collaboration is not covered by our investigation.

Distortions

Misunderstandings caused by ontological drift rooted in work cultural differences were often observed. The research methods the client (researcher) used had a lot of analytical expressions that were confusing to the programmers and the interaction designer. On the other hand, the programmers' and interaction designer's discussion opted for detailed functionalities of the system with technical terms beyond the client's reach.

Communication modality

Their communication was conducted mainly by oral means through the whole collaboration period. The professionals interacted largely through iterative oral information exchange that often looked very redundant from the observer's point of view. This tendency was very strong especially in the first half (first and second meeting) of the meetings. In addition to oral conversation, they used whiteboard and markers to draw the structure of systems in the first half of the meetings. However, the main communication was still carried by oral means.

In the latter half of the meetings (third and fourth meetings), they used screen and projector to show their initial system designs and functions by displaying pictures connected to their computer while discussing. In this sense, they had a shared display to look at. Thus, they added visual information means to the oral communication.

Such visual communication as drawings on whiteboard, displayed demo, facilitated communication to a large extent. Although oral conversation kept being the central mode of communication through the whole collaboration period, these peripheral artifacts gave a visual support to their collaboration.

Strategies for handling breakdowns

In this empirical investigation case, ontological drift was hardly externalized into visual signs or tangible artifacts. They mainly utilized oral expressions.

The projector and the screen were kept turned on during their discussions in the third and fourth meeting. The projector showed the demo system and facilitated the participants especially when they needed to discuss something conceptual or functions without a specific name. However, such computational artifacts were mainly used to show ideas and functions visually (e.g., conversation 3-2, 3-3, 4-3). This way of using computational artifacts differ from the other cases (ICE case, renovation case, and Svane case), in which computational artifacts take a central facilitation role and sometimes cause ontological drift and breakdowns.

In intercultural collaboration, it is often the case that professionals tend to continue dialog without noticing their ontological drift or even with uncertainty about meaning of certain terms. In such cases, their ontological drift can be externalized later triggered by interaction (see Section 2.3.5) in conversation with others or accomplished artifacts.

Usually, communication *breakdowns*, in which a person realize ontological drift, are initiated by a certain interaction with external representations (see Section 2.3.4) after continuing such an unstable condition for a short while. In our case, the observed breakdowns were almost always triggered by conversation especially in relation to the key expressions. This would happen when one of the professional encountered an unexpected and different usage of the term from what he had understood. This type of breakdowns happened iteratively and it seems there was no final settlement of the meaning of all concepts in our case.

Focusing on the key expressions in the case, one explanation of handling breakdowns would be as follows. In the first half of the meetings, the key expressions were used with an unstable definition. Since each professional understood them in a slightly different way (ontological drift), they repeated similar questions about the definitions of key expressions like *tree*, *coding* and *label*. They hardly realized that they made the same question twice. Or at least, they did not mention it clearly like "we have already defined the term" or "we agreed what the word (or expressions) mean". Thus, the meaning of a word which looked converged and settled down as a result of a long discussion could be brought to the discussion table soon after. In the latter half of the meetings, breakdowns were handled more consciously and systematically. When it came to the attitude toward unsettled words, expressions and concepts, they intentionally gave names to them.

Creation of words, expressions and sentences

In this case, three collaborative processes toward unstable concepts were observed. They were negotiation of meaning, creation of expressions, and convergence of expression usages [Yasuoka, 2006].

In **negotiation of meaning**, frequently used expressions, for example *label*, have been used by all members throughout all meetings. For example in the first 1.5 hours of the fist meeting, *label* was used 44 times while in the last 1.5 hours of the fourth meeting, the expression was used 39 times. Co-occurrence graphs of each member shows that co-occurrence relations between *label* and other key expressions differed drastically from person to person in the first meeting. However, over time each member's co-occurrence graph became quite similar. Figure4.5 shows how the co-occurrence graphs for *label* for two participants (programmer *A* as Asada and the client) become similar over time. Our empirical investigation shows that members seem to have exchanged questions and answers about *label* repeatedly. For example, conversation 1-8 in the first meeting discussed the definition of *label* in relation to *group*, in 1-9 in relation to *concept* and meta-concept, in 1-11 in relation to data and coding scheme, in conversation 4-1 in the fourth day discussed about definition of label in relation to *this (coding scheme)*, and so forth.

The same procedures for negotiation of meaning were observed for example in relation to coding scheme (1-1, 1-2, 1-8, 1-10, 1-11, 2-1,), comment annotation (1-4, 1-10), notes (2-3, 3-1, 3-4, 3-5) and so forth. Through out the whole discussion, the most frequent procedure was negotiation of meaning through confirmations in relation to other key expressions.

In this negotiation of meaning, participants discuss meanings of key expressions to define exact meanings among participants. The meanings often become unique to the participants and were often different from conventional dictionary definitions. Observing and analyzing both the co-occurrence graphs and conversation protocol, it became clear that a definition of key expressions (*label* in the example) is gradually fixed through iterative interactions among participants. The co-occurrence graph of all four members changed its semantic distance over time and became similar in the end. Thus, in this collaboration process, exact definitions of key expressions often did not exist in the beginning but they were created by negotiation.

In **Creation of Expressions**, the words *segment* and *table* have been used frequently

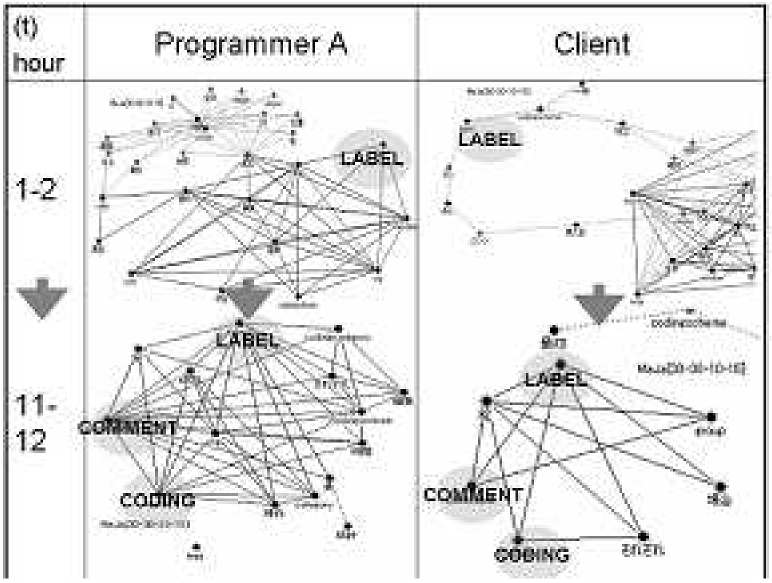

Figure 4.5: Co-occurrence graphs for *Label* for programmer *A* (Asada) and the client. The top and bottom of graphs are made from conversation data during hour 1-2 and 11-12 of total meeting time, respectively.

from the second meeting. The protocol analysis shows that the key expression, *segment table* was coined in the fourth meeting through the negotiation process shown in Conversation 4-2. The expression, *segment table* was used by all participants in the forth meeting. Conversation 3-6 is another example of creation of expressions. The programmers and the client discussed the name of the function and collaboratively created the name *NTDM, Note Temporal Distribution Map* intentionally.

In this creation of expressions, participants collaboratively coined names to new concepts during the discussion through negotiations. The co-occurrence graphs sometimes clearly show the moment when new expressions were coined. The communication protocol often shows a similar creation process of new expressions. Before participants started to use newly created expressions, they often discussed ideas or concepts that would lead to new expressions afterwords. It often occurred unintentionally but sometimes expressions were created intentionally, especially in the latter half of the collaboration.

Convergence of Expression Usages. The key expressions *tree* and *ki* (means a tree in Japanese) were used frequently in the beginning of meetings (e.x., Conversation 1-3). However, the usage of *ki* decreased over time. For example, in the first meeting, programmer *A* and the interaction designer used expression, *ki*, while programmer *B* and the client used the term *tree* as tree structure in their conversation (Conversation 1-12). On the other hand, reviewing the last meeting, all participants used the expression *tree* when they meant tree structures (Conversation 4-4).

- In the first half of the first meeting (Conversation 1-12)

Asada	This *ki* is
Kurakawa	When I think about this as a *tree* structure
Yasu	No, you mean the leaf of the *ki*-structure

- In the fourth meeting (Conversation 4-4)

Kurakawa	Which part of the *tree*?
Asada	Bottom part of the *tree*.

When participants have different expressions that indicate the same concept, the shared concept often converges to one expression through negotiations. Cross reference of co-occurrence graphs and communication protocols shows that when the number of usages of one expression increases drastically, it is sometimes caused by convergence of expressions.

In this case, new meanings or new expressions were added to key expressions or created during the collaboration period. In this analysis software design case, creations of expressions or concepts are observed quite occasionally as a succeeding event after externalization of ontological drift and breakdown. Typically, such created expressions became intensively utilized and relied on during the rest of collaborative period.

4.2 Case 2: Carlsberg Landscape design

4.2.1 Background

This empirical investigation case considers the collaboration process in the initial design phase of a contribution to an international competition on city planning. In this *Carlsberg landscape design case*, professionals who usually belonged to different organizations gathered and worked for the competition in this one-time project. Together with the renovation case (described in Section 4.3), the Carlsberg case and its analysis is partly presented as a comparative case study in [Yasuoka, 2007]

Participants

The stakeholders were eight professionals of which four were core members. The core members were: an architect (Kiyo, Japanese), a landscape architect (Hol, Dutch), an artist (Torben, Danish) and an illustrator (Fanny, Danish). The four non-core members were: a city planner (Danish), two computer graphics specialists (Dutch and Danish) and a print professional (Danish).

The initiative to the collaboration was taken by the illustrator in the middle of October 2006. She got the idea after working with the architect (Kiyo) for half a year. The other members have worked together several times previously. The participants' backgrounds differed since the members thought "they needed a wide variety of professionals that could cover the domains that the competition asked for". English was used as a common language since their nationalities and consequently their mother tongues were different.

Project background

The competition they targeted was an open international competition, called by the Danish beer manufacturer, Carlsberg A/S. The competition was for a conceptual plan for the original Carlsberg production and management site in Copenhagen. Since Carlsberg A/S planned to move production sites from the original site and keep only administrative functions in the current area, the need to redesign the site had been recognized. The objective of the competition was to design the 33 hectares of remaining area as one coherent complex facility.

The competition was open from the 1st of November 2006 to the 28th of February 2007. Carlsberg A/S offered a complete booklet and website [Voresby, 2006] which explained their objective and expectations of the competition and described a detailed pre-analysis of the site. The package for the competition included: (1) a map of Copenhagen, (2) a map of competition site in DWG format, (3) a 3D model of the competition site and the surrounding city areas, (4) various aerial photos of the competition site, (5) a collection of information to serve as inspiration including proposals and ideas from citizens and organizations, and (6) a description of neighboring districts. Competition candidates could also get additional material from the Carlsberg competition web site and from updated information as announced on the web site over time. Compared to other competitions, the Carlsberg A/S competition offered a large amount of information already in the beginning.

According to the Carlsberg booklet and homepage, "the purpose of the competition is to obtain ideas for the future identity and development of the city district from professionals from all over the world. Carlsberg A/S wants to create a new city, a vibrant city that sets new standards for quality of life in an active, dense and composite urban fabric: a city that challenges the future" and "this area should be converted into a dense vibrant and pulsating city district on a human scale in a setting that is both historical and contemporary". Carlsberg A/S also gave the title of the competition, "Our city", as well as conceptual ideas: "identity, city life, urban form, sustainability and realization are the key elements".

4.2.2 Analysis Method

An empirical approach (as described in Section 3.2.1) is taken in order to understand the collaborative process among professionals with different work cultural background. Several meetings and stakeholders' collaborative process in the architectural competition were observed and investigated. Their collaboration falls in the category of early design process. The project was terminated before the design development phase. The model of observation taken was "observing participants" [Gold, 1958]. As described in Section 3.2.1, observing participants are those "who are not participating in activities or intervening discussions but attending meetings as a pure observer".

As in the software design case, the observer occupied one corner at the discussion table so that all conversation and movements, gestures, activities and artifacts on the table were observed without disturbing the activities of the participants. Research notes during the meeting were taken and materials and drawings used during the meetings were collected. The research notes were translated and transcribed soon after the meetings. Interviews with several participants about their activities were conducted after the competition period. In contrast to the software design case, neither voice recording nor video recording were made in the Carlsberg case. Thus, the detailed parts of our description of the collaboration process were mainly reconstructed using transcriptions. For this reason, the descriptive style of this case may slightly differ from the previous software design case.

4.2.3 Case Details - Observation

Nine collective general meetings were made from the middle of October 2006 to February 2007. The first two meetings were used mainly for collecting information for initial idea-generation. The third to the fifth meeting were used for idea generation and in-depth analysis of the design of the site. The sixth meeting was made to sum up previous ideas, and the seventh to the ninth meeting were used for designing, drawing, and modeling.

The first meeting

The first meeting was held in the afternoon in the middle of October. There were four stakeholders attending the meeting: the architect, the illustrator, the designer and the landscape architect. The illustrator, the designer, the landscape architect knew each other and had worked together several times. The illustrator was a friend of the architect and brought him to the meeting so that he could meet the other two members for the first time.

There was no preparation for the meeting. Some participants came to the meeting with their own professional tools, such as pencils, paper and computers. The architects had prepared pens and paper and had Computer Aided Design software (CAD) installed on his computer. The illustrator and the artist had a computer with them. However, they did not prepare additional tools. There were three laptop computers on the table in total.

The members began the meeting by introducing each other. They then checked the web site of the Carlsberg competition together and tried to understand the setting of the competition. They investigated the descriptions offered on the web in detail. Two of them checked the website using their own laptops, while the remaining two shared a laptop. They read and skimmed the web pages silently and sometimes read aloud when they wanted others to know what they had found. After a brief research of the competition, the members discussed what “Our City” would need. Since they had just started to check the competition, they still only had limited understanding of it. Each tended to give his or her opinion and referred to the web site at the same time.

At this meeting, mainly oral conversation was used for discussion. Occasionally, the members pointed out sentences or pictures on the web when they wanted to explain something specific and discuss it. Only the architect tried to draw conceptual ideas and showed his understandings on paper. However none of others joined. The architect drew, erased, and redrew his ideas iteratively while the others only used oral means. Iterative reference to the web descriptions was made by all members.

A few days after the first meeting, each member got a packet from the competition administration that contained a paper booklet and digital CAD data. Each individual thoroughly investigated the booklet and the CAD data according to his or her profession.

The second meeting

The second meeting was made on the Carlsberg site on the 16th of November 2006. Almost all stakeholders, the architect, the artist, the illustrator, the landscape architect, the city planner and the computer graphics specialist participated in an open visiting session. The visit was arranged by the Carlsberg A/S competition promoter for all competition participants. They made a round tour of the designated site and were told which buildings or areas would remain and which would be demolished. They became acquainted with the history of the area including current statues of the area, functions of landscape and geometrical characteristics.

On the same day after the site visit, the stakeholders gathered again. They had insights both from the paper booklet and the visit. Most of the stakeholders had received the paper booklet previously and had investigated and analyzed it before going to the site visit. They brought pens, paper, laptops, and the paper booklet. Many of them had already read through the booklet individually and made notes in it. They investigated the identity of the city. First, they discussed mainly the current characteristics of the site. Then they moved on to a discussion about its future characteristics based on the paper booklet that Carlsberg had offered and site investigation they had made.

In this meeting, the members started to use unique expressions such as *slimy* (Conversation 2-1) and several names of animals such as *camel*, and *elephant*. *Slimy* was the name of a giant device for brewing that they saw while visiting the site and which was situated on the first floor of the Jacobsen house brewery (see Figure 4.6). The unique shape of the device reminded of a game character *Slime* with a long and thin head. The artist first mentioned *slimy*, pointing out pictures of the giant device for brewing and suggested using the shape of the brewery device as a core design concept of the site. He thought it was a unique landmark of the site that easily could get attention from visitors. From that moment, the members started to use the word *slimy* pointing to the unique *slime* shape. At the same time, the giant device for brewing came to be called the *slimy thing* or *slimy machine* among the members. Other expressions such as *camel* and *elephant* were also for specific conceptual design ideas.

Figure 4.6: A giant device for brewing beer called *slimy* among the collaboration members.

In this meeting, mainly oral conversation was used for discussion like in the previous meeting. But instead of pointing out objects on the website, they used the paper booklet instead. They also used a lot of gestures. Some drew lines and circles, but there were no concrete shapes. Their discussion was mainly conceptual in this stage making drawings hard to utilize.

The third meeting

The next meeting was held one week later. The architect, the illustrator, the artist, the landscape architect, and the computer graphics designers attended. The purpose of the meeting was to generate ideas. The stakeholders brought the paper booklet with a lot of notes, pens, paper and laptops. Each of them had investigated ideas. None of them, however, had prepared special external representations that could show their ideas. They first discussed conceptual ideas. In this meeting, several members including the architect and the landscape architect randomly used pen and paper to express their conceptual design ideas. On the other hand, the illustrator and the artist were reluctant to draw, and tried to stop others from doing it.

While talking about the conceptual ideas, the architect gave several ideas and images as for what kind of characteristics the site should have. He introduced several names of architects such as Jean Nouvel and Tadao Ando and used several adjectives that gave abstract images such as *cozy* and *relaxing*. The landscape architect also gave his ideas by pointing out several existing buildings or specific ideas such as *IKEA building*, *a 20th floors building* and *streets underground* like New York city or Shinjuku in Tokyo. The artist Torben insisted to make a logo which entailed the whole concept. He was interested in using animals such as *elephant* or *camel* in the previous meeting, and in this third meeting, he suggested a *horse* as logo and made a simple drawing.

After a while, the illustrator suggested using a concrete method for city planning, mainly for analytical purposes such as charts. Then, they made a list of what they should and what they should not do when designing the city. In the 'To do' column, they filled out such sentences as 'thinking about access to the site' as well as 'each building or place', 'leave green area, trees and flowers', 'thinking about density', 'thinking about which building should be left', and so on. In the 'Not To Do' column, sentences such as 'demolish less', 'keep holding reality' and so on were written.

After the conceptual discussion, they tried to sum up the theme and the keywords that came up during the discussion and relate these keywords to each other (Conversation 3-1). The keywords were often nouns and sometimes verbs and adjectives such as *walking, energy (power), residential, water, shop, transportation, move, sunlight, light, green, wind, snow, rain, roof, botanical, children, casino*. The keywords were grouped into one concrete idea. For example, keywords such as *roof, botanical, energy power and green* led to the concept rooftop garden.

Next, they moved to another analytical procedure. In general, the analysis process would start with zoning, diagram, elevation and section analysis (fundamental plan, field plan, floor plan, grade plan and 3D) according to architectural practice. In their discussion, the members drew geographical characteristics of the site on the table (see Figure 4.7) and analyzed the lateral view. While the architect was drawing the elevation plan of the buildings and the ground composition from the various view points, the artist pointed out that the preserved buildings made the shape of mountains when seen from the side. Except for the illustrator, the other members agreed that a possible keyword of the lateral view of the site could be mountain (Conversation 3-2) (see Figure 4.8).

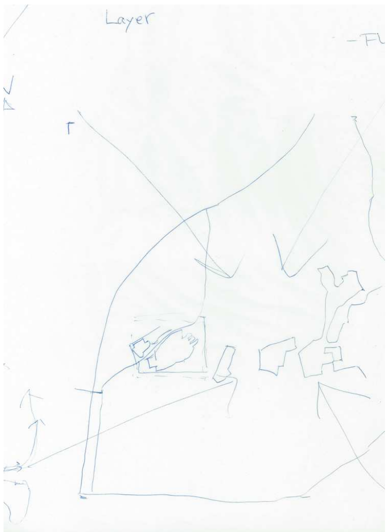

Figure 4.7: A hand drawing of the geographical characteristics of the site.

In this meeting, drawings, artifact references (description, drawing and pictures) as well as oral conversation was used in the discussion. Mainly the architect and the landscape architect drew, erased and redrew lines and figures. Several ideas and suggestions were made while some members were drawing and others were observing the process.

The forth meeting

The next meeting was held a week later. The participants were the architect, the illustrator, the artist, the landscape architect, and the computer graphics designer. The meeting was intended to be an in-depth analysis in order to make conceptual ideas more concrete.

They brought artifacts that they believed would reify their conceptual ideas of the site in addition to usual materials such as the booklet with a lot of notes, pens, paper and laptops. Present artifacts were pictures, logos, images and drawings. Pictures of architecture such as a famous Dutch building, Mori Building, Omote Sando Hills with logo and Roppongi Hills with logo were presented as representative cases. For example, Roppongi Hills is a famous Japanese complex facility where shops, offices, and hotels are integrated in one site, and has a unique logo that reifies its activities and concept. The members presented their ideas and concepts based on the artifacts they had brought. Using a Japanese complex facility with logo, the artist explained the importance of a logo since a logo can "give a clear and coherent image to a vague concept and helps to make a design move".

