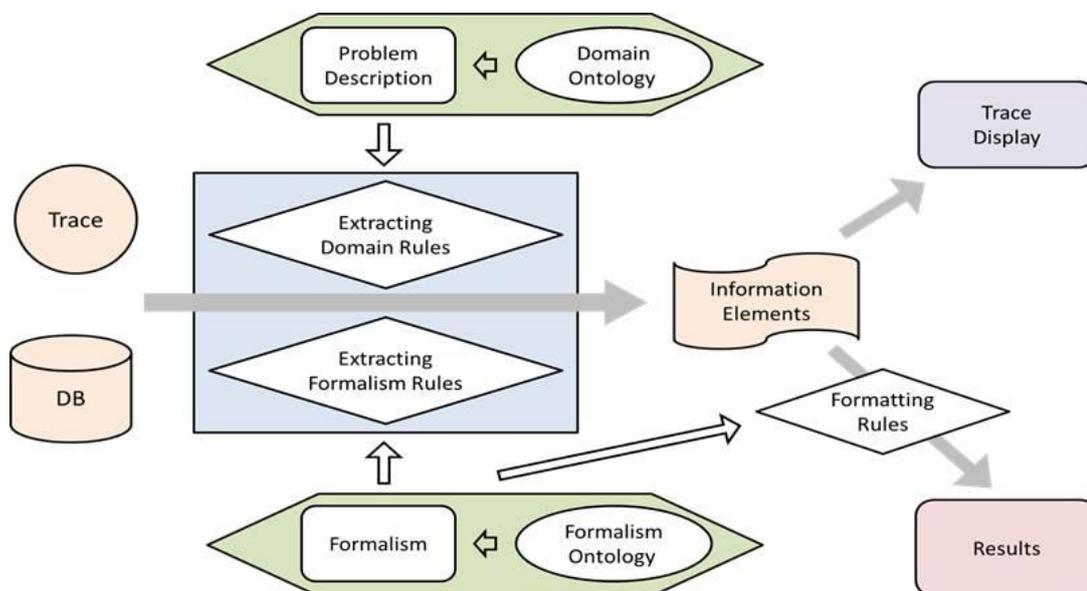Par **Qiang LI**

Modélisation et exploitation des traces d'interactions dans l'environnement de travail collaboratif

Thèse présentée
pour l'obtention du grade
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PHD THESIS

Modeling and Exploitation of the Traces of Interactions in the Collaborative Working Environment

Modélisation et Exploitation des Traces d'Interactions dans l'Environnement de Travail Collaboratif

by
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Declaration of Authorship

I, Qiang LI, declare that this thesis titled, "Modélisation et Exploitation des Traces d'Interactions dans l'Environnement de Travail Collaboratif" ("Modeling and Exploitation of the Traces of Interactions in the Collaborative Working Environment") and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.

- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.

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Signed:

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"Le temps est un grand professeur mais malheureusement il tue ses élèves."

Hector Berlioz (1803-1869)

Acknowledgements

Abstract

Human science and social progress cannot continue without collaboration. With the rapid development of information technologies and the popularity of smart devices, collaborative work is much simpler and more common than ever. People can work together irrespective of their geographical location or time limitation. In recently years, Web-based Collaborative Working Environments (CWE) are designed and devoted to support both individual and group work to a greater extent in various areas: research, business, learning and etc.

Any activity in an information system produces a set of traces. In a collaborative working context, such traces may be very voluminous and heterogeneous. For a typical Web-based Collaborative Working Environment, traces are mainly produced by collaborative activities or interactions and can be recorded. The modeled traces not only represent knowledge but also experience concerning the interactive actions among the actors or between actors and the system. With the increasing complexity of group structure and frequent collaboration needs, the existing interactions become more difficult to grasp and to analyze. And for the future work, people often need to retrieve more information from their previous collaborative activities.

This thesis focuses on defining, modeling and exploiting the various traces in the context of CWE, in particular, Collaborative Traces (CTs) in the group shared/collaborative workspace. A model of collaborative traces that can efficiently enrich group experience and assist group collaboration is proposed and detailed. In addition, we introduce and define a type of complex filter as a possible means to exploit the traces. Several basic scenarios of collaborative traces exploitation are presented describing their effects and advantages in CWE. Furthermore, a general traces exploitation framework is introduced and implemented in CWE. Three possible traces based collaborative approaches are discussed with comprehensive examples: SWOT Analysis, Capability Maturity Model Integration (CMMI) and Group Recommendation System. As a practical experience we tested our model in the context of the E-MEMORAe2.0 collaborative platform. Practical cases show that our proposed CT model and the exploitation framework for CWE can facilitate both personal and group work. This approach can be applied as a generic way for addressing different types of collaboration and trace issues/problems in CWE.

Keywords: Collaborative Working Environment; Trace-based System; Collaborative Trace; Collaborative Engineering; Experience Management

Résumé

Les sciences humaines et le progrès social ne peuvent pas se poursuivre sans collaboration. Avec le développement rapide des technologies de l'information et la popularité des appareils intelligents, le travail collaboratif est beaucoup plus simple et plus fréquents que jamais. Les gens peuvent travailler ensemble sans tenir compte de leur emplacement/location géographique ou de la limitation de temps. Les environnements de travail de collaboration basés sur le Web sont conçus et consacrés à supporter/soutenir le travail individuel et le travail en groupe dans divers domaines: la recherche, les affaires, l'éducation, etc.

N'importe quelle activité dans un système d'information produit un ensemble de traces. Dans un contexte de travail collaboratif, de telles traces peuvent être très volumineuses et hétérogènes. Pour un Environnement de Travail Collaboratif (ETC) typique Basé sur le Web, les traces sont principalement produites par des activités collaboratives ou des interactions collaboratives et peuvent être enregistrées. Les traces modélisées ne représentent pas seulement la connaissance, mais aussi l'expérience acquise par les acteurs via leurs interactions mutuelles ou les interactions qu'ils ont avec le système. Avec la complexité croissante de la structure de groupe et les besoins fréquents de collaboration, les interactions existantes deviennent de plus en plus difficiles à saisir et à analyser. Or, pour leurs travaux futurs, les gens ont souvent besoin de récupérer des informations issues de leurs activités de collaboration précédentes.

Cette thèse se concentre sur la définition, la modélisation et l'exploitation des différentes traces dans le contexte d'Environnement de Travail Collaboratif et en particulier aux Traces Collaboratives dans l'espace de travail partagé de groupe (ou l'espace de travail collaboratif). Un modèle de traces de collaboration qui peuvent efficacement enrichir l'expérience du groupe et aider à la collaboration de groupe est proposé et détaillé. Nous présentons ensuite et définissons un type de filtre complexe comme un moyen possible d'exploiter ces traces. Plusieurs scénarios de base d'exploitation des traces collaboratives sont présentés. Pour chacun d'entre eux, nous présentons leurs effets et les avantages procurés par ces effets dans l'environnement de travail collaboratif. Enfin, un cadre de l'exploitation des traces général est introduit et nous expliquons mis en œuvre dans un ETC. Trois approches collaboratives générant des traces sont discutées à l'aide d'exemples: l'Analyse SWOT, l'intégration de modèle de maturité de la capacité (CMMI) et le Système de Recommandation de Groupe. Une expérimentation de ce modèle a été réalisée dans le cadre de la plate-forme collaborative E-MEMORAe2.0. Cette expérience montre que notre modèle de trace collaborative et le cadre d'exploitation proposé pour l'environnement de travail collaboratif peuvent faciliter à la fois le travail personnel et

de groupe. Notre approche peut être appliquée comme un moyen générique pour traiter différents sujets et problèmes, qu'il s'agisse de collaboration ou de l'exploitation des traces laissées dans un ECT.

Mots clés: Environnement de Travail Collaboratif; Système à Base de Traces; Trace Collaborative; Ingénierie Collaborative; Gestion de l'Expériences

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Abbreviations

CSCW	Computer Supported Cooperative Work
CWE	Collaborative Working Eevironment
WCWE	Web-based Collaborative Working Eevironment
CT	Collaborative Trace
TBS	Trace Based Systems
TBMS	Trace Based Management Systems
SWOT	Strengths Weaknesses Opportunities Threats
CMMI	Capability Maturity Model Integration
CMM	Capability Maturity Model
IEs	Information Elements
SNS	Social Networking Service
TIP	Time Iteraction Performance
LAN	Local Area Network
CVW	Collaborative Virtual Workspace
MOO	Multi-User-Dimension Object Oriented
SNSs	Social Networking Sites
MIS	Management Information Systems
MS	Management Science
OR	Operation Research
IM	Instant Message
HCI	Human-Computer Interaction/Interfacing
KBS	Knowledge-Based System
ITS	Intelligent Tutoring System
EM	Experience Management
CTs	Collaborative Traces
CBR	Case-Based Reasoning
TBR	Trace Based Reasoning
JSON	JavaScript Object Notation
TOWS	Threats Opportunities Weaknesses Strengths
PEST	Political Economic Social Technological
ANP	Analytic Network Process
PP	Project Planning
REQM	Requirements Management
B2C	Business to Consumer
C2C	Consumer to Consumer
B2B	Business to Business
CF	Collaborative Filtering

Dedicated to my Family
With all my great Love and Respect

Introduction

Contents

1.1 Research Problems and Related Issues

Due to the rapid changes in information technology, people can work together using new and faster web-based collaborative working environments with less restrictions due to time or geographic position, and even to language or culture. Such environments can strongly promote and enhance different aspects of computer-supported cooperative/collaborative work, e.g. the process of organizational knowledge management, group communication or decision making. In a typical collaborative workspace, users can send email, edit wikis, share documents or have a video conference. Such interactions with the system or with other members of the group leave traces that contain information about the collaborative activities. In this thesis, research problems and related issues are mainly found at the intersection of two fields of study: Collaborative Working Environment (CWE) and Trace research.

1.1.1 Collaborative Working Environment Research

A collaborative working environment (CWE) represents a kind of computer-supported working environment that, according to Angelaccio and d'Ambroggio (Angelaccio 2007), "consists of a network of spatially dispersed actors (either humans or not) that play different roles and cooperate to achieve a common goal." It stems from the concept of

"virtual workspaces" (Schaffers 2006) and can be used to assist both individual work and cooperative work, e.g. e-work and e-professional as defined by Prinz et al. (Prinz 2006a). With various information and communication technologies and tools, group users could conduct their collaborative work through the CWE (Prinz 2006b). Actually, very basic factors found in CWE facilitate knowledge and information sharing in group as shown by Patel and Wilson (Patel 2012).

In software engineering, principally, collaborative activities can be divided into four types: "Mandatory, Called, Ad hoc, and Individual" as mentioned by Robillard and Robillard (Robillard 2000), e.g. scheduled video conferences, sending e-mails, or managing documents. In a typical CWE, most of the activities take place in the collaborative workspace (shared workspace) as remarked by Martinez et al. (Martínez-Carreras 2007). With the development of Internet and of wireless technology, time and space are no longer a strong constraint, therefore, CWE inherits and extends the concept of Groupware. In the early research stages, a shared workspace is designed as "a form of electronic white-board" that helps collaborators draw or write as mentioned by Whittaker et al. (Whittaker 1993). As the most important component of CWE, the group members' collaborative activities are made and taken according to the practical work requirements in the collaborative workspace. Normally, this involves several subsystems of Groupware: communication system (e.g. information sharing and exchanging), coordination system (modeling the interactions between collaborators, the group workflow) and conferencing system (e.g. real-time conferencing, or computer teleconferencing). Besides, knowledge management (e.g. document management, group wikis and task management) and social intercourse models (e.g. the forum and public wall) have been lately discussed and designed within the framework of CWE (Martínez-Carreras 2007, Churchill 2001).

In the context of CWE, our thesis concerns three aspects of collaborative activities research:

1. Group Modeling: The group shared workspace relies on the study of group (e.g., group size, group structure or group dynamics) that comes from the analysis and modeling of virtual communities in the Internet (Rheingold 2000, Steiner 1972, McGrath 1993). Vassileva and Mao analyze and explain the characteristics of virtual communities in their article (Mao 2007). The issue of group modeling is an interesting topic in CWE and CSCW research (Joosten 1993, Vennix 1996). We concentrate on the modeling of small groups (between 2 to 30 members) as proposed by Andersen and Richardson (Andersena 1997), James (James 1951) and Dholakia et al. (Dholakia 2004). Definitely, the amount of group members influences the communication and the potential collaborations among group members. Lacking frequent interactions would hinder the trust and creativity;

2. CWE Design: CWE is a class of collaborative systems that "allows two or more participants to communicate, coordinate and collaborate to accomplish a shared

objective" (Fontaine 2004). Combining the existing technologies from groupware, a CWE provides several shared or collaborative workspaces for the groups in different scenarios via the web-based platform (Martínez-Carreras 2007). In the meantime, users can handle the tasks in their private workspace. Commonly, we often face more and more complex projects that require more collaborative information, such as, who should collaborate with whom for which task. CWE not only provides some tools and shared workspace for a group of users but also should record and reuse their past collaborative experiences to support their collaboration;

3. Smart Devices Supported Collaboration: Collaboration is one of the sources of power for human society development and progress. Decades ago, group/team work often relied on a "computer" that was either a desktop or laptop (Grudin 1994). Nowadays, with the popularity of portable set/instrument (the term can also refer to a ubiquitous computing device (Ballagas 2006)), more and more work/tasks can be accomplished in a dynamic situation, e.g., mobile office or cloud computing. Therefore, modern Collaborative Working Environment is characterized by cross-operating systems and cross-devices. Certainly, the "web-based" condition greatly promote the synchronous and asynchronous activities among different devices;

1.1.2 Trace Research

The concept of trace appears in different contexts with various definitions, for example, trace is related to a square matrix or a linear transformation in mathematics, and it can also mean a history carried by a sign in semiology. The etymology of this term (noun form) can be found in the old French "Trace" and its basic meaning is "path that someone or something takes"[1] (Middle English). It is now completely defined as "a mark, object, or other indication of the existence or passing of something,"[2] for example: animals' footprints. In this sense, trace is strongly affected by the existent "environment" and the subject's "actions." It naturally represents a series of interactions between the subject and the coexisting environment associated with some index, e.g. time. As an extension of this connotation, in computer science, a trace usually concerns the interactive activities between the system and the actors.

Many researchers proposed definitions of traces[3] in different research projects. The MUSETTE approach (Modelling USEs and Tasks for Tracing Experience) was proposed by Mille and his colleagues in 2003 with the objective to "capture a user trace according to a general use model describing the objects and relations handled by the user of the computer system" (Champin 2003). Through MUSETTE, a trace is treated as "a task-

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[1]Oxford Dictionaries Online: http://oxforddictionaries.com
[2]Oxford Dictionaries Online: http://oxforddictionaries.com
[3]In this paper, unless annotated in particular, no differences are made among trace, interaction trace and trace of interaction.

neutral knowledge base" that can be reused by the system assistants. Moreover, from the illumination of Sun's work on the theory of Experience Management (Sun 2005), they proposed another approach "Trace-Based Management Systems (TBMS) (systems devoted to the management of modeled traces)" (Laflaquière 2006) to analyze and model personal interactive traces. A general framework was introduced to support Trace-Based System creation and experience reuse. In this case, a trace is defined as "temporal sequences of observed items." Recently they built a platform to represent the activities as a set of observed elements: a kernel for Trace-Based Systems[4]. For kTBS, a trace is defined as a container of observed elements. This platform is currently only a prototype. With minor variance, Clauzel and his colleagues defined an interaction trace as: "histories of users' actions collected in real time from their interactions with the software" (Clauzel 2009). They also talked about "Synchronous Collaborative Traces," but without further discussing its definition. More directly, Zarka and his colleagues defined a trace of interaction as "a record of the actions performed by a user on a system, in other words, a trace is a story of the user's actions, step by step" (Zarka 2011). In a different way, Settouti and his colleagues define a numerical trace as a "trace of the activity of a user who uses a tool to carry out this activity saved in a numerical medium" (Settouti 2009b). In the TRAIS project (Personalized and Collaborative Trails of Digital and Non-Digital Learning Objects)[5], a trace is analyzed in hypermedia as a sequence of actions and is used to identify the users' overall objective.

Taking into account the principal characteristics of collaborative working environment, especially, a web-based CWE, a trace does not simply records the interactions between user and system but also reflects the potential relationships among collaborators. In CWE, the research of trace often concerns three aspects/issues of Trace Theory:

1. Defining different kinds of traces in a group: As a result, interactions produce traces. In CWE, the interaction is not only between the actor and the system. More activities are among the actors, e.g., communications in the group. It is necessary to analyze and define different kinds of traces according to the users' relations in CWE;

2. Modeling traces with a view to support collaborative work: The primary issue for CWE is to facilitate collaboration. Obviously, there exist various kinds of traces. Therefore, we should define and model such traces with some basic notations, especially, the traces of collaboration. That is to say, the trace modeling aims at collaborative relationships and group modeling;

3. Exploiting the defined traces in line with the group and personal needs: In general, a trace model is a kind of formation to describe the finished/past interactions. We

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[4]kTBS Platform: http://liris.cnrs.fr/sbt-dev/ktbs
[5]http://www.noe-kaleidoscope.org/telearc/

can view previous actions in a chronological order and also "undo" these actions. However, in some practical cases, we always need to retrieve more information and details from our previous collaborative activities to discover and manage our "experiences." Moreover, we can take advantage of our CTs for supporting some collaborative tools/applications.

From these points, we distinguish different types of traces and focus onto the definition of a *Collaborative Trace* (CT) defined as follows: "A Collaborative Trace is a set of traces that are produced by a user belonging to a group and is aimed at that group" (Li 2012b). The following section introduces a model of collaborative trace and an exploitation framework together with some basic notations.

1.2 Our Approaches and Contributions

Considering these research problems and related issues, our proposed approach focuses on two aspects: (i) constructing a trace model that can record and analyze various activities of users in CWE, especially collaborative interactions; (ii) creating an exploitation framework that can implement and reuse the modeled traces to facilitate collaboration in CWE. In this thesis, we will explain three collaborative tools/applications that depend on our CT Model and the exploitation framework: SWOT Analysis, Capability Maturity Model Integration and Group Recommendation.

1.2.1 Collaborative Trace Model

All interactions or actions that concern different functionalities of CWE in the shared workspace can be recorded as traces. Thus, a trace model is necessary and strongly required in the process of experience management. It not only constitutes the historical list showing the user's past actions, but also reports the previous "experiences" helping to perceive and interpret his interactions with the system. The trace model proposed by Clauzel and his colleagues for the project ITHACA represents and visualizes traces in the context of synchronous collaborative learning platforms (Clauzel 2009). To address similar issues, Lafifi and his colleagues introduced a trace model for the project SYCATA (Lafifi 2010), concentrating on the global architecture of the collaborative learning system. In a different approach, the trace model proposed by Sehaba dealt with the transformation process for the adaptation of the shared trace in accordance with the user's profile (Sehaba 2011). For CWE, a collaborative trace model could facilitate the analysis and reuse of knowledge and experience in groups. It focuses on the activities that involve or engage the collaborators in group shared workspace.

Before explaining our model, a simple example is introduced. Assume that in an established CWE, some engineers collaborate within a project. John finds a crucial problem that may be helpful for all the group members. So, first of all, he sends a mail to the group, then creates a new entry on this issue in the group's wiki, and finally shares his solution (a pdf document) in the group workspace. In the meantime, Tom and Peter, whose opinions are similar but different from John's on this problem, both ask for a video conference with John in a reply email. John receives the emails and agrees to participate in a video conference with Tom and Peter. Finally, they obtain a satisfactory answer to the problem in the subgroup meeting.

Thinking about the meaning of an interaction trace and characteristics of collaboration, apparently, there are three basic components concerning the trace in CWE: (i) "Emitter" who produces the trace; (ii) "Receiver" who obtains the trace (the target of the trace); (iii) "Information as a set of properties and corresponding values," that are the elements of the active environment in which the trace is generated and utilized. In a practical web-based CWE, the definition of "Emitter" and "Receiver" depends on the structure of the collaborative group. A collaborative group is generally defined as *a set of users with the same collaborative objective* and can be expressed as:

$$g_j = \{u_i, u_k, ..., u_m\}$$

It may contain several subgroups and independent users. Moreover, a single user can be considered as a special type of collaborative group (a group of one person): $g_i^0 = \{u_i\}$.

A trace is formally defined as:

$$t_{i,j}^k = <E_i, D_j, Q_k>$$

where $t_{i,j}^k$ is the kth trace sent by the ith Emitters E_i (a set of users), and received by the jth Receivers D_j (a set of users), and Q_k is a subset of pairs of the set Q, each element including a property and some values: $Q = P \times V = \{<p_l, v_m>\}$. P is a set of properties (attributes) and V is a set of literals (values): $p_l \in P$ and $v_m \in V$. Different situations of Emitters and Receivers lead to identify three types of traces (Li 2012a): Private Trace, Collective Trace and Collaborative Trace.

The three factors above that depend on the macroscopical considerations and precise reconstruction of "collaborative relation" (i.e. who works/collaborates with whom for what goal and what is the result in the environment), are often limited to explain or characterize what an "Emitter" has done for "A property and a corresponding value." That is to say, we can hardly know/understand the "Emitter's actions." From this direction (Li 2012b), we proposed another definition/formation for trace. A **trace** of the ith user can be defined as a vector with four attributes:

$$t_i^k = < \text{Identity}, \text{Action}, \text{Content}, \text{Index} >, k \in N^+$$

Where "Identity" is the user who does the "Action" (e.g., "send a message"). "Content", is a description of the action and of its result (e.g., image, video, or text). "Index", an identifier depending on the trace sequence (e.g., time or geographical position).

Regarding the characteristics of collaborative interaction, one of the essential feature is the relation among the collaborators. Briefly, the first trace definition ($trace =<$ $\text{Emitter}, \text{Receiver}, < \text{Property}, \text{Value} >$) would be more restricted and accurate to record and reflect the collaborative interactions since any trace cannot exist without the interaction with the environment. As a response to this problem, we established a Collaborative Trace Model (CT Model) in order to analyze different kinds of interactions and facilitate the collaboration in CWE.

Following the first formal definition of trace ($t_{i,j}^k = < E_i, D_j, Q_k >$), a collaborative trace can be regarded as a type of trace that satisfies the conditions:

$$E_i = g_i^0 = \{u_i\}$$

and

$$D_j \neq g_i^0$$

Meaning that the trace is the result or the effect of an operation that has been made by an "Emitter" and then flows to another user or to a group.

In order to analyze and reuse collaborative traces, a *filter* is applied as a tool or a pattern in the CT model. The basic component of a filter is an extractor (operators to access some part of the trace), then elementary filters, and last, a complex filter (a combination of elementary filters). In practice, the most important part is the design of elementary filters. An elementary filter can be considered as a predicate testing the value associated with a specific property. Any given property may have many elementary filters. Formally, an elementary filter is defined as:

$$\xi : V \times V \to B, \; where \; B = \{true, false\}$$

For example: to find the traces that mention female members in the group, we apply

$$\xi_{sex}^{member} \equiv femaleEqual(\alpha(t, sex), female)$$

In brief, a collaborative trace model is a triple structure: (G, Q, Ξ), where G is the set of users: $G = \{g_j\}$, that for $\forall E_i \subset G, \forall D_j \subset G$, they meet the conditions: $E_i = g_i^0 = \{u_i\}$ and $D_j \neq g_i^0$. Q is a set in which each element includes a property and a value: $Q =$

$P \times V = \{< p_l, v_m >\}$. P is a set of properties (attributes in the environment) and V is a set of values : $p_l \in P$ and $v_m \in V$. Z is a set of elementary filters: $\Xi = \{\xi\}$. Indeed, programming can be greatly simplified using such a model of collaborative trace.

Continuing the explanation using the previous example: (i) Naturally, the email sent to the group by John was stored in the group shared workspace, but has it been read by all the group or just by a single person? The same question could be applied for the shared pdf document: did they open and view it or not? (ii) If Tom or Peter were absent, it would affect the results of the video conference with John? In other words: do Tom and Peter have the same competence on this problem and any one of them could be substituted for the other? (iii) Actually, John, Tom and Peter work together and can be regarded as a subgroup. Were the others in the group satisfied by their answers to the problem? Is the new added entry in the group wikis really helpful for their project? In CWE, such questions are common but difficult to answer. They are directly relevant to the issue of CTs retrieval and exploitation.

As we explained above, collaborative traces record past interactive activities in a group shared workspace and can be used to enhance an application, to generate adaptive scenarios and to assist members. In general, collaborative activities produce more information and knowledge than personal states. Therefore they may create a large number of CTs in the group space. Elementary filters are limited, when screening and analyzing a large amount of CTs against actual demands. A complex filter is thus proposed and designed to help addressing this issue. It is defined as a logical combination of elements of Ξ (Ξ is the set of elementary filters, $\Xi = \{\xi\}$).

Thus,

$$\zeta : T \times \Xi \times P \times V \to B$$

An example of group collaborative trace would be

$$\{t \mid t \in CT_{i,l} \wedge \xi_j^k(\alpha(t, p_j), v_l) \wedge ... \wedge \xi_m^n(\alpha(t, p_m), v_s)\}$$

This allows selecting some specific traces that are produced by a member, e.g. mentioning the concept of "language", or traces of messages sent to a particular subgroup during a certain period, or traces left by a specific user to a group, or traces made by a specific group, etc.

1.2.2   Framework of Collaborative Traces Exploitation

In the preceding section we described a trace as a triple structure to classify and analyze all kinds of user's interactions in a CWE. Particularly, the collaborative traces that are left in the group shared workspace could record and reflect their daily collaborative

activities. Furthermore, in order to assist both individual and group work (e.g., for some complex projects or difficult tasks), it is necessary to consider how to exploit the stored traces in conformity with the user's or the group's practical needs.

According to the research work of Mille and his colleagues, traces can be used to represent users' experience as a specific knowledge (Laflaquière 2006, Champin 2004). Therefore, the exploitation of traces concerns the issue of Experience Reuse in the Theory of Experience Management (Sun 2005, Schneider 2009) and Trace Theory (Mille 2006b, Mille 2006a). In general, in CWE, it has the following characteristics: "knowledge intensive; vague collaboration description; large collaboration/solution space; group size; highly dynamic" (Li 2012c). Once a team starts a complex project in CWE, it is convenient to exploit their existing traces in a group shared workspace. The progress of the exploitation of Collaborative Traces can often be broken into the following scenarios: Review and evaluate the group members' past collaborative interactions; Assist group future collaboration work; Enrich group experiences; Adjust the current collaboration strategies; Contribute to Awareness.
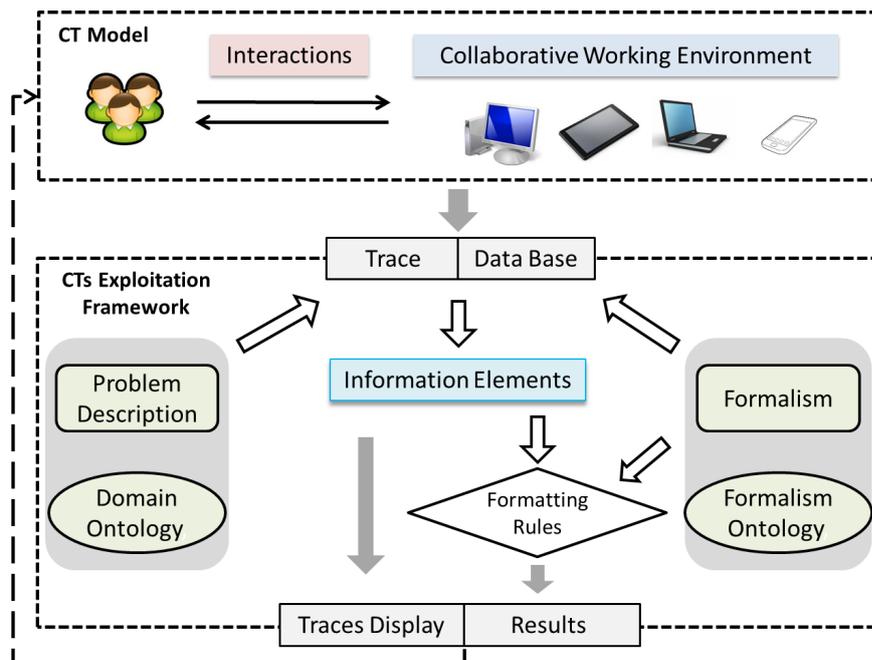
Figure 1.1: CT Model and CTs Exploitation Framework.