The fifth meeting

The fifth meeting was held a week later. The participants were the architect, the illustrator, the landscape architect, and the print professional. The print professional jointed the

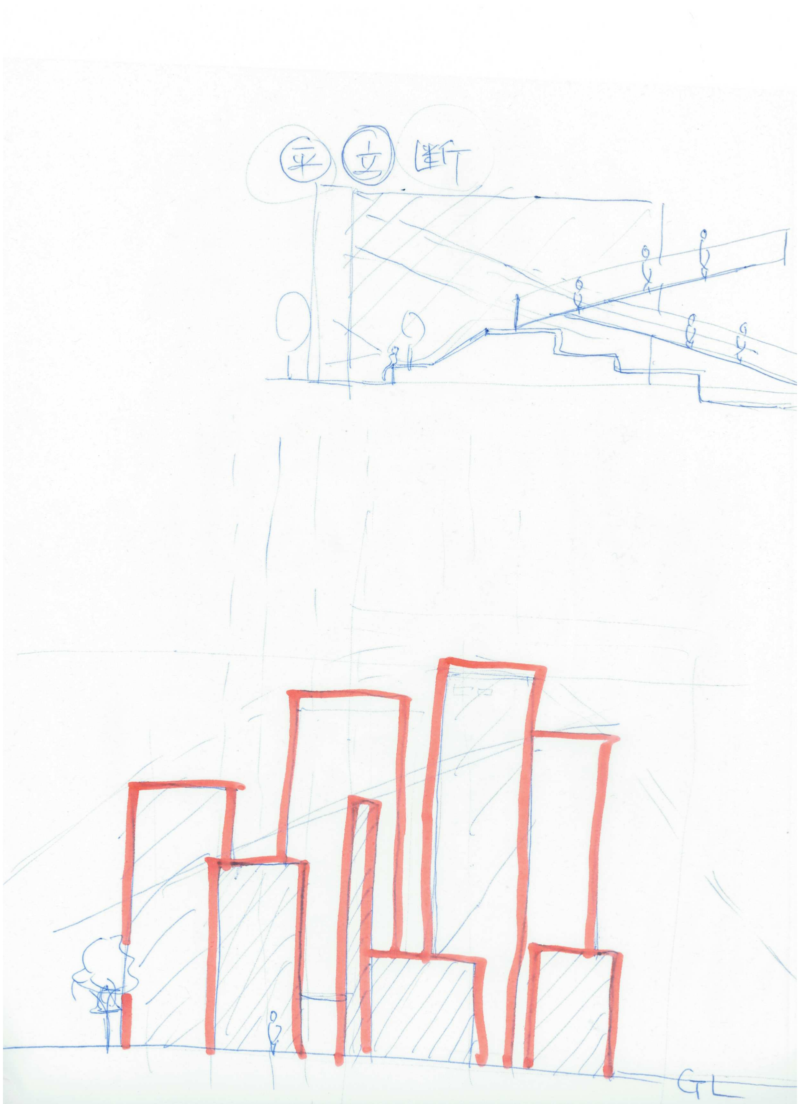

Figure 4.8: A hand drawing of lateral view, shaping like mountain.

meetings for the first time since the meeting was the first drawing session with A1 paper and tracing paper, where the print professional took an important role for printing matter. They brought the artifacts from last meeting as well as the booklet notes, pens, paper, and laptops. In addition, they prepared A1 prints on which fundamental CAD plan was printed. Every one used a pen including the illustrator who hesitated to draw at the previous meeting.

Since Carlsberg offered an original CAD format, they could utilize such detailed CAD prints from the beginning. First, the architect put a layer of tracing paper on the A1 CAD print. A tracing paper roll is cut to fit the designated area to be discussed. By placing a tracing paper over the original CAD print, they could discuss the fundamental plan, field plan, floor plan, grade plan and 3D plan over the print. Figure 4.9 shows one of the drawings that were made.

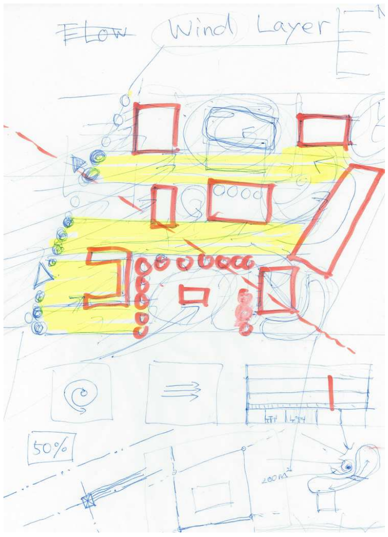

Figure 4.9: An example of a field plan. Buildings were traced with thick red pen.

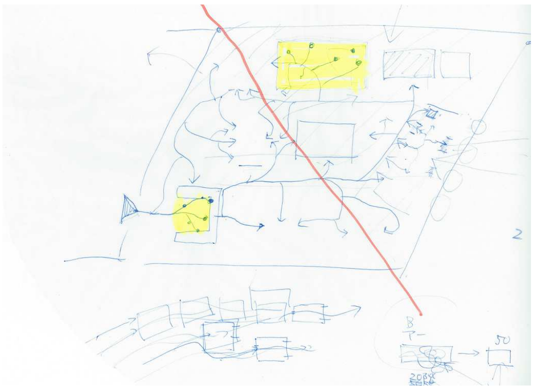

Figure 4.10: An example of a floor plan including flow of visitors.

They started with the fundamental plan. The boundary line and buildings on the CAD print were traced to the layered tracing paper. Next, they drew their ideas discussed at previous meetings regarding buildings that were to be demolished or newly constructed. When discussing fundamentals about the field plan, the members considered the mountain design again. Several participants reconsidered the design idea after analyzing their written ideas on the tracing paper and insisted that the mountain concept was still valid and appealing enough to represent as a reification that they would like to create. The professionals discussed a floor plan which would define visitors' moves in and out, by making a circulation diagram that showed the movements of visitors such as stop, move and elevate (see Figure 4.10). By drawing on paper, their idea and expectation of how visitor trajectories became more and more realistic. The stakeholders moved pencils from the entrance to the exit through several buildings depending on the characteristics of the agent they had created. They drew all these possible trajectories iteratively. Once they were satisfied with the field plan, they designed the floor plan and then went to the grade plan. Every time they moved to a different plan, they changed their ideas and wrote too much to fit a single piece of paper. They changed the tracing paper and started to draw on a new layer. After they discussed all plans, they started to discuss details of the design of the site and the building design itself.

While they were discussing where to situate a cafe, they had their first major dispute. The architect (Kiyo, Japanese) drew a cafe at the south east side of a building on the prints and suggested to plant trees and bushes by the windows. Soon after, the others, except the landscape architect (Hol, Ducth), argued against planting trees by the window, and the illustrator (Fanny, Danish) redrew a cafe at the other end on the south west side of the building. This became a trigger of discussion. When they described how the cafe should be used, their conceptual differences toward cafes and sunlight (Conversation 5-1) were revealed. When the architect heard the word sunlight, his image was light from the south-east direction. As a Japanese, he imagined morning sunlight. In order to avoid strong sunlight, trees should be planted by the windows. On the other hand, when the other members, except the landscape architect, heard the word sunlight, they imagined light from the south-west direction. They thought about sunlight in the evening at dawn. The image recalled by sunlight for them were beer and relaxation. In order to enjoy the setting sun, they never thought about planting trees that would make unwelcomed shadows.

After a while, they experienced a similar kind of dispute when they discussed how to use a large open space in one corner of the site. The architect drew trees and flowers on the prints and explained how important it was to create a space for interaction for visitors. He suggested to reserve the space for greens, trees, and flowers and not build anything. On the other hand, the illustrator over-drew his illustration, suggesting to put a low building. When the architect continued drawing, mentioning that it was important to let the wind blow, the others opposed strongly. The illustrator told that there should not be a long wide open path that would generate strong wind in the end. She explained that strong Danish wind is quite different from mild Japanese wind. Then the architect withdrew his idea. When the architect thought about wind, he imagined a warm breeze - something being welcome. On the other hand, the other members imagined a strong wind that would hit their face and should be eliminated from the area by buildings working as wind-breakers (5-2).

During the drawing process, the professionals used keywords consciously. There also existed keywords that were unconsciously being uttered. However, largely speaking, the members kept asking consciously to each other "what could be *keywords*", "What is the *key concept* of the design" while discussing through drawings. One interesting event was that professionals who had used abstract expressions in the beginning of the discussion tended to use concrete expressions in this phase while others who had used concrete expressions in the beginning started to use abstract expressions. For example, the artist suggested a concrete design of *the 50th floor building* (which was comparable with *the 20th floor building* defined by the landscape architect in the third meeting). On the other hand, the landscape architect who expressed concrete ideas earlier now used more abstract expressions (Conversation 5-3).

The keywords that the members consciously had been using during the first half of the discussion of this fifth meeting were *water, wind* and *green*. Most of these were already suggested and used in their previous meetings. Over time, the participants gradually began to connect each keyword. For example, the members mentioned connections like "If *wind* blows, *water* and *green* wave, then...". In the latter half of the discussion, *water* was not used anymore. One of the explanations could be that a water area with artificial canals had already been described on the prints. The keywords that members created and used frequently in the latter half of the meeting were, *proportion, pillar hall, human scale, organic, dense, wind, sunlight, west meet east, Omotesando, Dojunkai*. Some were conceptual while others were concrete terms.

In this meeting, intensive drawing as well as oral conversation was used for discussion. They used many layers of tracing paper and changed paper frequently. Drawing was the main critical activity accompanied with verbal and oral expressions. They often explained reasons as to why they drew lines orally while drawing but not always. They actually sometimes drew lines without speaking.

The sixth meeting

The sixth meeting was held in the beginning of 2007. Three members, the architect, the illustrator and the artist discussed the plan they had discussed in the previous session and assigned tasks and distributed responsibilities to each other. The architect reflected about overall ideas generated by previous discussions and made drawings in the CAD system. This was the first time digital formats were used.

The seventh meeting

The seventh meeting was held to evaluate progress. The architect constructed rough 3D drawings, and the illustrator and the landscape architect drew digital documents in 2D CAD. The artist mainly worked on tangible materials for submission.

The eighth meeting and the ninth meeting

These two meetings were used for modeling and checking the progress. In large, from the sixth to the ninth meeting each individual worked separately in a co-located environment. Meetings were used mainly for asking questions, confirming directions and reporting progress. Between meetings, many activities were made through exchanging documents and e-mail conversation.

4.2.4 Analysis on Collaboration

In this Section, we analyze the collaboration process betweenb the professionals that were involved in this Carlsberg landscape design case. The analysis focuses on communication aspects based on ethnographical investigation (described in Section 3.2.1). We briefly review several analytical aspects including *distortions, communication modality, strategies for handling breakdowns, and creation of words, expressions and sentences*, related to the problem of ontological drift (defined in Section 2.3.1) and its handling.

How They Collaborated

This empirical investigation mainly covers the very beginning of the design phase (from the first to the fifth meeting). The stakeholders were very interdependent on each other's professional knowledge and worked collaboratively in the first half of the project period. They conducted brain storming and generated ideas during their collaboration. On the other hand, in the very end of the design phase (from the sixth to the ninth meeting) their collaborative activity phased out and they worked independently with computational artifacts like CAD systems. n[1] They sometimes exchanged CAD drawings, e-mails and e-documents in between the co-located meetings but not with active collaborative activities. Each stakeholder was responsible for one part of the project at this stage and played his or her own role separately. Thus, their collaboration style in the latter half was very simple and without redundancy of communication. In this case, during the whole collaboration period, stakeholders used computational artifacts from time to time. However this was for referring, checking and understanding the project. Discussions facilitated by computational artifacts were rarely observed.

Distortions

Their collaboration challenges occurred mainly due to their ethnic as well as work culture differences. Because of such differences, ontological drift was often observed. Their understanding towards expressions and concepts differed because of their ethnic and work cultural differences. More precisely, their semantics for words and expressions was different as shown in Conversation 5-1 and 5-2. Their working style acquired from professional education and experience also differed, which is clearly shown in 5-3. In 5-3, some preferred drawing from the beginning while others did not draw intentionally to avoid fixation of ideas.

When they worked collaboratively, they were situated mainly co-sited while they were in a distributed setting when they worked independently. Thus, stakeholders in this case were not so much affected by distance as a distortion for collaboration. Computational artifacts which could potentially generate misalignment among the professionals, were also used from time to time. However, they were used mainly when professionals worked independently

[1] In spite of that, their work was very interdependent in the conventional CSCW sense since each professional was responsible for one part of the work and collected work will formulate one project work

and not in the collaborative setting. Thus, distortions caused by computer artifacts were rarely observed in this case.

Communication modalities

In the first half of the meetings, the stakeholders used language intentionally. They created keywords and expressions collaboratively, often intentionally such as slimy (in Conversation 2-1) and mountain (in Conversation 3-2). Some used abstract expressions in the beginning and concrete expression afterward, while others did it the other way around as shown in Conversation 5-3. Some preferred adjectives and verbs, others nouns. In the beginning of the meetings, participants used mainly such verbal expressions including oral conversations, and gradually they started to use drawing, signs and descriptions, together with oral conversation. In this phase, they used multiple tangible artifacts such as booklet, pictures, photos, drawings and signs together with oral conversation. After a while, they drew their design ideas by hands through oral conversation on blank paper, the booklet or pictures, and by doing so, they externalized their design ideas. The architect and the landscape architect drew their conceptual ideas, abstract, and half formed ideas in order to make them more concrete. The architect intentionally drew and interacted using paper and pen in order to acquire back-talk [Schön, 1983] by drawing. On the other hand, the illustrator and the artist, especially the illustrator, consciously avoided writing down their vague thoughts in order “not to trap by fixation of written images”. In the middle of the discussion, they finally started to use A1 print and tracing paper which was a design tool used by the architect, the landscape architect and the designer. In the very end of the design meeting when they had almost finished discussing collaboratively, they started to work independently with computational artifacts, CAD systems in order to reify their discussed design ideas.

Strategies for handling breakdowns

In this Carlsberg landscape design case, ontological drift was often observed and externalized. Collaboration breakdowns in this case caused by either ethnic cultural differences were mainly observed in the first half of the meetings, for example the discussions about sunlight (Conversation 5-1) and wind (Conversation 5-2).

In the example about sunlight (Conversation 5-1), conceptual differences between Scandinavian culture and Japanese culture were disclosed while discussing and interacting with drawings. The concept of sunlight caused a breakdown when the architect drew a cafe on the south east side of the building on the prints without any expectation to be opposed. The illustrator questioned his idea and redrew a cafe the other end of the building. This brought a further interaction and discussion. When they interacted with each other utilizing oral and written communicative means, by making stories about how the cafe would be used, their conceptual differences were revealed. The example about wind (Conversation 5-2) shows a similar kind of ontological drift and breakdown. They agreed to create a space for interaction between visitors. However, they had a different view point on how to deal with wind. The concept of wind which hold ontological drift bought a breakdown when the architect interacted with writing, by drawing trees, flowers and no buildings on the print while the illustrator opposed the idea and interacted also with writing by drawing buildings in the middle of the open space. When the architect thought about wind, as a Japanese, he imagined warm breeze refreshing breeze. On the other hand, the other members imagined uncomfortable cold wind.

Such ontological drift were in general externalized through the process of visualization mainly by interacting using drawing. It was often the case that one person drew in front of the other participants while discussing a certain design idea. Such interaction with writing was a trigger for breakdowns because idea externalized on paper often looked somewhat different from what other members expected to see.

Creation of words, expressions and sentences

In addition to externalization by drawing, the professionals utilized language vividly to facilitate their collaboration. They created expressions and keywords such as slimy (Conversation 2-1) and mountain (Conversation 3-2) in the course of interactive discussions which were shared among them in spite of their knowledge background differences. The keywords suggested during the discussion formed both conceptual and concrete entities, and tended to have unique meaning among the members and worked as common ground (see Section 2.3.2). Keywords were repeatedly used in oral form and they were sometimes externalized into material such as drawings. For example, the keyword *water* generated in the third meeting (Conversation 3-1), and iteratively used during conversation was drawn as an artificial river on the A1 paper in the fifth meeting. Some keywords and expressions kept being used during the meetings while others disappeared.

4.3 Case 3: Intercultural Collaboration Experiment

4.3.1 Background

This empirical investigation case considers a collaboration in a software development project with 31 participants from four Asian universities called the *Intercultural Collaboration Experiment (ICE)*. Professionals within the computer science domain discussed software design and implemented designed software in an environment distributed over four countries. The collaboration happened solely using two original computational communication tools that incorporated translation services between English and four Asian languages. Other kinds of communication channels such as phone and e-mail were prohibited during the project. The purpose of ICE was to investigate whether and how machine translation could be an effective technology for a collaborative process among members with different mother tongues. Machine translation for communication support is often regarded not as a facilitator but rather an obstacle for collaboration. In spite of such negative view toward the use of machine translation in collaboration, this experiment aimed at investigating the possibilities of overcoming language barriers with the help of computational artifacts. In the project, two tracks that lasted eight weeks respectively were carried out. In the middle of the two tracks, one face-to-face meeting was held in Kyoto among the leaders of each country. In the end of the project, a questionnaire to all participants were distributed and collected.

The scientific results of the ICE project have been published in various additional papers and reports [Nomura et al., 2003b, Nomura et al., 2003a, Yasuoka et al., 2003, Yasuoka, 2003].

Participants

There were 31 participants. They were mainly graduate and undergraduate students and faculty members of computer science departments from the following four Asian universities; Kyoto University (Japan), Shanghai Jiaotong University (China), Seoul National University and Handong University (South Korea), and University of Malaya (Malaysia). Almost everyone had at least four years computer science education and experience in software development. The largest difference was their ethnic cultural background. The participants were from four different countries and had four different mother tongues.

Instead of applying English as common language as is often done in international software development projects in the Asian region, the project offered specialized computational communication tools named TransWEB and TransBBS for communication purposes among the members (see Figure 4.11). These tools incorporate translation services[2] among, Chinese, Japanese, Korean, Malay and English. TransBBS was a multilingual Bulletin Board System (BBS). It was utilized as a daily discussion space. TransWEB enabled participants to browse software development documents in their mother tounges. Discussions in this experiment were held only on the TransBBS and TransWEB.

[2]Translation services were provided by arcnet/sangenjaya:http://sangenjaya.arc.net.my/index-e.html and J-server:http://www.jserver.com/index.shtml) via the Internet.

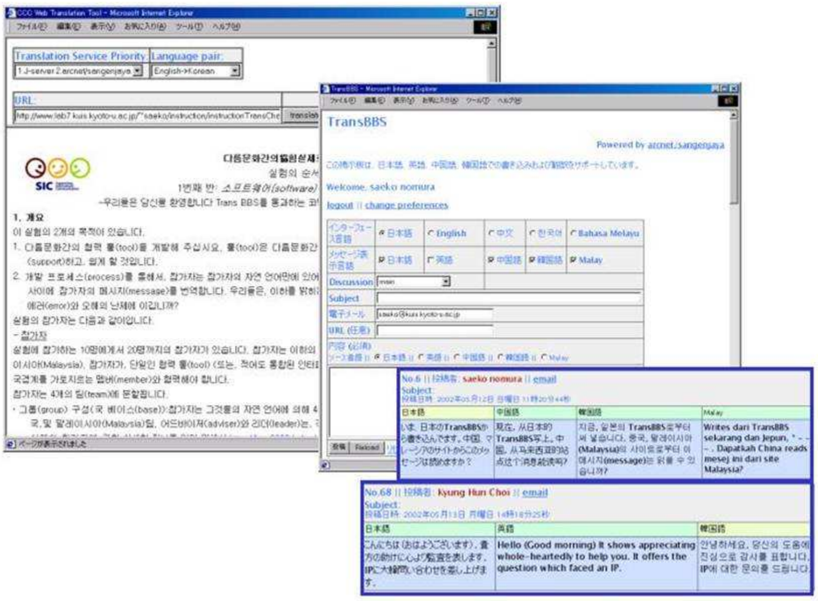

Figure 4.11: Communication Tool: TransBBS and TransWEB.

Project background

The project was initiated by Kyoto University in order to pursue technological possibilities of language support for collaborative purposes in intercultural software development projects. There were several urgent needs for support in such projects. First, in Asia-Pacific countries, along with the needs of offshore projects, the number of international software development projects has drastically increased. However, language issues such as deficiency of English skills among Japanese programmers and developers as well as ontology drift caused by English as second language exist as collaboration barriers. Second, the diversity of languages on the Internet has widened recently in contrast to the early period of the Internet when English was dominant.

The project team consisted of students and faculty of computer science departments of the four countries. Apart from the project team, an analysis team was formed. The analysis team consisted of four Japanese researchers at Kyoto University and took responsibility for analyzing the collaboration process using both qualitative and quantitative approaches. The first track was conducted from May to July 2002. To ensure smooth collaboration and progress in software development, the experiment was scheduled in the following two phases.

- Software Design Phase: Intercultural collaboration software is designed. The goal of this phase is to submit a system design proposal to implement software.

- Software Implementation Phase: Software based on the design proposal is implemented. The goal of this phase is to complete and release an intercultural collaboration tool.

Each phase consisted of four weeks respectively.

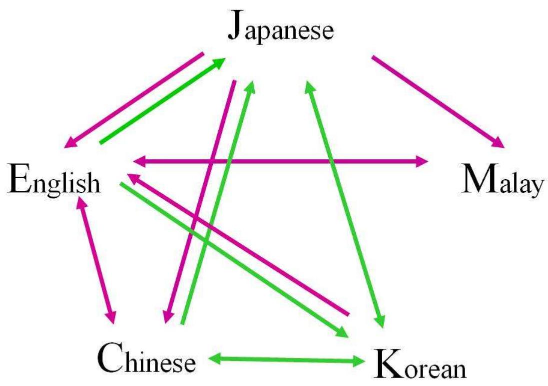

Figure 4.12: Default translation pair in ICE.

The provided tools, TransBBS and TransWEB (see Figure 4.11), incorporated translation services of Chinese, Japanese, Korean, Malay and English. Figure 4.12 shows default translation pairs selected from two translation services. Five servers in four locations were established and the TransBBS and TransWEB were synchronized on these five servers.

Because of this setting, each team member collaborated with other members on their own local TransBBS and TransWEB system. Since each message was synchronized between the five servers at regular time intervals, all members could view identical messages on their local TransBBS systems. During the experiment, participants were obliged to carry out discussions only on TransBBS and TransWEB whenever and whatever they communicated. For example, a participant of country A had to discuss design ideas with another participant from country A on TransBBS. Because of the characteristics of this experiment, communication via e-mail and chat systems were strongly prohibited.

TransBBS

TransBBS is a bulletin board system that incorporates a multilingual translation service (see Figure 4.13). This tool was used for daily conversation among the participants in order to exchange opinions and report progress. After the participants registered user information such as cultural background, one language of the BBS interface was chosen among five possible languages automatically. Messages posted on the TransBBS were sent to a translation server. After the translation, it was displayed on the TransBBS of each local server. Each member could select which language pairs to display on the

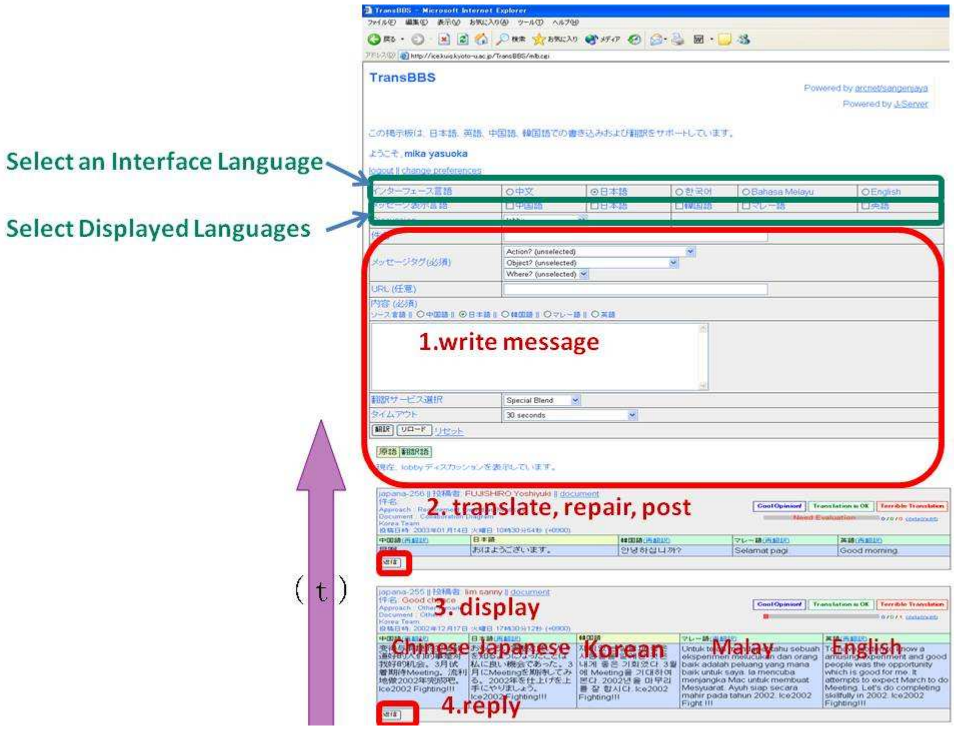

Figure 4.13: Intercultural Collaboration Tool: TransBBS.

transBBS. Also, some functions were provided in order to recover from system failure such as transmission errors between servers. To improve translation quality, the participants could use a retranslate button which enabled the participants to refine posted messages that failed in translation. To have quick response, a function which enables to change the transmission time of the translation server was also offered. TransBBS also had a function that allowed participants to build a new discussion room freely to meet their needs timely. Discussion rooms for each country and for reporting progress to other members were created beforehand in order to maintain effective discussions on software development.

Based on the analysis of the first track, the system functions were slightly changed in the second track. In the new system, participants could post messages after checking the translation result. This new function worked as follows. First a written message went through machine translation and were displayed on the BBS interface in five languages. Second, the user checked the result and if satisfied, the user posted it, which was reflected on the TransBBS soon after. If the user was not satisfied, the user could revise it and send it to the translation machine again. Since participants could confirm translation quality to their heart's content, they became more serious about being understood.

TransWEB

TransWEB is a web browser incorporating translation service between Chinese, Japanese, Korean, Malay and English just like TransBBS. It enables software development documents in HTML style to be translated to each language over the Web. It is important that system structure diagrams and data flow diagrams are shown when exchanging documents to achieve an effective software development process in distributed environments. Using this tool, participants from each country could make documents in their own mother tongue and participants from other countries could refer to the translated documents. TransWEB was used for better information sharing among the team members. From the second track, TransWEB was linked with TransBBS so that participants could follow a URL shown on TransBBS and automatically view translated documents. In the first track, participants had to move from TransBBS to TransWEB manually to view referred URLs so that they needed to have two hops to check translated documents. The efficiency of transWEB was enhanced by cutting these steps.

4.3.2 Analysis Method

In this ICE case, the mixed method described in Chapter 3 was deployed. For qualitative and quantitative analysis, conversation data on the TransBBS, digital documents on the TransWEB, and log data were collected in order to understand the collaborative process among professionals with different language backgrounds. Apart from data collected on the server, questionnaires were distributed to all participants of the development team after the project. The model of observation of the analysis team was fundamentally *observing participants* [Gold, 1958] who are not participating in activities, and occasionally become *participating observer* for the purpose of vitalization of on-line activities. In order to analyze collaboration among participants mediated with machine translation, conversation analysis [Have, 1999] and content analysis [Krippendorf, 1981] were applied. For analysis on questionnaire, statistical analysis was made.

Data Collection

Collected data from this case are message logs of the five languages on the TransBBS, digital documents on the TransWEB, CVS data and log data collected and synchronized in the five distributed servers. Data was logged in a total of 16 weeks, from May to July 2002 and October to December 2002. Each participant's log data such as log-in, log-off, and multi-activity data were checked every day as well conversation on the TransBBS. The five distributed servers were installed in each country; two in Japan including the central server and one in the other countries. The five distributed servers were synchronized regularly so that conversation data shown on the TransBBS and documents on the TransWEB were coherent despite the physical distance between the servers. Log data were also synchronized and used mainly for analytical purpose.

Web based questionnaires were conducted just after the experiment both in the first

	The First Phase	Adjustment Period	The Second Phase
The First Track	May 13 - June 10	June 11 - 22	June 23 - July 19
The Second Track	Oct 10 - Nov 6	Nov 7 - 17	Nov 18 - Dec 15

Figure 4.14: Schedule of the software development period.

and the second track. The first track questionnaire was composed of 91 questions related to interface and translation quality of TransBBS, communication patterns of TransBBS such as postings, understandings of other participants' messages and viewed languages, motivations of the project, engaged time, organizing and managing, and social networks in-group and out-group. The answers were collected from 22 out of 31 participants (71% return rate). The second track questionnaire was composed of 122 questions on 8 topics related to interface and translation quality as the questionnaire for the first track as well as questions on CVS, personal opinion toward the experiment and other participants, organizing and managing, schedule and installation of the TransBBS and TransWEB (only to leaders of each team). The answers were collected from all 17 participants.

4.3.3 Case Details - Observation

The project was carried out two times for eight weeks respectively (see Table 4.14). Based on conventional software development processes, each track was divided into two phases. The first one was the software design phase (the first phase) and the second was the software implementation phase (the second phase).

As mentioned earlier, conversation channels were strongly restricted only to TransBBS and TransWEB in the experiment. Participants were requested to discuss on either TransBBS or TransWEB and prohibited from using chat systems or e-mails no matter who attended the discussion. For example, the Japanese participants discussed software design with other Japanese participants on the TransBBS even though they were seated on the same floor.

Software Design Phase

The Software Design Phase was carried out from the 13th of May to the 10th of June (the first track) and the 10th of October to the 6th of November in 2002 (the second track) (see Figure 4.14). The first four weeks were used to discuss the fundamental design architecture of the software system, that would be develop in the second phase.

There were several conversations on the TransBBS that were unique to the first phase and rarely observed in the second phase. Some were related to quality of machine translation and human adjustment to machine translation, others were related to social cues that are one of the indicators of the level of focus in a collaboration [Henri, 1992]. The creation of unique expressions was also observed.

Quality of machine translation

Soon after the project started, participants started to realize the limitation of machine translation. Following is an example in which a Chinese participant, Calvin posted a message, mentioning that he could not understand the translated messages on the TransBBS (see Figure 4.15).

Figure 4.15: Limitation of machine translation quality.

In the experiment, the mechanism of machine translation itself was not improved to fit the characteristics of the controlled experiment. Because of this, in order to communicate, participants had to overcome the situation and started to repair [Schegloff, 1991] messages posted in the TransBBS gradually as the project proceeded. The repair activity was frequently observed in the first period. From the log file, it was clear that many participants started to display five languages over time [3] in order to check if posted messages were translated into the other four languages.

Furthermore, several participants tried to let their messages translate several times before posting them. They tried to understand the mechanism of machine translation and chose sentences that were easier to translate. For example, a Japanese participant who adapted to the mechanism of machine translation often used unnatural Japanese sentences (see Figure 4.16). The written conversation on a BBS with clear subject (I, You and so on) and polite form is very unnatural in Japanese written languages on BBSs. However, only by using such unnatural written Japanese, the translated English sentence became easier to understand.

At the same time, Figure 4.17 shows that one participant explained his findings on how machine translation works. One of the Chinese participants, Lindonghui pointed out that the Japanese sentences "kamo shiremasen; It is probable that..." hardly could be translated into proper Chinese.

[3] TransBBS has a function to display from one up to five languages. In the beginning of the project, participants tended to choose only their own mother tongue as displayed language. However, they started to display other languages as well. By doing so, they could check that their posting had at least passed through the machine translation mechanism and were visible to the other participants. But they could not check the quality of translation results.

Figure 4.16: Adaptation to Machine Translation.

china-147 2002/12/1 15:22:00 Lindonghui	对saeko的japana-109的翻译效果进行投票的时候，发现了一个问题。saeko的发言中有一句话。“カイケツできるかもしれません。”我认为，在日语中“かもしれません”的语法很常见，可是为什么翻译成中文的时候错误了呢？同样的问题在lobby中也出现过。saeko的japana-83中有这样一句话。“あなたのアカちゃんもアタタマルかもしれません。”翻译成中文的时候，也错了。如果“かもしれません”的翻译正确的话，那么我将会按“cool opinion”。
Re: Translation	When voting on the translation effect of japana-109 of saeko, it found one problem. There is a word in the remark of saeko.There is grammar of “カイケツできるかもしれません。” very well and however, in Japanese, I think that かもしれません” is why it is a mistake when translating Chinese.The problem to be same has appeared in lobby.It is when saying into japana-83 of saeko in a word in this way.When “あなたのアカちゃんもアタタマルかもしれません。” translated Chinese, it mistook.Then, if the translation of is right, I press " coolopinion".

Figure 4.17: Self-initiated repair.

Human adjustment to machine translation - Others-initiated repair

The conversation shown in 4.18 is another kind of repair activity. The conversation was exchanged between a Chinese and a Japanese participants and repaired collaboratively. When the Chinese participant posted a question about a translation result of a posting made by a Japanese called Iizawa, another Chinese participant expressed his opinion about the meaning of Iizawa's posting. Furthermore, a second Japanese (Miki) joined the discussion and confirmed that the Chinese members' understanding was correct. In the end of the whole dialog, all the members involved in the conversation could share correct knowledge about the translation result. This kind of repair could be called others-initiated repair in conversation analysis terms [Schegloff, 1991] and occured in a collaborative process with other conversation partners.

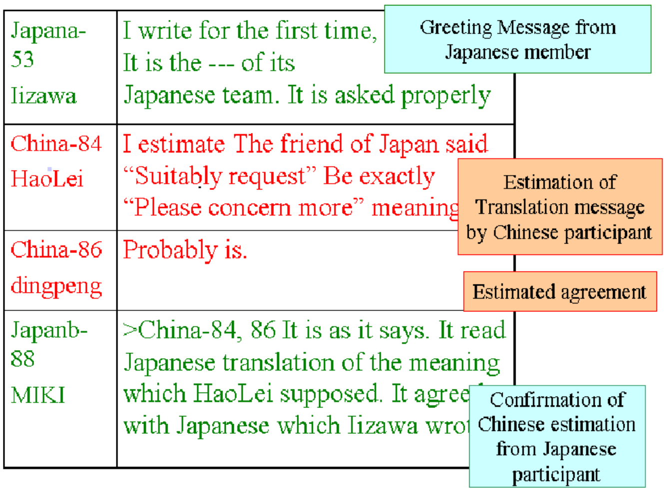

Figure 4.18: Other-initiated repair.

Greetings	Good morning, Good afternoon
Self introduction	I am Dingpeng of the Chinese group
Expression of feeling	It is very nice to meet everybody again!
Social Greetings	Has everyone had their lunch already?

Figure 4.19: Examples of social cues observed in the experiment.

Social Cues

Social cues were frequently observed in the software design phase. A social cue is defined as "a statement or part of a statement not related to the formal content of a subject matter" [Henri, 1992]. Social cues include self introduction, expression of feeling, greeting, closure (e.g., That's it for now), jokes and symbolic icons. Social cues are rarely observed in professional collaborative conversations, so the frequency of social cues might indicate the level of focus on the collaboration by the subjects [Henri, 1992]. Figure 4.19 lists examples of social cues observed in the experiment. Many were from the software design phase (the first phase). Only a few social cues were observed in the software development phase (the second phase).

There were also large differences in the use of social cues in the two tracks. In the first track, almost half of the postings in week one were social cues. In the second track, however, not many social cues were observed both in the first and the second phase. The experimental results between the two tracks were also different. The first track succeeded to submit an integrated software system while the second track did not [Yasuoka et al., 2003].

Creation of unique expressions

It was also in the first phase that participants created unique expressions. Wrongly translated but repeatedly used expressions and short funny expressions were shared sometimes gradually among the participants. For example, a statement often used by one Korean member, “Do our best!”, was translated into Japanese “Ganbaro”. [4] The meaning of the statement was not understandable from the context. However, the Japanese who displayed five languages figured out the intended meaning by referring to other languages. Over time, several Japanese started to use “Ganbaro” in many occasions. This statement was often used in different ways at the end of the first phase as a shared phrase to cheer up others.

Figure 4.20 shows another example of creation of unique expressions. The participants created expressions related to TransBBS and TransWEB, such as TransSMS, TransChat while they were discussing and brainstorming on ideas for multilingual functions in their collaboration support system. They called these functions TransXXX.


china-118 || 投稿者: Zhu Lejun || document
Subject: Re: China-117
投稿日時: 2002年06月09日 日曜日 09時13分21秒

日本語 (retranslate)	英語(retranslate)	中国語
Translation Error(Time out)	I feel TRANSSEARCH plan is very good, we should adopt this plan. But use which searches the service also need the careful consideration. If can't solve the TRANSSEARCH problem, I feel TRANSFLOW can also do Transbusiness plan seemingly more like a gateway website. We can at the skill of TRANS series all develops accomplish after use them to erect a TRANSBUSINESS demonstration web site again.	我觉得TransSearch的方案很好，我们应该采用这个方案。但是使用哪个搜索服务还需要仔细考虑。如果不能解决TransSearch的问题，那么我认为TransFlow也可以做一下。TransBusiness的方案似乎更象一个门户站点。我们可以在Trans系列的技术全部开发完成以后再用它们来架设一个TransBusiness的演示网站。

Figure 4.20: Creation of unique expressions.

Software Implementation Phase

The Software Implementation Phase took place from the 23rd of June to the 19th of July (the first track), and from the 18th of November to the 15th December (the second

[4] This “Ganbaro” is a encouragement expression meaning “keep trying” or “try hard”.

track) after a 10 days adjustment period following the first phase (see Figure 4.14). These additional four weeks were used to implement the integrated software that each country had designed in the first phase. The participants were expected to finalize their initial software design before the second phase and expected to implement and submit the final product in these four weeks of the development phase. In this phase, a Concurrent Versions System (CVS) was installed on the central server in order to maximize the efficiency of software development in the distributed environment. Also, a software integration team was formed beyond nationality to integrate modules developed in each country. The software integration team was composed of one member from each country.

In the software implementation phase, the number of social cues, repair activities, and created shared expressions observed in the first phase decreased drastically . Instead, lean conversation [Yamauchi et al., 2000] characterized by minimum topic, shortness, and professional computer science expressions became dominant.

Professional Topics

In contrast to the first phase, the conversation topic in the second phase was limited; mainly about software development. The sentences included more technical terms and code of computer languages rather than social cues such as weather topics, feelings, and greetings. Number of postings related to software development increased statistically as shown by the number of postings (see Figure 4.21) [Yasuoka et al., 2003].

Topics related to the professional domain tended to last longer. Figure 4.22 shows an example of technical conversation. One participant asked about the possibility of using translation functions in e-mails. This resulted in a discussion on the technical possibilities. In these conversations, the participants often used technical terms such as math formula, graphs and UML (see Figure 4.23), use-cases, data base entries and so on, which did not need to be translated in order to be understood by all participants.

Experiment Results

There were 281 message postings in the first phase of the first track, 200 postings in the second phase of the first track, 480 postings in the first phase of the second track, and 234 postings in the second phase of the second track as shown in Figure 4.24.

In the first track, groups from each country developed a software module independently as shown in Figure 4.25. Each module was designed in the first phase and integrated as software by an integration team in the second phase.

The Second Track

In the second track, groups from each country developed software modules independently as shown in Figure 4.26. However, modules developed in each team were not integrated by the end of the experiment in spite of a substantial effort by the integration team in the second track.

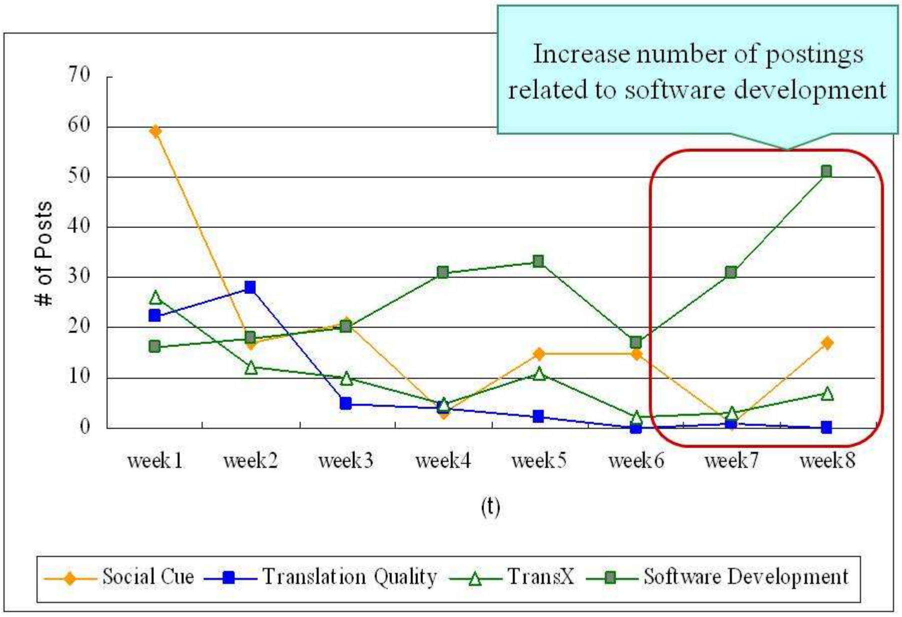

Figure 4.21: Topics about software development increased in the late second phase.

4.3.4 Analysis on Collaboration

In this section, we analyze the collaboration process among participants with different language background, who were involved in the ICE project. For this analysis, we deploy the mixed method (see Chapter 3). The analysis focuses on communication aspects based on conversation analysis [Schegloff, 1991] and statistical data analysis. We briefly review several analytical aspects including *distortions*, *communication modality*, *strategies for handling breakdowns*, *creation of words, expressions and sentences*.

How do they collaborate?

The collaboration style was interactive and active in the software design phase, and became a simple collaboration style with less interaction in the software implementation phase. This characteristic is clearer in the first track than in the second track even though the overall tendency of the two tracks are quite similar. In the software design phase, the participants discussed, exchanged opinions and created expressions iteratively. During this phase, the participants established a fundamental collaborative environment by understanding how TransBBS and TransWEB worked and getting to know the other members by posting messages categorized as social cues. In this software design phase, the participants started to use the same words, create expressions and sentences occasionally as shown in

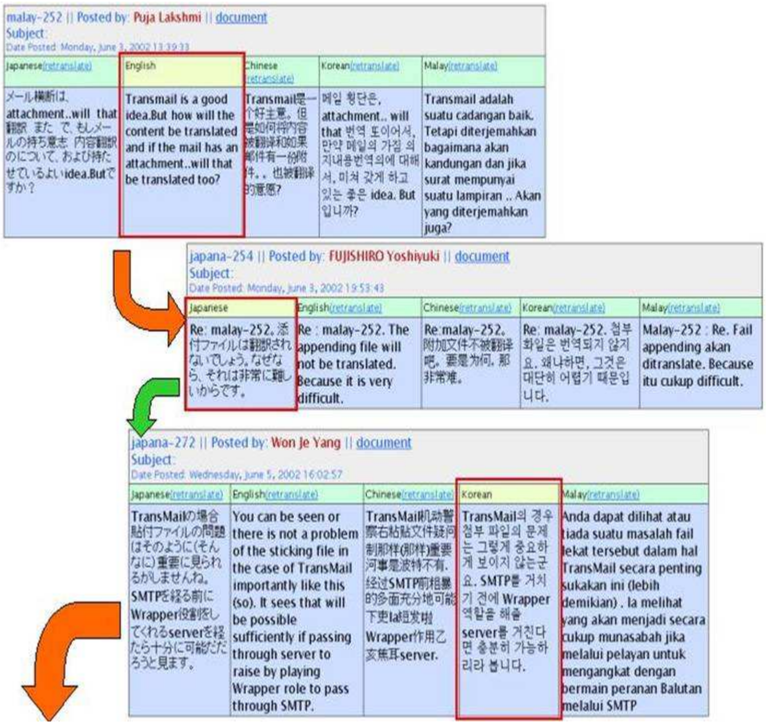

Figure 4.22: Topics about professional expressions last longer.