Based on our proposed concept of Collaborative Trace and on the corresponding Model, the CTs exploitation framework addresses the issue related to exploiting and reusing the collaborative traces for supporting the group collaboration work in different aspects. In this case, obviously, some complex filters are required to extract potential information both from the trace set and the data base. The process of exploiting traces[6] can be

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[6]Conforming to our formal definition of trace in CWE, Collaborative Trace is a subset of Trace. Thus, we use the term trace instead of collaborative trace in some particular contexts for a general sense.

divided into two levels in CWE (Figure 1.1): (i) According to the application formalism (e.g. SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis, CMMI (Capability Maturity Model Integration), Group Recommendation and so on), ontologies of formalism, the collaborative goal and domain knowledge ontologies, we extract the required information from the set of traces and the database by means of some complex filters. The retrieved information can be viewed as a series of Information Elements (IEs) that are naturally represented in various forms, for example: figures, texts or videos; (ii) Applying another kind of complex filters that depend on the application formalism to format the IEs into the final result, for instance: SWOT Matrix or CMMI Tables. The two stages are not independent but connected by the complex filters and the IEs flow. The whole procedure is defined as our proposed trace exploiting framework in CWE. Particularly, our approach can be really advantageous when the collaborative application needs more information from past collaborations. Consider the structured planning tools, such as SWOT (Strengths, Weakness, Opportunities and Threats) Analysis, it would be an ideal case to implement our framework. There are also other possible collaborative approaches that could use our framework: CMMI, Group Recommendation and so on.

1.3   Dissertation Organization

Our thesis begins by presenting the research problems and related issues in the area of CWE and Trace research, and introducing our proposed CT model and framework of traces exploitation in Chapter 1.

The rest of this thesis is organized as follows:

CHAPTER 2 ***Collaborative Working Environment*** In this chapter, we analyze the original interpretation of collaboration in distinct domains first, and then explain what is "Collaboration" and "Collaborative Working Environment." As a result, any collaboration process is generally composed of three elements: a group of people with a common goal, a set of collaborative tools and a shared workspace. It is a typical kind of group/social work relation that is very important and well worth looking into. For a Collaborative Working Environment, most of the research issues concern the three elements. But the most basic/complex element is the collaborative group: e.g., group size/structure, group needs or group members' interactions. Additionally, we propose a general framework in CWE for modeling the collaboration process. In consideration of various kinds of interactions (human-machine and human-human), this framework in CWE can be used to explain/model different collaboration scenarios and relations within groups.

CHAPTER 3 ***Trace and Trace-Based System*** In this chapter, primarily, we introduce and compare some important definitions of traces in the field of computer science. Generally, a trace is a set/sequence of elements which are inscribed in the digital environment

by the user's past interactive activities. Indeed, a digital trace not only contains the values from the environment properties but is also the result of a systematic recording of user's interactions with the environment. According to distinct situations, a trace can be manipulated by the actor for different purposes. In consideration of analyzing and exploiting the various traces with a set of "formulas/vocabularies," several typical trace models will be explained and compared in detail. The modeled traces can assist the user according to his practical needs, e.g. solve a new problem or make a decision. Consequently, a fundamental framework of Trace-Based System and its core elements will be presented and extended into a web-based system.

CHAPTER 4 ***Our Collaborative Trace Model*** In this chapter, we examine what is required to study traces in the context of a web-based Collaborative Working Environment. The objective of this chapter is to propose a definition of different kinds of traces and to build a model for classifying and analyzing the interactions with respect to both individual needs and group needs. In a CWE, the different types of traces can be divided into four categories: Private Trace, Collaborative Trace, Collective Trace and Personal Trace. A **Collaborative Trace** is "a set of traces that are produced by a user belonging to a group and is aimed at that group" (Li 2012b). The past collaborative activities in the group shared/collaborative workspace could be recorded and represented by collaborative traces. Moreover, we compare two formal definition of traces that we have already proposed (Li 2012b, Li 2012a). Based on the formal definition of CT, we establish a CT model with a series of basic notations.

CHAPTER 5 ***Our Framework of Collaborative Traces Exploitation*** Based on our proposed concept Collaborative Trace and the corresponding Model in Chapter 4, in this chapter, we focus on the issue that consists in exploiting and reusing collaborative traces in order to support the group collaboration work in different aspects in CWE. Naturally, this process requires a particular set of filters. In fact, elementary filters are limited to exploiting traces, and complex filters are thus proposed and defined as "a logical combination of elementary filters" (Li 2012c). When exploiting the traces, complex filters can naturally serve the group needs in different processes, for instance: information sharing, trace display, or collaborative project planning. Furthermore, based on the complex filter, we construct a general framework for exploiting traces in CWE. And three collaborative approaches (SWOT Analysis, CMMI and Group Recommendation Systems) are separately presented, based on our CT model and exploitation framework.

CHAPTER 6 ***Implementations and Experiments*** In this chapter, we evaluate our CT model, several complex filters and the exploitation framework on a web-based collaborative platform E-MEMORAe2.0. Several basic collaborative tools and the user's navigation history table are explained with some explicit figures. And two practical cases of trace exploitation: Trace Display and CTs based SWOT Analysis are presented in detail.

CHAPTER 7 ***Conclusions, Contributions and Perspectives*** In this chapter, we conclude this thesis by summarizing our contributions and we outline possible avenues for our future research.

Collaborative Working Environment

Contents

2.1 Introduction

Human, or more precisely, almost all the organisms could not live alone without any interactions with other species (co-evolution, (Thompson 2001)). For the human society or human evolutionary history, the "*collaboration/cooperation*" relations are one of the most important and complex collective behaviors. It is a kind of group work pattern

that includes every member's behaviors and characteristics. The group size cannot hinder the collaboration process but would make this process more complicated, e.g., the coordination or communication problems. As a matter of fact, from the study of simple case could help us analyze and understand the complex case. From the point of view of Chaos theory and Fractal theory, if it is assumed that human society as a dynamic system (Loye 1987), the collaboration work would be self-similarity from the simplest situation (collaborative pair works) to the most complex case (collaborations in organizations). In this chapter, from the study of different domains, we will explain that a collaboration process is composed of three elements in almost all cases: a group of people with a common goal, a set of collaborative tools and a shared workspace.

With the popularity of computer (as a type of collaborative tool) and the development of Internet, nowadays, people can work together with less limitation than ever, e.g., time or language. Using computers to better support collaborative works is a small group, as well as a large organization's main demands. The study of computer supported collaboration concerns various fields, such as sociology, psychology and computer science. Naturally, starting from the analysis of the etymology of "*Collaboration*" in different domains and the characteristics of collaboration, we will describe a general framework of **Collaborative Working Environment (CWE)** and introduce some research issues that are directly related to the three elements.

The following part of this chapter is organized as follows: Section 2.2 provides a brief background and retrospect of the concept "*collaboration*" in different domains (e.g. sociology, biology and psychology). We clarify the essential characteristics of collaboration and explain the relations between collaboration and culture. Besides, some possible tendencies of collaboration will be introduced. Back to the area of computer science, Section 2.3 is mainly about the thinking and idea of group and computer-supported collaboration. Section 2.4 continues this issue but focuses on the derivation of **Collaborative Working Environment** in the historical context of **Computer-Supported Cooperative Work** and **Groupware**. From the analysis of collaborative/shared workspace in CWE, Section 2.5 describes a general framework of collaboration in CWE, and concludes the work at the end of this chapter.

2.2 Etymology of "Collaboration"

Collaboration is the action of working with someone to produce something[1]. As the noun form of the verb "*collaborate*", this term originated from the French *collaboration* (1855-1860[2]). It was composed by a Late Latin noun "*collaboratus*" plus the French part

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[1]Oxford Dictionaries Online, 2012, http://oxforddictionaries.com/definition/english/collaboration

[2]From the Online Etymology Dictionary: http://www.etymonline.com/index.php?allowed_in_frame=0&search=collaboration&searchmode=none

"*-ion*". The verb "collaborate" is the back formation from "*collaborator*" that derives from the French "*collaborateur*" and had a negative sense during the Second World War, which refers to the people who work or help enemies or invaders occupying their own country (see more details from "Collaborationism"[3]). Indeed, the origin issued from the Late Latin verb "*collabōrāre*" that is formed by two terms: "*col-*" (one form of "*con-*": with, together or joint) and "*-labōrāre*" (from "*labor*": work, toil). In short, "collaborate" initial signification is "work together", and obviously, the subjects are only humans.

In the history of mankind, the term "work" (old english "weorc", "something done, deed, action") appeared later than "labor" (c1400, "a task, a project"). Both are used to describe the main human productive activities in the society. Before their widely usage, naturally, "pick" or "hunt" might be the principal ways to get the food for our ancestors. The distinction between "work" and "labor" probably was first discussed by Hannh Arendta (twentieth century political philosopher[4]). In her book *The Human Condition* (Arendt 1998), Arendt claimed that labor is a type of activity inextricably connected with the biological and natural processes (necessities of human existence) that basically maintain the human physical wellbeing. However, work is not only to sustain life but also the activity corresponds to the "unnaturalness of human existence". Work is to create artificial things independent from anything given in nature. More freedom, more happiness is the principal advantages of work.

From "labor together" to "work together", we have experienced not only the specification of social work (e.g. from "hunting" or "planting" to "operating" or "programming") but also the transformation of our social rights and roles in the society (e.g. from "slave" to "worker"). In economic discourse, according to the theoretical work of Karl Marx and Frederich Engels, this process is the result of the socialized production (the socialization of production) and strengthens the social productive forces. However, in comparison to Max Weber (or Weberian sociologists) (Kocka 1985), Marx paid insufficient attention to the aspect of social relations, i.e. the intersubjective life (not only the wage-slaves). For collaboration, it is affected by the nature characteristics of the economic form of society (the capitalism or the socialism) and also by the culture or religious. that concern the intersubjective aspect.

Naturally, with the needs of productive forces, "work together" progressively turns into a basic social pattern for both economics and the intersubjective parts. Although "work together" represents the core idea of "collaboration," in fact, this point must be appropriately conformed to a "common goal" or several "joint aims" for the collaborators. If there were no such apparent and realistic objective for them to "work together," this is not "collaboration" in the strict sense and could be considered as "cooperation" or "coordination" in the different situations. The principal differences and relations between

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[3]Collaborationism in Wikipedia: http://en.wikipedia.org/wiki/Collaborationism
[4]Hannah Arendt, 1906-1975: http://en.wikipedia.org/wiki/Hannah_Arendt

"Cooperation" and "Collaboration" will be clarified in the next section. On one hand, the common objective strengthens the collaborative relationships between the people, for example, more frequent interactions and dependences within the group members, and on the other hand, the strengthened collaborative relationships directly advance the achievement of the common objective. Obviously, this is an inter-dependent and mutually reinforcing process.

A negative meaning of "Collaboration" is that this term once was used frequently during the Second World of War to describe "traitorous cooperation with an enemy"[5]. This generates a more specific term "Collaborationism" to explain the phenomenon of "cooperation with enemies"[6]. Probably, this is one of the reasons that "Cooperation" is more acceptable and widely used than the term "Collaboration" in various domains. Although the two terms are very similar, each emphasizes different aspects in the "work together" process.

In the following sections, firstly, we will explain the differences and similarities between "Collaboration" and "Cooperation" (human society and economic). Then we follow the evolutionary timeline to look into the essential and general features of "Collaboration/Cooperation" (for all organisms)[7]. Besides, we will discuss some important relations between collaboration patterns and the culture factor in groups/organizations. In the final part, the new tendencies for "Collaboration" will be introduced with several practical examples.

2.2.1   Collaboration vs Cooperation

In general, "Cooperation" and "Collaboration" could both signify: "working together" as the most acceptable meanings to us. Obviously, they are very similar but they do have some differences. Winter and Ray (Winer 1994) explained the differences between "Collaboration", "Coordination" and "Collaboration" in their book. With their research result; see the table[8] 2.1 (here is only a partial part), the concepts "Collaboration" and "Cooperation" are compared in details.

From Table 2.1, we can clearly see the differences. Moreover, each concept places an emphasis on different facets of "work together." In business and management, "Cooperation" is not only every corporate behavior but also corporate culture (Denise 1999) in organization. That is to say, in the company or the group, cooperation is not only the opposite side of "working separately" but also the combination of people's behaviors,

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[5] http://oxforddictionaries.com/

[6] http://en.wikipedia.org/wiki/Collaborationism

[7] If no special instructions, in this Section 2.2, we think they are the synonyms.

[8] The original table is based on the research Winter and Ray done (Winer 1994): `http://www.ala.org/aasl/sites/ala.org.aasl/files/content/conferencesandevents/confarchive/CoopToCollab.pdf`

Collaboration	Cooperation
Long term	Short term
More pervasive relationship	Informal Relations
Commitment to a common mission	No clearly defined mission
Comprehensive planning	No planning effort
Results in a new structure	No defined structure
Comprehensive planning	No planning effort
Well defined communication channels at all levels	Partners share information about the project at hand
Collaborative structure determines authority	Individuals retain authority
Resources are shared	Resources are maintained separately
Greater risk: power is an issue	No Risk
Higher intensity	Lower intensity
-working together, having shared commitment and goals, developed in partnership. Leadership, resources, risk, control and results are shared. More accomplished than could have been individually.	-informal, no goals are defined jointly, no planning together, information is shared as needed.

Table 2.1: From Cooperation to Collaboration.

beliefs, etc. The organizational culture is progressively formed and developed from the cooperative progress. The needs from increased socialization to a culture make cooperation specific. Once the organizational culture is created, it is unique and difficult to duplicate. "Cooperation," in some way, has an orientation towards to the characteristic "collectivity" but it is sensitive to the disagreement and competition.

However, "Collaboration" is unlike "Cooperation," it doesn't emphasize the concordance: "collaboration thrives on differences and requires the sparks of dissent" (Denise 1999). It faces up to the competition and focuses on the creation. As Michael Schrage explains it in his book (Schrage 1990)<Shared Minds: The New Technologies of Collaboration>(p.140.): "...collaboration is the process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding that none had previously possessed or could have come to on their own. Collaboration creates a shared meaning about a process, a product, or an event. In this sense, there is nothing routine about it. Something is there that wasn't there before."

For human beings, collaboration has completely been integrated into our society and can not be replaced. As one of the most basic and necessary relations, collaboration also plays a crucial role in their evolution. From the perspectives of biology or ecology, co-operation (cooperation) focuses on the beneficial behaviors between organisms and

collaboration is always used to describe a loose association in the same species for mutual benefit. Without any special emphasis, "collaboration" and "co-operation" are applied as synonyms in the next section.

2.2.2   Collaboration/Co-operation in Evolution

From the beginning of organic evolution on Earth, the development of life has been never stopped and became more and more diversified, for example: from the unicellular eukaryotes, prokaryotes and archaea till fungi, plants, insects and animals (Roff 1993). Although we can see the changing of life form the "Evolutionary tree" (such as in figure 2.1) and the "Timeline of evolutionary history of life[9]," it is still hard to completely answer that question: "how life became complicated?"
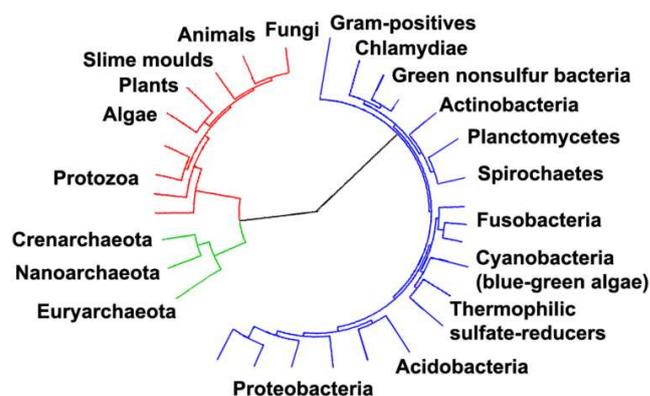
Figure 2.1: Evolutionary Tree (Ciccarelli 2006).

Before giving a convincing answer for the above question, it is necessary to look into the interactions in organisms through the process of evolution. As we know, on the Earth, all organisms are imperceptibly influenced by the evolution, as the form and also the behavior. The interactions between organisms are various and intricate, and normally, they produce things like: co-evolution, co-operation or conflict. The term "Coevolution" was probably first introduced by Paul Ehlrich and Peter Raven in a study of "the patterns of interactions" between plants and herbivores (Ehrlich 1964). It is used to describe the evolution between at least two species that each specie interacts with the others and adapts the corresponding changes, such as a pathogen and a host, or a predator and a prey. The conflict is not always negative and harmful to the organisms. Often, it plays an important role (as the first driving force) in the evolutionary changes, for example: from the study of genetic, the growing evidence showed that the conflicts between the selfish genetic elements and the rest are crucial for evolution and innovation (Werren 2011),

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[9]Timeline of evolutionary history of life: http://en.wikipedia.org/wiki/Timeline_of_evolution

like: origin of new species, mechanisms of sex determination or development. The co-operation exists in the same species as well as between different species (West 2007). For example: bees cooperate to build a honeycomb, cells collaborate to make multicellular algae, plants and animal. Another well-known case is that the interactions between the mycorrhizal fungi and plants (Hause 2005): the fungi grow on the roots of the plants and help absorbing nutrients from the soil, in the meantime, the sugars are produced by the plants from photosynthesis that can be used by the fungi. This typical reciprocal relationship could help the fungi to exchange the nutrients with their hosts. Actually, in this case, the fungi grow inside the plant' cells by sending signals to suppress the plant immune system.

To further understand the co-operative interaction between organisms, it is necessary to look into the symbiosis relationship. As we know, symbiosis means a series of close and often durable interactions between two or more species (Douglas 1994). To put it simply, it is just "living together and share something". Commonly, there are three types of symbiosis relations: commensalism, mutualism and parasitism. Commensalism[10] means a relationship between two species in which one benefits with little or no harm to the other. This term can be issued from the medieval latin word: "cum" and "mensa", which means "sharing a table". Here is an example of commensalism: the pests live with Humans or the barnacles live on turtles and whales. To compare with the two other relationships, the mutualism describes that two species both benefit from the interactions, and the parasitism in which one benefits while the other is harmed. From their definitions (commensalism and parasitism) and the goal of co-operation, it is clear to see that the co-operative interaction neither exists in commensalism nor parasitism. However, there are a numerous examples about "collaboration\co-operation" that exist in the mutualistic relationship.

The mutualism is the association between two species in which both can profit from the symbiotic arrangement. An example of mutualism is the partnership between shrimp and goby fish in the ocean, where the shrimp digs a burrow for the goby fish and goby fish looks after the shrimp. A further example is that the plover helps the crocodile cleaning his teeth. Indeed, there three types of mutualism in ecology (Ollerton 2006): Resource-resource relationships, Service-resource relationships and Service-service relationships. Separately, the examples above are Service-service and Service-resource. For the resource-resource, the mycorrihizal associations between plant roots and fungi is a case.

From the analysis and discussion above, we can summarize several characteristics for the "collaboration\co-operation" in organisms:

- Living together, for instance: in a same environment or ecosystem, it is the natural

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[10]Commensalism: http://en.wikipedia.org/wiki/Commensalism

platform for the interactions between species;

- Sharing something to keep the relationship (the base of co-operation), active or passive, i.e. the service or the resource that may benefit to the other species;

- Both benefits from the interactions (the essential objectify of collaboration or co-operation), or at least not harm each other;

- Often the co-operation is obligatory for surviving, i.e. the bees and some birds visit flowers in search of pollen and nectar. In this process, flowers are pollinated and bred;

- Once the environment changes, the co-operative object may be changed, i.e. the geographical position (latitude, longitude or altitude) affects the behaviors of bees in the process of pollination;

- Co-operation push the advance of evolution (particular, the co-evolution for a group of species) and natural selection, i.e. flower forms (hummingbirds and ornithophilous flowers);

The collaboration\co-operation between the organisms is always based on the life survival needs with the purpose of obtaining the greatest amount of resources. There are not so many choices when each organism struggles alone to face the challenges of adapting nature, the interspecific competition and so on. From the observation and examination of the cooperative interaction in ecology and biology, we wonder whether "collaboration\co-operation" in human society is similar or has some specific features in comparison to the other organisms. Nevertheless, a point can be confirmed for "collaboration\co-operation" is that any species cannot co-operate without "sharing something," for example: environment, resource, service, etc.

From the research of Sociology and Anthropology (Arendt 1998, Wood 1999, Collard 2007), we know that human beings are not only the primates, but also the unique living member of Homo Sapiens species which have a complex social and cultural structure, for example, religion or politics. We are gregarious (social) in nature not only for the survival needs but also the spiritual. As a natural and long-term phenomenon, collaboration is embedded into our DNA, then, it is induced and promoted from the gregarious state (e.g. the reproduction or survival needs). In such conditions, "sharing" is the most basic rule to follow for generating and accomplishing the collaborative relation. Their shared object is not limited to resources or environments, the ideas or beliefs could also be provided to other group members. Among a social network, sharing is the original force to connect people and expand their social sphere. In the next section, we will discuss some new tendencies or features for collaboration that are influenced by Social Networking Service, New tools\ techniques (e.g. tablet or smartphone) and Entertainment needs in contemporary era.

2.2.3 Collaboration and Culture

As a modern concept, culture involves various domains, such as sociology, management or anthropology, and has many different meanings. For most of us, it probably only refers to the characteristics of a specific phenomenon of a group people, defined by every element from their social habits, language, cuisine, religion and etc. Indeed, the term "culture[11]" is from Middle French word "culture", and the origin is directly from Latin "cultura" which means "a cultivating, agriculture". The figurative sense of "cultivation through education" is based on a notation used by Cicero in his *Tusculan Disputations* (Cicero 2007) where he explained "culture" as "a cultivation of the soul", i.e. man's natural perfection process. However, for anthropologists and other behavioral scientists, culture is generally considered as the full range of "learned and shared human patterns or models for living" (Damen 1987). As an very important concept in the field of anthropology and sociology research, it has other specific definitions, e.g., "Culture...consists in those patterns relative to behavior and the products of human action which may be inherited, that is, passed on from generation to generation independently of the biological genes" (Parsons 2010); "Culture is the collective programming of the mind which distinguishes the members of one category of people from another" (Hofstede 1984); or more specific, "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) Based on the discussion and study of this concept and globalization, other related domains, such as multi-culture, organizational culture or culture conflict, also evoke interest and enthusiasm in researchers.

In an organization or a team, there exists not only private behaviors but also a large number of interactions between members. As for "Collaboration" among a group of people, their "collaborative culture" plays a role like "an visible hand" that exerts a formative influence on their behaviors, for example, the created and shared beliefs or values in the group. It's a important topic in the field of organizational culture and management (Yang 2007, Kumar 1996, Clegg 2002). For instance, Evan Rosen in his book The Culture of Collaboration explored the relations between "collaborative culture" and "group work patterns" (Rosen 2007). From the study of several highly efficient collaborative organizations, such as Boeing, Toyota, DreamWorks Animation, The Dow Chemical Company, Industrial Light and Magic and so on, he explained "how collaborative culture is changing business models and the nature of work" and described "the significance of organizational, team and regional culture in collaboration" (Rosen 2007).

Since "Collaboration" is indeed a kind of group work pattern (Parsons 2010), naturally, this group would create a corresponding culture through the process of "work together", i.e., "Group/Organizational Culture" or "Collaborative Culture". The basic aspects of

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[11]Definition of "Culture" in the Oxford On-line English Dictionary: http://oxforddictionaries.com/definition/english/culture

collaborative culture is stable but it would be influenced by the changes of team members, i.e., different backgrounds or religions. From the other side, a good collaborative culture can make your group/organization more innovative and effective. "Collaboration" and "Collaborative Culture" are interdependent and mutually interrelated factors. There are some common ways to build a collaborative culture in the group/organization (Beyerlein 2003), such as: set a clear collaborative object, define and reward collaborative behaviors, embrace team diversity, transparent and friendly atmosphere and so on.

2.2.4 New tendencies in contemporary era

Collaboration always relies on the tool and the environment, for example: from the early telegram to the modern-day video-call; from the realistic environment to the virtual platform. These changes and substitutions lead to the advancement of collaboration, for instance: increased efficiency, more options and innovation. In recent years, with the development of techniques and the progress of society, three tightly interrelated forces emerge that strongly affect the pattern of collaboration:

- Smart Devices

  The era of Personal Computer is almost over since the traditional PC industry has difficultly to increase and had to slow down the pace in recent years[12]. The reason is not only from the contradistinction of annual growth rate of the worldwide PC shipment but also from the actual decline state of the industry giants such as HP, or DELL, in comparison with Apple. Smartphones and tablets, the Post-PC devices consumed more than half of the DARM chips in 2012 for the first time since the middle of 90s. Apparently, Web could probably be an ideal choice and with Cloud techniques, there would be a satisfied solution for the challenges of cross-os and cross-devices. Collaboration is no more limited to the PC and could be Cloud in next decade.

- Social Networking Service

  Based on an Internet communication model, Social Networking Service (SNS) (Ahn 2007) combines the Social Network Sites (SNSs), platforms and functions to encourage people to share their daily life and make new friends (Ellison 2007). It extremely expands the social relations in real life and certain on-line services could not easily be reproduced. Through smart devices, SNS close the gap between people and enhance their relationships. For collaboration, SNS is capable of facilitating the communication with less social distance (i.e. group chats not an

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[12]PC Shipments Set to Decline in 2012 for First Time in 11 Years: http://www.isuppli.com/home-and-consumer-electronics/news/pages/pc-shipments-set-to-decline-in-2012-for-first-time-in-11-years.aspx

email for all group member) and easily to share ideas or make friend (i.e. bringing creation and innovation for the team work). In general, SNS represents an individual-centered service whereas online community services are group-centered. The tendency for collaboration would be group-centered service, for example: two groups collaborate for a project, and the communication between them could be two levels.

- Entertainment Needs

  Recall the "labor together" case, the goal is only for benefits without any fun or happiness. Conversely, collaboration, for instance: in hunting, in fishing, in raising, in sports, in games, or in the art creations, brings us a joyous experience, and a kind of feeling that "working together" could be an enjoyable progress. Apparently, that's the sense of collective accomplishment. For group, the entertainment or game is necessary and efficient to balance the tiresome and tedious feeling of work. An ideal situation is that people enjoy work as they are playing games or entertaining with a lot of amusement. Make the group work funny is another interesting tendency for collaboration.

For collaboration, the above tendencies are some of the most interesting issues, but there still exist other open topics to which we should pay more attention in the future. As SNSs can create some unduplicated on-line social models, web-based collaborative working environment not only simulate the real collaboration scenarios but also can construct new models to facilitate team work.

2.3 Collaboration and Computer-Supported Work

As we mentioned above, the research issue of collaboration is multidisciplinary and concerns various research areas: e.g. psychology, sociology, management, anthropology, organizational patterns, group behavior and Computer-Supported Cooperative Work. Therefore, the realization of virtual collaboration in computer-supported working environment should consider different perspectives: e.g. individual role (Tajfel 1981), group dynamics (Levi 2010), organizational, social (Karau 1993) or psychological (Hardin 2006) influences and connections.

For computer-supported works, from the quantity of involved people for a task, it can generally be divided into two categories: individual and group. As a matter of fact, nowadays, almost all of the collaborative tasks are complex. Thus, the distinctions between the two categories are gradually reduced (e.g. the individual part is less important than collaborative or group part) by the complexity and feasibility of collaborative project. This is benefited from the development and improvement of computer-supported working systems and portable devices. For modern collaboration patterns, the computer

or smart device is not only a tool for accomplishing tasks but also an assistant to encourage collaboration. According to Stanoevska-Slabeva and Hoegg's work, collaboration can be normally divided into two types in computer-supported working systems (Stanoevska-Slabeva 2006):

- *Process-oriented collaboration setting:* in this case, that collaboration is regarded as a series of actions in organization and the system is designed to realize various interactive features, such as exchange information (Bentley 1995), share document or create group plans and so on;

- *Knowledge-centered collaboration setting:* where the objective is to integrate and generate knowledge resources, such as knowledge generating, sharing and discovering (Rice 2000);

This classification focuses on the needs and functionalities of collaboration. What's more, the gap between the two settings is based on the extend of collaborative interactions. From Figure 2.2, we could identify these changes. Here, the interactions are between the actors and the systems and among the actors themselves. Besides, the group structure and size directly affect the variation of interactions. As we can see, the separation between the two types of collaboration settings is obscure and indefinite when process-oriented transforms into knowledge-concentrated collaboration. Although it is necessary to classify the two types of collaboration settings, all of the modern computer-supported collaboration systems are nearly knowledge-concentrated and contains all the features of process-oriented features.