Section 4.3.3. On the other hand, in the implementation phase, the participants changed their collaborative attitude to one that can be characterized as professional behavior in a distributed setting, namely *lean collaboration* [Yamauchi et al., 2000]. Just like the end of the collaboration in the Software design case (Section 4.1), the end of the Carlsberg case (Section 4.2), the renovation case (Section 4.4) and the Svane case (Section 4.5), the participants in the ICE case became very independent and each participant had a clear role and objective and worked separately. Their interactions were limited to ask questions and report their progress on the TransBBS or TransWEB from time to time. In sum, with respect to conversation, it was active and informal in the software design phase, but became minimal and rational in the software development phase.

The fact that the first track had more complete integrated software systems than the second track may be explained by the activities in the first phase. Further investigation is necessary to draw any conclusions. But clear differences were seen in the quantity of social cues and the related important aspects of establishing a foundation for collaborative.

In the ICE case, even though the participants belonged to different ethnic cultures, they also belonged to the same culture of computer science. With such common ground (see Section 2.3.2) as computer scientists, they had shared computer science knowledge and experiences on how to develop software as well. The common ground was professional expressions and signs that they had learned in their computer science education and practical experience. For example, technical terms such as JAVA code, C language, use-case,

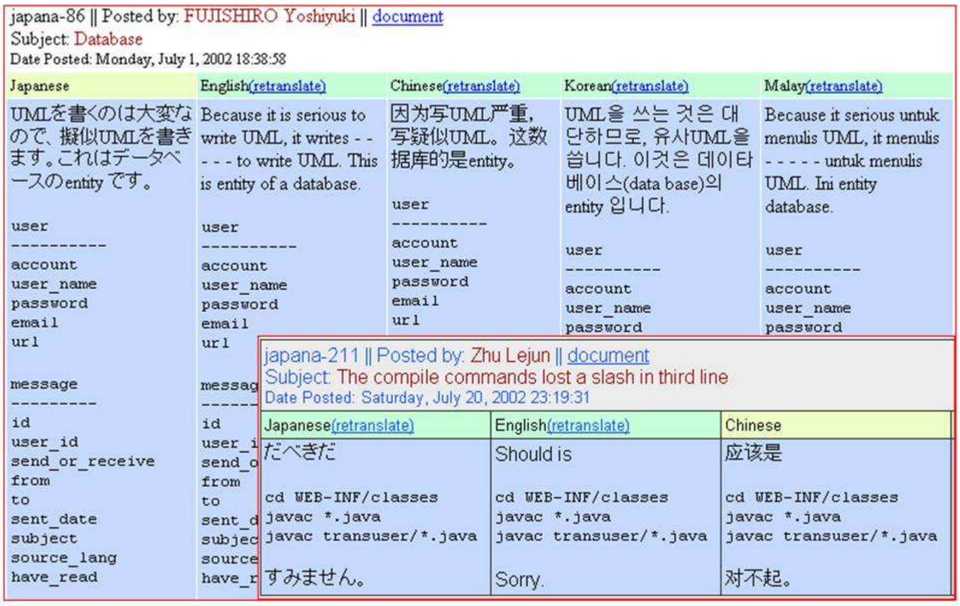

Figure 4.23: UML is a good communication mode for participants in ICE.

	The First Track	The Second Track
The First Phase	281	480
The Second Phase	200	234

Figure 4.24: Post number summary.

UML were often used especially in the second phase. It was observed that participants communicated with such professional expressions together with short simple messages. Another good example is related to scheduling and the process of software development. The members did not discuss scheduling nor development processes explicitly but such software development schedule knowledge might already have existed as common ground among members. Although there were several undergraduate students who had less experience in software development projects, they followed their seniors' activities and learned software development processes from them. In the ICE case, such learning process was observed and several orders as well as classification schemes also existed to some extent. However, this learning related matter will be discussed only in the final chapter 5 as it is less related to the focus of this thesis.

Group	Software	Function	Status
China	TransSearch	Translation service that show the translated results of five languages. Translate query terms and send them to google. Search results are browsed in TransWEB.	Complete
Japan	TransMail	Web based email module with five language translation function.	Complete
Korea	TransChat	Web based chat services with five language translation function	Incomplete
Malay	TransSMS	Short mail messaging service for PDAs and mobile devices	Complete

Figure 4.25: Developed modules of the first track.

Group	Software	Function	Status
China	TransSearch	Translation service that show the translated results of five languages. Translate query terms and send them to google. Search results are browsed in TransWEB.	Complete
Japan	TransGroupware	Support functions for group activity, schedule management and agent support functions.	Incomplete
Korea	TransChat	Web based chat services with five language translation function.	Complete
Malay	TransSMS	Short mail messaging service with five language translation focusing on security features of customizing a text-to-speech engine function.	Complete

Figure 4.26: Developed modules of the second track.

Distortions

Participants gathered for this experiment from different ethnic cultures with different mother tongues. Although they had common ground such as computer science educational background, ethnic culture differences among them were wide enough to lead to ontological drift. Distortions observed in the ICE case are first of all, one of the ethnic culture differences, language. A unique aspect of this case is that the language differences were supported by computational artifacts with automatic translation mechanisms. Thus ideally, language differences could not have been a distortion. Still, it was clear from the analysis that these computational artifacts became obstacles in many occasions, and it is reasonable to say that the language differences in ICE were not fully solved. However, it is important to note that many Asian programmers and engineers are typically very much reluctant to communicate with those who do not use the same mother tongue, but not in the ICE case. Stakeholders in ICE acquired a certain amount of language support for their collaborative project with machine translation functions embedded in computational artifacts. Consequently, in spite of the distortions observed in relation to computational artifacts, the potential of such intercultural collaboration support systems should not be neglected [Nomura et al., 2003b].

Communication modality

The communication tools that the participants could use in this case was only the computational artifacts; TransBBS and TransWEB. In the other cases (the software design, the Carlsberg, the renovation and the Svane cases), the stakeholders often or occasionally used oral conversation among participants. In this case participants were neither allowed to have face-to-face conversation nor to make phone calls. They did not interact with each other orally. Instead of using oral conversation, participants mainly utilized written expressions on the TransBBS for collaboration. Because of the barrier caused by unsatisfactory machine translation, they also invented their own communicative methods such as using math formula, computer languages and signs for computer scientists in addition to verbal sentences. They sometimes used TransWEB and showed their design ideas with UML which is a one kind of universal signs for computer scientists.

The participants had to learn as well as invent a better way to use the computational artifacts they were offered. Although they used only these limited computational artifacts, they used them in multiple ways. First, they translated sentences multiple times and compared translation results in English before posting to the BBS. They also compared multiple languages by displaying five languages at the same time. By displaying multiple languages, they were able to check the quality of translated messages. Even with minimal knowledge of the other languages, they could check the length of sentences, or simply check error messages. They also utilized multiple writing forms such as math formula, graphs and UML, use-cases and so forth as mentioned.

In sum, during the experiment, the following three communication tendencies in the use of computational artifacts were observed. First, technical terms were often used. Second, technical conversation lasted longer than conversation about other topics. Finally, third, multiple communication modalities with written conversation, figures, graphs and lists were used and such compound characteristics of communication were supported by computational artifacts.

Strategies for handling breakdowns

In the ICE case, ontological drift was often externalized in writing such as BBS messages, drawings and figures in the form of breakdowns. At the same time, breakdowns caused by computational artifacts were often observed. As mentioned before, TransBBS and TransWEB could support collaboration by offering machine translation functionalities, however it became clear a source of distortions.

Such distortions caused by computational artifacts should not be neglected. However, in spite of the dis-satisfactory quality of the offered machine translation, in the process of using computational artifacts, participants invented ways to make the most of what they were offered. Many participants devised ways of communicating effectively with other members such as conducting self-initiated repair before posting, posting new findings on how machine translation worked, and displaying five languages to check whether all posted sentences were at least translated into the four other languages. Throughout the two phases, the machine translation were used in different ways to overcome noise of computational artifacts such repair, use of common knowledge and creation of unique expressions. In that sense, the computational artifacts of the ICE case were used as boundary objects (see Section 2.3.3).

In order to avoid communication errors as much as possible, self initiated repair (e.g., see Figure 4.16 and 4.17) and other-initiated repair (e.g., see Figure 4.18) were often observed. Repair activities were often observed mainly in the software design phase. They were observed especially in connection with human adaptation to the mechanism of machine translation. The participants started to refine their postings in order for them to be accepted by the machine translation and get used to the way the machine translated their own mother tongue.

The participants refined postings again and again to look for sentences that would lead to more accurate machine translation. In the conversations where dialogs were extended over time (e.g., see Figure4.22), what the posters wrote in their mother tongue was often unnatural(as also shown in Figure4.16). This indicates that participants composed sentences in order to fit the machine translation mechanism even when using their mother tongue, and in the end they got used to write these unnatural compositions.

The participants verified each other's understanding consciously in order to convey their intentions. There were cases where participants asked about the meaning of postings by another participant with a different language, and someone else who understood or guessed the meaning answered the question (see Figure 4.18). In another case, the participants checked reactions from other participants to see if their understanding was correct (see Figure 4.17). Even if it was difficult to adapt to machine translation, the participants could interact with the machine consciously and tried to make better communication with others by confirming meanings and clarifying language structures.

In order to conduct self-initiated repair and others-initiated repair, the characteristics of computational artifacts contributed to a large extent. With the compound characteristics of the computational artifact such as displaying multiple aspects of one posting, the computational artifacts made it possible to externalize tacit knowledge, and visualize them as external representations, which otherwise invisible. Some of such external representation play a boundary object role in some cases.

Creation of words, expressions and sentences

The participants established unique expressions shared among members. They supported each other to make the most of the insufficient machine translation in the end. In conversations where the extension of the dialog over time was observed, the participants often used unique but already shared expressions among the members (see Section 4.3.3 and Figure 4.20).

Many new ideas for software design were suggested in discussions. For example, a unique keyword for a software design idea that one participant suggested in the beginning of the first phase but neglected over time, was often suggested again by other participants. Sometimes it became a core keyword for the software development in the end. The idea was created among participants, incubated during discussions and crystallized as a software design idea in the end.

4.4 Case 4: Copenhagen Building Renovation

4.4.1 Background

This empirical investigation case deals with the collaboration process in connection with the design and specification of the renovation of an old building situated in Copenhagen. Professionals with different knowledge background from different firms gathered and worked for this renovation case. They almost always collaborated in a distributed setting, by phone and by exchanging e-mails containing digital drawings and documents. They usually worked individually on the parts of the project they were responsible for. They had co-located meetings from time to time usually once a month.

Participants

There are six participants in total. The group consisted of two architects from different architect offices, a ventilation technician, an interior designer, a client and a user. The majority of the stakeholders had worked together on this project for two years. Many of them knew each other from this two year design phase even though they had a limited number of face-to-face meetings. Danish was used as common language since they all had Danish as mother tongue.

Project background

The renovation project of the old building was postponed several times. In the beginning, the project was supposed to finalize in a single year. However, due to constraints such as an official permission from the Copenhagen municipal office and design modifications suggested by the client, the project was considerably delayed. By the time we joined the project, the stakeholders had just reached to the final stage of the overall building design and had agreed on the initial drawings. Moreover, the project had just received an approval for the building renovation from the local municipal office. When we began to participate, the stakeholders were working on design development and had just started to discuss the details of the interior design and technical design.

4.4.2 Analysis Method

In this renovation case, an empirical approach (see Section 3.2.1) was taken in order to understand the collaborative process among professionals with different work culture backgrounds. Since the stakeholders mainly collaborated in a distributed environment, we targeted the work of an individual architect and observed him while he was working with CAD systems in his office. The observation was conducted during January to July 2007. Six co-located meetings during that period were conducted. However, only a part of the meetings were observed for practical reasons. After the main period in July 2007, an interview of the architect (see Section 3.2.1) was made.

The model of observation was *participating observer* [Gold, 1958], where the observer participates and intervenes in activities by asking about the subject's behavior or activities as described in Section 3.2.1. Observations were conducted from one corner of the architect's table. From that position, his hands movements, artifacts on the table and his computer display were easily observed without disturbing his activities. Phone conversations were also observed. Research notes about events, significant happenings and his replies toward our questions were recorded. In the interview with him, the interviewer had a seat next to him at one corner at his desk so that the interviewer could see the display of his computer screen and things he pointed out. Notes taken during the empirical investigation were transcribed shortly after each empirical session. Data collected from the case includes notes from observations, voice recording from interviews that were carried out in July 2007, and several digital pictures that capture the work environment.

When we began our observations, their collaboration were at the stage of design development. They had already discussed the initial design and had moved to specify details about the technical design rather than creating ideas. However, even though they were in the second design phase, the stakeholders sometimes found unsolved initial design issues. Individual work was tightly connected to the co-located meetings held each month. Each professional prepared for these meetings by updating and re-edit drawings and ideas. Individual work was investigated as a part of the collaborative processes.

4.4.3 Case Details - Observation and Interview

Observations and interviews were made from March to July 2007. Six collective but short co-located meetings were made during the period. Before the observation period started, the project members had already agreed on an overall design of the renovation plan. In the observed four months period, they mainly discussed the detailed design of each room, such as kitchen and conference rooms.

Stakeholders were situated in a distributed environment but worked tightly collaboratively. They worked on their own part they were responsible for. They exchanged their new or updated digital drawing data frequently in between the monthly co-located meetings. They used CAD drawings and CAD systems not only to reify finalized design ideas, but also to communicate new design ideas. They drew their own CAD drawing versions with their own signs and notations rather than sharing one standard. Even so, everyone almost always sent his drawings when he made another version. They exchanged their own digital drawings when they updated, and checked compatibilities between their own drawings and other members' drawings in order to avoid any technical issues. As a consequences, quite a large amount of drawings were to be regularly exchanged. This style is often used in collaboration especially when a project is small or middle sized.

At the collective meetings, prints of a targeted area were prepared and put on the wide table in the middle of the meeting room. In addition each professional usually brought his own latest CAD prints with him. They tended to bring their own version of CAD drawings, no matter what topic they decided to discuss at the meeting. For example, at the meeting when they discussed about conference room design, the ventilation engineer brought his own drawings that showed mainly ventilation lines. Similarly, the interior designer had his own drawings when the architect drawings were on the discussion table. At the meetings, the stakeholders discussed their progress, new suggestions, questions and issues that each member had faced when they drew CAD drawings of a target area as well as when they checked the CAD drawings of other members. They often changed discussion topic when someone had found a critical issue while checking the design such as in the conference room mentioned below. After the meetings, agreed design refinements were reflected on each CAD drawing. Each stakeholder sent the other members a set of revised CAD drawings in digital format of his part based on the discussion. In addition, several kinds of documents such as official records of meetings were shared via email.

This process was repeated in the observed period. After the design development period had ended, a large part of the responsibilities of the architects' design plan was taken over by a construction company. Our empirical investigation does not cover this part of the project. Next, we give details about the collaborative procedure using the discussion of the conference room as an example.

Design of the conference room

Stakeholders iterated the process of designing, checking compatibilities and revising drawings individually before the meeting. Before the each meeting, they exchanged their latest versions of digital drawings focusing on the areas they had decided to discuss in the previous meeting. By the co-located meetings, stakeholders had already exchanged their digital drawings several times and made a list of what to discuss further.

Just a few days before the meeting about the conference room, one architect compared the interior designer's CAD drawings with his own CAD drawings. He happened to find that a huge projector was to be embedded in the wall where a heating system was supposed to be situated. He phoned to the interior designer and discussed a revised design plan. After he revised the CAD drawing together with the interior designer by phoning and exchanging digital drawings, he sent a revised CAD drawing to all stakeholders. However, soon after he realized again that the refined plan was also not possible to construct because the expected trajectory of the projector to the screen was nearly cut by a huge steel frame that was planed to lie over the ceiling towards the wall in order to strengthen the buildings construction frame.

4.4.4 Analysis on Collaboration

In this section, we analyze the collaboration process among the professionals that were involved in the Copenhagen Building Renovation case. The analysis focuses on communication aspects based on ethnographical investigating (see Section 3.2.1). We briefly review several analytical aspects including *distortions, communication modality, strategies for handling breakdowns, and others*, related to the problem of ontological drift (see in Section2.3.1) and its handling.

How do they collaborate?

Their collaboration style was clearly professional. They were very independent and each professional had a clear role and worked separately. When they worked separately, their collaboration style has strong lean [Yamauchi et al., 2000] aspects characterized by minimum topic and short conversation. At the same time, they had co-located meetings once a month and they distributed their own refined drawings to the other stakeholders.

Distortion

The professionals gathered for this one time project from different design work cultures. Although they had common ground (see Section 2.3.2) such as being Danish and sharing a design related profession, breakdowns rooted in ontological drift cased by differences in work culture were often observed. In addition, they had another challenge, which was to collaborate through computational artifacts, mainly CAD systems. Since they were already in the design development phase and worked independently on their own responsibilities, potential misalignment happened less than in the early design period. However, the stakeholders in this case used different local practice of their own firms, some of which were supported by using CAD systems but not all. On the contrary, CAD systems sometimes became a source of distortion in addition to intercultural collaboration challenges such as ontological drift.

Danish architectural offices usually apply the CAD manual called "ibb 00" and set up data depositories on the web for their projects especially for bigger and longer projects to avoid misalignment. However they are time consuming, costly, and more over, professionals often prefer using their own local practice for their work effectiveness. In this case, professionals agreed beforehand not to formulate standard formats and used each other's local practice. Since the project was low-budget and it was expected to be only a short period project, the professionals of the development group did not initially think it was important to rigidly agree on a common format, for example, data structures, sign usage, and CAD system versions. However, standardized formats could have been applied just as in the Carlsberg case.

Each professional used his or her own format including notations on the CAD prints and their own CAD system. Because of the different usage of format and notations, each professional often faced CAD drawings by others that could not be read into their CAD systems. Even when they could open CAD files made by different CAD software, there were still a high chance that small details of other's CAD drawings were displayed wrongly. Just as shown in Section 4.4.3, it is reasonable to think that the architect and the interior designer's CAD drawing shows different drawings with different signs and notations. The area in which a huge projector were installed was shown as empty space in interior designer's CAD drawings. The architect and the interior designer did not notice this incompatibility since they worked on converted documents in order to use their own local format and they did not think about the possibility that documents were converted and described incorrectly until the moment that the architect found the incompatibility.

Communication modality

In the renovation case, the participants collaborated through oral conversation on phone calls, computational artifacts, and other kinds of artifacts such as drawings, mock-ups, pictures. In the face-to-face meeting, oral conversation was largely influenced by tangible artifacts such as hand drawings and multiple layers of CAD prints displayed on the table. Stakeholders sometimes interacted only with paper and CAD prints without speaking to each other. Computational artifacts such as e-mails, CAD systems and their peripherals took important roles for facilitating collaboration during the whole observed period. Especially, CAD systems offering compound roles of boundary object showed unique characteristics.

Professionals exchanged their updated CAD drawings frequently. Drawings that would have been exchanged in mail or fax a decade ago were now exchanged in the digital formats. For that reason, CAD systems were used not only to reify design ideas for their own sake but also to transmit their design ideas to others. For example in this case, the architect used CAD systems for reifying his own idea, sending his drawings, receiving others' drawings and refining them. All the more, received CAD digital drawings from other collaborators made him discover design mistakes before the collective meetings by comparing several drawings made by different professionals.

More importantly, CAD peripherals such as CAD prints generated by CAD systems facilitated collaborative work strongly among different professionals. For designing the building, the architects, the interior designer, and the ventilation technician created CAD drawings while the client and the user read CAD prints, drawings and models together with others. Digital CAD drawings were circulated, displayed and often printed out among the architects, the interior designer and the ventilation technician.

Strategies for handling breakdowns

In this renovation case, breakdowns caused by computational artifacts were often observed. One of the reasons was due to variations of CAD software. For example, one architect used MacCAD while another used AutoCAD. Different CAD systems have conversion functions so that in theory, they should not have any problems loading and saving digital documents of different CAD software. However, several issues occurred because of the different file formats used by stakeholders in this case. Ontological drift were often disclosed when data was transformed into tangible artifacts. Such tangible forms as CAD prints, were used both in collaboration settings and individual work environment. In collaborative settings, there were always pens, papers, markers,, post-it, other drawing equipments, mock-ups and some photos from the site together with CAD prints in A1 size on the discussion table. In addition, individuals brought their own print-out version. For example, the interior designer brought his own drawings that used notations which were unique to to him, while the architect used other notations that were not used by the interior designer. In individual work, professionals also kept CAD prints made by themselves as well as others. Tangible forms of their design were more visible than electronic formats and was comparable with others.

In addition, the professionals had invented several local conventions for collaboration such as sending PDF documents together with the original CAD drawings. Since PDF documents would keep the original style, the viewer could see exactly the same view that the sender intended to show.

Other findings

There are other unique findings related to the use of CAD systems in collaborations among professionals with different knowledge background. We observed that CAD systems were used occasionally for different collaborative purposes throughout the design processes, such as *allowing different sign usages, translating signs and expressions, and providing formats.* Below, we describe these findings.