Since collaboration is based on the group, the most important issue for computer-supported collaborative/cooperative work, is the study of group that relates to the group needs, structure, size, interaction model and so on. Once the group model is built, the collaboration is naturally supported by the computer or smart devices. In this section, we will begin with the discussion of the group analyzing for collaboration in consideration of the characteristics of computer-supported work. Then, computer-supported collaboration scenarios will be introduced with practical examples.

2.3.1 Collaborative Group Research

Collaboration is a collective activity that contains a series of interactive actions in group. The issue of collaboration is intimately interrelated with the research of group. Generally, group research can be issued from different domains: sociology (Levine 1990, Morgan 1996), psychology (Freud 1975), education (Phillips 1989, Sinagub 1996), management (Homans 1951), softer engineering (Glass 2002) and so on. Although the research of group is a very interesting and meaningful issue that many classical scholars,
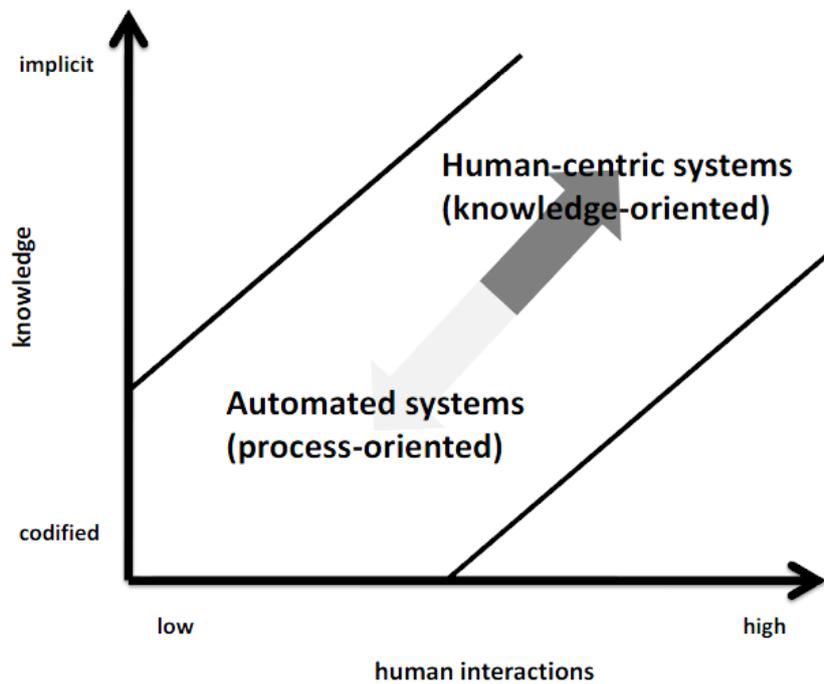
Figure 2.2: Collaboration Setting Classification (Stanoevska-Slabeva 2006).

such as Plato, Aristotle and etc. discussed the nature of group in order to explain the group-living properties of human being (Ettin 1992), there are some real difficult problems to solve, for example: the complexity and dynamic of group behaviors, the psychology of the individuals in the group-level process and etc.

With the progress of new experimental techniques and methods in sociology and psychology, the scientific study of groups scarcely arose from the beginning of the 20th century (Pepitone 1981). At the beginning, some social psychologists started to measure and to define the characteristics of humans and each novel method was directly applied to the study of individuals in groups (Wheelan 2005). The research of human behaviors aroused more concentrations for the emerging issues such as: group communications, group decisions, or organizational behaviors. In the middle of 20th century, numerous attempts have been made to specify the group structure in exact terms (Luce 1949, Festinger 1949, Freeman 1992), for instances: the overlaps between different groups (Homans 1951), the internal group structure (Davis 1941, Lewin 1951) or the interpersonal linkages in binary (Festinger 1949, Lévi-Strauss 1974). The issue of small groups has attracted the attention and interest of a growing number of researchers from various areas: sociology (Hare 1976), psychology (Levine 1990, Davis 1976), teaching (Tiberius 1990, Sharan 1976) management (Tuckman 1977) software engineering (Baecker 1993, Gutwin 1999) and so on. American psychologist Tuckman(1965) made

many important contributions for this issue (e.g. "Tuckman's Teamwork Theory") and also group dynamics (e.g. "Tuckman's Stage") (Tuckman 1964, Tuckman 1965, Tuckman 1977). In the past several decades, studies of group turned into the direction that how groups organize and process information (Hinsz 1997), intergroup process, transactive memory, group memory, group decision making, group knowledge management, social interactions and so on. What's more, their focus changed from the perceptions of individuals in different groups to the entire group (Moreland 1994, Sanna 1997). Literature overview on the issue of group research history (within the field of social psychology) can refer to the work of Forsyth and Burnette (Forsyth 2005), Levine and Moreland (Levine 1990, Levine 1998), McGrath (McGrath 1997) and so on. For other fields: communication issue can refer to Gouran's work (Gouran 1999); Groups and organizational behaviors can refer to Golembiewski's handbook (Golembiewski 2000).

Due to the popularity and development of computer-supported work, not only more and more scholars try to expand the theories and methodologies of group research (e.g. group work or social relations, group dynamics and etc.) into the area of computer science, in practice, engineers and developers attempt to simulate and model the real group structure, interactions and characteristics in the virtual platforms (Ellis 1991, Grudin 1994). Beginning from several reviews of the group definition, in the following subsections, we will discuss the group size, group structure, members' interactions and needs in the context of the features and objectives of computer-supported collaboration.

2.3.2 Group Definition

Depending on the subject of distinct research fields, the term "Group" has various definitions. The origin is from the French word "groupe"(17c.)[13]. And more precisely, the French "groupe" comes from the Italien term "gruppo." For collaboration, the essential definition can be issued from the research of sociology and psychology. A great amount of scholars provided their definitions from specific aspect of group search. As we can see in Table 2.2 and 2.3, the historical development of the "group" definition. Following these significant works, we want to denote and emphasize the "collaborative" relationship in group. Thus, a collaborative "group" can be defined as "a set of people(at least two persons) who work together for a common goal."

2.3.3 Group Size

As an important issue in group research (group dynamics), the group size can vary from two people to a large number of people and it straightly affects the levels and performances of collaboration, for instance, the participation, communication or satisfaction

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[13]Oxford online dictionary: http://oxforddictionaries.com/definition/english/group

Theorist	Central Features	Definition
Homans(1951)	Communication	"We mean by a group a number of persons who communicate with one another, often over a span of time, and who are few enough so that each person is able to communicate with all the others, not at second hand, through other people, but face-to-face" (Homans 1951) (p.1)
Sherif&Sherif(1956)	Structure	"A group is a social unit which consists of a number of individuals who stand in (more or less) definite status and role relationships to one another and which possesses a set of values or norms of its own regulating the behavior of individual members, at least in matters of consequence to the group" (Sherif 1956) (p.144)
Cartwright&Zander (1968)	Interdependence	"A group is a collection of individuals who have relations to one another that make them interdependent to some significant degree" (Cartwright 1968) (p.46)
Shaw(1981)	Influence	"Two or more persons who are interacting with one another in such a manner that each person influences and is influenced by each other person" (Shaw 1981) (p.454)
Turner(1982)	Categorization	"two or more individuals . . . [who] perceive themselves to be members of the same social category" (Turner 1982) (p.15)
McGrath(1984)	Interrelation	"A group is an aggregation of two or more people who are to some degree in dynamic interrelation with one another" (McGrath 1984) (p.8)

Table 2.2: Important "group" definitions in literature(Part I).

continued from previous page

Theorist	Central Features	Definition
Luft(1984)	Pattern	"a living system, self-regulating through shared perception and interaction, sensing and feedback, and through interchange with the environment. Each group has unique wholeness qualities that become patterned by way of member's thinking, feeling, and communicating, into structured subsystems." (Luft 1984) (p.2)
Johnson(1985)	Interaction	"A group is a social system involving regular interaction among members and a common group identity. This means that groups have a sense of 'weness' that enables members to identify themselves as belonging to a distinct entity" (Forsyth 2009) (p.4)
Brown(2000)	Shared identification	"A group . . . is two or more people possessing a common social identification and whose existence as a group is recognized by a third party" (Brown 2000) (p.19)
Arrow, McGrath, &Berdahl(2000)	Systems	"Groups are open and complex systems . . . a complex, adaptive, dynamic, coordinated, and bounded set of patterned relations among members, tasks, and tools" (Berdahl 2000) (p.34)
Keyton(2002)	Shared tasks and goals	"A group is defined as three or more people who work together interdependently on an agreed-upon activity or goal" (Forsyth 2009) (p.4)

Table 2.3: Important "group" definitions in literature(Part II).

of group members. Probably, Sibly was the first to ask whether the optimal group size was stable (Sibly 1983). Indeed, from the specific objectives or characteristics of group, the most appropriate number (size) of involving people in group is distinct. That is to say that the optimal size of a group is usually unstable. From Table 2.4, we can see that the ideal group size varies according to different situations.

Theorist	Group Size	Objective(Characteristic)
Pulliam &Caraco	Small: 20 (Maximum fitness); Medium: 55 (equal to a lone individual fitness)	"group member's fitness" (Pulliam 1984) (p59)
Dunbar(1993)	Small(bands): 30-50; Medium(cutural lineage): 100-200; Large(tribes): 500-2500;	"Groups of the size predicted from neocortex size for modern human" (Dunbar 1993)
Alexopoulou & Driver(1996)	Small: Fours or Pairs	"The social processes of knowledge construction in group settings" (Alexopoulou 1996)
Allen(2004)	General: 25 to 80; Best: 45-50;	"active group members for creative and technical group hovers" [13]
Laughlin(2006)	Small: Three to five	"Groups of three to five people perform better than the best individuals working alone on highly intellective problems" (Laughlin 2006)

Table 2.4: Examples of Human interactive group sizes.

For collaboration or cooperation in groups, according to the Dixit's model (Dixit 2003), the level of cooperation depends on the absolute size of the group in the community. In a dissimilar way, Choy built another model (Choy 2011) that found the percentage of the group could directly affect the level of invalid cooperation. Moreover, Hamburger et al. proved that small groups (3-7 members) are evidently more cooperative than large groups from their result of an experimental study (Hamburger 1975). Consider the theory of virtual community, the satisfaction and interaction within group members, for computer-supported collaboration, the range of each group (there is no subgroup in this group) is between 2 and 20 and the bound on the members of all the groups would be 55.

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[13]Allen, C., 2004, Dunbar & World of Warcraft. http://www.lifewithalacrity.com/recreation/

2.3.4   Group Development and Classification

Before introducing the principal classifications of groups in literature, it is necessary to explain several crucial theoretical models related to the formation and development of groups. Through the analysis of Bruce Tuckman (1965), there are four basic stages: Forming-Storming-Norming-Performing (Tuckman 1965) and several further development stages, e.g. Adjourning (after Performing) (Tuckman 1977), Re-Norming (Miller 2010) (p.4), etc. Here is Tuckman's model.

- Forming

  This is the first stage when people begin to learn about each other, the common tasks and the objective of their group: e.g. exchange the member's personal information, clarify who does what, when to finish, etc. In this stage, there are few conflicts and threats.

- Storming

  With the advancement of the members' work, some conflicts and threats naturally appear in the group, like: arguments about a decision, different ideas and opinions and so on. Patience and tolerance of each member is necessary and significant. Without such properties, team work will be inefficient and the group may dissolve after this period.

- Norming:

  The team unifies all the members' ideas and manages to build a common goal for further work. Definitely, several members should give up their own ideas and follow the others in order to accomplish the group target. Indicators include: Questioning performance, Reviewing/clarify objective, Changing/confirming roles, Opening risky issues, Assertiveness, Listening, Testing new ground, Identifying strengths and weaknesses (Tuckman 1977).

- Performing

  During this phase, the team can effortlessly confront the conflicts and threats as well as they perform as a whole unit to accomplish the group work. It is a relatively stable and mature state. Every member tries to accept other ones and the group cohesion is naturally formed in this stage.

- Adjourning

  This stage was added by Tuckman and Jensen in 1977 (Tuckman 1977). Once group project is complete, normally, the team will disband in this adjourning stage and members will feel sad and reluctant as they decide to leave. However, some groups are almost permanent (Luthans 2005).

Theorist	Model	Emphasis
Lewin (Lewin 1947)	Unfreezing-Change-Freezing	Individual change process
Fisher (Fisher 1970)	Orientation-Conflict-Emergence-Reinforcement	Decision emergence in groups
Cog (Charrier 1974)	Polite State-Why we're here-Bid for power-Constructive-Esprit	The dynamics of group work
Pooles (Poole 1983)	Task track-Relation track-Topic track-Breakpoints	Sequence of decision making
McGrath (McGrath 1991)	Inception-Technical Problem Solving-Conflict Resolution-Execution	Time, Interaction and Performance(TIP)
Tubbs (Tubbs 1995)	Orientation-Conflict-Consensus-Closure	Systems change

Table 2.5: Some important group development models.

Other important group development models can refer to the Table 2.5. Since there are numerous group development models, according to Van de Ven and Poole (Van de Ven 1995), generally, they can be separated into four categories: Life cycle models; Teleological models; Dialectical models; Evolutionary models;

Since the group formation is the basis/origin of group classification, similarly, there are many types of classification for groups. We introduce several important classifications.

Sociologist Charles Horton Cooley (1864–1929) suggested that groups can broadly be divided into two categories: primary groups and secondary groups (Cooley 1983).

- Primary groups: They are usually quite small and composed by several individuals who generally have the face-to-face relationships in the long-term. This type of group serves emotional needs: expressive functions rather than pragmatic ones, for example: the family, close friends or tight-knit peer groups.

- Secondary groups: They are often larger and collective. They may also be task-focused and have hierarchy. These groups serve an instrumental function rather than an expressive one, that is to say their characteristic is more goal-oriented or task-oriented than emotional. For instances: a classroom, congregations or work groups.

From the discussion of primary and secondary groups, there came a kind of classification of group: "Planned group" and "Emergent group" (McGrath 2000).

- Planned groups (concocted and founded): They are particularly formed for some purposes, for example: by the needs of group, or by some external individual demands. There are two types of planned groups: Concocted (planned by individuals

or authorities outside the group) and Founded (Planned by one or more individuals
who remain within the group);

- Emergent groups (circumstantial and self-organizing): These groups come into be-
  ing relatively spontaneously where members find themselves together in the same
  place, or where the same collection of people gradually come to know each other
  through conversation and interaction over a period of time. There are two kinds
  of emergent groups: Circumstantial groups (external, situational forces cause the
  groups arising) and Self-organizing groups (emerge when individuals interact grad-
  ually).

In practice, collaborative groups often change role in different specific situations, for ex-
ample: to produce an article, they collaborate as a planned group (secondary group); to
rescue a passenger in an airplane, several people collaborate as a emergent groups (pri-
mary group). Generally, for computer-supported collaboration, the group members work
together for a common goal and can usually be considered as the "the Planned group."
In the next subsection, we will study some typical scenarios of computer-supported col-
laboration.

2.3.5   Computer-Supported Collaboration

In a general sense, a computer is defined as an electronic device "that can store large
amounts of information and be given sets of instructions to organize and change it very
quickly"[14]. Ordinarily, it consists of a central processing unit (microprocessor) and a
kind form of memory. Between 1940 and 1945, the first electronic digital computers
were invented in the United Kingdom and United States in order to support military
activities[15]. With the development of CPU techniques (from the first microprocessor
Intel 4004 to Intel i7 processor), modern computers become more and more popular and
mobile from the industry to the daily life.

In the beginning, the computer was designed to merely support military computation
work. In the mid-1970s, the computer-supported group work was generated and attracted
the interest of many scholars in different domains, for example: business (Post 1992),
software engineering (Dewan 1993) or learning (Brandon 1999). From modeling the vir-
tual group interactions and communications to developing the computer-supported co-
operative work environment or groupware, computer-supported collaboration or cooper-
ation greatly simplifies the group work and facilitates information sharing in the groups.
This is a crucial issue that concerns various theories and techniques from many research
areas, for example: the modeling of group work (e.g. the group formation, structure or

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[14]Cambridge Academic Content Dictionary: http://dictionary.cambridge.org/dictionary/
american-english/
[15]Wikipedia: http://en.wikipedia.org/wiki/Computer

the interactions and communications between group members), computer networking, associated hardware, software, and services, even the culture and language.

Computer-Supported Collaboration mainly depends on the Collaborative Working Environment. However, with the popularity of smart-devices, modern Collaborative Working Environment is characterized by cross-operating systems and cross-devices. As a matter of fact, the term "Collaborative Working Environment" derived from a special branch of "Groupware" and is inextricably linked with the similar term "Computer-Supported Cooperative Work." In the next section, we will distinguish these terms cautiously through the study of the generation of the concept "Collaborative Working Environment."

2.4 Derivation of Collaborative Working Environment

From starting until accomplishing a complex project, since individual working alone is extremely time-consuming and labor-intensive, people need to collaborate as a group in a shared workspace. As for computer-supported collaboration, the task for modeling collaboration in the real world is not only to construct a virtual collaborative/shared workspace but also to simulate the group formation, interactions and communications by maximizing the usage of the current techniques and devices. In this section, we will discuss the derivation of the term "Collaborative Working Environment" with provision for the history of development of the human-computer interaction and computer-supported group/cooperative work.

2.4.1 Computer Supported Cooperative Work

Technology directly affects and gradually alters almost every aspect of our everyday lives, e.g. work pattern, social relations, etc. Unquestionably, it would like to be a help or a tool rather than a hurdle or an obstacle for our life, especially, our daily work. In fact, with the development of computer and other smart devices, the practical industry needs and the research interesting experienced a turning point from the individual to the group. Another realistic motivation is that the project or the task becomes more and more complex and tough with the modern society advance. Early in 1984, Paul Cashman and Irene Grief coined the term "computer-supported cooperative work" (or "CSCW") at a workshop, in order to find out how the technology could support people in their work (Grudin 1994). Since its birth, CSCW is widely used as a label or a mark referring to an identifiable research area about "supporting multiple individuals working together with computer systems" (Bannon 1989).

Before 1984, many researchers and developers had already tried and applied a number of approaches to support group work, for example: "Office Automation" (Olson 1982),

or "Groupware" (Ellis 1991). In the 1960s, the increasing demand and use of computers wildly spread in universities and research labs. In the 1970s, minicomputers/personal computers were gradually matured and extended to the market for supporting groups and organizations in more directive and interactive way. LAN techniques and a variety of protocols had been greatly developed and expanded from 1960s to 1980s. Based on these significant works, the creation of CSCW aroused great attention and efforts by researchers to learn from economists, social psychologists, anthropologists, organizational theorists and educators who can shed light on group research.

In general, the objective or starting point for Computer Supported Cooperative Work is to study the cooperative work that is carried out by a group people with computer and other smart devices. From the past decades, many researchers gave their own definition of CSCW. Carstensen and Schmidt thought that CSCW addresses "how collaborative activities and their coordination can be supported by means of computer systems" (Carstensen 1999). Not only do we need the technology to support group work, but also we should learn more about the effect of these technologies in practice. From this point, Baecker defined CSCW as "computer-assisted coordinated activity carried out by groups of collaborating individuals" (Baecker 1995). Conceivably, Bowers et al. offered a definition of CSCW that would be the most appropriate one: "CSCW examines the possibilities and effects of technological support for humans involved in collaborative group communication and work processes" (Bowers 1991). Although the objectives of CSCW and Groupware are alike, each of them has different starting point: "CSCW describes the research and Groupware describes the technology" (Grudin 1994). More precisely, Wilson explained (Wilson 1991) that "CSCW is a generic term, which combines the understanding of the way people work in groups with the enabling technologies of computer networking, and associated hardware, software, services and techniques".

The classification of CSCW systems can be categorized by its utilization (a set of tools). For Johansen's proposed Matrix, see Table 2.6, time and space are defined as two dimensions to identify the CSCW systems. From this table, we know that the human-computer interactive activities can come about in same physical space, for example: a meeting room, a conference room or a common workspace; but it also can take place in different spaces, for instances: video-conference rooms, group wikis, shared white-boards or documents. In addition, the temporal dimension of this matrix is progressively weaker because more and more tools are not so relevant to time, such as email, group wikis, version control, agendas, etc. Therefore, there are four types of tools in CSCW systems: synchronous / in the same place, synchronous / in different places, asynchronous / in the same place, asynchronous / in different places (Penichet 2007). The more functions the system has, the more complex it will be. According to Penichet et al. (Penichet 2007), this classification focuses on the point that a set of "groupware tools" constitute the CSCW systems. Besides, the classification for the systems is occasionally not clear be-

	Same Time	Different Time
Same Place	Face to face interaction	Asynchronous interaction
Different Place	Synchronous distributed interaction	Asynchronous distributed interaction

Table 2.6: Johansen Time-Space Matrix (Greenberg 1989).

	Same Place (One meeting Site)	Different Place (Multiple meeting sites)
Same Time (Synchronous communication)	**Face to Face Interactions** * Public computer displays * Electronic meeting rooms * Group decision support systems	**Remote Interactions** * Shared view desktop conferencing systems * Desktop conferencing with collaborative editors * Video conferencing * Media spaces
Different Time (Asynchronous communication)	**Ongoing Tasks** * Team rooms * Group displays * Shift work groupware * Project management	**Communication and Coordination** * Vanilla email * Asynchronous conferencing bulletin boards * Structured messaging systems * Workflow management * Version control * Meeting schedulers * Cooperative hypertext & organisational memory

Table 2.7: A CSCW Matrix ((Baecker 1995), p.742).

cause of the complexity of the tools [16], for example: the BSCW knowledge management system [17]. Johansen's Maritx is the original method to classify the CSCW systems and Baecker perfected this matrix in 1995 (Baecker 1995), see Table 2.7. Not all of the usages could be classified, in fact, there exists a collaborative mode "multi-synchronous" that cannot fit the matrix (Molli 2001).

The principal challenges of CSCW come from the modeling of group interactions in virtual environment, e.g. communication in groups, social relations, group needs, etc. To solve these difficulties, not only the technicians but also numerous researchers from various domains make great efforts for this issue. Indeed, CSCW systems considerably facilitate the group collaborative work, e.g. people can work without limitation of time and geographical position; support group information sharing and knowledge management, e.g. group wikis or shared documents; simplify group communication and coordination, e.g. email, chat room, video-conference and etc. All the functions of CSCW systems can-

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[16] http://www.it.bton.ac.uk/staff/rng/teaching/notes/CSCWgroupware.html
[17] BSCW, URL:http://bscw.fit.fraunhofer.de/

	Examples
Communication Level	synchronous conferencing; asynchronous conferencing; e-mail; faxing; voice mail; Wikis; Web publishing; revision control;
Conferencing Level	forums; online chat; instant messaging; video conferencing; data conferencing(with shared whiteboard); application sharing; electronic meeting systems;
Coordination (Collaborative Management) Level	electronic calendars; project management; online proofing; workflow systems; knowledge management systems; prediction markets; social software systems(e.g. enhance group social relations); enterprise bookmarking; online spreadsheets; could drive;

Table 2.8: Examples of groupware tools.

not be separated from the corresponding technology. As we mentioned above, "CSCW describes the research and Groupware describes the technology" (Grudin 1994). In the following section, the concept "Groupware" will be discussed with more considerations to technology effects.

2.4.2 Groupware

Groupware (or Collaborative Software) was originally defined as "intentional group processes plus software to support them" by Peter and Trudy Jhonson-Lenz (Johnson-Lenz 1981). Ten years later, Ellis et al. gave another more comprehensive definition saying that Groupware is a kind of computer-based system that supports "a common task" for group work and provide "a shared environment" (Ellis 1991). In an dissimilar way, Krasner et al. defined that groupware is "Computer-based technology that actively facilitates two or more users working on a common task, possibly simultaneously, using a shared environment and provides synergistic mechanisms for coordinating each user's actions with respect to the rest of the group and the system" (Krasner 1991). Following that, in the words of Malone, groupware is defined as "information technology used to help people work together more effectively" (Coleman 1992) in 1992. For a year afterwards, Baecker summarized that groupware is "the multi-user software supporting CSCW systems" (Baecker 1993). Later after the Groupware creation, the term CSCW was coined by Paul Cashman and Irene Grief at a workshop in 1984 (Grudin 1994).

As we mentioned above, groupware focus on the "technology", and with "Time-Space Matrix," we could classify the tools of groupware for different levels of collaboration (**Communication**: exchanging information, e.g. instant message; **Conferencing**: interactive work for a common goal, e.g. brainstorming, **Co-ordination**: interdependent

work for a common goal, e.g. collaborative management) [18]. Consequently, there are three types of tools (Mittleman 2008), see Table 2.8. This mainly explains the services that each groupware tool could provide to support collaboration but it is actually not a strict classification. From practical needs, Koch et al. (Koch 2006) provided a functional classification for groupware applications that contains the following classes:

- Awareness support: this is one of the essential functions in groupware. In comparison with other multi-user softwares, groupware facilitates and simplifies the coordination between each other for mutual activities. It could be integrated and applied in the tools and the designing process;

- Communication support: although awareness support can be regarded as an indirect form of (implicit) communication, both synchronous (chat, video conference) and asynchronous (discussion forum) communication tools are required for explicit communications;

- Coordination support: for coordination, awareness has a great contribution at the fundamental level, but there is a need for supporting coordination activities more explicitly, e.g. workflow management solutions;

- Team support: this category concerns the supports for special group types and their special needs, e.g. team rooms in this domain;

- Community support: in contrast to team, communities have different structure of needs and require applications, e.g. knowledge management domain;

Besides, in consideration of the web-based feature, we can divide these groupware tools into two categories: web-based collaborative tools and software collaborative tools. With the development of cloud computing, more and more tools will heavily depend on web-based characteristics. As an extending subclass of groupware, a web-based collaborative working environment takes full advantage of the Internet features and focuses on the group practical collaboration realization.

2.4.3 Collaborative Working Environment

A collaborative working environment (CWE) represents a kind of computer-supported working environment that "consists of a network of spatially dispersed actors (either humans or not) that play different roles and cooperate to achieve a common goal" (Angelaccio 2007). It stems from the utilization of collaborative software in a "virtual workspaces" (or a shared workspace) (see (Schaffers 2006)) and can be used to

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[18]Groupware - Communication, Collaboration and Coordination, 1995, Lotus Development Corporation. http://gcc.uni-paderborn.de/www/wi/wi2/wi2_lit.nsf/0/5098c20fcf549d15412564ca00333bc2?OpenDocument&Click=

assist both the individual work and the cooperative work, e.g., e-work and e-professional (Prinz 2006a). With various information and communication technologies and tools, group users could conduct their collaborative work through the CWE (Prinz 2006b). Actually, very basic factors found in CWE facilitate knowledge and information sharing in groups (Patel 2012). For an original or classical CWE, the "web-based" condition is crucial but not an integrant part. In fact, the modern CWE is more and more inseparable from the "web-based" circumstance. In this thesis, since our model and applications entirely rely on the web-based platform, we do not make a difference between Web-based Collaborative Working Environment (WCWE) and Collaborative Working Environment (CWE) unless explained in particular for the Web-based condition.

Based on the Internet protocol technology, the "World Wide Web" or "Web" for short dramatically promotes information sharing and improves working efficiency in a revolutionary way, for example using Wikipedia or webmail. In the past decades, the "Web" passed through different "eras" (Fuchs 2010). The "Web 1.0" represents the earlier stage of the Web evolution, and in this era, the Web was only read and static as "a common information space" (Berners-Lee 2001). It was commonly used as a kind of tool for cognition. The term "Web 2.0" was coined to delineate a general set of techniques, applications or platforms that are connected together spanning separate devices (OReilly 2007). From its first appearance in 1999 (DiNucci 1999), this issue evoked the researchers' great interest from numerous domains, for instances: education (Alexander 2006), business (OReilly 2007) or social work (Lai 2008). Correspondingly, there emerged a flurry of "2.0" suffixes added to many familiar concepts: e.g. Enterprise 2.0 (McAfee 2006), Learning 2.0 (Brown 2008), Travel 2.0 (Adam 2007), Science 2.0 (Waldrop 2008), and so on. Compared with the Web 1.0, the Web 2.0 has some significant features that can be summarized as follows: rich user experience, e.g. dynamic interfaces or multimedia services; user as a contributor and participant, e.g. wikis or forums; dispersion and classification of information, e.g. Bit Torrent or Flickr. All the features abundantly enhance the interactive actions between user and web-based platforms and also enrich the types of applications on the Internet. As a medium for human communication and cooperation, the Web 2.0 focuses on the human experience. The concept Web 3.0 is introduced with the research of "Semantic Web" (Hendler 2009) but it is still a very open topic without precise definition. The evaluation of the Web essentially relies on some typical techniques both in the client-side and server-side, for example: Ajax or JSON.

For a Web-based CWE (WCWE), these techniques are directly applied in group shared spaces, for example: the JavaScirpt Document Object Model technique helps group members to edit and share documents. Since dynamicity is one of the most critical features of collaborative interaction, neither the intranet CWE nor the desktop CWE, CWE without Web 2.0 applications would not be complete. The ideal collaborative situation is that people work in assorted OS (e.g. Linux, Windows, iOS or Android), with distinct devices (e.g. PC, Laptop, Smartphone or Tablet), in different places and times,

even with dissimilar languages. Considering the advantages of "Web-based" conditions (e.g. synchronous sharing or asynchronous sharing), it is easy to understand why more and more CWEs are built on the Web. In fact, "Web-based" conditions gradually become a key features of CWE with the development of Web-Technology. That's the reason why we do not make a difference between WCWE and CWE. As we mentioned above, the term "CWE" comes from the usage of collaborative software in a group workspace (for instance: virtual workspaces and e-work, see Prinz et al. (Prinz 2006a) or Schaffers et al. (Schaffers 2006)). As to Collaborative Software (also referred to as Groupware), a CWE is a subclass term but with more attention to the conditions of "web-based" and "group workspace" (Figure 2.3).
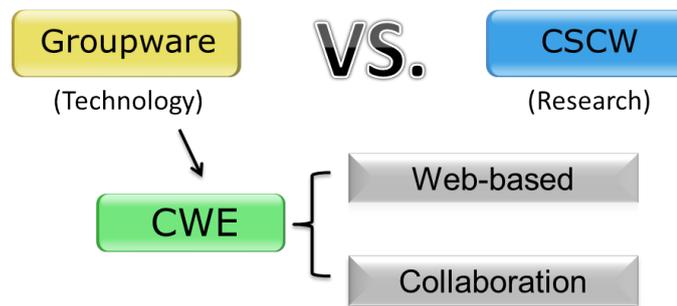
Figure 2.3: Collaborative Working Environment.

As a subclass of Groupware (Collaborative Software), CWE inherits its principal features and core ideas that concern organizational, technical, and social issues (Wangsa 2011), for example: information sharing, group communication, or coordination. Moreover, CWE pays more attention to the design of the group shared/collaborative work space, for instance: the classification of group interactions and needs. With the Web-techniques, CWE is much closer to the original goal of Groupware (Martínez-Carreras 2007).

2.5   General Framework of CWE

From the previous sections, we know that CWE is a class of collaborative systems that "allows two or more participants to communicate, coordinate and collaborate to accomplish a shared objective" (Fontaine 2004). Combining the existing technologies from groupware, a CWE provides several shared or collaborative workspaces for the groups in different scenarios via the web-based platform. In the meantime, users can handle the task in their private workspaces. As the human-computer interaction in the background, human-human interaction through a computer as a medium is more and more important in CWE. Since virtual collaborations take place in the group shared/collaborative

workspace and this process is human-oriented, the challenges come from the implementation and realization of the functions for the three levels of collaboration in consideration of the group formation.

In this section, we will discuss the structure and the functions of group shared/collaborative workspace at first. Then, from the study of group interactions and needs, we will introduce a general analysis for the framework of CWE with some practical examples.

2.5.1   Collaborative workspace/Group shared workspace

As computers or smart devices are progressively integrated into nearly every aspect of our daily lives, the interactions between people change significantly with less limitations of time or geographical position, even language or culture. As the most important component of CWE, the group members' collaborative activities and interactions are taken according to the practical work requirements in the group shared workspace. In the early research stage, a shared workspace is simply defined as "a form of an electronic white-board" that helps collaborators draw or write (Whittaker 1993). It is the principal embodiment of the original idea of "shared workspace" but without much concerns on the "collaboration" requirements. From this point of view, Spellman et al. (Spellman 1997) described a Collaborative Virtual Workspace (CVW) as "a MOO (Multi-User-Dimension, Object Oriented)-based collaboration framework in which people interact with documents and each other in a shared virtual space, using both synchronous and asynchronous tools." Obviously, the tools are built via the careful consideration of group interaction needs.
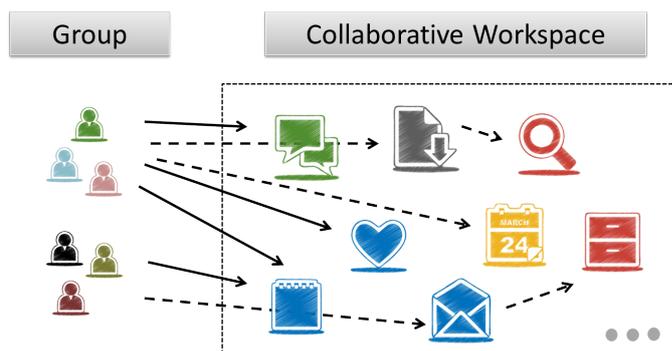
Figure 2.4: Example of collaborative workspace.

Designing collaborative systems has been explained as a complex and tough process that usually can generate some difficult issues (e.g. delayed and fragile trust in the group communication (Bos 2002)). It is to propose a series of approaches that are not only extensively explored but also can contribute to better understanding of a "group" in

collaborative system design. In the practical development process, Chatterjee et al. defined a collaborative workspace as "a set of independently operable software applications" (e.g. an email application, a file system application, or others) that a group of users can work together via "collaborative access" to these applications (Chatterjee 2005). Normally, this involves several subsystems/tools of Groupware: communication system (e.g. information sharing and exchanging), coordination system (e.g. the group workflow and project management, electronic calendars) and conferencing system (e.g. real-time conferencing, or computer teleconferencing). Besides, knowledge management (e.g. document management, group wikis and task management) and social intercourse models (e.g. the forum and public wall) are lately discussed and designed within the framework of CWE (Martínez-Carreras 2007).
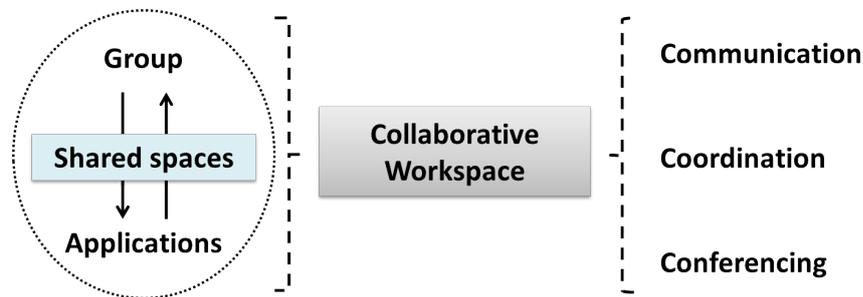
Figure 2.5: Formation of Collaborative Workspace.

For WCWE, a collaborative workspace could be considered as a shared workplace containing a set of web-based applications that any member in the group could access them for achieving a common goal (Figure 2.4). From Figure 2.4, we can see that the group member can use the collaborative applications in group shared space, for instances: email, chat, document sharing, or calender. Apparently, in the collaborative workspace, the various kinds of interactions come from the utilizations of the tools or applications. Moreover, they are also based on the group formation (e.g. group members, group structure, group size and so on). In a word, a collaborative workspace is founded on three elements: "a shared space", "a set of collaborative tools" and "several groups" (e.g. group structure or size affect the workspace formation). As we can see in Figure 2.5, a collaborative workspace is based on the group structure and a set of collaborative applications. From the utilization of the tools in group shared space, group members can communicate, coordinate and conference according to the practical collaborative needs (three levels of collaboration, refer to groupware tools classification).

2.5.2 A conceptual analysis of CWE framework

To construct a Web-based Collaborative Working Environment, the developers confront the challenges both from the theory and the technique which derive from the abstract and

modeling of the real group interactions as well as various creations of the collaborative applications depending on the web-based conditions. For example: in a real group collaboration workspace, we communicate with each other face-to-face or through a letter exchange, and in the CWE, we build chat room, use email or IM tools to simulate the real communication process; Group decisions predicting and making could be considered as a creative tool based on the artificial intelligence and cloud computing techniques.
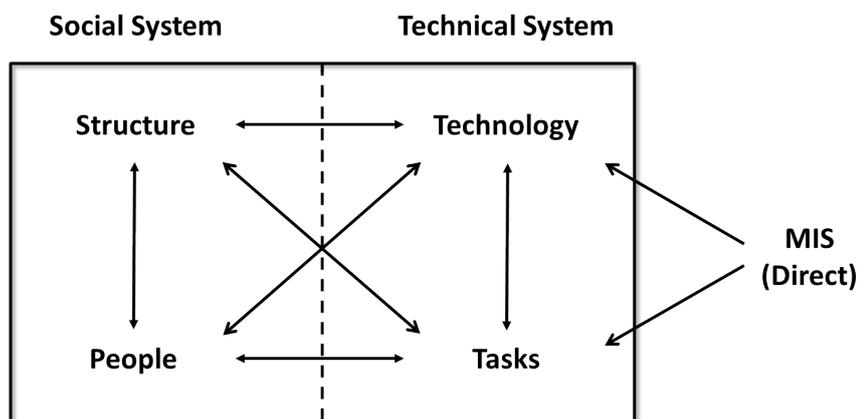
Figure 2.6: The Interacting Variable Classes Within a Work System (Bostrom 1977).

This issue crosses from the social system to the technical system since the group interactions and dynamics are so complex and hard to draw every detail. From the analysis of Management Information Systems (MIS) and Management Science/Operations Research (MS/OR), Bostrom and Heinen (Bostrom 1977) explained the process between the social system and the technical system, see the Figure 2.6 (P.25). Although it is similar to the interactive situations in CWE, we should pay more attention to the collaborative relationship in groups (social system would be too general for CWE).

Figure 2.7: The collaboration framework (Weiseth 2006).

Weiseth et al. proposed a general framework (Weiseth 2006) to explain the collaboration in groups. From the Figure 2.7, we can see that the collaboration framework consists of three elements: collaboration environment (the nature of the task and the organizational setting), process (coordination, production and decision-making) and support (organi-

zational measures, services and tools). In fact, this framework focuses on the business operation process with less consideration of the collaboration group. McGrath et al. extended the characteristics of a group in a collaborative environment (McGrath 1993), as the following sets indicate:

- A set of members (a goup composition and structure);

- A set of collective or shared purposes;

- A set of tools (Technology);

- A set of activities and the outcomes by using a particular set of tools;

It makes up for the deficiency of the group aspect in collaboration. Therefore, for CWE, a general framework could be formed by three elements (Figure 2.8):

- Collaboration Requirement (group [19]: composition or structure)

- Collaboration Process (communication, conferencing, coordination, production and decision-making)

- Collaboration Support (technology: tools or applications)
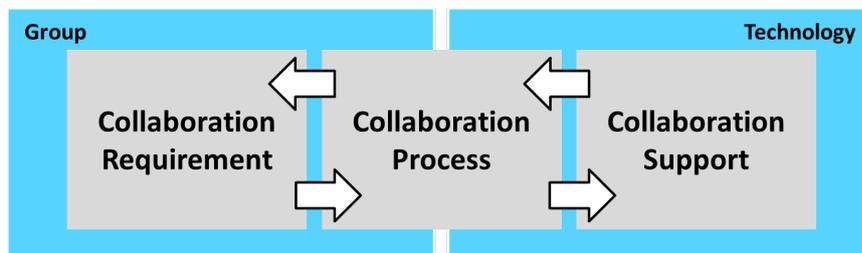
Figure 2.8: The general framework for CWE.

Elements of this model will influence each other in specific scenarios. Besides, there are two opposite directions/flows in the framework that represent the fundamental dynamics features in the framework:

- requirement → process → support → process; This flow describes the normal collaborative activities generation, for instance, several engineers work together for designing a product with the collaborative applications. They also make a plan and assign tasks to every member in the group. This direction explain how collaboration generates in CWE.

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[19]A single user can be regarded as a particular case of group: a group containing a unique element.

- process → support → process → requirement (or requirement ← process ← support ← process;); This opposite flow explains the existing collaborative activity feedback and output, for example: they have several video-conferencing or discuss in the chat room to adjust their plan because of a difficult technical problem. Then, they utilize some other collaborative applications (e.g. Question Answering or Decision making tools) to replan and assign the new tasks to every member. From this orientation, we could see the adjustment for the original collaborative manner and group structure.

There are other relations in this framework, e.g. requirement ↔ process or process ↔ support. Briefly, these relations reflect the human-machine and human-human (group) interactions. Besides, they may possibly vary over time with a large amount of additional dynamics that brings more complexity to the dependencies' structure (McGrath 1993). However, no matter how dynamical it will be, all their interactions would be stored and re-constructed through our collaborative trace model.

2.6   Conclusion

Collaboration is not only a type of human social relation but also a group work pattern. Generally, it means "a group of people working together towards a common goal". In this chapter, beginning from the analysis of the original interpretation of collaboration in distinct domains, we mainly focused on the issues: what is "Collaboration" and how this process works in "Collaborative Working Environment". As a result, any collaboration process is generally composed of three elements: a group of people with a common goal, a set of collaborative tools and a shared workspace. It is also the same case in CWE. Besides, for a group of people working together in CWE, all of their interactions (human-machine and human-human) can be recorded in the data set, and then reused to construct the real collaboration scenarios and relations. Additionally, we exposed a general framework of CWE in order to explaining and modeling the real collaboration process. In the next chapters, we will build a collaborative trace model in consideration of the various finished interactions in groups that are based on the group formation and the utilization of the tools in collaborative workspace.

Trace and Trace-Based System

Contents

3.1 Introduction

In the area of computer science, the issue related to the term "trace" or "digital trace" has aroused more and more researchers' interests and attentions, but sometimes over-flows in the mainstream press refers to some specific cases in reality (e.g. information or data securities). Our thesis focus on the "digital trace" (trace numérique) in the information systems or more precisely, the trace in the collaborative working environment. A digital trace can be regarded as an influence of the activity on the exiting environment, and definitely, the scope of this environment depends on its context of utilization and "can range from a simple window application configuration until all tools available to the user at a given time[1]"(Mille 2006b). Indeed, a digital trace not only contains the values from the environment properties but also the result of a systematic recording of user's interactions with the environment. According to distinct situations, a trace can be manipulated by the actor for different purposes. This is mainly from the single user's point of view and concentrates in the interactions between a human and an inanimate medium (e.g. a computer)(Lund 2009). However, in the domain of Computer-Supported Collaborative Work (ref to the Chapter 2), we should pay more attention to the group interactions (the inner connections between members) via the computer-supported systems or devices. Especially, for a group or an organization, the traces of their collaboration activities would be more complex and vague to describe

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[1]Translation from the French original: "*puisse aller d'une simple fenêtre de configuration d'une application jusqu'à l'ensemble des outils disponibles à l'utilisateur à un instant donné*".

the tightness of the interactive relationships between them. Besides, as we explained in the Chapter 2, human collaboration patterns have been changed and enriched by the evolution of the tools, e.g. "silent" communications via email or text messages. Anyway, the potential or implicit human-human interactions can be recorded and reconstructed by their their finished collaborative actions. The trace of interactions could be a basis for the defining and modeling the trace of their collaborations.

In this chapter, we are not going to detail our proposed concept Collaborative Trace and Model but focus on the issue: the definition, the modeling and the exploitation of trace in the area of information science. Starting from tracking the original definition of trace, Section 3.2 will overview the principal significant definitions of trace. Section 3.3 will explain some important trace models and a general structure of a trace-based system.

3.2 Trace and its Definitions

The concept of trace appears in different contexts with various definitions, for example, in the world of nature, usually, a trace is a mark, an indication or an object denoting the existence or passing of activities (e.g. a series of animal footprints in the wood); in the field of mathematics trace means a square matrix or a linear transformation, and it can also mean a history carried by a sign in semiology; other significations can refer to Figure 3.1. The etymology of this term (noun form, Middle English) can be found in the old French "Trace" and its basic meaning is "path that someone or something takes".[2] The etymon is from the latin verb "*tractiāre*[3]" (cf. Spanish *trazar* "to trace, devise, plan out"; Italien *tracciare* "to pull, draw").

Figure 3.1: Multiple significations of Trace.

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[2]Oxford Dictionaries Online: http://oxforddictionaries.com
[3]Online Etymology Dictionary: http://www.etymonline.com/index.php?term=trace

The Indo-European root is *tragh*-"to draw, to drag" (Schwartzman 1994). As a matter of fact, *draw* and *drag* (in Native English) is cognate, via Proto-Indo-European root *dherāgh*-. When you drag or draw something, naturally, a track or a mark is left by the passage of movements. Therefore, a trace can be issued from "a mark left by the passage of something". Besides, in this sense, *trace* and *drag* or *draw* are related words to record a series of actions. It is now frequently used as "a mark, object, or other indication of the existence or passing of something,"[4] for example: "remove all traces of the gum". And, this naturally could be applied to represent a series of interactions between the subject and the coexisting environment with a certain type of index, e.g. time or position changes. In the physical world, the term "interaction" usually means "an occasion when two or more people or things communicate with or react to each other"[5] and any interactions record the subject's actions on the environment. From Figure 3.1 (e.g. trace in the real world) and the etymological discussion, obviously, we can conclude that any kind of trace is strongly affected by the existent "**environment**" and the subject's "**actions**".

As an extension of this connotation, in computer science, a trace usually concerns the interactive activities between the system and the actors. This concerns the study of the interactions between human and computer. The Human-Computer Interaction/Interfacing (HCI[6]), sometimes called as Man-Machine Interaction or Interfacing, is mainly about the study of the user's actions with the system or the machine (Dix 2004), e.g. the operation and application interface design. It is generally regarded as the connection of the computer science, design, behavioral sciences, psychology and some other fields of learning. Briefly, it draws from the knowledge on both machine as well as the human side. A basic objective of HCI is to progress the interactions among users as well as computers by making computers or smart devices more working (be handedly easily) and open (user friendly) to the user's requirements (Myers 1998). HCI comprises both computer hardware and software side, for instance: the ubiquitous graphical interface (Microsoft Windows) or the Mouse design. Moreover, the HCI research hot spot gradually shifted to the relations between actors in recent years, e.g. the emotion (Peter 2008) or the social relations (Raisinghani 2006). Therefore, the digital traces of interaction could be a series of temporally observed actions that might either be the interactions with computer or the interactions between mediated actors by computer (or other smart devices). To obtain a trace, it is necessary to create from every elements of its existence conditions and from the possibilities of its registrations/stored. That's to say, it is the system designer who may have determined what would be this trace a priori (e.g. in the level of its compositions: the data types). In this sense, a trace is not a "given", but a "constructed(combined)" recorded information at a certain time on the machine.

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[4]Oxford Dictionaries Online: http://oxforddictionaries.com
[5]Cambridge Online English Dictionary: http://dictionary.cambridge.org/
[6]HCI is defined by the ACM as "a discipline concerned with the design, evaluation and implementation of interactive systems for human use and with the study of major phenomena surrounding them".

Many researchers proposed their definitions of traces[7] from several research projects. The MUSETTE approach (Modelling USEs and Tasks for Tracing Experience) was proposed by Mille and his colleagues in 2003 with the objective to "capture a user trace according to a general use model describing the objects and relations handled by the user of the computer system" (Champin 2003). Through MUSETTE, the trace is treated as "a task-neutral knowledge base" that can be reused by the system assistants. Moreover, from the illumination of Sun's work on the theory of Experience Management (Sun 2005), they proposed another approach "Trace-Based Management Systems (TBMS) (systems devoted to the management of modeled traces)" (Laflaquière 2006) to analyze and modeling personal interactive traces. A general framework was introduced to support Trace-Based System creation and experience reuse. In this case, a trace is defined as "temporal sequences of observed items". The "sequence" means that any trace has an index representing "a history of the user's interaction" that results from the observed activity (Settouti 2009a). Recently they built a platform to represent the activities as a set of observed elements: a kernel for Trace-Based Systems[8]. For kTBS, a trace is defined as a container of observed elements. Nevertheless, this platform is currently only a prototype. With minor variance, Clauzel and his colleagues defined an interaction trace as: "histories of users' actions collected in real time from their interactions with the software" (Clauzel 2009). They also talk about "Synchronous Collaborative Traces," but without further discussing the definition. More directly, Zarka and his colleagues define a trace of interaction as "a record of the actions performed by a user on a system, in other words, a trace is a story of the user's actions, step by step" (Zarka 2011). In a different way, Settouti and his colleagues define a digital trace as a "trace of the activity of a user who uses a tool to carry out this activity saved on a digital medium" (Settouti 2009b). They applied the framework of trace-based system in Technology-Enhanced Learning (TEL) Systems that can meet the needs of personal services. In the TRAIS project (Personalized and Collaborative Trails of Digital and Non-Digital Learning Objects)[9], a trace is analyzed in hypermedia as a sequence of actions and is used to identify the users' overall objective.

This definitional work has shown that a fundamental connection and some differences (extensions) exist between the general notion of trace in the physical world and the trace in the virtual world. In conclude, a digital trace can be considered as a set of information recording the user's interactions within the framework of the system. Trace can be considered as a type of resources in the information system. Consequently, it is necessary to build a model to analyze and exploit the traces that could assist user's work in many possibilities, e.g. decision making, planning, etc. Moreover, we could establish a Trace-Based System or implement the trace model as a subsystem the whole framework.

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[7]In the following part, unless annotated in particular, no differences are among digital trace, trace, interaction trace and trace of interaction.

[8]kTBS Platform: http://liris.cnrs.fr/sbt-dev/ktbs

[9]TRAIS Project: http://www.noe-kaleidoscope.org/telearc/

3.3   Trace Modeling

The definition of trace helps us clarify and record our finished actions in the system. If we want to exploit and reuse the traces, a trace model is certainly required and built in different forms (since the concept "trace" may be defined in the different context). In the following part, we illustrate some important trace models from related domains.

In the research field of Knowledge-Based System (KBS), according to Mille and his colleagues (Settouti 2009a), plausibly, a trace model is a quadruple structure that contains: $<\mathcal{T}$ (how time is represented), C (how observed elements are categorized, R (what relations may exist between observed elements), A (what attributes further describe each observed elements)$>$. With the domain and range functions, any types of relations and attributes from the observed element could be constrained. According to this model, they defined a modeled trace("a sequence of observed elements recorded from a user's interaction and navigation through a specific system") as a tuple that consists of: a set of typed observed elements that each is linked with a unique identifier, located in time, relations with each other, and described by attribute values (Settouti 2009a). The objective of this model is to support reasoning about the traces(represents user's knowledge and experiences of activities with the system) and their interpretation. Additionally, they proposed a language and a framework in order to build a Trace-Based System (TBS) that relies on this model.

For the Intelligent Tutoring System[10] (ITS), Settouti proposed a similar trace model to study how to interpret and dynamically use the traces for the real-time or retrospective exploitation scenarios (Settouti 2006). In this trace model, a trace is defined as a quadruple structure $Trace = (D_p, O_{t_r}, R_t, R_s)$, where D_p is a time domain, O_{t_r} is a finite set of trace objects, R_t is a bunch of temporal relations between D_p and O_{t_r}, R_s a series of structure relations. And the trace model is defined as a binary structure: $\Theta = (\Theta_c, \Theta_r)$, where Θ_c represents a finite set of objects describing the observed trace, Θ_r signifies a finite set of relationships between Θ_c. For example, Θ_c may be concepts or educational activities, and Θ_r can be the relations between the concepts and the activities. The observed data can reformed as a trace that is linked to a time interval belonging to the time domain. The modeled traces can be considered as a valuable information source to fully understand how learners could better work or how teachers could better action. Especially, this model could be a considerable way to regulate the executive scenarios in ITS and allow the personalization for each learner. They also mentioned a very similar TBS and wanted to apply the model in the system.

In order to share the experiences between different users in a information system, Sehaba proposed another trace model (Sehaba 2011). This allow users to exchange their prefer-

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[10]In French, it is called as "Les Environnements Informatiques pour l'Apprentissage Humain" (EIAH) http://en.wikipedia.org/wiki/Intelligent_tutoring_system

ences, skills or abilities from the traces of activities. Particularly, they concentrated in the transformation process to adapt the shared traces according to the target user's profile. In this case, a trace is defined as a triple structure: $T = <u, task, (o_1, o_2, o_3, ..., o_n)>$, where u is the tracked user, $task$ is a description of the user's tasks, o_i is an observed trace that contains a pair $<A_i, M_i>$ (A_i is the user's actions, M_i is a mode of interaction with a physical device and a interaction language). This model contains the defined Trace T, the user's profile P and a similarity function ϕ. For this approach, he assumed that the uers' properties are sufficiently different, except for the properties related to the modality in question.

Their also exists other trace models in the related domains. However, carefully take the characteristics of trace (e.g. from its definitions or etymological analysis) into consideration, our basic idea for trace modeling is: use a formal defined trace to record the users' interactions and exploit them as our experiences from the past activities in the system. Although starting from different points, the trace models in distinct forms can be naturally interpreted in the general framework (perhaps, different parts in the framework) of trace based systems.

3.3.1 Trace-Based System

In the information system, the implementation and the exploitation of recoding the user's interactions as traces is a crucial research issue. It is involved with various domains, for example: HCI, CSCW and so on. Broadly to say, the possibility for an actor to reflect on his finished activities depends on his recorded interactions with the machine/computer. From the above definition of a digital trace, it is necessary to establish an overall framework for the trace implementation and exploitation. Correspondingly, the traces based applications can be formed in this framework.

Certainly, Mille and his research team firstly proposed a Trace-Based System (TBS) in order to exploit an explicit representation of different kinds of knowledge whose main source of knowledge is the set of traces subsuming user-system interactions and evolving with his/her activities (Settouti 2009a) (Figure 3.2). As shown in Figure 3.2, the top is the tracking part that some captures collect the target information from different interactive resources, for example: interface events, or log files, etc.). They defined the observed data from the tracking part as the "primary traces" (often low level) from active or passive capturing sources. Particularly, in a web-based environment, the captured elements involves two sources: the on-line traces and the off-line traces. Then, the collected primary traces are filtered, reorganized, aggregated and so on. in a given context. Through this transformation process, the primary traces turns into the modeled traces that could be more easily and exploitable by the traces based applications. At last, the outputs will be presented in various forms to support user's reflexivity. In
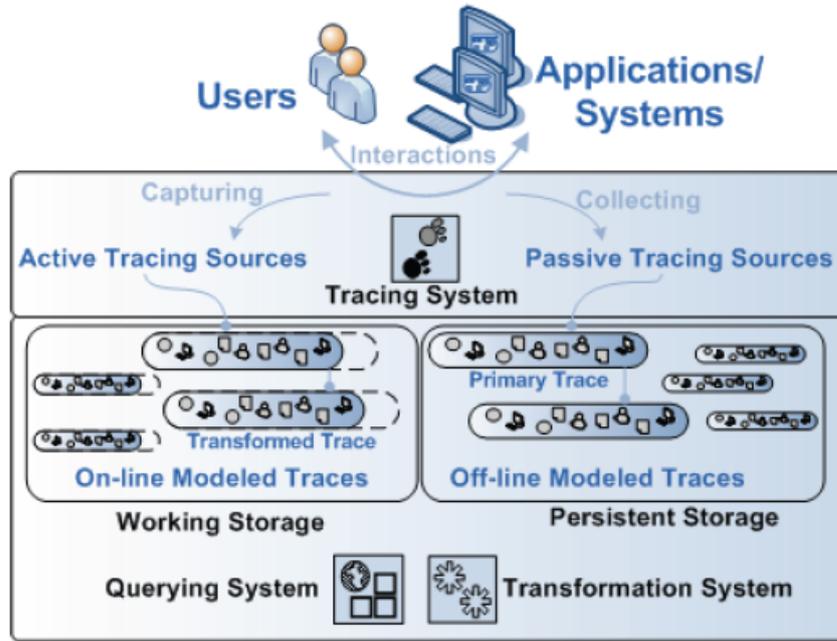
Figure 3.2: Trace-Based System Architecture (Settouti 2009a).