Computational artifacts **allow different sign usages**. In this case, original data was exchanged in the owner's CAD format. This meant that local conventional formats of the first author, which differed from place to place were preserved when the digital data was distributed to stakeholders. If the receivers of the digital documents used a different format or a different version of CAD system, the CAD drawings could be converted into the receiver's format. CAD systems usually have functions to make two systems compatible. As one architect mentioned "CAD software has translation functions", digital data often have to be converted in order to be read. This auto-converting function in CAD systems could be understood as similar cases of the auto-converting systems that exist between Macintosh and Microsoft operating system for example. As a Macintosh user knows, files made by Microsoft Office Word can be converted to a Macintosh document. So, a Macintosh user can read documents written by Microsoft software. However, as Macintosh users also know, there is a high risk that the converted documents miss indentation or format information. Thus, professionals in this renovation case often sent PDF files together with digital CAD documents. In addition, when the design professionals had face-to-face meetings occasionally, each member brought his own CAD blueprints as described previously. Each professional took his own version of CAD prints with him, no matter which topic was discussed. One architect commented about this behavior,

> All members use CAD systems. However, it is often the case that each has some difficulties to read others' CAD drawings. The interior designer uses different lines, descriptions and signs.

It is often the case that each professional needs his or her version of CAD prints with familiar signs, lines and notations in order to understand the shared prints displayed on the discussion table better. Except for projects where a standard format is defined and agreed beforehand, professionals collaborate under influence of unfamiliar usage of CAD systems, and thus they face a certain amount of continuous ambiguities.

Computational artifacts **translate signs and expressions**. In this renovation case, the members largely relied on the converting functions of their own CAD systems when they checked, utilized, and merged a part of or all of another CAD drawing in spite the common understanding of deficiencies of the converting functions. The main reason is that they can easily manipulate the CAD data if they are not PDF files. As a result of using such convertible digital documents, they experienced a lot of challenges caused by miss conversions made by the CAD systems.

One experienced architect commented,

> Machine translation doesn't work even if its function is perfect. If the translation looks perfect then I may not realize it is translated. It is hard to know whether the machine has correctly interpreted the drawings of other authors. Just like Microsoft Word, you may forget when a document written in Word has changed the date automatically.

To solve this issue, as mentioned earlier, professionals use the conventional solution to send PDF together with digital drawings. One architect said,

> When sharing CAD data, it is necessary also to send a PDF version rather than sending only the digital drawing. Each member tends to use different CAD systems which cause problems with compatibilities. Many CAD systems have 'translators' to change format from one to another, however, sometimes they change lines or layout. It is difficult to find out.

However, at the same time, it is still important to exchange digital data so that professionals can modify drawings of others easily, and merge with their own data.

Computational artifacts **provide formats**. CAD systems can provide standard formats by restricting the version of the system, usages of layers, and data structures among stakeholders. In many collaboration cases such as the Carlsberg case, standardization is made for maintaining better collaboration and avoiding ontological drift among stakeholders caused by computer systems. Ontological drift or mistakes shown in the conference room design example in Section 4.4.3 happened largely because each professional used different layers, different versions of the same CAD systems, or different CAD systems. For example, when each stakeholder uses different layers, some important information, signs and notations are sometimes not shown. This kind of trouble caused by layer usage can be avoided if they share a standard format rather than using local formats. In the renovation case, the architect, the interior designer, and the ventilation engineer used different CAD systems, which made it difficult for them to read drawings precisely in spite of all the support functions of CAD systems.

However, there are disadvantages of using standard formats especially in small groups and in short projects. The main disadvantage is the overhead of learning new formats, versions and systems imposed on each individual. Moreover, Some professionals joining the project might not be accustomed to use the shared format. In this case, those who are not familiar with the specific format have to spend a significant amount of time to acquire skills. One architect specifically mentioned this as the reason that they did not choose to use a standardized format,

> We use localized formats because the project is short and it is expected to be very costly if we have to decide on shared signs or (ask several members to) learn another format.

The burden for accommodating to another work cultural tradition is too large in this project. To work using different practice is very pragmatic especially in the beginning of a collaboration. The more specialized the professional skills of the collaborators are, the more problematic it becomes to ask for a change of their practice. Professionals prefer their own way of doing things that has required a long and hard work to learn and acquire. This was pointed out as one of the challenges that collaboration among professionals with different knowledge background faces.

> [...] interactions across practices are not inconsequential; the knowledge that people accumulate and use is often "at stake." They are reluctant to change their hard-won outcomes because it is costly to change their knowledge and skills. The cross-boundary challenge is not just that communication is hard, but that to resolve the negative consequences by the individuals from each function they have to be willing to alter their own knowledge, but also be capable of influencing or transforming the knowledge used by the other function [Carlile, 2002] (p.445).

4.5 Case 5: Svane Illuminated Sign

4.5.1 Background

This empirical investigation case deals with a collaboration process carried out by a small light technology company called LEDlumina A/S (LEDlumina). LEDlumina owns a unique illumination technology for Light Emitting Diodes (LEDs). In this empirical case, LEDlumina was responsible for the design and production of a large illuminated sign for the headquarter of a kitchen design company called SVANE A/S (SVANE). In order to deliver products, professionals with different knowledge background formed a project team. LEDlumina and the customer, SVANE, rarely met during the project, and even the other professionals on the project almost always collaborated with each other in a distributed setting, by phoning, exchanging e-mails, digital drawings and documents. Each professional knew that each role in the project was defined and established, and they worked independently in their individual offices. LEDlumina took a central role in this project and its responsibility was to design, produce and deliver laminated signs to SVANE.

Participants

There were four stakeholders. Two of them were from LEDlumina; one was a lightning engineer (Kai), and the other was a manufacturer (Thomas). The others were a sign maker (Martin) and a customer. Thomas' factory joined LEDlumina 1.5 years ago so Thomas and Kai knew each other moderately well. Martin knew Kai through business for 5 years, and got an order from SVANE in order to develop a lightning solution for signs. Martin contacted the customer from time to time, however the others did not meet the customer through the whole process. Kai and Thomas and Kai and Martin often met face-to-face during the project. However, the three of them, Kai, Thomas and Martin did not have collective meetings or co-located offices. Danish was used as a common language since they all had danish as mother tongue.

Project background

This project was initiated by the sign maker, Martin. SVANE asked him for an illuminated sign solution for their building's company logo. Since SVANE already had their own original logo, the task was to (1) comply with their original logo design, (2) design in right size and proportion, (3) choose the right and effective amount of diodes to illuminate the signs, and (4) choose the right color coating for the sign plates. In contrast to the other empirical cases, they did not discuss the detailed design of the product (initial design phase) but were already in the development phase.

4.5.2 Analysis Method

In this Svane case, an empirical approach (see Section 3.2.1) was taken in order to understand the collaborative process among the professionals. After the project, e-mails

Figure 4.27: Svane illuminated sign on the headquarter building.

together with attached documents, related documents, hand drawings and digital drawings that were often made with Photoshop or Illustrator were collected. Several photos were also taken in order to capture working environment and activities of a targeted subject (Kai). In addition, intensive interviews (see Section 3.2.1) about the project were made after the project had finished. In the interview, the observer occupied the seat next to Kai at one corner of his desk so that the display on his computer screen and things he pointed out were visible.

The collaboration process covered in this case was the whole design and production process, from the design of an original lightning solution to the development of a product. Since the initial design of the product of this case already had been decided, the case is categorized as a development phase project in order to differentiate it from cases considering the initial design phase. All e-mail dialogs during the project period (four months) were collected and analyzed as well as interviews.

The office environment

The office was a standard but well equipped room with office facilities. There were two office tables with three chairs, a fax-copy machine and four middle size shelves filled with files, books and lightning sign models. On his table, there were a computer display, a phone, papers, pens, written memos and so on. In the shelf on his left side, there were A4 sized white files ordered from A to Z with information about all customers that LEDlumina had dealt with. The files contained technical information, light analysis, site analysis, instruction manuals from LEDlumina (For customers reference to know how to install the illuminated signs), general expense calculation for diodes, accurate expense calculation for diodes, all transactions, print out of important dialogs among stakeholders, digital and hand sketches both from customers and engineers and diagrams. For each case, the documents were sorted in the order old to new, and closed cases had a final drawing together with an installation manual on the top of the bundle of documents. Some documents were drawn with handwriting and others were untainted printouts.

In addition to this physical paper base filing system, LEDlumina also had a digital filing system on a sever. It was used to store digital drawings and PDF files. Data structure of Illustrator (.ai) files were predefined and all Illustrator documents had names such as DD/MM/YYName/Name.ai. Digital files were not exactly equivalent to the physical files on the shelves. Some PDF files were printed out and filed in white folders, while some hand drawings were scanned and stored digitally. The digital storage and physical filing system formed mutually complementary format.

The collected data from the case were 11 e-mails from the 25th of April to the 10th of August 2007, one Word file, three Illustrator files, one Photoshop file, and four PDF files. Empirical observations were carried out in five days, four hours each. In addition, an intensive interview after the project was carried out on the 24th November 2007 with the illumination engineer and CEO of LEDlumina, Kai at his office. During the interview, seven photos were taken.

4.5.3 Case Details - Observation and Interview

The project lasted four months from the end of April to the beginning of September 2007 (the products were delivered in September). During the project, five main dialogs were made among the professionals. Every professional had his own area of responsibility and they organized their own tasks by themselves. The project was initiated when Martin brought the SVANE illuminated sign order to the illumination professional, Kai in the end of April.

The first dialog

The first dialog was about a cost estimation of the products. Martin asked Kai about the estimated price of two signs with an illuminated solution using LEDs. Kai calculated the number of diodes and peripheral power adapters, and computed the total price. The price of a diode solution for two signs was sent to Thomas, the technician and factory owner (e-mail.1). Thomas calculated the price for two sign plates, coating material, and other additional necessities for producing signs. In the afternoon of the same day, Thomas replied by e-mail with an attached document file containing the total price of the two signs for SVANE (e-mail.2).

(e-mail #1) Sent: 25. April 2007 15:07
Title: SVANE KØKKENET
Input til din kalkulation:
Antal dioder i SCANE: 588stk
Antal strømadapter:5 stk
Antal SnapFix: 28 stk store og 47 stk små i alt 75 stk
Jeg kalkulere med DiBond LED til hele skiltet.
Med venlig hilsen
Kai XXX XXX

(e-mail #2) Sent: 25. April 2007 17:00
Title: Re: SVANE KØKKENET
Price for 2 sets Svane Køkken
- Thomas
Attachment: SVANE.doc

The price calculation was sent to Kai. The next day, Kai issued and sent a quote with a unique bid number "07-100451" attached with the term of acceptance (e-mail.3). In addition, Kai phoned Martin to discuss the coloring of the signs which they had not discussed so far.

(e-mail #3) Sent: 26. April 2007 07:14
Title: Re: Tilbud SVANE KØKKENET
Hej, Martin
Se venligst vedhftet tilbud.
Jeg ringer for at vi kan aftake næmere bl.a. vedr. Lakering.
Med venlig hilsen,
Kai XXX XXX
Attachment: invoice.pdf, terms of condition.pdf

Together with the invoice and the terms of condition, Martin returned to SVANE.

The second dialog

The second dialog was about recalculating the total price of the products. Before this second dialog, SVANE had discussed several sign makers price estimates. SVANE finally contacted Martin in the end of May, and Martin contacted Kai about SVANE's acceptance and a slight change of the order; three sets of signs instead of two. Following the change requested from SVANE, Kai recalculated the price (e-mail.4).

(e-mail #4) Sent: 1. June 2007 09:58
Title: Tilbud på stkKoronaskilte: Svane Køkken
Hej Martin
Jf leverancebeskrivelse I vores tilbud nr. 07-100451 tilbydes hermed:
Med venlig hilsen,
Kai XXX XXX

After two months, the order was made by SVANE and LEDlumina confirmed. At this time, they agreed that the products would be handed over to Martin by Monday the 20th of August, 2007 (e-mail.5).

(e-mail #5) Sent: 25. July 2007 15:48
Title: Orderbekræftelse/ Order comfirmation
Hej Martin,
Vi takker for ordn jf tilbud nr. 07-100451 tilbydes og bekræfter hermed,
at delene til de to skilte vil blive afsendt senest mandag den 20. August 2007.
Jeg ser frem til a modtage grafiske filer i morgen.
Med venlig hilsen,
Kai XXX XXX

The third dialog

The third dialog was about adjusting some details of the sign and diode design. Since the order was confirmed, they finally started to develop the products. Martin, who was the contact to SVANE was responsible for distributing digital drawings to the others when the customer finished the basic drawing specification with the size and details. However, the drawing Kai first received did not have any specifications. "I cannot remember anything else. But this is not right so ask to send the correct version. They have to have a right measure" (From the interview). So, in the e-mail.#6, Kai asked Martin to send the digital file next day. Martin sent a Photoshop file (.eps) to Kai.

(e-mail #6) Sent: 30. July 2007 15:11
Title: VS:Ordre
Hej Kai
Jeg skal bruge 3 logoer paa br. 450*150 cm. udføres som tilbud 07-100451
[...]
Attachment: Svane_logo.eps

In order to make the changes and add the diodes position on the drawing, Kai opened the Photoshop file from Martin with Illustrator that Kai always used for designing. The Photoshop file (.eps) was converted when Kai opened the file with Ilustrator so that Kai could manipulate and add design. Next, Kai sent three digital files to Thomas: One was the digital drawings originally sent by Martin and converted by Illustrator, another was the same file in a different format, and the last was the diode layout drawing. Kai knew from his experience that the receivers of the XXX-V7.ai file could have problems of opening it or drawing in proportion even though Kay always used the V7 document format. For that reason, Kai often attached another version of the Illustrator file that was more widely used among designers.

(e-mail #7) Sent: 31. July 2007 17:46
Title: Logo SVANE KOEKKEN
Hej Thomas
Hermed logofiler til projeket.
Jeg regner med at vi skal tilpasse til det layout, der er skitseret I skLED.pdf
Med venlig hilsen
Kai XXX XXX
Attachment: Svane_logo-V7.ai, Svane_logo.ai, skLED.pdf

When Thomas received the documents, he noticed that the drawing displayed with Illustrator looked different from the original logo of SVANE. The proportions of the *swan* logo and the characters *SVANE* were not equivalent. The body length of the swan logo was shorter than the other drawing (wrong and correct scale see Figure4.28). Thomas phoned Kai. After talking for a while, Kai asked Martin to check and confirm the correct drawing file.

Figure 4.28: Left: Wrong scale. Right: Correct scale.

(e-mail #8) Sent: 31. July 2007 20:06
Title: VS:Ordre
Hej Martin
[...]
[...]
Mvh
Kai
Attachment: Svane_logo-V7[Konverteret].ai

The forth dialog

The fourth dialog was about confirmation of the new design of the illuminated sign. A few days after the previous dialog, Martin confirmed that the file Kai had sent to him had incorrect proportions. Kai and Thomas worked on correcting the logo and Thomas drew a digital file and asked Kai to confirm with PDF file.

(e-mail #9) Sent: 3. August 2007 22:55
Title:
Håber det kan bruges
Mvh. thomas
Attachment: svane opsætning.pdf

The fifth dialog

The fifth dialog was about the color choice for the sign lacquer. First, Martin talked to Kai about the customer's wish regarding the signs finishing color with lacquer. After the phone conversation, Kai visited Thomas and discussed it. The request from SVANE was a silver color with a mat rather than shiny finish. Thomas selected the color and a product with silver and mat finish produced by a specific manufacturer. Detailed information about manufacturing company, paint type, and paint color was sent to Martin. Martin confirmed the color to SVANE. Kai and Martin did not understand the details about the products but just referred to the company's name, and the paint type and color code.

(e-mail #10) Sent: 9. August 2007 07:35
Title: Farvevalg til SVANE KOEKKENET
Hej Martin
Vi forslaar foelgende lak:
Fabrikat: PALINAL
TYPE: Polypal 607/816, Wisaluminium
FARVE: RAL 9006
Denne lak fremstaar som taet på 'sølvfarvet' i en mat finish.
Kender du denne farve eller har du brug for en prove?
Du er velkommen til at ringe herom.
Med venlig hilsen
Kai XXX XXX
Attachment: svane opsætning.pdf

(e-mail #11) Sent: 10. August 2007 13:44
Title: Re: Farvevalg til SVANE KØKKENET
Hej Kai
Farven er godkendt!
Med venlig hilsen
[...]
Martin XXX
Address_ID: 13540 / Project_ID: 15394

After these dialogs (see also Figure 4.29), the products were delivered to SVANE in September 2007. Three illuminated signs were mounted on the wall of the headquarter building of SVANE.

4.5.4 Analysis of Collaboration

In this section, we analyze collaboration process among the professionals involved in the Svane illuminated design case. The analysis focus on communication aspects based on ethnographical investigating (see Section 3.2.1). Since we followed the case from Kai's perspective, we first have a brief look at *how does Kai collaborate*. Next, we review several analytical aspects including *distortions, communication modality and strategies for handling breakdowns*, related to the problem of ontological drift (see Section 2.3.1) and its handling.

How did Kai collaborates

Kai has run LEDlumina for 5 years. Before this job, he was a product developer at Bang and Olufsen for 30 years and business consultant for 10 years. For that reason, he has profound professional knowledge about product development and collaboration techniques along with high professionalism.

Pay attention to technical drawings

With long and multiple experiences in different firms, he realizes problems with technical drawings, such as compatibility issues and collaboration issues. There are several inventions that he uses in the collaborative setting. They are; make phone calls often, pay visits to collaborators if they are near by, pay attention to different file formats and use PDF files. His main trick for better collaboration is to pay attention to the computer-based drawing environment of collaborators and use different digital formats to different professionals. He knows that different professionals use different file formats and it creates issues among stakeholders during the collaboration. In his work, the role of each professional in the collaborative setting is almost always clear. Thus, he uses Illustrator (.ai) files to exchange drawings, PDFs for customers, and CAD/CAM formats for manufacturers. Since he does not use CAD/CAM, he asks one of the other company members to convert .ai files to CAD/CAM files.

Print out digital drawings

Kai is engineer and accustomed to use computers. He mainly uses computers for drawings without first drawing sketches using pen and paper as designers typically do. Still, he uses printouts to check the compatibility of designs and final drawings. In order to keep record, he also prints out digital drawings and files them in folders. "I cannot remember what I did without looking at the digital files. It is difficult to remember what is inside. It is easier to see in printouts rather than retrieve the digital files".

How do they collaborate?

Their collaboration style was clearly professional. They were very independent and each stakeholder understood his own role and worked separately. When they worked separately, their collaboration style has strong lean [Yamauchi et al., 2000] aspects characterized by minimum topic and short conversation as shown in 11 e-mails. They did not need even a single co-located meeting during the four month project period. Firstly because each knew well what his role was, and secondly because the fundamental design of signs were provided from the customer so that they were in the development phase from the beginning rather than in the collaborative design phase. When they needed to collaborate, they contacted each other by phone, or by digital means such as e-mails, digital drawings and documents in order to inform, discuss, confirm, and disseminate information. The purpose was never to design collaboratively. For example, the professionals' interaction in e-mail was very simple with no social cues [Krippendorf, 1981] but focused on the main topic such as informing about progress. They only exchanged 11 e-mails and the number of exchanged digital files was also very small. There were three contracts related documents (two PDF files), one drawing file in Photoshop (.eps) format, three drawing files in Illustrator (.ai) formats, and two drawing files in PDF. The 11 e-mails with files were very short and some of them were only a single line. Even when they phoned, it took less than 5 minutes on average. These data shows that their collaboration was very lean without redundant information.

Distortions

They were from different work cultures and worked in a distributed environment. However, ontological drift caused by work culture differences were not clearly observed in this case. In this case, ontological drift hardly occurred because the case was less complicated and had less collaborative design, compared with the other cases. The collaboration was less complicated because almost all of them had worked together intensively for one year and just for one kind of sign production. Through such period, they constructed common ground (see Section 2.3.2) such as knowledge about each other and how to proceed work together in addition to common ground based on Danish nationality and design related profession. There were less elements of collaborative design because the logo existed before hand and there were no complications additional to duplicating the exact design. At the same time, all production work for the sign was articulated and distributed to each professional. What they needed to do was to do was work within their own professional domain. In that sense, their work was largely depending on individual knowledge and skills. One critical obstacle, however, was the difference of computational software each stakeholder used which sometimes showed drawings in wrong scale.

Communication modality

In this Svane case, they collaborated through computational artifacts and phone calls. They had their own server, e-mails and design software (Illustrator, Photoshop and CAD system), Word files and PDF files as computational artifacts, some of which work as boundary objects (see Section 2.3.3). The server of LEDlumina was set for internal use. All employees were distributed over Denmark (three in Copenhagen, two in Jutlland and two in the office in Jutland). Employees outside the intranet had access through a VPN Client. A large part of the communication was made by e-mail. However, there was not much discussion and the number of exchanged e-mails was very small, only 11 with short contents and very little discussion. As for computational artifacts for drawing designs, both Kai and Thomas used Illustrator, while Martin and the customer used Photoshop. 95% of sign makers and sign manufacturers in Denmark use Illustrator as a de-facto standard, while designers tend to use Photoshop (.esp). When sign manufacturers use machines for production, they tend to use CAD/CAM systems (In other projects carried out by LEDlumina, CAD drawings are often used). Different from renovation case (see Section 4.4) in which CAD systems are used for collaboration, CAD systems in this Svane case were used only as a tool for individual work. Since professionals in this Svane case did not have face-to-face meetings, co-sited collaborative discussions did not happen. Instead of displaying technical drawings physically in the middle of a discussion table in face-to-face meetings as often the case in the renovation case, they were revised, added, and finally circulated among professionals in digital format.

In the Svane case, professionals used oral conversation only by phone and mainly for asking questions and confirming orders or design ideas. The rest of the collaborative work was made by exchanging e-mails sometimes with digital files such as drawings and contracts. Since they worked in the distributed environment, writings shared among professionals tended to be more elaborate rather than impromptu sketches as observed in Carlsberg case. The design drawing of the illuminated sign took the most active role in the collaboration in this case. Professionals often had rich conversation using drawings. One of the most frequently used communication was through this written digital representation.