Figure 3.3, we can see the abstract of the core elements from the architecture of TBS (Laflaquière 2009). A full explanation will be detailed in the Section 3.3.2.
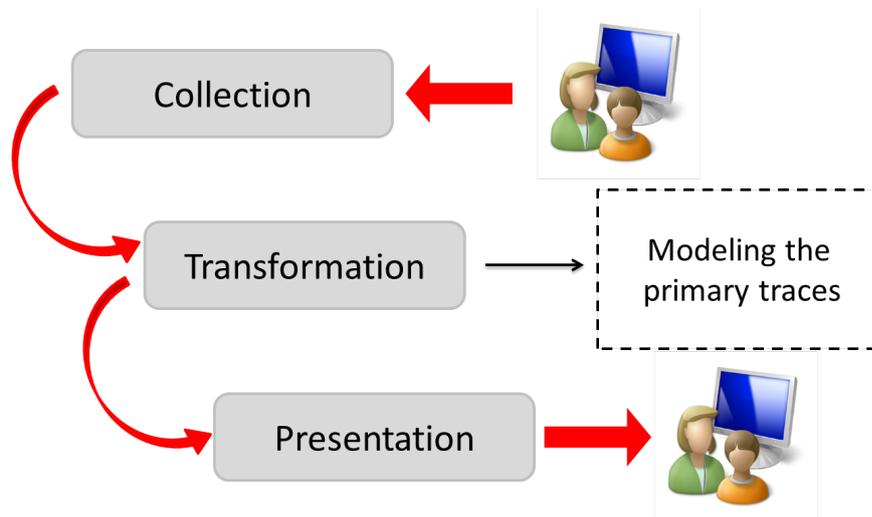
Figure 3.3: Abstract of TBS Architecture (Laflaquière 2009).

In the theoretical level, TBS is strongly tied to the soviet activity theory (Vygotskiĭ 1978) and experience management theory (Bergmann 2002). In the practical application level, as a kind of knowledge-based system (KBS), TBS supports the user's "reflective activities" or "self-awareness process" through his past interactions in the information systems, for example: Human Learning Environment. The idea was firstly implemented by the

Silex team (Lab Liris[11]) in the project MUSETTE (Champin 2003). The fundamental framework of TBS is based on the modeled traces and can be applied and interpreted in the different trace exploitation processes. That's to say, the formal definition of the trace model could not directly affect the trace exploitation in the system's integral framework, for example: for the Collaborative Working Environment or for the Collaborative Learning Systems, the process of traces exploitation follows the same steps but may assistant the user in different forms.

3.3.2   Fundamental Structure of TBS

The primary framework of a trace-based system is usually composed of three processes as we mentioned above (Laflaquière 2006). In a very general sense, the two last ones involves the exploitation of traces.

- (i) Collection: with diverse sensors or collectors, the users' actions can be observed and stored as formatted traces. For example, a trace may contains all the events occurring during an interaction as objects of interest. The sources of a trace are often the files or the data streams in an unspecified format. From these primary information/data, a defined trace will be constructed in a specific form;

- (ii) Transformation: calculation and classification of formatted traces with assorted filters. Actually, the transformation of traces is directly affected by the environment framework and the programming language. Moreover, in this process, we can modify and adjust the model of trace (e.g. updating the traces base) by a set of formal rules (e.g. queries in the data base).

- (iii) Presentation: the last process that concerns explanation, e.g. what to explain and how to present in a understandable way. The mainstream probably is the visualization. Nevertheless, audio presentations can also be helpful and effective.

Consider the three elements in the general TBS framework, typically, we can apply this to a web based system as shown in Figure 3.4. For a web-based system, because of the counting filter features, tables and figures are more appropriate choices in the Presentation process. Besides, in a web-based environment, the main data include text documents, hypertext documents, link structures, server logs, browser logs, and so on.

3.4   Conclusion

In this chapter, primarily, we introduced and compared some important definitions of trace in the area of computer science. Generally, a trace is a set/sequence of elements

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[11]Laboratoire d'InfoRmatique en Image et Systèmes d'information: http://liris.cnrs.fr/
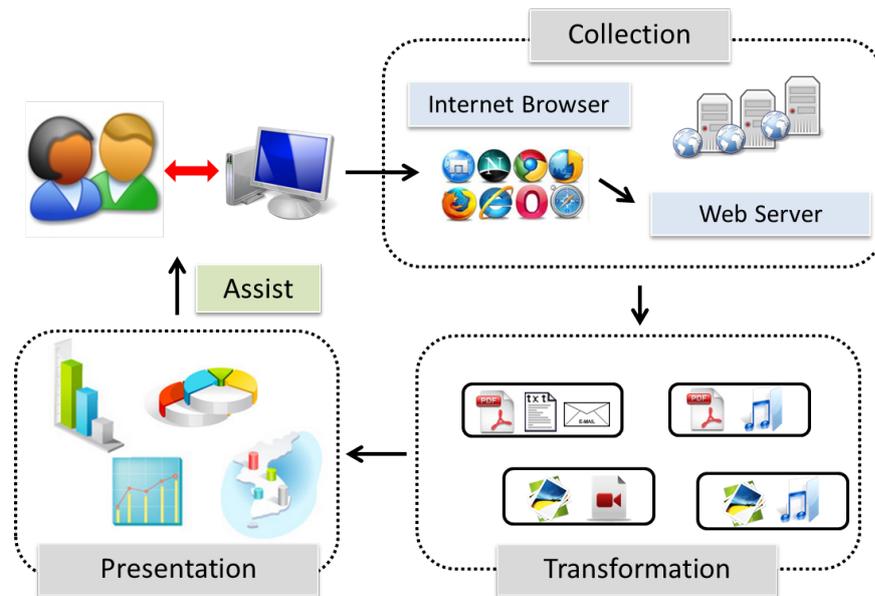
Figure 3.4: A general TBS framework for a web based system.

which are inscribed in the digital environment by the user's past interactive activities. In consideration of analyzing and exploiting the various traces with a set of "formulas/vocabularies", several typical trace models are explained in detail. The modeled traces can assist the user according to his practical needs, e.g. solve a new problem or make a decision. Consequently, a fundamental framework of Trace-Based System and its core elements are presented and extended into a web-based system.

Since trace represents the user's experience from his past activities, for the CWE, user's activities could more complex and greatly rely on the group relations/structure. The user's traces not only contain the experiences with the system but also with the collaborators in the group. In the next chapter, we will propose a new concept: Collaborative Trace, then explain its definition and corresponding model with some practical examples.

Our Collaborative Trace Model

Contents

4.1 Introduction

With the fast development of Internet and wireless techniques, collaboration becomes much more flexible and effortless, for example: people can work together using various devices (e.g. tablets, laptops, smart phones, or PCs) with less restriction of time, language, or geographical position. In a Web-based Collaborative Working Environment (CWE), users' actions always leave traces, for example: when users exchange messages, edit wikis, have a video conference or manage documents. Such traces [1] come from the past or finished interactions and contain a great deal of information. In this Chapter, we do not intend to enter the debate about information, knowledge and experience, but accept a common point of view found in the IT literature. Namely, information is "processed data,"

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[1] In this article, we do not make a difference between trace, interactive trace and trace of interaction unless annotated in specific situation.

knowledge is "authenticated information" (Dretske 1981, Machlup 1984, Zins 2007), and "experience" can be considered a special case or a refined form of knowledge at a higher level (Sun 2005, Schneider 2009). In particular, Clauzel and his colleagues claim that traces can be regarded as "knowledge sources" (Clauzel 2011). Morevoer, according to Mille and his team, both user and group knowledge can be captured from the modeled traces (Champin 2004). They also explain that traces from the complex tasks reflect experience more than simple knowledge (Laflaquière 2006). More precisely, Laflaquière showed that almost all past interactions represent a kind of trace that can be used to measure the user's working experience (Laflaquière 2006).

The research work above substantially concentrates in defining and analyzing personal traces but with less interest of the interactive relations between collaborators. For group work, collaboration always depends on shared "Knowledge" but more precisely, it requires collaborative "Experiences." Such "Experiences" often come from the past interactions among the actors themselves or between the actors and the system. Considering Web-based CWE, building a trace model for the purpose of enriching group experience and facilitating collaboration is an interesting research issue that does not seem to have available or satisfying solution currently. The problem involves three critical research facets: (i) definition and modeling of collaborative traces taking into account characteristics of CWE, e.g. collaboration mode or group workflow; (ii) group modeling and structure design, which is widely discussed for groupware; and (iii) exploitation and reuse of collaborative traces, e.g. collaborative traces based SWOT Analysis for group to support future decisions and planning. Indeed, in CWE, the members' or group's actions or interactions are mainly taken in the group shared/collaborative workspace. Therefore, the Collaborative Traces are crucially important and should be studied and analyzed.

In this chapter, principally, we propose a definition of **Collaborative Trace** (Li 2012b) and introduce a general model that is based on this definition and a group model (Li 2012b, Li 2012a). The following part is structured as follows: In Section 4.2, starting from the analysis of traces (traces of interactions) in the group shared workspace, two formal definitions of trace in CWE will be compared in detail. Grounded on one chosen trace formal definition, our proposed term **Collaborative Trace** will be introduced and defined with practical example. Then we classify the existing various traces in CWE: Private Trace, Collaborative Trace, Collective Trace and Personal Trace. Beginning with a practical example, Section 4.3 presents our model of collaborative trace with a series of basic notations. In order to make up for the deficiencies of the Elementary Filters, we propose a Complex Filter for CTs retrieval in the last Section 4.4.

4.2   Collaboration and Traces

As we discussed above, basically, *"collaboration"* is the action of working jointly with someone to produce something[2]. The development and progress of human society cannot maintain and advance without "collaboration". Especially, the evaluation of tool imperceptibly affects and changes our behaviors and habits of collaborating as we explained in Chapter 2. Decades ago, with the popularity of computer and invention of Internet, mankind collaborative work is totally liberated from the limitation of time, language, geographical position, etc. Naturally, the interactions between man and machine, or more commonly human computer interactions becomes more and more important since our work (not only the collaboration activities but also personal task) has become increasingly inseparable from the support of computer and Internet, e.g. the information exchanging and sharing, the communication and so on. The user's any actions in the digital environment could leave numerous traces that could be reused to support group collaboration in different aspects.

4.2.1   Traces in CWE

As we know, a web-based collaborative platform is always available and stable in distinct operation systems and devices, for example: Windows or Linux, laptop or tablet. Undoubtedly, it can be used as an ideal object to support both personal and collaborative work in a variety of devices.For CWE, almost all of the collaborative interactions are taken in the group shared/collaborative workspace. In the early research period, a shared workspace is defined as "a form of an electronic white-board" that could assist users in drawing or writing (Whittaker 1993). As the most important component of CWE, the group members' collaborative activities are made and taken according to the practical work requirements in the collaborative workspace. Normally, this involves several subsystems of Groupware: communication system(e.g. information sharing and exchanging), coordination system(modeling the interactions between collaborators, the group workflow) and conferencing system (e.g. real-time conferencing, or computer teleconferencing). Besides, knowledge management (e.g. document management, group wikis and task management) and social intercourse models (e.g. the forum and public wall) are lately discussed and designed within the framework of CWE (Martínez-Carreras 2007).

Obviously, in the shared workspace, there exists various kinds of interactions based on the group formation. Normally, it relies on the study of group structure that comes from the analysis and modeling of virtual community (Rheingold 2000) in Internet. Vassileva and Mao analyze and explain the characteristics of virtual communities in their article (Mao 2007). The issue of group modeling is an interesting topic in CWE and CSCW

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[2]Retrieved from Oxford Dictionaries Online, 2012, http://oxforddictionaries.com

research (Joosten 1993, Vennix 1996). In our Collaborative Trace model, we concentrate on the modeling of small groups (between 2 to 30 members) as proposed by Andersen et al. (Andersena 1997), James (James 1951) and Dholakia et al. (Dholakia 2004). Definitely, the amount of group members influences the communication and the potential collaborations among group members. Lack of frequent interactions would hinder the trust and creativity.

In order to completely understand how the "collaboration" process generates (e.g. who collaborates with whom and the result) and affects the group members (e.g. the relationships or the interactions in the groups), it is necessary to analysis all kinds of past or finished interactions in the group shared/collaborative workspace. In consideration of the principal characteristics of collaborative working environment, especially, a web-based CWE, a trace not just records the interactions between user and system but also reflects the potential relationships between collaborators. From this point, we distinguished different types of traces and focused on the definition of a "Collaborative Trace (CT)" (Li 2012b). It is based on the explication and clarification of the concept of trace. The following section introduces the definition of Collaborative Trace and analyses various kinds of traces with some basic notations in CWE.

4.2.2 Collaborative Trace

Consider the means of collaboration and the correlation of group and individual, naturally, a **Collaborative Trace** (CT) that is based on the definition of "*trace*" or "*trace of interaction*", it can be defined as follows: "**A Collaborative Trace is a set of traces that are produced by a user belonging to a group and is aimed at that group**" (Li 2012b).

Two points about this definition need to be clarified: (i) "*a user belonging to a group*"; (ii) "*a set of traces*";

A user belonging to a group means the traces in a group strongly rely on the group structure. Once the collaboration relation changes, the group member's collaborative traces are rebuilt. It concerns the theory of groupware model (or team modeling) which is a complex issue in CWE theory, and may involve the group size, the framework of the group, and many other features. More details can be found in the work of Sartori (Sartori 2006), Levi (Levi 2010), Forsyth (Forsyth 2009) or Pankiewicz (Pankiewicz 2010). Our particular interest here is to answer the question: "how to define these collaborative traces?" Two types of trace formation are proposed with piratical examples in the following part. Besides, necessary comparisons between the two forms of trace are carefully explained.

Trace order signifies that the analyzed traces have an order, for instance: a temporal

series or an importance series. In general, users' activities are saved and organized according to a time line. Although the "time sequence" is the most common choice, we could use other standards like geographical position, importance level, or urgency level to define this sequence. Thus, some kind of filtering is needed to classify the traces for a specific usage. For example, in a group, we may want to see which document has been most used by whom in a given time interval.

Before explaining the formal definition of trace in CWE, a simple example is introduced at first. Suppose that in an established CWE, some engineers collaborate within a project. John finds a crucial problem that may be helpful for all the group members. So, first of all, he sends a mail to the group (every member in this group), then creates a new entry on this issue in group's wikis (every group member can edit and refine it) and his private wikis, and finally shares his solution (a pdf document) in the group workspace. In the meantime, Tom and Peter, whose views are similar but different from John's on this problem, both request a video conference with John in the reply email. John receives the emails and agrees on a video conference with Tom and Peter. At last, they obtain a satisfactory answer for this problem in the subgroup meeting and the group wiki is enriched by the new entry.

From the example and the discussed definitions of trace, we can state that a trace is composed of three basic items:

1. "Emitters" who leave the trace (the subject);

2. "Receivers" who receive the trace or the object of the trace;

3. "A property and a corresponding value", i.e. an original trace can generally be considered as a set of information having several properties. For each property, there exists a corresponding value.

With these three factors, for the i'th user in CWE, a trace can be defined as:

$$trace_i^k = < \text{Emitter}, \text{Receiver}, < \text{Property}, \text{Value} >, k \in N^+$$

Moreover, the strict definitions of "Emitters" and "Receivers" depend on the group structure. Consequently, recall the previous example and from the collaborative interactions between different "Emitter" and "Receiver", we can define

```
<John, the group, <message, 'content'> >
```

or

```
<Tom , John, <message, 'content'> >
```

or

```
<John, the group, <document_type, 'pdf'> >
```

as collaborative traces.

The three factors above that depend on the macroscopical consideration and precise reconstruction of "collaborative relation" (i.e. who works/collaborates with whom for what goal and what is the result in the environment) are often limited to explain or characterize what an "Emitter" has done for "A property and a corresponding value". That is to say, we can hardly know the "Emitter's" actions. Starting from this point, we explained another definition/formation for trace in one of our previous article (Li 2012b). A trace of the i'th user can be defined as a vector with four attributes:

1. "Identity", the person who is the agent (does this "action");

2. "Actions", the type of action, a transfer action, personal action or group action; for example, "send a message" is a transfer action and "post a message to share it" is a group action;

3. "Content", is a description of the action and of its result. It depends on the capturing ability and could be a vector with several values, for example, image, video, text, or geographical position;

4. "Index", an identifier depending on the trace sequence. A common index is "time", in practical situations the geographical location could also be chosen.

From this sense/formation, a trace can be defined as:

$$trace_i^k = < \text{Identity}, \text{Action}, \text{Content}, \text{Index} >, k \in N^+$$

Based on this four basic factors, from our example above, some collaborative traces would be:

```
<John, Sends a message, 'content', "2011-09-02, 10:23:45">
```

or

```
<Tom , Sends a message, 'content', "Office A108">
```

or

```
<John, Shares a document, 'pdf', "2011-09-02, 15:30:52">
```

Normally, with this definition, the collaborative trace is not obvious (form) and can not directly be defined. Accordingly, a mapping from the group structure space to the trace space is proposed to find the corresponding collaborative traces (Figure 4.1).
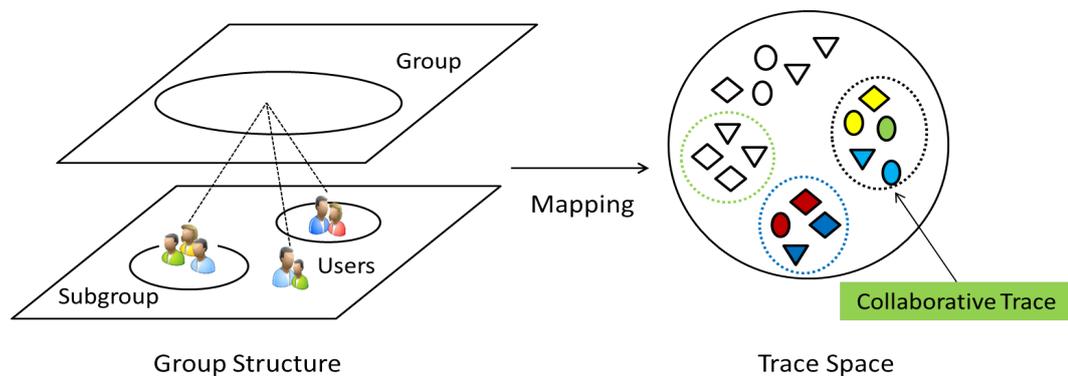
Figure 4.1: Group structure and Trace space.

The mapping reflects the group composition in the set of traces. Compared with the first definition or formation of trace ($trace =<$ Emitter, Receiver, $<$ Property, Value $>$), the second one ($trace =<$ Identity, Action, Content, Index $>$) mainly emphasizes the flow sense of "action". However, it is exacting and intricate when the group collaboration becomes more frequent (e.g. more and more random collaborative subgroups) and the trace space turns much larger (e.g. ,more interactions produce more traces that need more time/calculation to mapping). From Table 4.1, we can clearly see the advantages and differences for each definition:

In comprehensive consideration of the fundamental characteristics and the real needs of CWE, briefly, the first trace definition would be more restricted and accurate to record and reflect the collaborative interactions since any trace can not exist without the interaction with the environment. As for the collaborative interaction, the essential part is the relation of the collaborators. Based on this point, we establish a Collaborative Trace Model (CT Model) to greatly facilitate the group collaboration in CWE.

However, no matter for which formation of trace in CWE, indeed, the formal definition of trace can not be separated from the definition of group model and structure. Definitely, the amount of group members influences the communication and the potential

Trace	First Definition	Second Definition
Formation	$<$ Emitter, Receiver, $<$ Property, Value $>>$	$<$ Identity, Action, Content, Index $>$
Emphasis	**Relations** between group members	**Actions** of each member
Starting point	Group	Individual
To generate Collaborative Trace	Connections between "Emitter" and "Receiver"	Mapping from the group structure(model) to the trace space
Environment	Collaborative Working Environment	Computer Supported Cooperative Working Environment
Self-complexity	High	Low

Table 4.1: Comparison of two proposed trace in CWE.

collaborations among group members. Lack of frequent interactions would hinder the trust and creativity. In the next section, from the modeling of the group structure, we will explain every integral factor in our CT model with the basic notations.

4.3   Collaborative Trace Model

Our model is based on the CT definition that was first proposed in (Li 2012b). For the Elementary filter and the Group structure that was early introduced with basic notations in (Li 2012a). Besides, since the essential needs of CWE is facilitating collaboration, the first one ($trace = <$ Emitter, Receiver, $<$ Property, Value $>$) would be used as the formal definition of trace in this model.

4.3.1   Structure of a Group of Users

In a WCWE, users may work in groups. A user may belong to zero or more groups. Let U be the set of users: $U = \{u_i\}$. Let G be the set of groups: $G = \{g_j\}$ each **group** being defined as *a set of some users*:

$$g_j = \{u_i, u_k, ..., u_m\}$$

However a group may contain other groups and single users who do not belong to other groups (Figure 4.2), and be naturally written as

$$g_j = G_j \cup \ U_j \ where \ G_j \subset G \ and \ U_j \subset U$$

The definitions of G_j and U_j are: $G_j = \{g_l, ..., g_s\}$ and $U_j = \{u_i, ..., u_l\}$. A group, g_j, is a set of users, and a subgroup of the set of groups. One can extend the concept of group

by considering single users as belonging to a group of one person.

$$g_i^0 = \{u_i\}$$
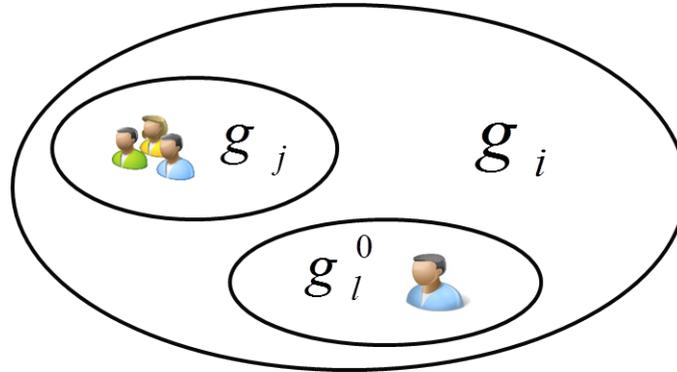
Figure 4.2: A general group structure.

4.3.2 Formalism of a Trace

A trace is the result of an action done by someone or by a set of individuals and is addressed to a group (remember that a group may be a set of one person). A trace is formally defined as:

$$t_{i,j}^k = < E_i, D_j, Q_k >$$

where $t_{i,j}^k$ is the kth trace emitted by a set of users, E_i (emitters), and sent to a set of users, D_j (receivers), and Q_k is a subset of pairs defining the set Q, each element including a property and a value.

$$Q = P \times V = \{< p_l, v_m >\}$$

P is a set of properties (attributes) and V is a set of literals (values):

$$p_l \in P \ and \ v_m \in V$$

Users included in the set E_i or D_j need not belong to groups. However, in the following we make the assumption that they do:

$$E_i, D_j \in G$$

where $E_i \neq \emptyset$ and $D_j \neq \emptyset$.

4.3.3   Classification of Traces in CWE

In CWE, a collaborative process needs at least two people to take a series of actions for a common object. Nevertheless, there exists other kinds of interaction not only among the actors (collaborative or collective activities) but also between actor and machine/system (e.g. private activities). Basically, from the formula definition of trace in CWE, we can classify the various traces into four types (Figure 4.3): Private Trace, Collaborative Trace, Collective Trace and Personal Trace.
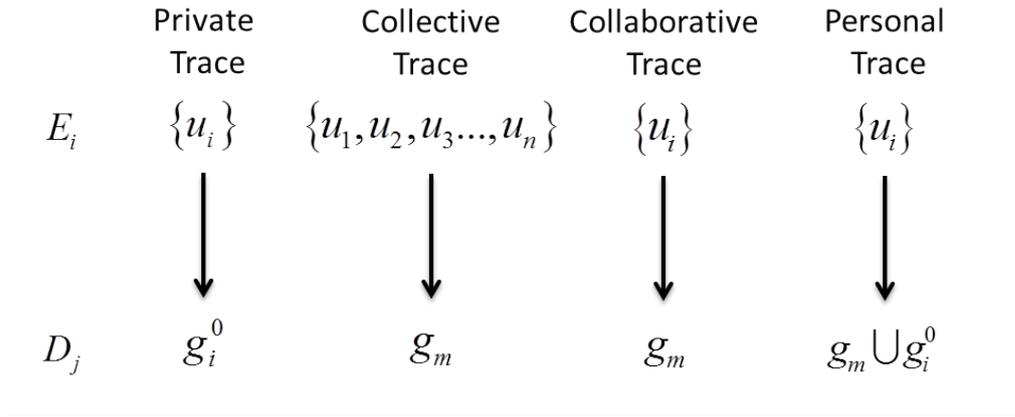
Figure 4.3: Example of different types of trace.

1. **Private Trace**

   If $E_i = D_j = g_j^0$, then the trace is the result of an action done by a user with destination this user. It is a private trace. With the consideration of privacy, additionally, we decide that a private trace will not be visible by anybody else than its owner u_j, e.g. edit private wikis.

2. **Collective Trace**

   If $|E_i| > 1$ then the trace is the result of a collective action and is defined as a collective trace, i.e. the trace emitted by a group action (e.g. every group member has voted for some candidates).

3. **Collaborative Trace**

   A collaborative trace can be regarded as a type of trace that satisfies the conditions:

   $$E_i = g_i^0 = \{u_i\}$$

   and

   $$D_j \neq g_i^0$$

   In accordance with the conditions above, indeed, this kind of trace is the result of an action that have been done by a user and addressed to another user or to a

group. In particular, we can classify different types of collaborative traces based on the relations between "Emitter" and "Receiver":

(a) The trace is produced and transferred within a group:

$$u_i \in g_k, D_j \subset g_k$$

That is to say, the emitter is belonging to the receivers group. However, considering the relation between D_j and g_k, there are two types of sub-situations:

 i. The collaborative trace is between the subgroups:

$$u_i \in g_k, D_j \subseteq g_k$$

This means that collaboration is among the subgroup. For example: a member sends a message to several group members that constitute a subgroup.

 ii. The trace is inside the whole group:

$$u_i \in g_k, D_j = g_k$$

In this case, the collaboration is inside the group. For instance: a member announces the result of voting for candidates in group (that a message is sent to all the group members).

(b) The collaborative trace is between two groups:

$$\exists g_k, u_i \notin g_k$$

and

$$D_j \subseteq g_k$$

which means that the collaboration is between two groups. From Figure 4.4, we can see the differences between them.
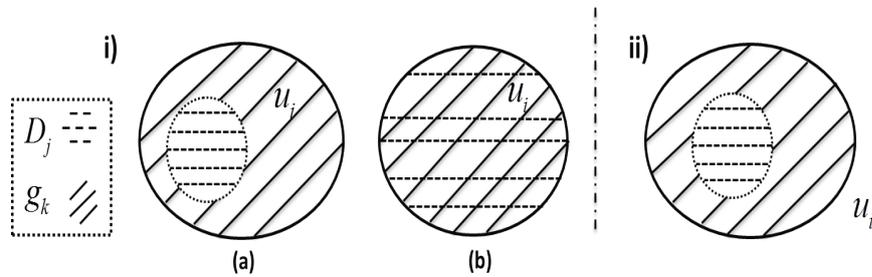
Figure 4.4: Example of two types of collaborative trace.

4. **Personal Trace**

If $|E_i| = 1$ $(E_i = g_i^0 = \{u_i\})$, the trace is produced by one of the unique member in the group and aimed at a group. From the distinct cases of "D_j(receivers)": a) $D_j = g_j^0$; b) $D_j \neq g_i^0$, we could identify the personal trace that is either a private trace (case a)) or a collaborative trace (case b)). This can effortlessly be understood since our behaviors might be cooperative (social aspect) or private (secluded/unsocial aspect) in a collaborative environment.

4.3.4 Elementary Filters

In a collaborative systems traces can be spread around at different locations. However, regardless of where they are stored, we want to define filters allowing us to retrieve a subset of traces for further processing. First we will define accessors (operators to access some part of a trace), then elementary filters. Accessors are operators allowing us to access part of a trace.