The use of tangible artifacts was not often observed in this case. However in an usual LEDlumina project, prototypes could be sent in the beginning of the project and to facilitate collaboration among the stakeholders because “Customers have no idea what kind of possibilities there are” (from interview with Kai). The customer can also send prototypes and drawings back. When digital drawings are provided from the customer, it is often the case that half of the work is done. The rest is to design the allocation of diodes. From that point, they can work only with drawings and limited conversation by phone. In addition, conversation by e-mail becomes extremely limited with a few line messages as shown in 11 e-mails.

Strategies for handling breakdowns

In this Svane case, ontological drift was not clearly observed. On the other hand, breakdowns caused by computational artifacts were occasionally observed. Both Illustrator and Photoshop have conversion function so that exchange of files between different software are theoretically possible. However, because of the different file format, one clear issue emerged during the case, which might be rooted in the compatibility issues between Photoshop and Illustrator. In addition, even though Kai and Thomas used the same software, Illustrator, they used different versions so that Kai had to send two identical drawings in different versions.

One clear breakdown happened when Kai and Thomas found the drawing sent by Martin was not in the right proportion (see "dialog three"). Kai and Thomas worked in a distributed environment so that their conversation was with drawing-files and short e-mails. It is reasonable to think that Thomas knew the original drawings of the SVANE logo with the right proportions before receiving the wrong drawing file. Thomas might also have looked at two different logos and compared them with each other. We could not confirm that he put two drawings on the table and compare them, however, in some way, he happened to compare two kinds of logo drawings that ought to have the exactly the same proportion. Receiving the news from Thomas about this wrong proportion of logo drawings, Kai compared the two drawings in printed A4 size paper. By doing so, it was clear to Kai that the first drawing sent by Martin for the sign design had wrong proportions.

In order to avoid confusion about the conversion of files between different file formats, Kai and Thomas also used PDF files several times. Except in the case above, professionals in this case collaborated without critical issues, by being careful on different file format, conducting cross check, and often utilizing PDF.

They also utilized classification schemes as another conventional cooperative work settings (For cooperative work, see Section 2.2.2). Each professional worked on several projects at the same time and each tended to have his own classification of projects. Kai numbered all projects with a unique number when price estimation was sent, so did Martin. However, they had a different numbering system; the case was numbered as "tilbud 07-100451" by Kai while Martin numbered it as "Project_ID: 15394". That could have easily generated confusion. However, they had already learned each others' classification schemes over time. Professionals often used "tilbud 07-100451" for the formal requests or order while the name of the customer SVANE or SVANE KØEKKEN was also used at the same time in 7 out of the 11 e-mails.

	Date	Sender-Receiver	Contents
1	25.04.07	Kai -Thomas	Calculation for lightning part of the two signs (.doc)
		Thomas-Kai	Calculation for the total price for the two signs
		Kai - Martin	Sent an invoice (.pdf)
2	01.06.07	Kai - Martin	Recalculation for 3 logos.
	25.07.07	Kai - Martin	Confirmation of the SVANE order to Martin
3	30.07.07	Martin - Kai	Sent drawing (.eps) to Kai. Promise to confirm the order to SVANE
	31.07.07	Kai - Thomas	Sent drawings sent by Martin and Kai's original (.ai, pdf)
		Kai - Martin	Sent converted drawings (.ai) to Martin in order to confirm the correct design to SVANE. Estimated delivery date 22.09.07
4	03.08.07	Thomas - Kai	Sent a drawing (.pdf)
5	09.08.07	Kai - Martin	Referenced specific silver color paint for the signs
	10.08.07	Martin - Kai	Confirmed the color paint

Figure 4.29: Time line, e-mail dialogs.

Chapter 5

Analysis and discussion

The observation and analysis of the five different intercultural collaboration projects in the preceding chapter allow us to outline some salient features of intercultural collaboration and its communication. Our observations of intercultural collaboration processes suggest that when highly specialized professionals with different knowledge background collaborate for collective concerns in the early design period of relatively short term projects, their collaboration style is characterized by creating what we will refer to as *local and temporary alignment of practices* (or LTAP for short) facilitated by complexes of interrelated communication modalities. At the same time as a part of such collaboration, ontological drift is observed as unavoidable integral aspects of collaboration. Our cases had such an identical characteristic in varied levels.

Before starting our analysis and discussion, we briefly remind the reader about each of the cases.

- Case 1 *Software design case*: Japanese software design professionals with different work culture background discussed and designed a new software tool for scientific conversation analysis. The professionals collaborated mainly through oral communication.

- Case 2 *Carlsberg case*: Design professionals with different nationalities discussed landscape design. The professionals collaborated through drawing design ideas, referring to pictures and sketches, and expressing their opinions through oral communication.

- Case 3 *ICE case*: Computer science professionals with different nationality and located in different countries designed and constructed software systems using solely a computer based intercultural collaboration support systems with integrated multilingual machine translation. The professionals collaborated through a written communication functionality (BBS system) of the collaboration support system. This case was the only experimental case among the five cases.

- Case 4 *Renovation case*: Danish design professionals from the construction domain with different work cultures discussed a renovation plan of an old building. The professionals collaborated through oral discussions, CAD prints, written memos in co-located meetings and design data of CAD systems send between the members.

- Case 5 *Svane case*: Danish design professionals from the sign industry with different work culture backgrounds produced LED illuminated signs in a distributed environment. The professionals collaborated through phone calls and exchanging design data from design support systems.

In this chapter, we will first describe three kinds of collaborative processes that lead to LTAP. They are *negotiation*, *integration*, and *creation*. Second, based on our observations, we discuss which aspects of the collaboration process that may contribute to the emergence of LTAP and what characterizes the process of creating it. We approach these two questions from two major viewpoints. They are the role of communication modalities and the role of computational artifacts. As we discussed in Section 2.5, the mode of communication is one of the keys to understand computer mediated collaboration. In our studies, a wide range of communication modalities were used in the collaboration projects and their usage was often interwoven. As we will see in the following, this communication style was important for creating LTAP.

Computational artifacts also played an important role among professionals for creating LTAP. They carry signs, which facilitate communication by translating and exchanging information and in this way offer multiple capabilities for facilitating collaboration processes among professionals with different knowledge background. Together with communication modalities, computational artifacts offer a wide potential for breaking barriers of collaboration among professionals with different knowledge background as *boundary objects* (see Section 2.3.3). Thus, we argue that understanding the creation of LTAP in our intercultural collaboration cases requires an interrogation of the interwoven communication modalities carried in computational artifacts.

5.1 Local and Temporary Alignment of Practices (LTAP)

The investigations and understanding of our five collaboration cases among professionals with different knowledge background makes it possible for us to examine how professionals collaborate in the intersection of different ethnic and work cultures. Our observations suggest that when highly specialized professionals from such different cultures collaborate for collective concerns in the early design period of relatively short term projects, they often create, what we call, local and temporary alignment of practices (LTAP). The creation of LTAP contributes to intercultural collaboration to a large extent, facilitated by complexes of interrelated of communication modalities.

Our empirical investigation shows that in the later stage of collaboration when professionals cooperate by coordinating their work responsibilities and when divisions of labor are clarified, the learning process of their group knowledge become more critical. In this stage, cooperative work arrangement and articulation work become significant and inevitable, and specialized constructs such as coordinative mechanism [Carstensen, 1996] and ordering systems [Schmidt and Wagner, 2004] become distinctive. Our cases confirmed that they are constructs from high complexes of interrelated coodinative practices and artifacts as Schmidt [Schmidt, 2002] and others argue.

On the other hand, when focusing on the initial design phase when professionals design software, form landscapes, make architecture, and design information systems collaboratively by generating ideas by interacting with each other and artifacts, it is clear that a creative process of LTAP is dominant in stead of coodinative practices. And such *local and temporary languages* or *project jargon* [1] appear to contribute promoting collaborative activities.

Based on the mixed method this thesis applies (see Chapter 3), we treat data both from a qualitative and quantitative perspective. Through this approach, three kinds of complemented styles of project jargon are identified. Professionals achieve LTAP through negotiation, convergence, and creation and their aligned practices range over concepts, words, expressions and even procedures.

5.1.1 LTAP through Negotiation

The first creation of project jargon observed in our cases is the negotiation processes in which professionals interact with artifacts, systems and peer professionals to discuss concepts, words, expressions to reach local, temporary and collective alignment of practices.

Frequently used expressions throughout all meetings in the software design case (see Section 4.1), for example *label*, were used by all professionals since the first meeting. For example in the first 1.5 hours of the fist meeting, *label* was used 44 times while in the last 1.5 hours of the fourth meeting, the expression was used 39 times. Co-occurrence graphs of each professional shows that co-occurrence relations between *label* and other key expressions drifted drastically from person to person in the first meeting. Over time, however, each professional's co-occurrence graph came to have stronger similarity. Figure 4.5 shows how the co-occurrence graphs for *label* for two participants (Asada (programmer A) and Kurakawa (client)) become similar over time. To our knowledge, it is the first time that such negotiation characteristics of a conversation have been visually and statistically clarified and silhouetted in a graphical structure.

Ethnographical investigation (see Section 3.2.1) shows that the members seem to have exchanged questions and answers about *label* repeatedly. For example, conversation 1-8 in the first day was a discussion about the definition of *label* in relation to *group* , in 1-9 in relation to *concept* and *meta-concept*, in 1-11 in relation to *data* and *coding scheme*, in conversation 4-1 on the fourth day, the definition of *label* was discussed in relation to "this (*coding scheme*)", and so forth.

[1] *Jargon* is defined as "the technical terminology or characteristic idiom of a special activity or group", or "a characteristic language of a particular group" in Webster's dictionary. According to Robinson [Robinson and Bannon, 1991], "the difficulties of working in situations where several groups have different practices, traditions, and working objectives are well known.[...] They communicate different in "jargon"."

The same procedures of reaching LTAP through negotiation were observed for example in relation to *coding scheme* (1-1, 1-2, 1-8, 1-10, 1-11, 2-1), *comment annotation* (1-4, 1-10), *notes* (2-3, 3-1, 3-4, 3-5) and so on. Reaching LTAP through confirmations in the relation to other key expressions was the most frequent construct through out the whole discussion in the software design case.

When reaching LTAP through negotiation, professionals discussed key expressions to negotiate alignment among participants in this specific collaboration case. These expressions often became unique for the participants and could often be different from conventional dictionary definitions. Observing and analyzing both the co-occurrence graphs and conversation protocols, it became clear that a definition of key expressions (like *label* in the example above) is gradually converged local and temporary through iterative interactions among professionals. Shown in visualization graphs of oral communication processes for example in Figure 4.5, the co-occurrence graph of each of the four members changed its semantic distance over time and became most similar in the end of the collaboration period (Note that they never became perfectly identical, however). In this collaboration process, exact definitions of key expressions did not exist at any moment, from the beginning till the end. Until to the end, such definitions were iteratively created and renegotiated.

Seen from an observation and analysis perspective, the oral conversation in the software design case was characterized by being recurring and redundant at a first sight. The interaction designer questioned a definition of certain terms iteratively and extensively repeatedly to the extent of such prolix utterances, while the client gave somewhat similar answers over and over again. However, its semantics appear to kept changing iteratively.

In the ICE case (see Section 4.3), LTAP through negotiation was also observed in the process of self-initiated repair. Self-initiated repair activities often occurred in the initial period of collaboration, and in many cases, posted massages on transBBS initiated LTAP through negotiation by checking results of machine translations and sometimes by members exchanging each others understanding of translations over transBBS. Understanding the limitations of machine translation is as if the stakeholders and the machine negotiate which expressions should be used. Figure 4.16 shows such self-initiated repair activities posted by Japanese participant Fujishiro (Introduced in the ICE case as an example of "Adaptation to Machine Translation"). He posted a message using formal Japanese grammar with an awkward polite sentence and unnecessary subject [2] for the message to be translated correctly. He learned how to compose sentences by receiving incomprehensible translation results of repetitive postings by refining his message through a negotiating process referring the translation results generated by machine translation.

Both the renovation case (see Section 4.4) and the Svane case (see Section 4.5) had examples of reaching LTAP through negotiation using a combination of communication modalities such as speech and drawings. For example digital drawings of *the meeting room* in the renovation case had to be brought to the discussion table iteratively. There were different versions of the drawings as a result of repeated exchanges of digital documents.

[2] Natural Japanese sentences tend to omit the subject such as *I, you or we* in sentences. For instance Japanese write (or speak) "go home" instead of "*I* go home"

Digital drawings received from colleagues were opened, rewritten and manipulated with different CAD systems by different professionals, and such digital drawings of the meeting room were displayed with different CAD layers that showed different structures of the building. At the same time, they often printed drawings out, displayed them on the table and compared them. Similar negotiations were seen for the SVANE sign drawings in the Svane case. Misaligned "logo and characters" shown in Figure 4.28 were printed out and displayed at Kai's office. The problematic areas of the drawings were compared and discussed and the most appropriate choice for every one was approved in the course of negotiation. As such, combined with speech, the graphical and portable characteristics of drawings influence the negotiation process to a large extent.

5.1.2 LTAP through Convergence

LTAP through convergence observed in our cases shows that concepts, words, expressions and even systems used among professionals are brought together and integrated. In other words, unique personal concepts, words, and expressions become commoditized and shared. In many cases, one participant's semantic of an expression or way of using an expression is deployed among the other group members.

In the software design case, the key expressions *tree* and *ki* (means trees in Japanese) were used frequently in the beginning of the meetings (e.g., conversation 1-3). However, the usage of *ki* decreased over time. For example, in the first meeting, programmer A and the interaction designer used the expression *ki*, while programmer B and the client used the term *tree* about tree structures in their conversation (Conversation 1-12). On the other hand, in the last meeting, all professionals used the expression *tree* when they meant "tree structures" (Conversation 4-4).

When achieving LTAP through convergence, the participants have different expressions denoting the same concept. Such local and temporary aligned concepts with two expressions often converge to one expression. Cross references of co-occurrence graphs and communication protocols show that the frequency of one expression may suddenly increase drastically, sometimes caused by convergence of expressions.

LTAP through convergence was observed more clearly in cases in which ethnic culture was a source of distortion. The Carlsberg case (see Section 4.2) presented several outstanding examples of the usage of expressions and their semantics. In the case of *wind*, the Japanese architect imagined a soft spring breeze, while the Danish participants imagined a strong winter wind. In the case of *sunlight*, the Japanese imagined morning sun, while the Danish participants imagined evening sun. In these examples, the process of LTAP through convergence was initiated through visual external representations - drawings.

While the professionals discussed the drawings that the Japanese architect was in charge of, he drew a cafe in a position where cafe-customers could enjoy sitting at the cafe corner bathed in morning sunlight. Moreover, he drew a path so that the wind could blow through the landscape of the area. In the case of wind and sunlight, the Japanese architect accepted others interpretation of expressions rather than negotiated his point of view because the site was situated in Denmark where the wind blow strongly and evening sunlight is the most appreciated. In this Carlsberg case, one expression with several associated concepts converged to one semantically equivalent concept, while in the software design case, few expressions with a single concept converged to one expression.

The conversation between a Japanese and a Chinese shown in Figure 4.18, is a good example of LTAP through convergence in the ICE case. In this conversation, a Chinese and a Japanese participant were involved in other-initiated repairs in which the conversation was exchanged among them and repeated collaboratively. In this conversation, the challenge for the Chinese participants was to find out what Japanese-Iizawa's posting meant and not to define a meaning of the posting by themselves. Thus, we argue that their process of alignment assumed an increasingly converging aspect rather than negotiation. The collaboration support tool made this conversation possible between the Japanese and Chinese participants because they could refer to previous postings, check meanings, and validate translation results and spend enough time to investigate the matter over and over again as a part of characteristics of writing (see Section 2.5). This retentive characteristic of Trans-BBS contributed largely to the process of LTAP. In conventional conversation situations such as face-to-face and other synchronous settings, the intervention of the conversation made by the Japanese in Figure 4.18 would have been suspended either due to distance distortion (the Japanese and Chinese members work in distributed environments) or ethnic culture - more precisely language - distortion (The Japanese Iizawa was not capable of understanding Chinese.)

5.1.3 LTAP through Creation

Our cases show that professionals craft and generate concepts, words, expressions, and even procedures that are unique for their collaborative projects. This achievement of LTAP through creation is a third development style of jargon identified in our case studies. The word *segment* and *table* were used frequently from the second meeting in the software design case. Our empirical investigation shows that the key expression, *segment table* was coined on the fourth day through the negotiation process shown in Conversation 4-2. Later on the forth day, it was confirmed that the expression *segment table* was used by all participants. Conversation 3-6 is another example. The programmers and the client discussed the name of a function and collaboratively created the name *Note Temporal Distribution Map, NTDM* through an intentional creation process. In this LTAP through creation, it was apparent the professionals collaboratively coined concepts and words during the discussion through oral conversation. The communication protocol data often shows such creation processes and the co-occurrence graphs also sometimes very clearly indicate a particular point in time where new concepts or expressions were coined. Before participants started to use newly created expressions, they often discussed ideas or concepts that would lead to new expressions afterward. It often occurred without intention but sometimes expressions were created intentionally, especially in the former half of the collaboration in the software design case.

Drawings accelerate the process of LTAP through creation. Examples of this are the created expressions *slimy* and *mountain* in the Carlsberg case. They are not always unique expressions in themself such as NTDM of the software design case, but they still often have unique meanings aligned local and temporary between collaborators that differ from dictionary definitions. *Slimy* does not just mean a slimy shape or slimy texture. It refers to a specific Carlsberg beer factory machine and consequently indicates a specific building in which the machine is located. The created expression *Mountain* in their discussion did also not just mean a natural elevation of the earth's surface rising more or less abruptly to a summit, but the shape of a collection of buildings seen from a vertical angle of the landscape.

The ICE case is another rich source of reaching LTAP through creation. To name a few, expressions such as *TransSearch* and *TransChat* were locally created and used temporary. In this example, a collaboration support system called TransBBS and TransWEB already existed. Thus, created words such as *TransSearch* and *TransChat* automatically takes on the features of translation functionality in their suggested systems. In spite of the high communication barriers in the ICE case, many stakeholders from different countries gradually used the same expressions in collective discussions among distributed members.

5.2 The Role of Communication Modalities

Communication is a key for collaboration among professionals with different knowledge background. More precisely, the communication modality the professionals use has a large impact on their collaborative process. In our studies, a wide range of communication modalities were provided through artifacts and other external representations. Such communication modalities were often complexly interwoven and they offered a potential for breaking barriers observed in intercultural collaboration as boundary objects. In our cases, such a web of communication modalities offered activities that lead to the establishment of LTAP as shown in the preceding section and ontological drift is observed as unavoidable integral aspects.

For example, in the software design case, professionals kept on discussing the same topic iteratively by communicating only via speech while the professionals in the Carlsberg case found semantic difference toward *wind* by communicating orally supported by graphical drawings. Graphical drawing is a strong communicative mode as it gives a written evidence of oral communication. In the ICE case, the professionals checked preceding postings back and forth to investigate others' intention by retrieving stored written posted messages. Furthermore, the professionals exchanged software design ideas in the form of source code and use-cases in addition to the written conversation in BBS. These examples show that in order to understand collaboration, it is not enough to examine only conventional mode of communication, namely conversation.

To briefly iterate the discussion in Section 2.5, Roy Harris [Harris, 1986] argues that sign systems have communication purposes. "A writing system, whatever else it may be, is a system of signs; and all systems of signs presuppose communication purposes for which they are used" (P127). In addition, "graphic systems are independent of oral communication" (p.150) as well as "verbal communication" (p.151). So that, it is critical to focus not only conventional communication - oral conversation, but signs and written artifacts as well.

Consequently, understanding intercultural collaboration requires us to investigate an interrogation of the interwoven communication modalities. In the following section, we investigate the different roles of communication modalities; retentive, graphical and portable, which we found had a potentially strong influence on creation of LTAP.

5.2.1 Retentive

Several modes of communication used in the cases had a tendency to have retentive characteristics especially in the mode of writing. Except for the software design case in which the basic communication modality was oral conversation [3], writing modes of communication played a critical role for retention in the rest of the cases.

In the theories of writing, it has been insisted for decades that writing can retain. According to such theories, writing is inscribed in parchment, stones and papers which enable writing to retain permanently beyond time and space. Thus, "writing can be inspected in much greater detail, in its part as well as its whole, backwards as well as forwards, out of context as well as in its setting" [Goody, 1986]. Roy Harris [Harris, 1986] argues for this point thoroughly and cautiously in his study of writing. To iterate his argument introduced in Section 2.5, writing has to be seen from a temporal perspective because writing has duration. Based on his argument, it is not necessarily true that "all kinds of writing makes it possible to inspect parts as well as whole, backwards as well as forwards".

In our cases, his argument is demonstrated clearly. The architects drew design ideas on paper as a communicative mode, which retains its form for a certain period. Sometimes but not always, the drawings made on paper in the early stage of the collaboration was referred to during the whole project. Drawings made on paper could provide retention due to its material characteristics, which would not be possible if communication was made by oral means.

On the other hand, with respect to drawings made by computational artifacts, premises that were valid for drawings on paper would not be applicable. Design ideas written with *Illustrator* (the Svane case) would disappear unless they were saved as a digital files to be retained. However, saving digital files is not enough. Even if a file is saved on the hard disk of the author's computer, once the file is converted to be shown on a collaborator's computer with a different OS, a different software or different versions to open files, retentive characteristics of this external representation will not be guaranteed. We will continue to discuss this unique feature accompanied with computational artifacts in the next Section 5.3.

[3] Speech can only retain a short moment unless using voice recorder or similar equipment (which was not used for collaborative purpose in the software design case)

5.2.2 Graphical

Many modes of communication used in the cases also have graphical characteristics especially in writing. In cases where drawing, graphs and tables were used, they were rich communicative tools that could not be substituted by simple and conventional oral conversation. Graphical expressions make several things possible that are otherwise impossible. If we try to express and explain a table structure and its contents in a face-to-face conversation without any drawings, we face a serious challenge. Remember Harris' discussion of script and chart. To iterate, charts are systems which make semiological use of absolute locations in a given graphic space, while scripts are systems based on the recognition and relative sequencing of the members of an inventory of characters, such as letters, numerals, syllabaries, differentiated by their form. As shown in Figure 2.2, graphical differences between script and chart requires different processing and interpretation. As a consequence, graphical communication can have a strong influence on collaboration. It enriches communication by offering visibility and tangibility. Consequently it contributes to lowering ambiguity in intercultural collaboration.

Discussions among design professionals were largely facilitated by drawings by the Japanese landscape architect Kiyo in the Carlsberg case. The professionals agreed to situate a cafe on a corner where sunlight could reach cafe-visitors. They would probably not have realized their ontological drift in with respect to semantic differences toward *sunlight* and *wind* unless visual drawings had been presented in their discussions. In short, since the Japanese architect drew a cafe in a different corner of the buildings in a visible manner to everyone while others were watching his hand movements, it was obvious that Kiyo had different understanding of the expression *sunlight* than the danish professionals.

In the software design case in which their communication were mainly through oral conversation, they occasionally used computational artifacts. When the programmers explained their initial design of the developed software, they displayed their design ideas on the screen graphically by connecting their computer to the projector. They built demos of the developed system and manipulated it on the screen in front of them. They sometimes displayed web pages similar to their design ideas when they were asked or suggested by others. In the case of software design, computational artifacts did take a less influential facilitation role for their intercultural collaboration. However, the case shows how computational artifacts can offer a wide range of graphical modalities, which have different characteristics than graphical modalities carried on non-computational artifacts.

5.2.3 Portable

Many modes of communication used in cases have portable characteristics. Hand drawings on paper by architects, CAD drawings printed on paper, and building models made of paper are carried with the professionals whenever they are mobile. As a consequences, their artifacts became mobile, too.

Latour [Latour, 1990] presented a concept of *immutable mobile* in the discussion of characteristics of modern inscription. When investigating and evaluating the quality of modern inscription, he mentioned its mobility, to be precise, its immutable mobility.

> Immutability is ensured by the process of printing many identical copies: mobility by the number of copies, the paper and the movable type. The links between different places in time and space are completely modified by this fantastic acceleration of immutable mobiles which circulate everywhere and in all directions in Europe. [...] For the first time, a location can accumulate other places far away in space and time, and present them synoptically to the eye; better still, this synoptic presentation, once reworked, amended or disrupted, can be spread with no modification to other places and made available at other times.

The architects' and designers' drawings of software architecture (the software design case), landscape and buildings (the Carlsberg and the renovation case) were carried in and out. Pictures, printed logos, booklets and maps were brought to the discussion table (Carlsberg case). Such artifacts traveled from one place to the other; from office to meeting tables. Such artifacts are immutable mobiles as defined in Latour's remark since they could go for a voyage away from the authors without changing their notations, descriptions, naming, classification, identifications and forms. They could go beyond time and space.

Computational artifacts also offer portability but in a different way than the conventional tangible artifacts mentioned above. In the renovation case and the Svane case, design professionals exchanged their CAD drawings in digital format regularly. One drawing traveled from architect to designer and to the customer. Still, such computational artifacts do not offer immutable mobility. Drawings made with *Illustrator* are digitally portable and can be printed out on paper, but they can be rewritten, edited, and erased as long as they are in digital formats. When it comes to computational artifacts, immutable mobility characterized as visible and mobile entities is not scalable any more. In order to achieve immutable mobility, written forms in computational artifacts should be transformed to a format like PDF. When PDF formats are formed from these drawings, they can finally and for the first time be characterized as immutable mobile entities. The reason is that PDF can offer a fixed graphical presentation. Consider the Svane case, in which engineer, Kai, noticed a scale misalignment of the drawings shown on *Illustrator* (mobile but not immutable) by comparing with a PDF of the same drawings (immutable mobile). Kai compared two digital formats but they had different characteristics. In the renovation case, the interviewed architect also mentioned the use of PDF (immutable mobile) together with digital drawings (mobile but not immutable) because of its fixed graphical representation.

5.3 The Role of Computational Artifacts

As shown in our case studies, some external representations facilitate the process of collaboration among professionals with different knowledge background. To reiterate, external representations could be formed, in not only oral conversations but also written artifacts, signs reified on tangible artifacts and computational artifacts. Among all kinds of external representations, computational artifacts can offer a special uniqueness in the sense that they offer multiple dimensional communication modalities and compound characteristics. We found that such multifaceted as well as compound computational artifacts also had a facilitating role in many intercultural collaborations.

In reality, in many cases, computational artifacts provided both distortion and facilitation of collaboration. It is well known that distortions almost always exist in intercultural collaborative settings by default. We claim, however, that computational artifacts could add further distortion. In the five cases, distance, knowledge differences generated from work and ethnic culture differences and computational artifacts are potential misalignment for collaboration. In our cases, distance had less impact than knowledge differences. Computational artifacts were often supportive for collaboration but at the same time, they could easily cause critical distortions. For example, in the ICE, the renovation, and the Svane cases, the professionals were facilitated by computational artifacts such as intercultural collaboration support systems *TransBBS*, CAD systems and other design support systems such as *Illustrator* and *Photoshop*. However, professionals at the same time encountered significant challenges in collaborating together because of the barriers generated by their computational artifacts.

In this section, we overview the role of computational artifacts in our cases. We show how computational artifacts may facilitate as well as impede intercultural collaboration.

5.3.1 External Representations in Our Cases

Before describing the role of computational artifacts in our collaboration cases, we briefly describe external representations (First introduced in Section 2.3.4) that mediate collaboration among professionals with different knowledge background. In our cases, varied external representations were used in the collaborative process from oral expression to tangible artifacts. Many of them including oral expressions contributed the collaboration processes to varied extents.

The software design case shows an interesting example in which oral expressions took a central communicative role and facilitated collaboration. It would be imprecise to call these expressions boundary objects since oral expressions are intangible and do not retain. It might be reasonable, however, to say that oral expressions facilitated collaboration in some way. Several key expressions were iteratively used in the intersection of several communities of practice. Iterative use of unique expressions such as *label* played a facilitating role that led breakdowns among professionals. That the professionals realized that something was wrong was triggered by the inconsistent usage of the term *label*. What we observed was that the expression *label* initiated the professionals' discussion and caused a gradual crystallization of a single concept.

Several tangible artifacts functioned as external representations. Such tangible external representations sometimes "inhabited several communities of practice and satisfied the informational requirements of each of them and adapted to local needs and constraints of several parties while maintaining identity across sites" [Bowker and Star, 1999]. In the Carlsberg case, while professionals in architectural design discussed at the co-located meeting, the Japanese architect used maps, tracing paper, and pens to draw his ideas. In this discussion, his hand drawings played the role of a boundary object that could reify his design ideas even without requiring other professionals to understand architectural expressions. The participants could even recognize the ontological drift of *sunlight* and *wind* through these externalized representations in the form of drawings. In this way, not always but sometimes a certain external representation could lead to breakdowns to solve ontological drift among participants.

5.3.2 Computational Artifacts as Collaboration Facilitator

Computer Aided Design (CAD) systems and other design support tools were often used as shared tools among the collaborators in the architectural design and information design process. Apart from their original functions for supporting individual design work, to some extent, they were used as tools for sharing information by exchanging architectural and technical drawings in practice. Although neither CAD systems nor other design support tools have been designed for collaborative purposes, demands for collaboration brought such use of the design systems in a collaborative setting.

In contrast, the collaboration support system TransBBS introduced in the ICE case and other systems such as EVIDII [Ohira, 2001] and Knowledge Nebula Crystallizer [Amitani, 2005] introduced in Section 2.2 are designed as shared tools to facilitate intercultural collaboration processes. Thus, some computational artifacts have already been developed aiming at facilitating collaboration. However, the systems presented above are still on an experimental stage.

In this thesis, we consider computational artifacts such as CAD systems and collaborative systems as facilitators of collaboration among professionals with different knowledge backgrounds. In other words, we consider such computational artifacts to be boundary objects. The reason for this is that computational artifacts have surprisingly many characteristics of boundary objects in our investigation. Even though this does not mean that computational artifacts always play the role of boundary objects, it is feasible to see computational artifacts used in collaborative settings as collaborative facilitator for several reasons.

First, computational artifacts *enable joint activity as a common information space* by offering repositories, ideal types, coincident boundaries, and standardized forms. For example, professionals in the construction domain often define data formats of computational artifacts ahead of a project, and all collaborators use such standardized forms, in which computational artifacts offer depositories as well as default space as shown in the Carlsberg case. Second, computational artifacts *translate meanings* often directly via their provided functions and sometimes indirectly. When collaborators use local formats instead of defining standardized formats just like the renovation case, computational artifacts can convert them to fit to the user's preference. Computational artifacts also offer *multiple perspectives of a single artifact*. Computational artifacts are strong enough to make it possible to change views as well as forms depending on the viewers' preferences. For example, layer functions of CAD systems make it possible to depict selected layers to customize the view to ventilation engineers in which critical layers for lightning designers but not for ventilation engineers are omitted as shown in the renovation case. Third, computational artifacts *never require shared goal* and let each professional work on their own jobs in their own world. For example, although they have an ultimate objective such as constructing a building, their individual goal may differ. One group may be designing the kitchen areas while other groups wire electric lines and design ventilation flows, and still they need to work together. CAD systems do not require coverage of a complete construction. Rather, they give users freedom of choice about what to work on. As *compound artifacts*, CAD systems and other design support software have such non-static features by transforming their shape iteratively in a collaborative process. Computational artifacts are multi-facets carrying multiple communications modes.

5.3.3 Computational Artifacts in Use

In many case studies introduced in this thesis, computational artifacts were actively used by almost all collaborative members and took a central role in the collaboration. During the meetings of the design development phase of the Carlsberg case, CAD systems were used by all core members; architects, illustrators, artists, and landscape designers in the last phase. In the ICE case , the collaboration support system, TransBBS, was used by all participants by default. In the renovation case, CAD systems were used by architects, engineers and other design professionals in the four design phases. In this case, the client and the user did not use CAD systems by themselves. In spite of that, both the client and the user discussed outputs from CAD systems such as CAD prints, drawings, and physical models when they attended design meetings together with the other members. In the Svane case, the design support systems were mainly used by engineers, manufacturers, and sign makers. The client did not create drawings using a computer system similar to the client of the renovation case. But as in this case, the client was an active user of computational artifacts by looking at CAD drawings and checking them from time to time. Consequently, throughout the collaborative design process, computational artifacts played a critical and central facilitating role in the professionals' collaboration for different purposes. They were occasionally used for exchanging data and documents, creating and exchanging ideas, and confirming designs through signs on artifacts.

In this discussion, we are going to describe several characteristics of the facilitating role of computational artifacts observed in our five collaboration cases. The following selections might not cover all aspects of computational artifacts in collaborative use, but we believe that it is suitable enough to discuss our cases. The characteristics that will be discussed are; translation ability, format provider, idea generator, visibility and redundancy, and portability and tangibility.

Translation ability

In intercultural collaboration, collaborators often suffer from ontological drift (see Section 2.3.1). In our cases, it is observed that computational artifacts played a facilitating role by offering translation capabilities and contributed in overcoming such ontological drift. In our cases, different semantics in signs which usually generate ontological drift can be translated through computational artifacts.

In the ICE case, participants' communication were supported largely by translation ability of computational artifacts. The central function of the collaboration support system was natural language translation so that they communicated using their mother tongue, which was profitable especially for Asian participants who tended to consider English as barrier for intercultural collaboration. Although the results of machine translation were far from satisfactory because of the limitation of the current technology, participants could collaborate under conditions where it otherwise would be impossible even to communicate. All the more, participants gradually invented local and temporary conventions such as displaying five languages - from one (often their mother language) or two (often English) to five (other translated three languages with English) - and compare them to improve their understanding (e.g., by checking the English translation together with translated results in other languages).

In the renovation case, professionals communication were also supported largely by translation ability of computational artifacts. When CAD drawings were exchanged among professionals, they could be translated or converted to fit to the receiver's format, or CAD system. Usually, CAD drawings were sent in the senders' local format, and the drawings were opened with the receivers' format. This is possible because CAD systems offer functions to make two systems compatible. However, at the same time, participants in the renovation case occasionally experienced miss-translations or mis-conversions made by the CAD systems. This *lost in translation* could occur anywhere in our targeted collaboration. Similar to the renovation case, in the ICE case, mistranslation or incapability of machine translation occurred and discouraged collaboration among participants as shown in many postings with complaints about the translation quality of TransBBS (see e.g., Figure 4.15). Still, professionals largely relied on the converting function of CAD systems when they checked, utilized, and merged a part of or all of another CAD drawing. Although the result of the converting function of CAD systems was somewhat limited, participants could exchange data without taking extra time to adjust to the formats of others. The same was true for the participants using the TransBBS collaboration system.

All the more, interestingly, professionals gradually established their own inventions to make collaboration work when using such collaboration support systems. As mentioned above, the participants in the ICE case gradually increased the number of displayed languages, and the more the experiment period proceeded, the more participants displayed multiple languages. Professionals in the renovation case and the Svane case invented local and temporary conventions, such as sending PDF files together with digital CAD drawings, since digital data allows professionals to modify the drawings of others and merge their own data, while PDF files allows them to confirm the correct sketches, size and scales. In addition, when professionals in the renovation case had face-to-face meetings, each member brought his own CAD blueprints. As described previously, each professional took his own version of CAD prints with him, no matter which topic were discussed, and he compared his prints with the shared CAD prints displayed on the table. It was often the case that each professional needed his or her version of CAD prints with familiar signs, lines and notations in order to understand the shared prints displayed on the discussion table better. Except for cases where a standard format was defined beforehand, professionals collaborated under influence of unfamiliar usage of CAD systems in the beginning, and they thus faced a certain amount of ambiguity. By doing so, professionals avoided to be lost in translation and utilized most of the translation ability that computational artifacts can offer. Methodologies have accumulated through the professional's experience and new local methods were invented through practice. Some of these invented methods may seem like an unnecessary redundancy at first sight. But such invented redundant methods as showing five languages at one time in the ICE case, turned out to be essential and indispensable for avoiding further challenges when translation functions were intervened in collaboration.

Format provider

Computational artifacts can offer standardized as well as localized formats for collaborative settings. In both cases, computational artifacts work as facilitators by enabling joint activities. The collaboration styles, however, tend to differ depending on whether the collaboration requires standardized or localized formats.

The Carlsberg case is a good example of using computational artifacts as *standardized formats*. The competition organizers offered a large amount of data including digital CAD data in DWG format (AutoCAD format) that showed the current landscape and buildings in the designated site. In addition, the competition office offered a brochure that mentioned the core concepts of an ideal design together with a large number of key words. In this way, the competition organizers offered standardized frameworks including CAD formats, signs and descriptions that should be followed by all competition participants. These standardized formats worked as devices for collaboration among participants by offering a shared foundation. It was only in the end phase of the collaboration that the professionals in the Carlsberg case used the provided standardized digital format. Until the end phase, they had an intense and creative discussion without any needs to reflect on the format. Although several disputes caused by ontological drift were observed during the initial design discussion period, no disputes were observed during the reification period largely because the standardized format offered a good foundation for the professionals to collaborate efficiently through CAD systems. When they digitalized their design ideas, they had already agreed on the design specifications, which generated less confusion in the reification phase. At the same time, the standardized format was to be followed. Thus, there was no room left to apply individual localized formats which could cause issues when merging data due to different use of lines, notations and signs. The work load for making the submission package was evenly distributed between the professionals in the Carlsberg case. The members worked with CAD systems individually and exchanged their updated digital drawings based on the standardized formats via e-mails, brought their latest blueprints for their discussions without translation loss. Although some of the members had not been accustomed to use the offered formats, which put a large burden of learning cost on them, no critical confusion was observed with respect to the collaboration perspective. No special approach, inventions or devices for collaboration in using CAD systems were made or clearly observed in the Carlsberg case. The members simply followed the designated format and conducted cooperative work.

The situations where *localized formats* were used in the cases (the renovation case and the Svane case) were different. For example, in the renovation case, since the project had low budget and it was originally planed as a short project, the professionals of the development group did not initially agree on a common format such as a data structure, sign usage, and CAD system version. They did not think that it was reasonable to make a rigid agreement about standardized formats only for this short project because it was almost always accompanied with an individual learning burden. Standardized formats could have been applied in the renovation case - just like the Carlsberg case - if the project had been larger, or planned to continue for a longer period. However, the architect office did not apply the Danish standard CAD manual called “ibb00”, or set up data deposits on the web for this project. This is often the case for larger and longer projects as default in Denmark. Each professional used familiar localized formats which did not work as devices for collaboration among participants as in the Carlsberg case. Each professional used his or her own format including signs and notations on the CAD prints and his or her own CAD system. Because of the different usage of formats, signs and notations, each professional often had to deal with CAD drawings that could not be read correctly with their CAD system. Even when they could read CAD drawings made by different CAD systems or software versions, there still was a high possibility to display small details in a slightly different manner. This made it difficult for each professional to read drawings precisely.

The professionals could still work together without changing their local format, because the CAD systems made it possible to work with vagueness. Certain small signs in form A might not be translated into the correct signs in form B. However, such problems would not collapse the whole data set. It would still be possible to display almost correctly. It was the local format users who utilized local conventions for collaboration such as sending PDF documents together with the original CAD drawings which was not observed among standardized format users in our cases. In such case, PDF documents kept the original style such that the viewer could see exactly the same view that the sender intended to show, and thus worked as boundary objects. Sending a PDF file had the purpose of confirming the correct drawing, while the validity of the original digital document was insecure.

Idea generator

Several professionals used CAD systems and design support tools already in the very beginning of the design phase, namely, in the initial design phase. In such cases, computational artifacts could support professionals collectively and individually for generating their design ideas in spite of the widely recognized point of view that designers, artists and professionals in related fields use pen and paper for idea generation [Suwa and Tversky, 1997, Alistair McGowna and Rodgersb, 1998]. Although it was still common for the professionals to use conventional methods such as hand drawings, tangible models out of paper, plastics and other materials, some professionals used 2D and 3D CAD systems for generating their ideas. In such cases, the professionals interacted with the CAD systems, proceeded reflected-in-action [Schön, 1983] by drawing, erasing and re-drawing to create further ideas.

In the software design case, new ideas were generated through interaction between participants without any help from computational artifacts. Since their interaction was mainly oral, iterative discussions concerning the same topics were central in such idea generation. In the Carlsberg case, professionals did not use CAD systems in the initial design phase where they discussed ideas and conducted brain-storming during the meetings. During these discussions, the architects sometimes made drawings on paper. Others just spoke out their ideas and discussed them orally. In the Svane case, the fundamental design was already made so that an initial design phase was not observed. The use of CAD systems in the idea generation phase rarely led to the collaborative use of CAD systems in any of the three studied cases above.

On the other hand, the collaboration support system in the ICE case was used for collective idea creation. In the initial design phase, new design ideas were often generated collectively through digital interaction among participants. One participant's opinion expressed on the TransBBS became a trigger to a new idea of another participant. In contrast to the software design case, where oral conversation was dominant, opinions expressed in written form could "be inspected in much greater detail, in its parts as well as its whole, backwards as well as forwards [...]" [Goody, 1986]. Thus, participants sometimes replied to messages posted a couple of weeks ago in connection with the latest opinion. We also observed a good example of idea generation facilitated by computational artifacts in the interview with the architect of the renovation case. The architect explained that one of his colleagues, who was the youngest architect and had newly graduated from the architect school, used a 3D CAD system when he drew his design ideas and exhibited his drawings to others in digital formats as well. When stakeholders gathered together to discuss initial design ideas, several tangible artifacts were brought to the table. One of them was digital 3D CAD drawings, and others were conventional hand drawings. It is beyond our observations to discuss advantages in idea generation between 3D CAD and hand drawings, however, 3D CAD digital drawings can show design ideas from any angles fitting the discussion, which seems to have a strong potential to activate discussions in some collective meetings.

Visibility and redundancy

The visibility and redundancy offered by computational artifacts provided an additional source of facilitation to the intercultural collaboration. Visibility could offer the users the ability to compare, and redundancy strengthened this comparing ability and made it easier to confirm what was received through communication. Visibility can be strengthened by computational artifacts because they can provide richer and compound communication modalities, which can not be achieved only by speech, the conventional communication mode. In our cases, especially visibility facilitated comparison activities. The computational artifacts could show several candidates of choice at one time which the users could compare and make a choice from.

For example, one architect in the renovation case and an engineer in the Svane case found their mistakes by comparing drawings made by CAD systems. Computer scientists in the ICE case experienced a breakdown, which was found to be a translation failure by comparing multiple translated results in several languages. It seems to be more important to offer comparative data that professionals can check with their common sense rather than offering only translated results that they can not reason about how the machine created. The reason is clear from our cases: consider what would happen if the machine translation functionality in the ICE case and the drawings converted from different CAD systems in the renovation case looked perfect but in reality had critical flaws. The participants in each case knew that the machine translation and the conversion function of CAD systems respectively, did not work perfect, so they kept an eye on mistranslations in what they received.