1. *Property Extractor*

   Let t be a trace, the property extractor, π, when applied to a trace returns the set of properties present in this trace:

   $$\pi(t) = \{p_i\}$$

   Thus,

   $$\pi : T \to \mathfrak{P}(P)$$

2. *Value Extractor*

   Let t be a trace, the property extractor, α, when applied to a trace and a specific property returns the value associated with this property present in this trace:

   $$\alpha(t, p_j) = v_j$$

   Thus,

   $$\alpha : T \times P \to V$$

   Note that nothing is said about what should be a value except that it is a literal. It may be a number, a symbol, a text, an image, a video, or anything else than can have a numeric representation.

3. *Emitter Extractor*

   Let t be a trace, the emitter extractor, ε, when applied to a trace returns the set

of emitters, i.e. the set of users that performed the action that led to this trace:

$$\varepsilon(t) = \{u_j\}$$

Thus,

$$\varepsilon : T \to \mathfrak{P}(U)$$

where $\mathfrak{P}(U)$ represents the power set of U. Note that for most traces the set contains a single value.

4. *Receiver Extractor*

   Let t be a trace, the receiver extractor, δ, when applied to a trace returns the set of receivers, i.e. the set of users that received the result of the action that led to this trace:

$$\delta(t) = \{g_k\}$$

   Thus,

$$\delta : T \to G$$

An elementary filter is a predicate testing the value associated with a particular property of a trace. Thus, it is associated with a specific property. There may be many elementary filters associated with a single property. An elementary filter is a predicate defined as:

$$\xi : V \times V \to B, \ where \ B = \{true, false\}$$

It is used to select a set of particular traces: $\{t \ | \xi_j^k(\alpha(t, p_j), v_m)\}$ where ξ_j^k is one of the operators associated with property p_j and v_m is a reference value. Example: We'd like to extract all traces that mention adults. We apply

$$\xi_{age}^{adult} \equiv greater(\alpha(t, age), 18)$$

1. *Personal Traces Corresponding to a Specific Property and a Preference Value*

   For property p_j and reference value v_m, it is obtained as:

$$\{t \ | \ t \in I_i \wedge \xi_j^k(\alpha(t, p_j), v_m)\}$$

2. *User Collaborative Traces Corresponding to a Specific Property in a Group*

   For user u_i, group g_l, property p_j and reference value v_m, it is obtained as:

$$\{t \ | \ t \in CT_{i,l} \wedge \xi_j^k(\alpha(t, p_j), v_m)\}$$

4.3.5 Trace Subsets

Using the operators we can define some specific subsets of traces.

1. *Private Traces*

    Private Traces are the set of traces that can only be viewed by a user:

$$PT_i = \{t \mid \{\varepsilon(t) = \{u_i\} \wedge \{\delta(t) = g_i^0\}\}$$

2. *Personal Traces*

    Personal traces are the set of traces sent by a user to himself:

$$I_i = \{t \mid \varepsilon(t) = \{u_i\}\}$$

    Personal traces are equal to the union of private traces and personal collaborative traces (Figure 4.5). Formally, we have:

$$I_i = CT_{i,j} \bigcup PT_i$$
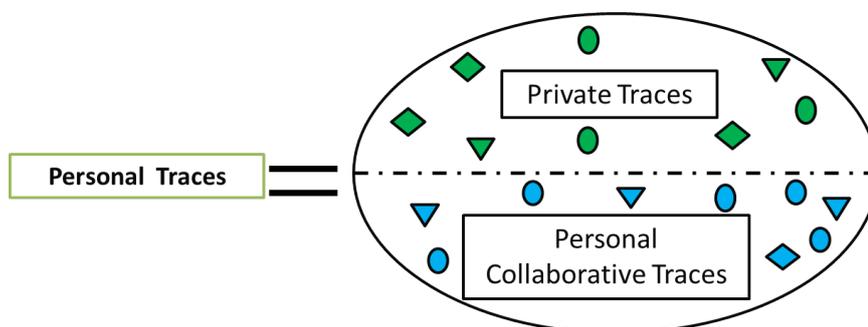
Figure 4.5: Personal Trace.

3. *Collaborative Traces*

    Collaborative traces are the set of traces received by a group:

$$TI_i = \{t \mid \delta(t) = g_i\}$$

4. *Personal Collaborative Traces*

    Personal collaborative traces are the set of traces emitted by a particular user, u_i, and received by a group, g_j:

$$CT_{i,j} = \{t \mid \{\varepsilon(t) = g_i^0\} \wedge \{\delta(t) = g_j\}\}$$

5. *Collective Collaborative Traces*

   Collective collaborative traces are the set of traces emitted by a particular group, g_i, and received by another group, g_j:

$$GT_{i,j} = \{t \mid \{\delta(t) = g_i \wedge |g_i| > 1\} \wedge \{\delta(t) = g_j\}\}$$

Concisely, a collaborative trace model is a triple structure:

$$(G, Q, \Xi)$$

where G is the set of users: $G = \{g_j\}$, that for $\forall E_i \subset G, \forall D_j \subset G$, they meet the conditions: $E_i = g_i^0 = \{u_i\}$ and $D_j \neq g_i^0$. Q is a set in which each element includes a property and a value: $Q = P \times V = \{< p_l, v_m >\}$. P is a set of properties (attributes in the environment) and V is a set of values : $p_l \in P$ and $v_m \in V$. Z is a set of elementary filters: $\Xi = \{\xi\}$. Indeed, programming can be greatly simplified using this model of collaborative trace.

In the area of trace research, our proposed CT Model is the first trace model that focuses on the issue of defining and analyzing group member's collaborative interactions and connections in Collaborative Working Environment. Beginning from modeling of group structure (foundation of collaborative relation), we suggested two formal definitions of trace to describe the user's past interactions in groups. Moreover, in consideration of the essential characteristic of collaboration is the relationship between collaborators. Therefore, the triple structure trace ($trace = <$ Emitter, Receiver, $<$ Property, Value $>>$) was preferred and consequently, every element in our CT Model was explained in detail. There also exist other formal trace definitions and models in different domains with the exception of the collaborative working environment.

4.4 Collaborative Trace Retrieval

In CWE, usually, it is effortless to extract the simple information resources that mainly concerns the collaborative interactions via the elementary filters, for example: the ith member can look up all his exchanged messages that are particularly with the jth member: $content \equiv CT_{i,j} \wedge \xi_{message}^{member_i}(\alpha(t, message), content)$. However, if we want to know more details about a collaboration process between any members or subgroups in the shared workspace, the elementary filter usually is not enough and not capable of accomplishing these complex tasks, for instance: an elementary filter can only extract a value from the corresponding property, regularly, it is deficient to answer such question: "who collaborates with whom most frequently in the group" and so on.

4.4.1 Complex Filter

Continuing the example above: (i) Naturally, the email and shared pdf document were stored in the group collaborative workspace, but have they been read by all the members in group or just by a single person? Same question for other shared resources (e.g. images, wikis, etc.): did they open and view it or not? (ii) If any one of them (e.g. John or Tom) were absent, it would affect the video conference. In other words: does this subgroup have other substituted member or expert who has the same competence on this problem? (iii) In fact, John, Tom and Peter work together as a subgroup. Did other members in the group accept their proposed solutions/answers for this problem? Are the new added resources (e.g. the wiki entry or documents) in the group collaborative workspace really helpful for their project? In CWE, such questions are common but difficult to answer. They are directly relevant to the issue of CT retrieval.

As we explained in Section 4.2.2, collaborative traces record past interactive activities in a group shared workspace and can be used as tools to enhance an application, to generate adaptive scenarios and to assist members in their collaborative tasks. In general, the collaborative activities produce more information and knowledge than personal states. Therefore it may create a large number of CTs in the group space. Elementary filters are limited, when screening and analyzing a large amount of CTs against actual demands. A **Complex Filter** is thus proposed and designed to help addressing this issue. It is defined as **a logical combination of elements** of Ξ (Ξ is the set of elementary filters, $\Xi = \{\xi\}$).

Thus,

$$\zeta : T \times \Xi \times P \times V \to B$$

An example of group collaborative trace would be

$$\{t \mid t \in CT_{i,l} \wedge \xi_j^k(\alpha(t, p_j), v_l) \wedge ... \wedge \xi_m^n(\alpha(t, p_m), v_s)\}$$

This allows selecting for example traces emitted by a user, mentioning the concept of "culture", or traces sent to a particular group during a specific week, or traces of messages sent by a specific user to a specific group, etc.

As trace can represent the user's experiences (see Laflaquière et al. (Laflaquière 2006)) when they mediated with the system. In this sense, "experience" signifies "a special case or a refined form of knowledge in a higher level" (refer to Sun and Finnie (Sun 2005), and Schneider (Schneider 2009)). Thus, the retrieval of collaborative traces is a kind of experience retrieval (as a type of specific knowledge retrieval, refer to Baeza-Yates et al. (Baeza-Yates 1999)) and focus on the collaboration relation and group knowledge exploitation in comparison with the traditional information retrieval(e.g. inference or representation methods), for instance: Traces Based Reasoning (Mille 2006a) and so

on. Moreover, in practice, the retrieval process can server various group collaboration requirements in different situations, e.g. project planning or decision making.

4.4.2   Basic Extraction Scenarios

In some definite situations, the complex filter would be more needed than the elementary filter to provide better information services via the retrieval techniques (e.g. querying, scanning or clustering). Four primary scenarios are explained as follows:

- *Effective Traces Retrieval*

  In this case, the complex filter combines several elementary filters that can be considered as an effective retrieval method to facilitate the practical techniques implementation, e.g. Natural Language Processing or Neural Networks. On the basis of the measures of effectiveness that have been proposed in the domains of Information Retrieval (Manning 2008) and Knowledge Retrieval (Omoigui 2002), correspondingly, some approaches can be extended and applied to improve the "precision and recall" measures for traces, for example: with an "adjusted" complex filter, it is more effective to find out what we have done in a certain period, what decisions have been made and so on.

- *Complex Task Representations*

  In a CWE, a complex task means a teamwork or collaborative work that needs at least two members work together in the group shared workspace. Multimedia indexing (e.g. images, videos and sound databases), text retrieval and document classification certainly involve in this process. Moreover, the accomplished or current ongoing collaborative tasks can be described by the complex filter in two levels: (i) the collaboration relationships, for instance: who works with whom in the group; (ii) the progress or the status of the concerned task, for example: their decisions and results. The outputs of the complex filter can be displayed in various forms, for example: figures, tables, lines and so on.

- *Integrated Solutions*

  A traditional text retrieval system is probably a tool that can be used to solve part of an organization's information management problems. Often, they could make a comprehensive decision that depends on more information. Although information consists of facts and data organized to describe a particular situation or condition, we still need experience (as a specific kind of knowledge) to get a solution, e.g. make a decision or a plan. Collaborative Traces could record our historical cooperative activities and represent them as a kind of knowledge that consists of the past facts, relations, perspectives and concepts, judgments and expectations, methodologies

and know-how.   With the pre-defined complex filter, we could extract a set of collaborative traces that interpret the information about the situation and the knowledge about the previous in order to support generate a convinced solution.

- *Efficient, Flexible Indexing and Classifying*

    Many different features of a system can have an impact on the process of information extracting (indexing and classifying), normally, such as query response time and indexing speed that are frequently involved in the text-based systems. For a typical CWE, the group structure and members' relationships could be characterized by the complex filters. Additionally, once the quantity of group members is increased, the frequency and efficiency of the retrieval result is directly affected. The other aspect of indexing that is considered very important is the capability of handling a wide variety of document formats. Every value for the matching property can be completely identified in the piratical applications. Since a modern CWE deeply relies on the web-based condition, the distributed collaborative traces could be gathered and analyzed without the normal limitations, e.g. the time of access or the solid connection positions.

The above four basic scenarios are not independent but own the potential relations. As a matter of fact, the formal definition of CTs complex filter brings us a general way/approach to extract the CTs according to the group needs. Besides, the output of complex filter is one of the elementary resources for the CTs exploitation process.

4.5   Conclusion

This chapter examines what is required to study traces in the context of a collaborative working environment (CWE). The objective is to propose a definition of the different kinds of traces and to build a model for classifying and analyzing the interactions with respect to both individual needs and group needs. In a CWE, the different types of traces can be divided into four categories: Private Trace, Collaborative Trace, Collective Trace and Personal Trace. The past collaborative activities in the group shared/collaborative workspace could be recorded and represented by collaborative traces.

Beginning from the Collaborative Trace definition, a collaborative trace model have been proposed and discussed in the context of CWE in Section 4.3. The concept of collaborative trace was introduced to meet several issues in CWE, which can be summarized in three key points: (i) Classify and organize users' interactions a posteriori to understand the use of the CWE; (ii) share working experiences: the collaborative trace, which can assist both personal and group work; (iii) support the design of CWE - the different aspects of group modeling and user experience.   Additionally, to support analyze the

synchronous and asynchronous interactions in CWE, a set of elementary filter was proposed with practical examples. The filter keeps the information that we gather from the observing process of the collaborative trace. However, in CWE it is effortless to extract the simple information resources that mainly concerns the collaborative interactions via the elementary filters. Therefore, we constructed a series of Complex Filter to make up the shortages of the Elementary Filter in the Section 4.4. As one of the most important resources, the outputs of complex filter could serve the CTs Exploitation process that will be detailed in the next Chapter.

Our Framework of Collaborative Traces Exploitation

Contents

5.1 Introduction

In a Collaborative Working Environment, people's activities are principally concentrated in the group shared workspace, for instance: users can exchange messages, edit wikis, share documents, or participate in video conferences. Any collaborative interactions could leave a series of collaborative traces. Since the essential demand of CWE is to support collaboration, the research on collaborative trace is crucial and imperative. In order to help further studies, we established a Collaborative Trace model (CT model) (Li 2012a, Li 2012c). Concisely, a CT model is defined as a triple structure: (G, Q, Ξ), where G is the set of users, Q is a set in which each element includes a property and a value, Ξ represents a set of elementary filters: $\Xi = \{\xi\}$. In fact, elementary filters are limited to exploit traces, and complex filters are thus proposed and defined as "a logical combination of elementary filters" (Li 2012c). When applied in CWE, a complex filter can naturally serve the group needs in different processes, for instance: information sharing, trace exploitation, or collaborative project planning.

Based on our proposed concept Collaborative Trace and the corresponding Model in Chapter 4, this Chapter addresses the issue related to exploit and reuse the collaborative traces in consideration of supporting the group collaboration work in different aspects. In this case, obviously, some complex filters are required to extract more potential information both from the trace set and the data base. The process of exploiting traces[1] can be divided into two levels in CWE: (i) According to the application formalism (e.g. SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis, CMMI (Capability Maturity Model Integration), Group Recommendation and so on), ontologies of formalism, the collaborative goal and domain knowledge ontologies, we extract the required information from the set of traces and the data base by some complex filters. The retrieved information can be considered as a series of Information Elements (IEs) that naturally are represented in various forms, for example: figures, texts or videos; (ii) Applying another kind of complex filters that depend on the application formalism to format the IEs into the final result, for instance: SWOT Matrix or CMMI Tables. The two stages are not independent but connected by the complex filters and the IEs flow. The whole procedure is defined as our proposed trace exploiting framework in CWE. Particularly, our approach can be greatly advantageous when the collaborative application that needs more information from their finished collaborations. Consider the structured planning tools, such as SWOT (Strengths, Weakness, Opportunities and Threats) Analysis, it would be an ideal case to implement our framework. There are also other possible collaborative approaches that could use our framework: CMMI, Group Recommendation and so on.

In this Chapter, we focus on the following issue: construct a general framework for trace exploitation and implement it with SWOT Analysis, CMMI and Group Recommendation applications to facilitate group collaboration and information retrieval. This chapter is structured as follows: starting from analyzing the principal characteristics of collaborative activities in CEW, we will introduce several typical exploitation scenarios and our framework of CTs exploitation in the Section 5.2. In the Section 5.3, we will separately present three collaborative approaches (SWOT Analysis, CMMI and Group Recommendation Systems) that are based on our CT model and exploitation framework.

5.2   Exploitation of Collaborative Traces

In the Chapter above, we concluded that a trace can be defined as a triple structure to classify and analyze all kinds of user interactions in CWE. Furthermore, in order to assist both individual and group work, it is necessary to consider how to exploit the stored traces according to users' factual needs. Before explaining our framework of collaborative

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[1]Conforming to our formal definition of trace in CWE, Collaborative Trace is a subset of Trace. Thus, we use the term trace instead of collaborative trace in some particular contexts for a general sense.

traces exploitation, a short example is introduced at first: Suppose that, in a typical CWE, some engineers are collaborating for a project in the different cities around the world. Julien (in Paris), one of them, sends a mail to his colleagues Wang (in Hong Kong) and Peter (in New York) about a technical problem. At the same time, he edits his personal wiki concerning this issue and shares some related documents about this issue in the group collaborative space. Wang finds that the question is very meaningful and crucial for designing their product. So he proposes to hold a video conference to discuss the possible answers/solutions to the questions, by sending a mail, then he posts a message to the group. Furthermore, he adds an entry in the group wiki so that every group member can edit and refine it. Peter carefully reads these shared documents and comments on some paragraphs in the group collaborative space so that each member can see his notes. Finally Julien, Wang and Peter obtain a satisfactory answer and the resources in the group collaborative space are increased: e.g. the new entry of group wiki and the shared documents. This is a very common collaboration scenario in CWE.

With consideration of their recorded collaborative activities, naturally, we have some relevant questions: (i) Usually, the email/message that is sent to the group (by Julien) is stored in the group shared workspace, but has it been read by all the members in group or just by a single person? Same question for the shared pdf document: did they open and view it or not? (ii) If Wang or Peter were absent, it would affect the results of the video conference with Julien? In other words: do Wang and Peter have the same competence on this problem and any one of them could be substituted for the other? (iii) Actually, Julien, Wang and Peter collaborate together and can be regarded as a subgroup. Were the others in the group satisfied by their answers to the problem? Is the new added entry in the group wikis really helpful for their project in the future? Collaboration usually is a complex process, therefore such questions are very common in CWE but difficult to answer. Since their past interactions could be recorded and modeled by the different kinds of traces, these questions are directly relevant to the issue of CTs exploitation (based on the extracted CTs) in CWE. This issue relates to the domains of Experience Management (from the inner connections between Trace and Experience) and Traces Based Reasoning (from the system design and practical application needs). In the following sections, we will separately explain the two aspects.

Since CT can record and represent the collaborative experience, the CTs Exploitation is an important issue concerning experience sharing and reusing in Experience Management (EM) theory (refer to (Bergmann 2002), (Basili 1994) and (Tautz 2001)). As a speical kind of Knowledge Management, Experience management deals with collecting, modeling, storing, exploiting and implementing experience, i.e., specific knowledge from the problem solving process (Bergmann 2002). Normally, *experience* can be regarded as a type of "previous knowledge or skill one obtained in everyday life" (Sun 2004), e.g. experience of hiking. As a result, experience is always situated in a certain, very specific problem solving context, for example: an expert has more considerable experience

in a specific filed than an ordinary worker. There are many kinds of experience[2] re-
lated to different aspects in our life, for instance: physical experience from the object or
environment changes or social experience via the interactions with other people.

As a kind of wisdom (Bellinger 2004), experience often depends on the knowledge
from a specific domain. The term "Knowledge" owns many definitions and has been
characterized in various domains, such as philosophy (e.g. by Plato, Aristotle, Au-
gustine, Descartes, Russel, Popper and etc.)[3] (Zalta 2006), economy (Bellinger 2004,
Burton-Jones 2011), cognitive psychology (Newell 1981, Abecker 1998), management
(Alavi 2001, Holsapple 2000), computer science (Aamodt 1995, Feigenbaum 1980) and
etc. More precisely, for the knowledge based system, the knowledge management process
by computers is completely based on the data and information proceeding. Therefore,
the term *knowledge* should be distinguished from the concept *information* and *data*.
As we explained in Chapter 4, we don't want to enter the debate about information,
knowledge and experience since it is not the main issue in this Chapter.

However, before we explain our CTs Exploitation Framework, at least, it is required a
brief comparison of the related terms in the point of view of Experience Management. We
conform the clarification work that has been presented by Bergmann (Bergmann 2002).
Data is a set of "syntactic entities", e.g. unstructured events or facts that can be stored
by computers. **Information** is "interpreted data", e.g. contextualized, categorized or
calculated data. This means the data with relevance and purpose (Bali 2009). **Knowl-
edge** is a collection of related information from a deterministic process (Bellinger 2004).
As a set of information with pragmatics, knowledge can be interpreted into a con-
text via a given goal or a certain task (Bergmann 2002). Besides, some agents can
act and reuse the knowledge for the reasoning process. Concisely, the relations be-
tween data, information and knowledge are clearly concluded in the knowledge pyramid
(Figure 5.1) (Bergmann 2002, Wolf 1999) (this pyramid is different from the classical
knowledge pyramid which explains the relations between Data, Information, Knowl-
edge and Wisdom (DIKW Model) in a general sense of Knowledge Management Theory
(Ackoff 1989, Wallace 2007)). This architecture is from the point of view of "Reasoning".
In this sense, **Experience** is considered as "stored specific knowledge" that was obtained
by an agent from "a previous problem solving process" (Bergmann 2002).

Traces, as records of past activities are useful to capture the context of a problem solving
experience. It can be considered as a variable or a tool to measure the user's experi-
ence for the past interactions. These experiences or traces of interactions are the only
indirect "records" of implicit knowledge emerging during concrete action in the computer-
based environment (Mille 2005). Reasoning is the act or process of consistent recall of
previous knowledge (implicit and explicit) to draw some conclusions for a certain goal

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[2]Experience in Wikipedia, http://en.wikipedia.org/wiki/Experience
[3]The Standford Encyclopedia of Philosophy, http://plato.stanford.edu/
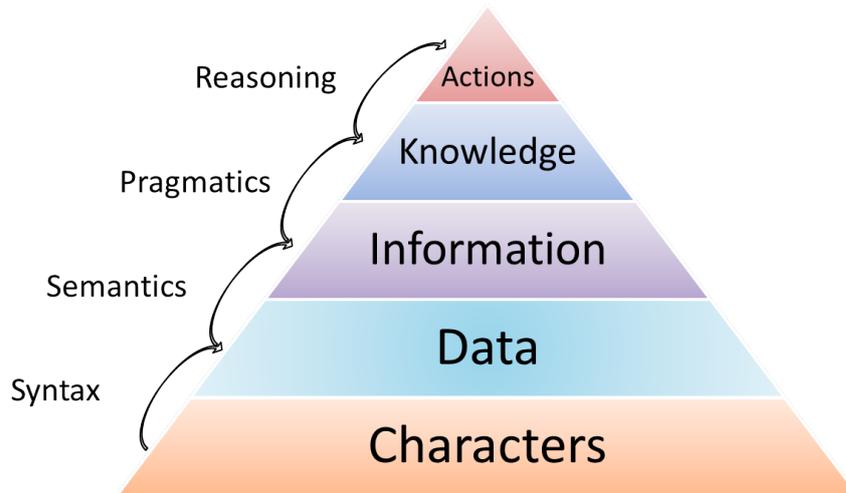
Figure 5.1: Knowledge Pyramid (adapted from (Wolf 1999)).

(Kaufmann 2000). Particularly, for the process of Case-Based Reasoning (CBR), i.e., solving new problems based on the solutions of similar past problems (Aamodt 1994), generally, it greatly relies on the stored knowledge and "a case" is the description of a previous problem solving episode (Mille 2006a), e.g. a computer repairman who fixes a display card by recalling another computer mainboard that exhibited similar features is using case-based reasoning.

CBR systems (e.g. SMART (Acorn 1992), CLAVIER (Hinkle 1994) and so on) exploiting the temporal dimension of cases are often deficient, e.g. case descriptions are not compulsorily connected with time series, besides, a problem solving case is usually regarded as an independent episode of its different contexts (Mille 2006a). As a kind of generalization of CBR principles, Traces Based Reasoning (TBR) was first introduced by Mille almost in a decade ago (Mille 2005). In the TBR process, traces offer the possibility to form new case structures and to extend the context of corresponding cases (Cordier 2009). TBR is a very meaningful and valuable example of exploiting traces as a kind of experiences from the users' finished interactions in the process of problem solving. It provides a general idea or a basic framework for traces reusing and exploitation in other applications/processes, e.g. traces based SWOT Analysis. The classical CBR cycle (Retrieve, Reuse, Revise and Retain) (Aamodt 1994) covers parts of TBR cycle. Additionally, the TBR cycle dynamically elaborates episodes which could be potentially helpful in available traces according to some task indexes (Mille 2005). In practical system design, the exploitation of traces follows the TBS basic structure. Based on the TBR cycle and EM theory, for the issue of CTs exploitation in CWE, we pay more attention to the practical system design/framework and the possible CTs based applications.

As we introduced in the Chapter 3, the TBS architecture is mainly composed by three parts: Collection (record and store the primary traces by some sensors); Transformation
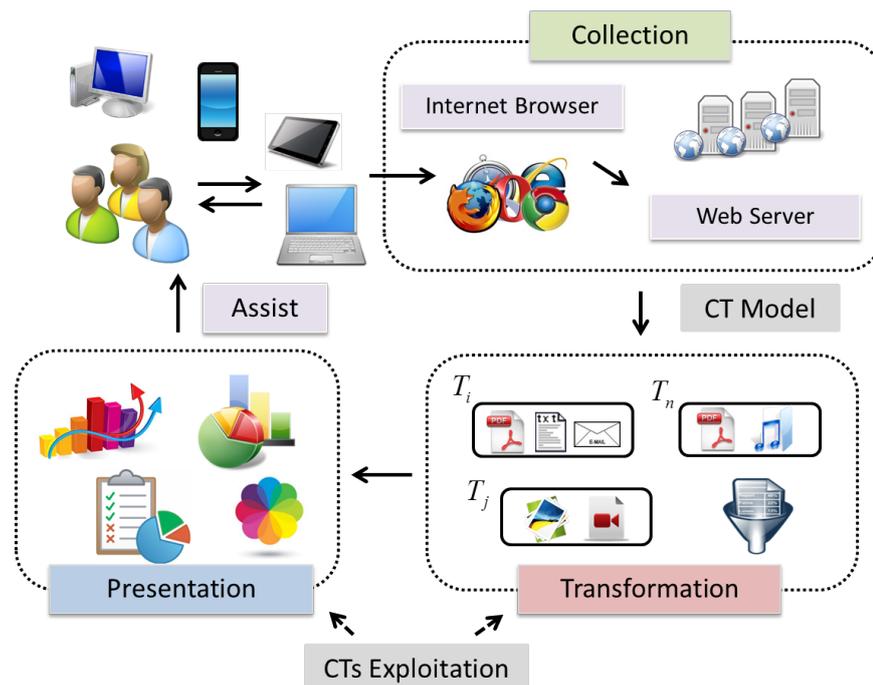
Figure 5.2: A general TBS framework in CWE.

(model, classify and filter the traces); Presentation (present and show the traces in a understandable way). In a web-based CWE, the main data consists of text documents, hypertext documents, linked structures, server logs, browser logs and so on. The level of capture determines the diversity of the values. Collecting can be done on-line or off-line. Besides, the programming language and the practical collaboration needs (e.g. the number of users, the hardware support, etc.) directly affect the efficiency and accuracy.

Indeed, this core framework can be applied in other systems or platforms in order to model and exploit the user's traces. For a typical web-based CWE, the exploitation of collaborative traces is principally focused on the transformation and the presentation process, as shown in Figure 5.2. Since for CWE, more features and functions of the CTs exploitation process are only performed for collaboration that greatly depend up on the framework of TBS.

5.2.1   Principal Characteristics

Although experience has some inner connections with knowledge (e.g. as "a specialization of knowledge" (Sun 2005)), in some particular situations, we are much more dependent on our experiences, e.g. make a decision or solve a new/complex problem. On the basis of our shared experiences in the group, certainly, we can work more efficiently and dynamically.