Redundancy was not aimed at being eliminated in our intercultural collaboration cases. Due to the translation limitations, the participants in the ICE case displayed five different translation results of postings, and design professionals in the renovation case gathered their own version of CAD prints for co-located meetings. It turns out that such behavior that at a first glance seems unnecessarily redundant is, as a matter of fact, a strong functionality for avoiding further troubles. The participants in the ICE case who chose to display five languages in their translation results posted more actively. Many of such active participants spent more time to figure out postings by others and to write and rewrite their own messages to get them translated better. In messages from other participants, even when translation results were far from being understood, they repeatedly utilized several translation results, compared them and tried to find out what the author's intention was. They actively posted questions and their own opinions regarding postings by others. In their own messages, they checked translated results iteratively before posting them [Yasuoka et al., 2003]. In the same manner, the professionals in the renovation case that took their own CAD prints to the co-located meetings could check signs, notations and memos on their own CAD prints when they faced issues during the discussions.

Portability and tangibility

Typically, computational artifacts were used to exchange data throughout the whole collaboration period. Digital drawings were created, updated, refined, corrected and passed down to other professionals via the Internet. This was done for other kinds of written artifacts as well. Such digital data has portable characteristics in nature. Digital data can freely migrate from one professional to another and from one location to another very fast. On the other hand, once digital data is granted physical entity in the form of print-outs on paper to be used in co-located environments or at co-located meetings, it will have tangible in addition to portable characteristics. Print-outs of digital data such as CAD prints are good examples of such tangibility.

Portability was clearly one of the advantages of digital data. When the collaboration was made in a distributed environment, digital formats could be used easily to exchange design ideas. Usually, stakeholders in such cases iterated the process of designing, checking compatibilities with other drawings, revising and sending the latest drawings to each other. Before co-located meetings, they exchanged their latest versions of digital drawings focusing on the areas that they had decided to discuss in the previous meeting.

In the software design case and the Carlsberg case, the meetings were mainly held at the same location. In the software design case, the professionals did not use computational artifacts as a central tool, and in the Carlsberg case, CAD systems were hardly used during discussions except for checking small details of the site description in the CAD drawings offered by the competition organizers office. In the very end of the project when each member worked individually, the members started to exchange their drawings in digital formats. In reality, their overall design was already agreed at that time so that they used CAD systems to finalize, digitalizes and reify their discussed ideas in visible and recognizable forms. On the other hand, in the ICE, the renovation case (except at the regular co-located meetings) and the Svane case, the professionals were situated in a distributed environment. Thus, they were required to exchange their new or updated system design or architect design data frequently in digital formats. Data portability made it possible to collaborate in such highly distributed settings. In these cases, the collaboration support systems, CAD systems and design support tools were used not to reify finalized design ideas, but to communicate design ideas.

In the renovation case, in between regular meetings, the professionals utilized computational artifacts to exchange data. In this case, the professionals almost always exchanged their own digital drawings when they updated, and checked compatibilities between their own drawings and drawings of other members in order not to have any technical design issues. However, it was not always the case that those who were responsible noticed the issues. For example, when one architect checked the interior designer's CAD drawings together with his own CAD drawings, he found that a huge projector was planned to be embedded in the wall where a heating system was supposed to be situated. After he revised the CAD drawing together with the interior designer and sent a revised CAD drawing to all stakeholders, he realized that the refined plan was also not possible to construct because the expected trajectory of the projector to the screen was nearly cut by a large steel frame that was planed to lie over the ceiling towards the wall in order to strengthen the construction frame of the building. Such misunderstandings or mistakes happened largely because each professional used different layers of drawings so that their drawings did not show such issues.

Tangibility is added to the characteristics of digital data when they acquire physical form, usually by being printed out. When physical artifacts such as CAD prints were used in distributed environments by individual professionals, the digital artifacts became more visible. The architects' usage of pens, pencils and picture cards shows that tangible artifacts have the ability to make the design move by leading to breakdowns. In our intercultural collaborations, tangible artifacts often led to breakdowns which helped overcoming ontological drift and misunderstandings. For example, tangibility made it easier for professionals to compare several print-outs at the same time, which often made it possible to reveal incompatible parts of drawings. When artifacts were used in co-located meetings, several print-outs were often displayed on the table. Tangible artifacts were easier to put on the table, shuffle, compare and organize. Through this activity, many design mistakes were found and new designs were created.

In the renovation case, each professional normally had his own most recent CAD prints no matter what topic they decided to discuss. For example, even when the topic was kitchen design and kitchen design CAD prints were displayed on the discussion table, the ventilation professional and the architects still had their own CAD print versions at hand. The professionals commented on this behavior by “it is easier to follow the discussion with my own drawings”. They often changed discussion topics when someone had found critical issues while checking the design such as the projector case mentioned above. No matter what topic they discussed, the professionals could always refer to his or her own prints and the shared one on the table. As such, the professionals in our cases used most of the advantages of portable and tangible objects by simply sending, duplicating and printing out digital data.

5.4 Additional Communication Facilitators

Traditionally, a large part of the investigations in collaboration has focused on ordinary work situations which are different from the situations studied in this thesis. Below we emphasize these differences. Conventional collaboration is characterized by a well-established collaboration style where the collaboration is long-term *routine work* in an unchanging social context. In such cooperative work, professionals coordinate their work. *Divisions of labor* are clarified and *learning processes* of their shared knowledge become more critical [Schmidt, 2002, Carstensen, 1996, Wenger, 1999]. On the other hand, our target is short-term collaborations with highly specialized and project based collaboration among professionals with different knowledge backgrounds, which is drastically increased collaboration style during last few decades. The professionals gather only for this single occasion, collaborate temporarily and disperse when the project is over. They are already experienced, established and highly skilled professionals in their own work community. Thus, each has a different work culture knowledge bases that is hard to change just for one collaboration project. Such professional knowledge is a valuable reason to work together beyond community borders in an intercultural collaboration. In spite of their differences, they still have a shared goal - to complete the assigned project - and some common ground. Such limited levels of common ground can be natural language such as English in the Carlsberg case, Danish in the renovation case and the Svane case and Japanese in the software design case, and professional knowledge such as computer science background shown in the ICE case and common sense for design professionals in the renovation case and the Svane case. In our cases, it is clear that there exists something in common even in intercultural collaborations which tends to be neglected or too implicit to be seen since it is hidden behind the massive differences that the professionals in collaboration have to face. These differences are so wide that they need *something* more to bridge their differences in spite of their similarities in the collaborative processes that lead to LTAP.

In collaboration, the importance of shared social context among collaborative professionals is often pointed out. Such social context embedded in procedures, expressions, and terms which are unique in the collaborative group have been investigated and - to mention a few - been named *community language* and *work language* [Andersen, 1990, Bjørn, 2006]. Many report the existence of such special local languages. However, the process of creating such community language and work language among professionals who have different knowledge background, for example how such languages would emerge, develop and settle in intercultural collaboration, has not been clearly mentioned to our knowledge.

The characteristics of communication in the early phase of intercultural collaboration that we focus on in this thesis are understood as the process of occurrence of ontological drift, externalized breakdown and development and creation of local and temporary alignment of practices (LTAP) facilitated by complexes of interrelated communication modalities. In such collaborations, creative activities among professionals become a key factor. Collaboratively created LTAP becomes a common ground for collaboration as an essential social context. Based on the concept of communication modalities, we found three kinds of creation of LTAP, LTAP through *negotiation*, *convergence*, and *creation*. We regard something is created during the collaborative process that lead to LTAP and such *something* can be utilized by professionals with different knowledge background as things in common during the collaboration period.

Such creative characteristics of *something* facilitating collaboration have been pointed out by a few. Most notably, Lee [Lee, 2004, Lee, 2005, Lee, 2007] who investigated this *something* in relation to boundary objects argues for her view as follows. Boundary objects have originally been investigated in relation to standardization by Star and Griesemer [Star and Griesemer, 1988], and thus, the target of investigation has always been "works with clear and anticipatable steps, experienced workers, and established division of labor, stable resources and strategies for managing expected contingencies" [Lee, 2007] (p.314). However, there exists novel collaborations in non-routine work, with lacking pre-existing standards and thus collaboration with people with different knowledge background, and *something* facilitating such collaborations would not be explained within the range of conventional concepts of boundary objects. Such something, "(1) does not presuppose fairly high levels of coordination, (2) does not focus on coordinative aspects of artifacts at the expense of disruptive aspects, and (3) involves artifacts that are not "standardized inscribed artifacts" such as those found in boundary objects or ordering systems" [Lee, 2007].

Even though her approach of seeing boundary objects from a negotiation process point of view (and thus, call this *something* boundary negotiating artifacts [4], which is different from our approach that sees intercultural collaboration as a creation process. Even though the details of her interpretations of boundary objects are not fully agreeable, our understanding based on the five cases and Lee's view based on a single case (museum exhibition about wild and domestic dogs) have a lot in common regarding the importance of *some-*

[4] To be precise, Lee investigates the creation process of boundary objects as objects comprised of the iterative use of interwoven sets of boundary negotiation practices and boundary negotiating artifacts. As such, she focused on negotiation in her study.

thing facilitating and a creation process for facilitation of the collaborative process between people from different communities of practice.

We refer to this *something* as *project jargon* mainly to our convenience and to articulate it as local and temporary language shared among professionals gathered for a collective concern. Expressions and terms of project jargon are created in the process of collaboration that lead to LTAP, and would disappear after the project is over. We can recognize the existence of such project jargon because it tends to be externalized in expressions or signs that are continually and rigorously used during the collaboration period. Project jargon does not belong to any communities of practice because they are created through interactions among professionals belonging to different communities of practice. Project jargon can facilitate intercultural collaboration because it is a part of LTAP created through collaboration process.

In our observation cases of intercultural collaboration, some cases were facilitated by computational artifacts - or more precisely, signs expressed in the computational artifacts. The signs on computational artifacts are visible and often tangible which often accelerate intercultural collaboration. In such intercultural collaboration, professionals often do not share community language. Instead, they gradually create their own language which is valid only locally and temporarily in the specific group of the project. Such project jargon can also be created without being facilitated by computational artifacts, however, computational artifacts can better facilitate the process of creation of project jargon because it has high semiotic characteristics, and it offer high visibility and tangibility in nature. So, one question emerge. How does the creation of project jargon happen?

5.4.1 Project Jargon

In each intercultural collaborative case, the creation of project jargon was observed to a very varied extent. Largely speaking, in cases where initial design were discussed (such as the software design case and the ICE case), the creation process of project jargon seems to be more active than in other cases. For example, in the software design case, professionals mainly used oral conversation. Thus, the creation process of project jargon was rather invisible and implicit to participants as well as to observers. In the Carlsberg case, the creation of project jargon was observed mainly in the first half of the meetings (from first to fifth meeting) when no routine procedures existed and pre-existing standards were lacking. Similar to the software design case, professionals in the Carlsberg case mainly discussed with oral means, but at the same time, they often drew on tracing paper over plans while conducting discussions. Such tangible and visible drawing made during discussions often led to LTAP through negotiation, convergence and creation, and new expressions such as *sunlight, wind, slime* and *slimy* were created. In the ICE case in which intercultural collaboration was carried out with the help of the collaboration support system, TransBBS, participants also created project jargon. TransBBS with machine translation facilitated their collaboration from a communication perspective. A design idea for the developed software system might have been neglected when the idea was posted on TransBBS, but later came back to life by another participant who reviewed past postings. It was not rare to see some expressions on such postings become core conceptual keywords for designing software in the end. As shown, such creation activity of project jargon was especially vitalized in the early stage of collaboration where participants discussed their design ideas. The renovation case and the Svane case were slightly different from the other cases since their initial design phase was already over. In the cases, the creation process of project jargon was less active.

5.4.2 Process of Project Jargon Advancement

Intercultural collaboration is often interrupted by ontological drift. Recall that ontological drift is caused by different preferences, culture, senses of values and terminology. People misunderstand each other because different cultures have different semantics for identical symbols and representations. This is also true in our observed cases. In order to overcome this ontological drift and to create project jargon, it was observed that professionals in our case studies utilized several community languages. For example, in the ICE case where computational artifacts took a facilitation role, the participants compared five natural languages on the display and tried to understand what the sender meant in the original message. In the Carlsberg case on the other hand, professionals realized the difference of semantics of *sunlight* through the Japanese architect's iterative oral explanation and hand-drawings on papers. When participants in each case interacted with each other, they used and compared whatever they could find in their work environment. By doing so, breakdowns happened occasionally sometimes triggered by computational artifacts and sometimes by other kind of artifacts.

Figure 5.1 illustrates the usage of several community languages observed in the cases. In the observations, we found that professionals used at least three kinds of languages in collaborative settings together with common knowledge [Yasuoka et al., 2003]. The identified languages are; *Language A* which is participant A's community language, *language B* which is participant B's community language, and finally, *language X* which both A and B find an equally comprehensible translated language. For participant A, B's community language might be incomprehensible and vice versa. However, both can somewhat understand *language X*. Through these languages, *project jargon* is socially constructed iteratively, locally and temporarily during the collaborative process. Due to these multiple languages used in communicative as well as social acts, their intercultural collaboration can be facilitated even when weak and unreliable communication modalities are used .

For example, the ICE case offered several natural languages through TransBBS. The Japanese participants used Japanese (Language A) and translated language (Language X which is often English), and they usually did not understand Chinese, Korean and Malay (Language B). Even such incomprehensible languages sometimes became an information source through visualization on computational artifacts. For example, displaying five languages helped to detect technical failures. Even if translated messages of the Chinese members made no sense either in English or language A for non-Chinese speakers, it was still possible to know whether the Chinese members were active or not. In this way, even incomprehensible languages could provide a certain level of awareness. In the

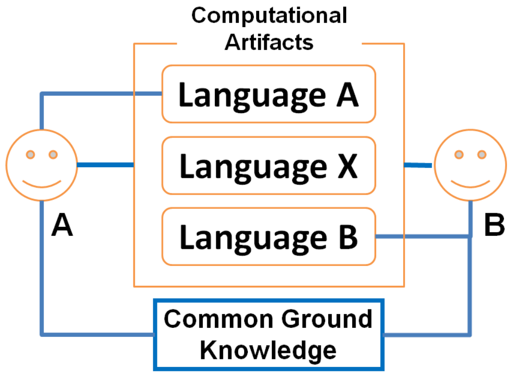

Figure 5.1: The three identified languages.

same manner, the renovation case offered language from CAD style A (Language A), CAD style B (Language B) and converted style through computational artifacts (Language X). Through such varied languages, breakdown was triggered, and consequently project jargon was constructed. While, in the software design case and the Carlsberg case which are not facilitated by computational artifacts, only Language A (professional knowledge A, ethnic culture A), Language B (professional knowledge B, ethnic culture B) existed. By using computational artifacts, the professionals moreover were able to visualize what they had in front of them and compare. Although it is beyond the reach of this thesis to analyze the detailed impact on collaboration in settings with and without computational artifacts, it seems that interactions among professionals and artifacts utilizing the three languages lead to breakdowns and consequently caused the creation of project jargon.

When professionals with different knowledge background collaborated, they typically applied the following three procedures to achieve project jargon. First, they face issues caused by ontological drift. Then, but not always, they realize that something is wrong with their current understanding, in other words, breakdowns happens. In our cases, it was observed that by visualizing and comparing several communication modalities or languages, ontological drift or implicit cultural differences became more visible and lead to breakdowns. Finally, after facing breakdowns, professionals create project jargon that is valid locally and temporarily in their short project period. We found that this last stage is different from what usually happens in collaborative activities in a community of practice where conventional expressions and classifications are learned from an authority of senior participants by participating peripheral legitimacy. The collaborative process in the intercultural collaborations that we have observed can be expressed as follows; first, misunderstanding, second breakdown, and third *creation* instead of misunderstanding, breakdown and learning in cooperative work.

There are still many missing pieces of the puzzle in order to define the role of project jargon further. However, the pragmatic approach of the thesis limits our discussion to go further beyond the observations in the five cases. Further investigation would be required to identify the characteristics of project jargon and its relation to collaboration between professionals with different knowledge background.

5.4.3 Intercultural Collaboration in Two Foundation (Derived discussion)

Before concluding this thesis, let us consider what happens to classifications and ordering systems in our setting which take an important role in conventional routine cooperative work. Are they of no importance in intercultural collaboration? Do professionals in intercultural collaboration collaborate together without standard, foundations, and understanding at all? One of the answers is that such global standard coexist together with local standards and so as project jargon. In the cases introduced in this thesis, classifications and ordering systems also existed to some extent and contributed to create project jargon. These standard foundations worked as common knowledge that had already been shared (They can be natural language, professional knowledge such as computer scientists knowledge, or common sense for design professionals). As shown briefly in the previous discussion and in Figure 5.1, certain common knowledge which might also be extremely primitive classification such as knowledge shared as being human beings, can be one of the supportive means to create project jargon. In this way, no matter to what small extent it may be, classification and ordering systems exist, and thus they are also important to understand the creation of project jargon.

Chapter 6

Conclusion

The empirical observations of five intercultural collaborations offer the possibility to examine how professionals from different knowledge backgrounds collaborate. Our observations suggest that when highly specialized professionals with different knowledge background collaborate for collective concerns in the early design period of relatively short term projects, their collaboration style is characterized by creating local and temporary alignment of practices facilitated by complexes of interrelated communication modalities in use. At the same time, ontological drift is observed as unavoidable integral parts of collaboration in varied levels.

Our observations also suggest that distortions which are especially caused by knowledge differences in collaborative setting matters. In spite of that, in order to overcome such knowledge differences, we observed that professionals use strategies that have a high ability to handle breakdowns. Some strategies used by professionals were learned during their professional education and others were invented during the project period. Not all strategies found in our cases were supported directly by computational artifacts and not all distortions found in our cases were solved using of computational artifacts. However, a large number of challenges seen in our collaboration cases were handled and could benefit from the use of computational artifacts. Computational artifacts takes the role of different communication modalities such as *retentive, graphical, and portable*, and the used computational artifacts showed high facilitation abilities such as *translation ability, format provider, idea generation, visibility and redundancy, and portability and tangibility.* Furthermore, computational artifacts as compound artifacts have the advantage to provide complexes of interrelated communication modalities.

When professionals collaborate in the early stage of collaborative design, creation of local and temporary alignment of practices is of key importance while learning matters when they collaborate on development and implementation. In the early stage of intercultural collaboration, especially the creation of project jargon among collaborators seems to contribute to a large extent to the progress of the projects. Our results showing the importance of creation imply new challenges with respect to improving and designing computational artifacts to better support intercultural collaboration.

6.1 Implications and Future Work

"The clashing point of two subjects, two disciplines, two cultures ought to produce creative chaos." - C.P. Snow

Why does such intercultural collaboration among professionals with different knowledge background appeal to people when they know that piles of well-known challenges are obviously standing just in front of them? As shown in *symmetry of ignorance* [Fischer, 2000], one of the reasons comes from necessity since single individuals with limited knowledge capacity have to collaborate to solve complex technical, economical and social issues nowadays. The challenge of collaboration is sometimes taken just as a necessary evil. Further, in this thesis we ask whether computational artifacts used in these collaborations only are an additional source of distortion. Based on our observations, this thesis analyzed collaboration from a communication point of view and tried to determine how computational artifacts could facilitate collaboration among professionals with different knowledge background.

As recent work has gradually demonstrated, intercultural collaboration generates creativity [Sawyer, 2007, Page, 2007]. Diversity is not a barrier for creativity but a source of it especially for the kind of of problem solving where people with diverse backgrounds gather and conduct work together. Seen from another angle, in order to increase creativity, intentional construction of a group in the intersection of diverse knowledge could be tactically and deliberately done. Such intersection of knowledge is a source of innovative thoughts that is too precious to be neglected in spite of all the difficulties of intercultural collaboration. As Snow said, differences among cultures is a source of innovation [Snow, 1993]. In addition, if computational artifacts could facilitate these collaborations, there is a high potential that they can yield fruitful and innovative creation of new ideas, new concepts, new words, expressions, artifacts, and solutions to a diverse group with collective concerns. This could be a second reason (in addition to symmetry of ignorance) to why people are attracted to these collaborations. At the same time, it also explains why people are still keen on designing computational artifacts for collaboration.

To relate to such creativity studies, our study could be understood as a certain kind of creation process observed in collaboration among professionals with different knowledge background. Precisely speaking, we have to admit that our cases and the data introduced in this thesis are not enough to show that diversity generates creative minds. Thus, it is too early to argue that several observed creative activities in our cases directly connect to a construction of creative artifacts for which current complex technologies, economics and society would aspire. Nonetheless, our study gives a hint of creativity by showing how intercultural collaboration proceed with the help of creation of project jargon in spite of such challenges as *ontological drift*.

This thesis took a very pragmatic approach to understand collaborative work among professionals with different knowledge background by observing and analyzing communication from complexes of modalities used in the collaboration. Even though it is unusual in the field of ethnographical investigation, a mixed method was applied. We believe that the mixed method could reveal the detailed communication process intercultural collaboration better than a purely qualitative or purely quantitative approach. Because of this characteristic of the thesis and all the more because of the nature of intercultural collaboration, it was rather difficult to show a comprehensible view of intercultural collaboration and its communication. Our approach had wide coverage but was not able to cover every aspect of communication that might have been revealed with alternative approaches.

This thesis is a step towards understanding how communication in intercultural collaboration is carried out and how computational artifacts across such social world facilitate processes especially in the early stage of collaboration. Future work may identify how computational artifacts can be designed to facilitate such processes. There is still much left undone, but by showing how unique collaborative communities build local and temporary alignment of practice and demonstrating how computational artifacts contribute to this creation, this thesis has made a contribution to our understanding of intercultural collaboration and its support via computational artifacts.

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