In CWE, similar to other complex scenarios, e.g. electronic commerce, diagnosis of complex technical equipment or electronics design, any collaborative activity has the following characteristics:

- *Knowledge intensive*

  Collaborative knowledge, e.g., about group project (e.g., project description and budgeting, task management, human resources, re-set target), group member (e.g., background, competence, character, etc.) and group management (e.g., leadership and hierarchical relationships) directly influences every phrase and is enriched with group needs. However, it is not easy to measure and model;

- *Vague collaboration description*

  The goal of group collaboration are often vague, incompletely specified or even fickle. To clarify the problem and the objective, regular meetings are recommended for all the group members. Moreover, group chat room, whiteboard and project management tool can also assist group member clearly delineating the task and goal. The "web-based" feature can greatly support the group in dynamically adjusting and adapting their collaborative plans;

- *Large collaboration/solution space*

  The more possible collaborations and solutions there are, the larger the space would be in CWE and a single collaboration or solution is not enough for a complex project. Normally, these solutions depend on the quantity of tasks and involved people. Some potential solutions not only depends on the group's experiences but also the group creativity techniques, such as brainstorming;

- *Group size*

  Different kinds of people (e.g., engineers, experts or manager) are needed in every process of problem solving and act in a collaborative task. However, for the this issue, most of the research works examine small size (Steiner 1972) and (Ellis 1991). A great challenge for CWE is the large size of collaborative groups;

- *Highly dynamic*

  The rapid change and development of technology has a great effect on the renewal of knowledge, the people involved, the potential collaboration, the working style and so on. Smart devices, such as glasses or watch, will abundantly change our traditional life style. However, all the advanced devices increasingly rely on the "web-based" condition.

In view of the characteristics of CWE and the definition of CT, briefly, the features of CTs Reuse and Exploitation can be summarized as follows:

- *Collaborative relations and connections concentrated*

  As a class of computer supported collaborative systems, CWE provides a web-based collaborative workspace and various group collaborative tools for a group of users to "communicate, coordinate and collaborate to accomplish a shared objective" (Fontaine 2004). This feature concerns the beginning point of CWE, i.e., facilitate collaboration for the group in a virtual environment. From the natural social structure classification[4], apparently, collaboration is a strong/close relationship between participants, i.e., the relationships relies on the common object. Therefore, the past collaborative activities can be described as a series of CTs that reflect the users' relationships, e.g. who works with whom (Emitter and Receiver connections).

- *Group oriented*

  Groups are indeed composed of individuals, but that a group forms implies a connection, at some level, among group members. The connections implies the structure and formation of group through the collaboration process. The "group oriented" or "group orientation", more generally, refers to the "collectivism[5]" that emphasize the interdependence of every member in the group. Normally, CWE is designed and built for supporting both the individual and group work but the personal usage is within the group scope. That's to say, the functionalities and services are primarily provided for the group (e.g. group communication or co-ordination) and then the private user (e.g. private workspace). Therefore, CTs exploitation also is group oriented.

- *Cross-platform and devices*

  The main advantage of "web-based" feature for CWE is that users can work in different operating systems with distinct devices, which means that users can switch from one platform or one device to the other without converting their data to a new format. e.g. sending an email by a tablet (android) or by a smart phone (ios), sharing a document by a laptop (Linux) or by a tablet (Windows). The interface of CWE may be different in distinct devices/platforms but the basic functions must be similar and user-friendly. The user's CTs are collected from multi platforms, then exploited to assist the user's work in these platforms. Besides, the user's traces will be synchronized and updated once logged in. The different types of browser will affect the CTs exploitation process since the compatibility for some web program languages are different, e.g. some features of CSS3 or HTML5 are partially supported by different browsers [6].

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[4]Social Structure: http://en.wikipedia.org/wiki/Social_structure
[5]Collectivism: http://en.wikipedia.org/wiki/Collectivism
[6]In April 2013, CSS3 and HTML5 support situations: http://fmbip.com/litmus

5.2.2   Typical Exploitation Scenarios

Like the sketched situations above, a complex project is heavily based on collaborative experience. Collaborative traces sharing and reuse enable helping individuals and groups to avoid making same mistakes over again. To understand the process of exploiting collaborative traces, four basic scenarios are introduced as follows:

- *Review and evaluate the group members' past collaborative interactions* with parallel consequences in a chronological order or a particular index. That is to say, the simplest and most direct way to reuse Collaborative Traces is to examine "who collaborated with whom for which issue and the equivalent results," for example: the preference and usage status of shared documents in group collaborative workspace or the exchanges of messages (reflecting the tightness of collaborative relationship).

- *Assist group future collaboration work*: in this case, from the analysis of group members' collaborative traces, we could identify their contributions to the project or more precisely, the level of collaborative participation. As a "guide" or "reference" for future work, the filtered CTs can be considered as a tool or an assistant for project planning or decision to avoid making the same mistakes as before, for instance: SWOT Analysis based on CTs.

- *Enrich group experiences*: in this circumstance, the objective of exploitation is mostly to discover the potential collaboration relationships and knowledge in a group, for example: with the strategies and techniques of social and group recommendation, we could develop a recommendation engine based on CTs to reinforce the group knowledge base. Somehow, it can automatically provide a possible solution for the group collaboration demands (e.g. information and experts).

- *Adjust the current collaboration strategies*: this scenario can be subdivided into two cases: (i) the measurement of project advancement and the evaluation of collaboration efficiency, for example: we can check that subtasks are finished in time or have some delays; (ii) the reconstruction of group collaboration relationships, for instance: the personnel adjustment. Since collaboration is obliquely influenced by the participants' personal characteristics and work pattern/habit, the adjustment of collaboration strategies could increase work efficiency.

- *Contribute to Awareness*: This scenario requires various awareness information in the group shared workspace, e.g., group, workspace or contextual awareness. Thanks to some defined filters for CTs, we can present the results in various form, e.g., figures or tables, which can contribute to improve awareness. The difference with the previous points is that awareness has a more real-time flavor. In this scenario, compared to other awareness tools, such as: Portholes tools (Lee 2002),

Tickertape tools ([Fitzpatrick 1998](#)), our approach pays more attentions to the collaborative relation, i.e., the interactions or connections among group members.

5.2.3   Our Framework of CTs Exploitation

Apparently, Collaborative Trace is a particular type of Trace, recall the formal definition of Trace ($trace = <$ Emitter, Receiver, $<$ Property, Value $>$):

$$t_{i,j}^k = < E_i, D_j, Q_k >$$

where $t_{i,j}^k$ is the kth trace emitted by a set of users, E_i (emitters), and sent to a set of users, D_j (receivers), and Q_k is a subset of pairs defining the set Q, each element including a property and a value: $Q = P \times V = \{< p_l, v_m >\}$

Therefore, collaborative traces based exploitation can be considered as a sub case of traces based exploitation process since the conditions:

$$E_i = g_i^0 = \{u_i\}$$

and

$$D_j \neq g_i^0$$

that can identify a subset of Traces with the Collaborative Traces. As we explained in the previous section, the complex filter ($\{\zeta\}$) let us acquire a specific subset of traces that can be considered as a subset of Information Elements (IEs). The IEs from CTs record the real scope and extent of collaboration in CWE. From Figure [5.3](#), we can see a general framework of trace based exploitation process.

The resources come from two parts in CWE: the Data Base and the users' Traces. With the object (e.g. design of an artifact or analyze the market) and the corresponding domain ontologies, we can define a set of complex filters that rely on the domain rules to retrieve some special information from the Trace and Data Base. In the lower part, there is the Formalism of the exploitation (e.g. SWOT Analysis, CMMI or Group Recommendation Systems) and its ontologies. Via the formalism and the ontologies, we can also define some complex filters that depend on the formalism rules. Then, applying these defined complex filters, it is facile to extract a definite set of information that can be regarded as a series of Information Elements (IEs) in CWE. At last, we can present these filtered traces in various forms: e.g. figures, tables, audios and so on. In the meantime, these IEs will be given in the form using the formating rules from the formalism, e.g. for SWOT Analysis formalism, the result would be a SWOT Matrix.

The core part of this framework consists two sets of rules for constructing the complex filters (i.e., "Extracting Domain Rules" and "Extracting Formalism Rules") that separately
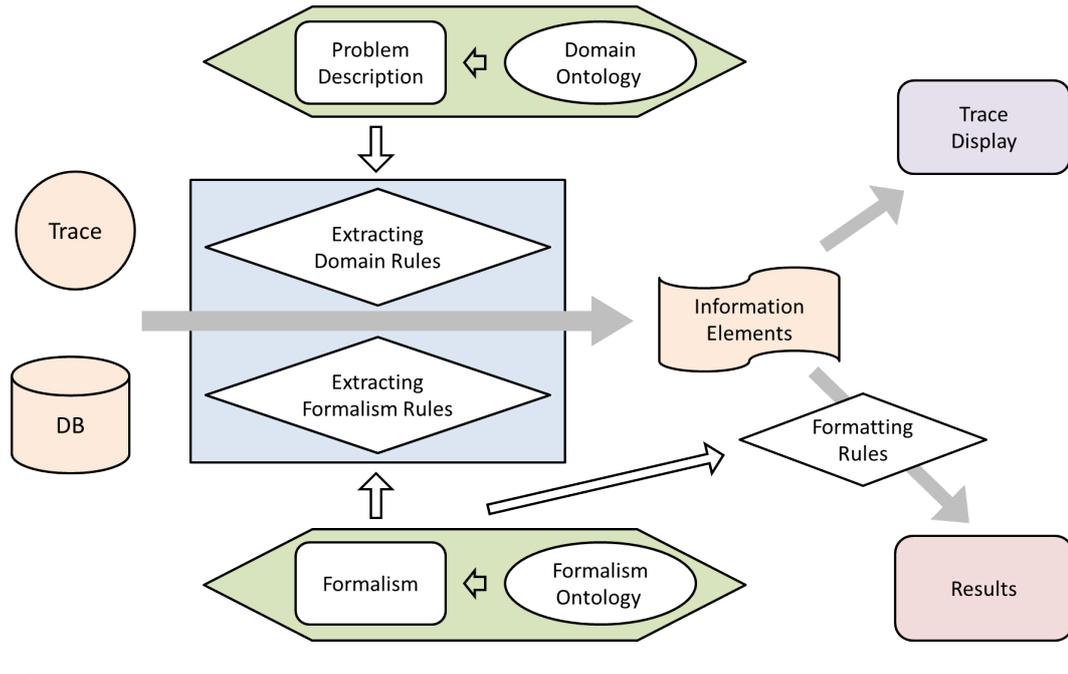
Figure 5.3: A General Traces Exploitation Framework in CWE.

come from "Problem Description" and "Formalism". In general, the complex filter is not simple to define but with some rules from our collaborative goal and the application formalism, it would be more effortless and comprehensive in practice. Complex filters (for the CTs and Data Base) provide particular resources (IEs) that would be the basis for the objective applications. However, only the complex filter for the CTs is not enough. For the "Formatting Rules" from the "Formalism" and "Formalism Ontology," they will be used to support exploit the IEs in the collaborative application, for example: building some advanced filters (e.g. filters for IEs) in this application. That is to say, "Formating Rules" assist the application in accomplishing the process of "CTs exploitation". The ideal application would be more dependent on the traces and collaboration information (group activities).

This proposed framework pays more attention to the practical system design and construct. In CWE, the advantages of our framework can be summarized in three key points:

1. Make up the deficiencies of trace research in CWE: CT model and CTs based exploitation framework;

2. Support information retrieval process: e.g. more potential or implicit collaboration information can be collected by complex filters;

3. Assist group collaboration in various aspects, as well as SWOT Analysis, other tools, such as Group Recommendation Systems or CMMI can also be benefited by

the traces based exploitation process.

5.3   CTs-Based Collaborative Approaches

In the group shared workspace, the users' activities are numerous and varied, for example: resulting from sharing calendars and documents, assigning tasks, charting history, sending email, writing wikis and so on. Such finished interactions/actions primarily deal with the collaborative activities. As a kind of trace, CT can record and represent the collaborative activities. Moreover, CT reflects the group's collaboration process, for instance: a long-term or temporary collaboration relationships. Any collaborative application or system, i.e., which mainly provide services for supporting group collaboration, would not be completely independent of the user's previous activities, e.g., his preferences or stored knowledge. Such different degrees of dependency, it is precisely the reason why CTs exploitation would be possible and necessary. In this section, we will introduce three collaborative approaches that greatly rely on the CTs: SWOT Analysis, CMMI and Group Recommendation Systems. They can be considered as a practical implementation of our proposed CTs exploitation framework in different collaboration scenarios. For SWOT Analysis, we will propose some basic notations to explain this process. For CMMI and Group Recommendation Systems, we just prove the possibilities of reusing CTs in theory.

5.3.1   SWOT Analysis

To well understand the needs of CTs exploitation in CWE, a comprehensible example is presented at first. In a high-tech company(interesting in smart phone and tablet), one team have to select several engineers and experts to launch a new project: designing a new tablet that is more lightweight and easier to carry, e.g. the size becomes much smaller: from ten inch to seven inch. The team manager sends a mail(if there any volunteers for this project) to all of the members in the team and shares a questionnaire to collect some creative ideas in the collaborative workspace. A few days later, a new group is formed with some excellent ideas. Although they have plenty experiences of designing and producing the large size tablet, they still doubt about the current situation, e.g. the competences, the weakness, the threats, etc. Anyway, they could accomplish a SWOT Analysis that is based on the collaborative traces and the data base to generate a comprehensive evaluation for this new project. Not only the SWOT Analysis can take advantage of CTs, but also other application or system that requires more information about the group finished collaborative activities.

As a prominent strategy tool to audit an organization and its environment, SWOT (acronym for Strengths, Weaknesses, Opportunities, and Threats) Analysis is widely

used in different research areas: business ([Fleisher 2003](#), [Hackbarth 2000](#)), management ([Jackson 2003](#), [Helms 2010](#)) or policy ([Wheelen 2011](#), [Yüksel 2007](#)). SWOT Analysis (Figure 5.4) is probably credited to Albert Humphrey who led a research project for the United States' Fortune 500 at Standford University in the 1960s and 1970s ([Friesner 2011](#)). During this period, he extended his Team Action Model that allows groups face the changing challenges. SWOT was to have originated from his "Stakeholders Concept and Analysis" ([Humphrey 2004](#)).

Figure 5.4: SWOT Analysis (adapted from ([Humphrey 2004](#))).

In the practical scenarios, SWOT is frequently utilized as a very powerful strategic planning method in an organization or a company to evaluate all sorts of situation, meanwhile, in conjunction with others can help the group or the company to make informed decisions if necessary, for instance: it can support the company uncover opportunities that they should be well placed to exploit. Furthermore, it can equally serve in other circumstances, such as community health and development, education, and even personal growth. For example, used in a personal context, it helps this person better improve himself and develop his career in a way that takes best advantage of his talents, abilities and opportunities, e.g., one employs the existing strengths, redresses existing weaknesses, exploits opportunities and defends against threats.

The main aim of any SWOT analysis is to identify the key internal and external factors that are important to achieving the objective. The internal factors basically contain Strengths and Weaknesses, and the external generally include Opportunities and Threats. For this reason the SWOT Analysis is sometimes called Internal-External Analysis and it is often interpreted and used as a SWOT Analysis 2x2 Matrix, especially in business and marketing planning. Based on the Internal and External factors, the SWOT Matrix

	Internal Strengths	**Internal Weakness**
External Opportunities	SO: Maxi-Maxi This SO strategy attempts to maximize both strengths and opportunities.	WO: Mini-Maxi This WO strategy attempts to minimize the weaknesses and to maximize tile opportunities.
External Threats	ST: Maxi-Mini This ST strategy is based on the strengths of the organization that can deal with threats in the environment.	WT: Mini-Mini In general, the aim of the WT strategy is to minimize both weaknesses and threats.

Table 5.1: TWOS Matrix (Weihrich 1982).

is also called an IE Matrix. From Figure 5.4, it is clear to see that the SWOT 2x2 "Internal/External" matrix method only considers "external" threats and opportunities. Meanwhile, performing a SWOT is to reveal positive forces that work together and potential problems that need to be addressed or at least recognized: i.e., A strength is a positive internal factor; A weakness is a negative internal factor; An opportunity is a positive external factor; A threat is a negative external factor (Figure 5.4). The four factors own strong inner connections and could be transformed into each other with the passage of time, e.g., for any business, a key challenge is to convert weaknesses into strengths, and for every perceived threat, it presents an opportunity.

For the classical SWOT Analysis, commonly, it is limited to analyze the internal "Strengths" and "Weaknesses" and the external "Opportunities" and "Threats", for example: we see only what we want to see, "These are our strengths and our weaknesses", etc. Beginning from the other side, TOWS (Weihrich 1982) (each letter is an acronym same to the acronym of SWOT) Analysis is looking for "what we don't want to see but need to see", see Table 5.1. Not just simply SWOT spelled backwards, indeed, TOWS Analysis is an effective way of combining a) internal strengths with external opportunities and threats; b) internal weaknesses with external opportunities and threats to develop a strategy. As a matter of fact, for TWOS Analysis, the threats and opportunities are examined first and weaknesses and strengths are examined last. TWOS is actually a variation of SWOT analysis that focuses on "the strategical actions" that the company or the organization should take. SWOT or TOWS analysis can help the strategists to get a better and more complete understanding of the strategic choices that they face. Consider the characteristics of CWE and the features of CTs, we primarily consider the process of SWOT Analysis (TWOS Analysis would be similar).

There exists other strategy tools, such as PEST (Political, Economic, Social and Technological) Analysis or Porter's Five Forces to assist the company or organization evaluate the current business environment and make a decision. PEST Analysis, as a simple and effective tool, it supports the company to analyze the Political, Economic, Socio-Cultural,

and Technological changes in the business environment. The creator of PEST Analysis would probably be the Harvard professor Francis Aguilar. He proposed a scanning tool called ETPS in his 1967 book "Scanning the Business Environment" (Aguilar 1967). The name was later tweaked to create the current acronym (PEST). People (e.g., for business or policy) often apply SWOT and PEST analysis methods together in order to analyze and understand the feasibility of a new product, project or possible expansion, etc. However, the differences between SWOT and PEST are obvious (Glaister 1999): SWOT is more flexible and can be applied to various forms of functions (e.g., group collaboration or business decision); PEST is more nonconforming, used only to fully understand the implications of entering a new market. In practice, it is often to perform the PEST and then use the results in the opportunities and threat section of the SWOT.

The Porter's Five Forces tool is a another simple but useful tool/framework for industry analysis and business strategy development that was proposed by Michael E. Porter of Harvard Business School in 1979 (Porter 1979). The Five Forces Analysis (Porter 1979) assumes that there are five important forces that determine competitive advantages in a business/industry situation: Threat of new entrants, Threat of substitute products or services, Threat of substitute products or services, Bargaining power of customers/buyers, Bargaining power of suppliers. The analysis of the five forces is used to examine the organization's own strengths, weaknesses as well as threats and opportunities. Basically, the Five Forces Analysis and SWOT Analysis are similar but the former is applied more specifically to the competitive environment of the business world while SWOT can be used to analyze more sorts of situations, e.g. personal or group, business or policy.

In CWE, SWOT Analysis can greatly support the group work (e.g. evaluate a new project or make a decision) that the benefits more than make up for the time and effort this process may take. Generally, as a way of summarizing the current state and helping to devise a plan for the future, a SWOT analysis results from the answers to a series of questions about the four factors, for example:

- **STRENGTHS:**
    * What are your assets?
    * Which asset is strongest?
    * What do people in your group see as your strengths?
    * Do you have immensely talented people/experts on your staff?
    etc.

- **OPPORTUNITES:**
    * What trends/choices might impact your team?
    * Are you provide a new technique or service?

  * What interesting changes is your group aware of?

  * Is there an unmet need/want that your project can fulfill?

  etc.

- **WEAKNESSES:**

  * What areas do your group need to improve on?

  * What necessary expertise/manpower do your group currently lack?

  * What should your group avoid?

  * Do your team have adequate foundation (money and time) to sustain a new project?

  etc.

- **THREATS:**

  * What if you had a natural disaster?

  * What if your experts/members were absent for some uncontrollable reasons?

  * What obstacles do your group face?

  * Are your core members satisfied in their work?

  etc.

In order to obtain a SWOT analysis (see Table 5.2), one must extract and reconstruct such general questions with a confirmed objective so that the computer or the system can process them and help us to find the right answers. Some approaches are proposed to solve this issue, such as Analytic Network Process(ANP) (Yüksel 2007), Fuzzy logic based ANP (Sevkli 2012) in the expert system. They suppose that the SWOT factors are independent or potentially independent of each other. In our case, we concentrate to the rebuilding of questions but do not deny the relations between them, for instance: to the question "Do you have immensely talented people/experts on your staff? ", the response can either be Strength or Weakness. The rule can be regarded as an abstract of the SWOT question answering "condition" for distinct object(e.g IEs or DB) such as "if...then..." structure, for instance, R_S ={ if (expert quantity > 2) then: Strength}, $R_I E$ ={ Expert (Competence = Screen Design), Name? Age?} and R_T ={Emitter (Traces>20% messages on "screen design")}. The output Δ is a series of evaluations with the details, for instance: { Strength: Expert (Name, Age, Competence(20% in System Design, 50% in Screen Design, 10% in Wifi Techniques, 20% Others)); Opportunities: Innovation(Screen Size, Wireless Charging) }, etc. The reconstruction of general SWOT questions could refer to the techniques of Natural Language Processing, such as Parsing (Aho 1972) or Question answering (Lehnert 1978).

	Positive	**Negative**
Internal	*Strengths* • Do you have immensely talented experts and engineers in your group? • What important resources do you have? • ...	*Weaknesses* • Does the group have a pool of skilled employees/experts? • What is the major focus area of our group? • ...
External	*Opportunities* • Is your group advanced in technology? • What are the interesting trends that might impact your group? • ...	*Threats* • What obstacles do you face? • What if your members(experts or engineers) were absent for the unexpectable reasons? • ...

Table 5.2: SWOT Questions Matrix

The SWOT technique can facilitate the group collaboration since it directly generates an objective evaluation about the current circumstance (e.g. the advantages or disadvantages for this collaborative project) and support group members make a decision. Obviously, this process greatly depends on the group's historical activities (a particular set of Collaborative Traces). As we explained in the section above, the complex filters can be used to extract a specific set of CTs in the group shared workspace. These CTs record the members' finished collaborative interactions and the results but not enough to SWOT Analysis. In addition, the CWE's Data Base is another principal resource.

Formally, a collaborative traces based SWOT Analysis process is composed by two levels of operations: (i) the retrieval of a series of IEs from the Data Base and Trace set; (ii) the implementation and formating the IEs into a SWOT Matrix. For the first stage, we apply a kind of complex filer that depends on the Data Base DB, the series of SWOT questions Qu, the properties and values set $Q = P \times V$, the formalism F, the elementary filters $\xi(t)$, the object of collaboration Γ that is defined as a triple structure: $\Gamma = \{< p, v, f >\}$ where $p \in P$, $v \in V$ and f is defined as an operator (basically, there exists three types of f to measure the values of the matching properties: ">", "<", "=", e.g $\Gamma = \{< screensize, = (equal), 7.5(inches) >\}$ or $\Gamma = \{< weight, < (less), 745(grams) >\}$), the group structure G, the ontologies of domain knowledge O_D, the ontologies of formalism

O_F:

$$\Psi(\xi(t), DB, G, \Gamma, R_{IE}) \to IE_\Gamma$$

And the rules R_{IE} for Ψ is defined as:

$$F(Qu, \Gamma, O_D) = R_{IE}$$

The second level focuses on generating a SWOT Matrix (producing a result for SWOT) by an another type of complex filters Θ:

$$\Theta(IE_\Gamma, R_S) \to \Delta = < SWOT >$$

where the rule R_S for Θ is defined as:

$$F(Qu, \Gamma, O_F) = R_S$$

Besides, the rule set is:
$$R = \{R_S, R_{IE}\}$$

and the ontology set is:
$$O = \{O_D, O_F\}$$

.

The result Δ is an evaluation of the current circumstance with details, for example: {Strength: Expert (Name, Age, Involved Projects, Competences (System Design (30%), Wifi Techniques (30%), Wireless charging technology (20%), Others (20%))); Experiences (related projects, brainstorming reports, costumers' reviews)}; {Opportunities: Innovation (Screen Size, Screen Resolution, Eye-tracking technology)}, etc. It can greatly aid the decision and planning making for the group. In our framework, the SWOT factors are supposed to be dependent or to have some inner/potential connections, for example: the Strengths would be the Weakness if the answer of the question "Do you have immensely talented experts and engineers in your group" were negative. Moreover, not all of the questions would have a definite machine proposed answer and not all of the answers can be trust or understood. For some case, naturally, we can collect the answers from the group members (e.g., questionnaires or tests), and then generate a comprehensive answer.

5.3.2 Capability Maturity Model Integration

In the information age, companies are forced to deliver their products better, faster and cheaper. At the same time, products are becoming more and more complex and the same is true for the way the products are developed. More now than ever, a single company usually does not develop all the components that compose a product. Also, own components are usually not developed at one single location but rather in a multi-national effort at different development locations. Since most of the innovations are based on software and electronics, software and systems engineering has become a critical part of their business. For such cases, the Capability Maturity Model Integration (CMMI) Product Suite was proposed and designed to help organizations/companies improve the way they do business, for example: improve product quality and the ability to meet project targets (on-time, on-spec, on-budget), reduce cost and cycle time control suppliers or manage multi-national development cooperation.

The Capability Maturity Model Integration (CMMI) is a structured representation of software development processes that can support an organization's software process improvement (SPI) strategies (Niazi 2007). CMMI can be issued from the CMMI project that was chaired by the Carnegie Mellon Software Engineering Institute (SEI). The object of CMMI project was to improve the usability of maturity models by integrating many different models into one framework (Chrissis 2011). Commonly, CMMI is used as a model/framework and authentic industry standard that consists of best practices that address the development and maintenance of products and services. It covers the life cycle of a product from conception through delivery to maintenance. Besides, CMMI integrates essential compositions/elements of knowledge for developing products, such as software engineering, systems engineering, and acquisition. In January of 2013, the whole CMMI product suite was transferred from the SEI to the CMMI Institute (a newly formed organization at Carnegie Mellon University [7]).

Normally, CMMI focus topics are mainly concentrated in the three areas (Chrissis 2011): Product and service development — CMMI for Development (CMMI-DEV); Service establishment, management — CMMI for Services (CMMI-SVC), and Product and service acquisition — CMMI for Acquisition (CMMI-ACQ). In general, CMMI can be represented in two cases: continuous and staged (Godfrey 2008). The first situation is to allow the user to focus on the certain processes that are considered important for the organization's immediate objectives or the risks. The staged case is to provide a standard sequence of improvements that can serve as a basis for comparing the maturity of different projects or organizations.

In CMMI models with a staged representation, there are five maturity levels that can classify the process areas. According to the latest CMMI version 1.3 (Chrissis 2011),

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[7]Refer to CMMI - Software Engineering Institute - Carnegie Mellon University: http://www.sei.cmu.edu/cmmi/

there are 22 process areas that can be covered by the organization's processes [8]). CMMI for Development: Initial; Managed; Defined; Quantitatively Managed; Optimizing. More specifically, the process areas of the maturity levels are partially different according to the objects of CMMI, i.e., some areas only for Acquisition, for Services or for Development. For example, in the third maturity level "Defined", only CMMI for Acquisition contains Risk Management (RSKM). Commonly, companies were expected to be formally assessed as to their maturity level. As they achieved each level, they formed a plan to get to the next. Similar to CMMI, there exists also other process maturity models, such as CMM (Capability Maturity Model) or E-learning Maturity Model (EMM).

The capability maturity model (CMM) (Paulk 1993) is an assessment model developed by the Software Engineering Institute at Carnegie Mellon University in 1990. Implementation of CMM raised many challenges that led to development of CMMI as an improvement over CMM. Actually, CMMI is different from CMM although they have some interior connections (Royce 2002). CMM is a reference model of matured practices in a specified discipline like Systems Engineering CMM, Software CMM, People CMM, Software Acquisition CMM, etc. But they were difficult to integrate when required in some cases, e.g., lack of standardization or overlapping for processes. CMMI is the successor of the CMM and evolved as a more matured set of guidelines and was built combining the best components of individual disciplines of CMM (e.g., Software CMM, People CMM, etc). It can be applied to product manufacturing, People management, Software development, etc. CMM describes about the software engineering alone where as CMMI Integrated processes and disciplines as it applies both to software and systems engineering. CMMI also incorporates the Integrated Process and Product Development and the supplier sourcing. Besides, CMM is concerned at recording processes whereas CMMI documentation and meetings focus on strategic goals of the organizations.

The latest CMMI version[9] contains 22 process areas that each process area contains a range of specific and generic practices (things you need to do). For instance, in the Level 2, Requirements Management (REQM) (Team 2010) is used to manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project's plans and work products. There are five specific practices for REQM (Team 2010), respectively, Understand Requirements; Obtain Commitment to Requirements; Manage Requirements Changes; Maintain Bidirectional Traceability of Requirements; Ensure Alignment Between Project Work and Requirements. Every specific practice needs to be evaluated by certain processes in order to achieve some goals. There are two categories of goals and practices: generic (part of every process area) and specific (specific to a given process area) (Chrissis 2011).

The group's CTs, as a specific type of knowledge, can support the processes evaluation

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[8]The CMMI version 1.3, Process area: `http://en.wikipedia.org/wiki/Process_area_%28CMMI%29`
[9]The CMMI version 1.3, Process area: `http://en.wikipedia.org/wiki/Process_area_%28CMMI%29`

and analysis in several process areas in according to practical conditions, for instance: Project Planning (PP) or Measurement and Analysis (MA). For example: the CMMI for Development, in the Maturity Level 2 - Managed, the specific process area "Project Planning (PP)" is to establish and keep plans for defining project activities (Team 2010). It is a part of Project Management. There are three specific goals for PP process: Establish Estimates; Develop a Project Plan, and Obtain Commitment to the Plan. For the third specific goal, i.e., Obtain Commitment to the Plan, it contains three specific practices: Review Plans that Affect the Project, Reconcile Work and Resource Levels and Obtain Plan Commitment. To accomplish a review for the plan (or establish the project plan - one of the practices of "Develop a Project Plan"), it is necessary to compare with the previous similar projects and corresponding plans that concerns a series of question to determine the scope of the current plan or event:

- What kind of a project or plan was it?

- How long did the project/plan last?

- How many people and groups were affected?

- What kinds of things impacted schedule, resources, or quality ?

- How did it run? Were there significant problems or alternations?

- Did the team do better or worse than the last similar project?

- What, if any, review work has already been done?

- Were there some comparable projects/plans? And how did they finish?

- etc.

Such questions will drive us to identify the stored former projects' data/knowledge that we need to collect and the fished activities that we should reconsider for our investigation. CTs could be one of the most important sources for this process since traces record our interactions (the actions and the results) with the environment. In practical "review" progress, we can define some filters to retrieval our CTs in accordance with the certain goal and practice. What's more, CTs can help us to reconsider our contributions/solutions of the previous project. If the new project or plan were similar to the previous (e.g., many connections or overlaps), the prior solutions could be reused to for the current project. Actually, almost all the Process Areas or Specific Practices depend on the company or organization's stored knowledge or experience in varying degrees. Thus, CTs or more generally, different kinds of traces can support CMMI framework.

5.3.3   Group Recommendation Systems

In recent years, as the scale of the Internet are getting larger and larger, recommender systems have become extremely common, a few examples of such systems in different areas:

- E-commerce

  Recommender systems are used by companies to suggest products to their customers and to provide consumers with information to help them decide which products to purchase (Schafer 2001). The product knowledge is either from the comments or behaviors of other customers or from the experts or consultants that would be the basis of any recommendations. The forms of recommendation are various, e.g., providing a list or a series of products to the consumer, suggesting personalized products, collecting community opinion and critiques and so on. Actually, these recommendations are within the scope of personalization for every customer. Generally, via recommendation systems, there are three ways to enhance E-commerce sites (Schafer 1999): Converting Browsers into Buyers (help consumers quickly find what they need/want); Improving Cross-sell (recommend additional products to purchase); Creating Loyalty (build a stable relation/connection with customers). A very well-known example is the Amazon site. E-commence sites, either the B2C, C2C or B2B, they are increasingly inseparable from recommender systems, such as Taobao, Alibaba or eBay.

- Social Networks

  Social network systems/sites, like Facebook or Twitter, play a significant role in our daily life. Social Networks sites often use the structure and the preferences tags on the users as an additional source of information to make recommendations (Wang 2013). The proposed objects are not only the interesting news or images but also some people that you may know, for example: Facebook friend recommendations. The users' dynamical behaviors and the enormous amounts of contents published every second would be great challenges for social recommender systems (Guy 2010). This research area usually is constrained by the short of good data sets. Since the companies that have both users' histories and relationships among users worry about privacy.

- E-learning

  For E-learning and Web based education areas, such as Beginners or Findtutorials, recommender systems is used to personalize the user's learning materials, such as courses, lectures, multimedia resources, etc (Zaíane 2002). These recommendations can assist learners better navigate the learning materials by quickly finding relevant resources and help to select pertinent learning activities that would improve

their performance based on the behaviors of advanced learners (Bobadilla 2009). Particularly, several pedagogy features in recommendation should be considered, e.g., learner's interest or background knowledge.

- Web Music/Video Sharing

  In this area, a great amount of systems are directly based on a recommender engine. A very well-known example is Pandora Radio[10] that provides a music service transmitted via the Internet. Another famous example is Youtube. As the most popular online free video community in the world, Youtube utilizes recommendation systems to propose personalized videos to users based on their activity on the site (Davidson 2010). These kinds of recommender systems are designed to increase the numbers of musics/videos the user will listen/watch, increase the length of time he spends on the site, and maximize his enjoyment.

As a subclass of information filtering system, Recommender Systems or Recommendation Systems were originally defined as ones in which "people provide recommendations as inputs, which the system then aggregates and directs to appropriate recipients" (Resnick 1997); and more generally, it can be defined as "the effect of guiding the user in a personalized way to interesting or useful objects in a large space of possible options" (Burke 2002). A recommendation system actually builds a bridge among the "Items" and the "Users" (Figure 5.5). Typically, it is a very important and effective way for personalization, e.g., personal interested information retrieval and content discovery. From the user's preferences and the set of items, recommender system predicts the potential items to user. Generally, the users' preferences are measured by "Ratings" or "User profiles".
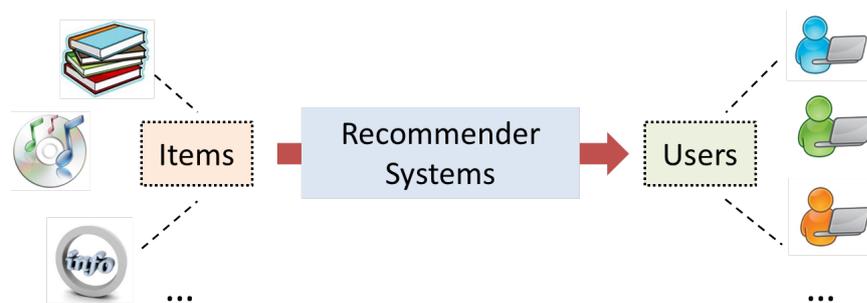

Figure 5.5: Recommendation Systems.

There are generally three basic categories of algorithms/techniques for recommender systems (Ricci 2011):

- Collaborative Filtering

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[10]Pandora Radio, http://en.wikipedia.org/wiki/Pandora_Radio

The term "Collaborative Filtering (CF)" was first discussed by Goldberg et al. (Goldberg 1992). Generally, Collaborative Filtering is a process that uses filtering techniques for extracting information including collaboration among data sources, multiple agents, standpoints, and so on (Terveen 2001). Practically, collaborative filtering is used to make predictions about the interests of a user (e.g., additional topics or products that he might like) by collecting preferences or taste information from other users (collaborative). There typically are three kinds of collaborative filtering methods (Su 2009):

– Memory-based: This mechanism utilizes the entire user "rating" database to compute similarity between users or items, i.e., from the user-item rating matrix to generate similarity matrix. Then, we can find/define k neighbors and aggregate neighborhood ratings/similarities to return a top-N lists. Two kinds of nearest CF algorithms exist: user-based and item-based (Su 2009).

– Model-based: Model-based CF algorithms/techniques make possible predictions by using the model learned from existing ratings (Su 2009). There are two popular models for model-based method: Cluster models and Bayesian networks. Basically, these models are developed by machine learning algorithms to find patterns based on training data.

– Hybrid: This method combines the memory-based and the model-based CF algorithms (Su 2009). It improves the CF prediction performance. Especially, it overcomes the some challenges for CF such as sparsity and loss of information.

The main advantage of CF based recommender systems is that they are based on the users' ratings, without any requirement of content-related analysis. Additionally, CF based methods can deal with any kind of content and recommend any items, even the ones that are dissimilar to those seen in the past. However, CF-based recommender systems have some limitations (Schafer 2007):

– Cold start: CF greatly relies on the users and their ratings for the items. Without enough user and item rating data, this method would be difficult to use.

– Data Sparsity: For CF based recommender system, several ratings already obtained but the amount is usually very small and hard to compare with required the number of ratings.

– Scalability: Once the number of users/items grows greatly, CF algorithms may suffer serious scalability problems, e.g., computational resources will go beyond acceptable levels in practice(Su 2009).

• Content-Based Filtering

As another important subclass of CF based systems, Content-based filtering approach provides recommendations by analyzing and comparing candidate item's content representation with the target user's profile (e.g., a structured representation of user interests) (Melville 2002). This process basically consists in matching up the attributes of the user profile against the attributes of a content object. Besides, in content-based filtering, each user is assumed to operate independently and the predictions usually represent the user's level of interest in that object (Melville 2002). It is basically composed by three steps: first items are analyzed and represented; then a user profile is reconstructed; and some algorithms are used to find similarities between item representation and user's profile and make recommendations.

The principal advantages of content-based filtering is that content information can help to bridge the gap from existing items to new items, by inferring similarities among them (Melville 2002). Therefore, we can make recommendations for new items that might be similar to the recommended items. However, content-based recommendation also has some limitations (Adomavicius 2005):

- Limited content analysis: Content-based techniques are based on the features of the concerned items. The systems can automatically assign the features to items and this process can also be manually. However, both methods could not be sufficient to define distinctive aspects of items that would be necessary for the elicitation of user interests.

- New user: A new user can not obtain reliable recommendations until the system understands the user's profile, i.e., his preferences. Sufficient information, e.g. enough ratings, has to be collected before a content-based recommender system can understand user's preferences and then provide precise predictions. Therefore, users have to provide sufficient information to help a content-based system to create user profile. As for a new user, few ratings would not be sufficient.

- Over specialization: in content-based recommender systems, when a user has only rated specific type of items, he will be constricted to recommendations just involving that kind of items. A typical content-based recommender system would rarely find anything novel, and limit the originality of recommendations.

• Hybrid Recommender Approaches

Hybrid recommendation algorithms combine both collaborative filtering approaches and content-based methods, in consideration of overcoming their own shortcomings and getting better performance (Burke 2002). Some hybrid systems add content-based components to collaborative filtering, e.g., "collaboration via content" approach (Pazzani 1999) or Fab system (Balabanović 1997). There are

also several hybrid systems that incorporate collaborative features to content-based models, e.g., utilize dimensionality reduction techniques on a group of content-based profiles (Burke 2002).

In the past few years, numerous techniques from different domains, such as: statistical, machine learning or information retrieval were used to develop recommendation algorithms for various applications. Recommender systems generally provide services for two kinds of objects:

- Individual: Primarily, recommender systems were designed to meet the personal needs, i.e., using recommendation techniques to accommodate the differences among individual users. The personal preferences usually come from either the explicit given information (e.g., individual profile) or his implicit behaviors (e.g., private actions).

- Group: There are at least four different kinds of group for recommender systems (Boratto 2011):

  1. Established group: several persons who share the similar and long-term interests in long-term, e.g., a collaborative group;

  2. Occasional group: a few persons who occasionally do something together, e.g., a tourist group;

  3. Random group: a number of persons who just share an environment, e.g., a group of passengers;

  4. Automatically identified group: a quantity of persons who are detected by their preferences, e.g., a group of game partners.

For recommender systems, no matter the object is group or individual, the prediction is based on the object's preferences. Since trace represents the user's experience, practically, it can be exploited to estimate the user's historical actions and consequences. Trace is an important resource for describing the object's preferences. In CWE, a large part of the activities is related to the collaboration. And the system service target is principally the groups. Since CT represents not the only the relations among users (e.g., "who shared a document with whom") but also the results of interactions (e.g., two shared PDFs concerning a certain topic), CTs can be naturally used to support group recommendations. What's more, it covers two basic elements of collaboration: collaborator (e.g., a person or a group) and resources (e.g., the shared information or knowledge).

For CTs based group recommendation systems, the algorithm from collaborative filtering or content based filtering could be applied to support prediction of users' or group's preferences. For collaborative filtering approaches, we can generate a matrix of ratings

by users' CTs, i.e., transform the CTs into the ratings. In consideration of the formal definition of trace (a trace is defined as a vector: $t_{i,j}^k =< E_i, D_j, Q_k >$, $trace =<$ Emitter, Receiver, $<$ Property, Value $>$), there would be two possible CTs based ratings tables: Emitters-Properties Table or Emitters-Receivers Table. In each table, the rating can be the frequencies or times that are concluded from their relation: e.g., for the Emitters-Receivers Table, the times of shared documents (e.g., three documents were shared during one week)or communication frequencies (e.g., at least ten messages every day). For content-based filtering methods, a new item would be a new shared document or a new colleague. The groups' profiles can be aggregated from their CTs, e.g., the popular shared documents or the added group wiki entry, etc.

In theory, CTs based group recommendation systems would be necessary and useful to facilitate group collaboration since the group needs to adjust their plan and discover more valuable resources from their previous activities. For practical applications, we can build a recommender engine that is based on our proposed CTs based exploitation framework, refer to Figure 5.3. A connection between Matlab and MySQL is examined by JAVA interface that would be helpful to test different group recommendation algorithms. Nevertheless, the main challenge for CTs based group recommendation is from the transformation between CTs and the group's preferences.

5.4   Conclusion

In this chapter, we introduced a traces based exploitation framework and implemented it in the three possible collaborative approaches (SWOT Analysis, CMMI and Group Recommendation Systems) in order to facilitate group collaboration, e.g., decision making or project planning. Moreover, this framework can be applied in other applications/tools that rely on the user's CTs, for instances: knowledge or information sharing. Its primary part is to build a series of Complex Filters to retrieve a particular set of CTs. Generally, the complex filter is not simple to define but with some rules from our collaborative goal and the application formalism, it would be more effortless and comprehensive in practice.

In CWE, the advantages of our framework can be summarized in three key points: (i) Make up the deficiencies of trace research in CWE; (ii) Support information retrieval process: e.g. more potential or implicit collaboration information can be collected by complex filters; (iii) Assist group collaboration in various aspects, as well as SWOT Analysis, other tools, such as group recommendation or CMMI can also be benefited by the traces based exploitation process. However, there are some remarks for all the CTs based approaches: i) cold start: requires a large amounts of traces, i.e., frequent use of the corresponding CWE; ii) group oriented: almost every element of group will affect the exploitation process in different degrees: e.g., group size or structure; iii) fallibleness for

the new and independent issue, i.e., CTs strongly depend on our previous collaborative activities. In practice, the more traces we can store and model, the more difficult our exploitations will be. In implementing this process, we must take a particular care of the user interface. As a practical experience we will test our model in the context of the E-MEMORAe2.0 collaborative platform in the next chapter.

Implementations and Experiments

Contents

6.1   Introduction

As a natural part of our life, collaboration is one of the most important skills that we should be good at. Whether in the real workspace or in the virtual workspace, people always need collaborative tools to accomplish tasks, e.g., a marker board or an online chat room. Normally, a web-based CWE involves several sub-systems with various tools in order to facilitate different levels of collaboration (e.g., communication or coordination) in groups, e.g., Document management systems, Electronic conferencing systems, Work-Flow systems, or Knowledge management systems. Indeed, the users' actions always leave traces that come from past interactions in the use of the tools and contain rich information, for example: when they exchange messages, edit wikis or handle documents. As we explained in Chapter 4 and 5, our proposed CT model focuses on this issue (i.e., defining and modeling different types of traces in CWE, mainly, Collaborative Traces) and our proposed CTs exploitation framework can be applied to reuse CTs in various collaborative scenarios. In CWE, generally, the CTs based tools/applications could support both group and individual works, such as: review of past collaborative activities or private actions. As a practical experience, our proposed CT model and exploitation framework can be implemented and applied in the context of different collaborative platforms.

In this chapter, we will evaluate our CT model, several complex filters and the exploitation framework on a web-based collaborative platform E-MEMORAe2.0. The reminder of this chapter is organized as follows: Section 6.2 introduces our collaborative platform: E-MEMORAe2.0. Several basic collaborative tools and the user's navigation history table will be explained with some explicit figures. In Section 6.3, two practical cases of traces exploitation: Traces Display and CTs based SWOT Analysis will be presented in detail.

6.2   Collaborative Platform: E-MEMORAe2.0

The Web protocols and models have been initially designed and applied to support geographically dispersed information sharing and extracting by means of tools, e.g., e-mail or search engine. It has mostly been used to make information available to a global audience. With the popularity of Web techniques and smart devices, Web-based platforms gradually run into our lives, e.g., social networks or e-commerce. Especially, for group work, there emerge more and more collaborative platforms/systems (Bafoutsou 2002). As explained in Chapter 2, Collaborative Working Environment is a subclass of groupware that supports group collaboration as well as individual work. Generally, CWE provides a group shared workspace with a set of collaborative tools/applications, e.g., document management, calender or video conferencing. People can work together for a common goal or project irrespective of their geographical location and time limitation, i.e., "collaboration" via a web-based platform.

There are numerous collaborative systems or platforms[1], e.g. IBM Lotus Domino, IBM Sametime, Scribblar, or Collabtive. Each owns its features, although all of them provide similar services with some basic collaboration tools/applications, like e-mail or calendar. As a knowledge based collaborative platform, E-MEMORAe2.0 is used to support group learning and working with various tools. We choose platform E-MEMORAe2.0 to exploit and test our CT Model and possible CTs based applications. Before explaining our experiments, it is necessary to describes the main characteristics of this platform that relate to our CT model, i.e., the collaborative tools and the historical tables.

6.2.1   E-MEMORAe2.0

Within the MEMORAe approach (Abel 2008), E-MEMORAe2.0 was conceived and developed to facilitate organizational learning and knowledge capitalization by proposing to associate:

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[1]List   of   collaborative   software: http://en.wikipedia.org/wiki/List_of_collaborative_software#Web-based_software

- Knowledge engineering and educational engineering: support of capitalization;

- Semantic Web: support of sharing and interoperability;

- Web 2.0 technologies: support of the social process.

E-MEMORAe2.0 can manage the fields of expertise of the organization and favor collaboration. For the purpose of defining, structuring and capitalizing explicit knowledge, the learning organizational memory is structured by means of ontologies that define knowledge within the organization on this platform (Abel 2009). E-MEMORAe2.0 has two versions, each implementing the basic MEOMRAeCore model: one using HTML and the other using Flash. On this platform, generally, the user can:

- Manage users and user groups (transactions only the administrator);

- Manage memories, private spaces and group workspaces: these spaces associated with the memories which the user has access to it are simultaneously visible, and it is facile to transfer content from one space to another;

- Access to knowledge map (ontology) and content (resources) based on the active shared space: i.e., individual, group , and organizational spaces;

- Add and share the resources, e.g., PDFs or images;

- View and navigate through the concept map;

- Annotate concepts and resources;

- Utilize the concepts and the individuals of the knowledge map to index the resources;

- Collaborate by means of Web2.0 tools to support informal communication and spontaneous production of knowledge, e.g., semantic wiki, chat or forum;

- Manage each user's or group's entry points (a set of concepts that represent a particular interest for the user or the group): via the interface, the user can directly access the ontological concepts of his choice.

As shown in Figure 6.1, the main interface of the environment[2] provides the user with several elements:

- Knowledge map visible in the center of the screen and the focus centered on the concept (the shared knowledge map);

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[2]This is the Flash version of E-MEMORAe2.0, refer to: http://www.hds.utc.fr/memorae/.
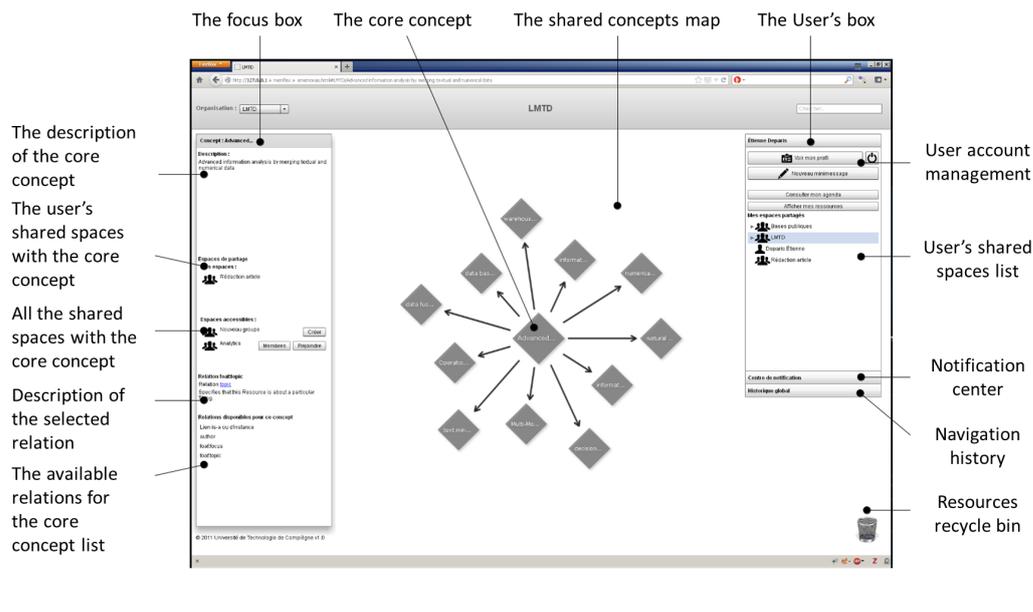
Figure 6.1: The collaborative platform E-MEMORAe2.0 (in French).

- A definition of the concept focus placed on top of the ontology;

- The user's navigation history that contains the list of operations performed by the user within the environment;

- A selection window memory: allows the user to choose the memories that want to view;

- The description of the core concept in the left focus box;

- Resources recycle bin is temporary storage for files that have been deleted by the user;

- Boxes showing different workspaces associated with the selected memory/concept;

- The shared workspaces with several groups:

    - A list of concepts (Points d'entrées);

    - Members: a group of users in this shared space;

    - Resources: a list of files classified according to the predefined ontology, e.g., PDFs, images, etc.

- Analysis of the user's traces;

To personalize this environment, the user can choose suitable entry points to work or move boxes according to his needs. Based on MEMORAeCore model several types of resources are recognized in the environment (Figure 6.2):
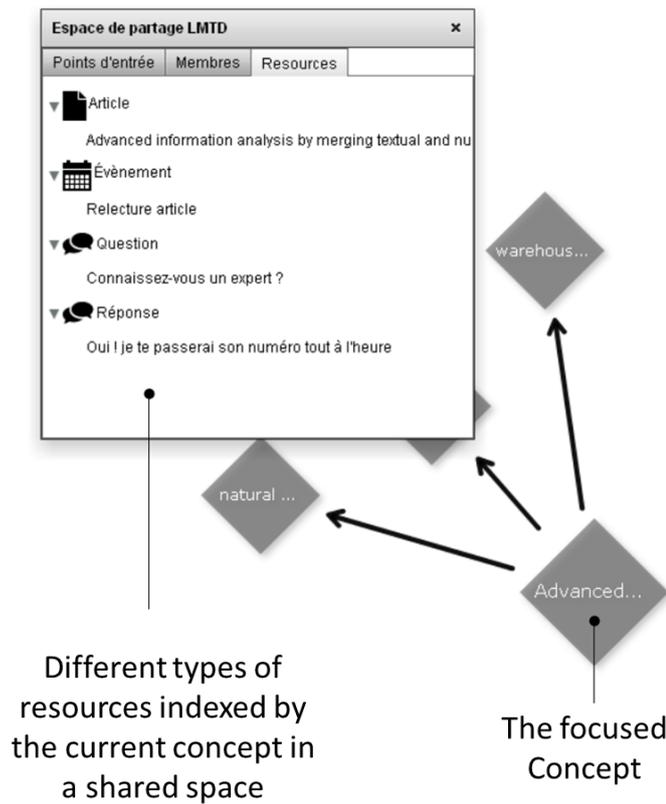
Figure 6.2: Different resources in a shared workspace.

- Resources of communication: chat, forum, wiki, e-mail.

- Resources of coordination: agenda.

- Resources of cooperation: slideshows, websites, courses, documents, files, annotations made by the user, etc.

Resources are generally derived from the process of using a variety of tools and can be indexed with one or more concepts of the ontology.

6.2.2   Collaboration Tools

The environment has a set of tools for sharing information and supporting communication. We present several principal collaborative tools in this part:

- Forum

  Form (or message board) is considered as a set of micro resources constituted by the elements of a forum (questions and answers) and indexed with concepts of

knowledge map. Each group has its own forum. All elements of a forum (questions/answers about different concepts of the knowledge map (ontology)) are thus part of the overall group forum. When the user wants to create a forum topic on the concept that is being consulted, he first chooses the memory of the group to which the subject is intended. Once created , the subject of forum is open to all members of the selected group (from the workspace corresponding to the group). Group members can then consult and possibly formulate responses (Figure 6.3).
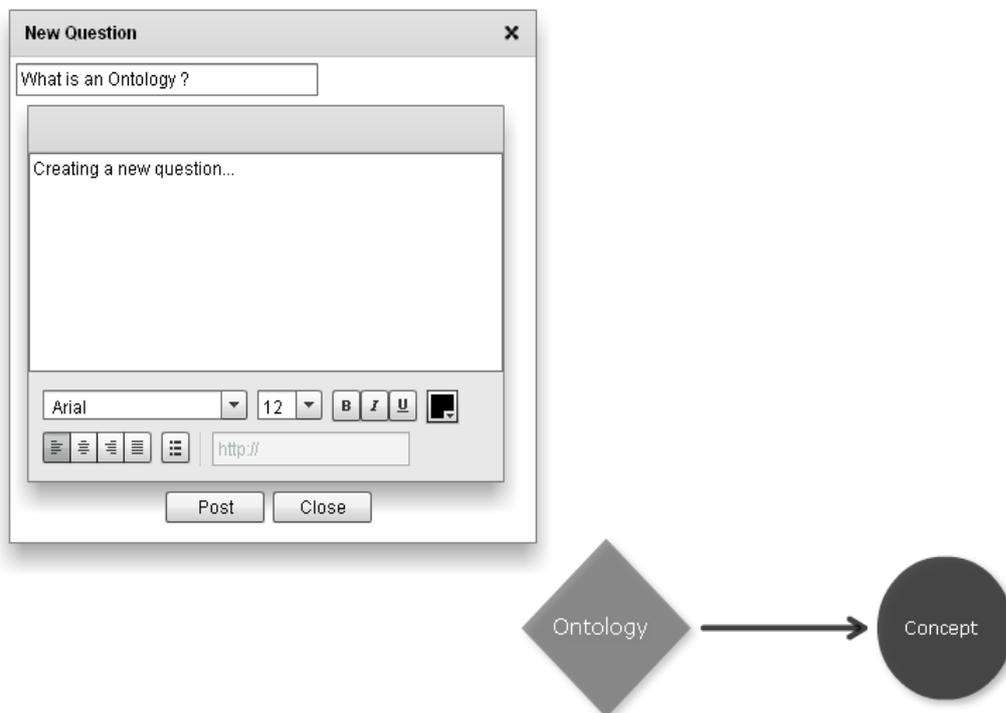
Figure 6.3: Insert a new question on this platform for a given concept (here "Ontoloy") (Deparis 2011a).

The advantage of this solution is that it allows the user to post message (e.g., questions or reponses) around a shared knowledge map (or ontology) in which each member can navigate to access resources.

- Chat

Chat[3] is a text-based communication tool for real-time message exchange between two or more group members. Such text-based conversation allows users to reread of previous messages if there's a need, e.g. to achieve a better understanding. As shown in Figure 6.4, the message can be connected with a certain concept of knowledge map. Besides, we can reuse these chatting messages as a type of resource. Even though a chat is a synchronous tool, responses do not necessarily

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[3]This interface is HTML version E-MEMORAe2.0.

have to be simultaneous and conversations may last for hours.

Figure 6.4: Start chat on this platform for a given concept.

- Wiki

  Wiki is a tool that allows users to create, edit or delete a content that is linked to a concept in the knowledge map. These features makes it very easy to collaborate with group members, e.g., in situations where they cannot meet face to face or they want to keep the group updated on a project. In E-MEMORAe2.0, every group member can use an on-line rich-text editor to add or edit a wiki entry (Figure 6.5).

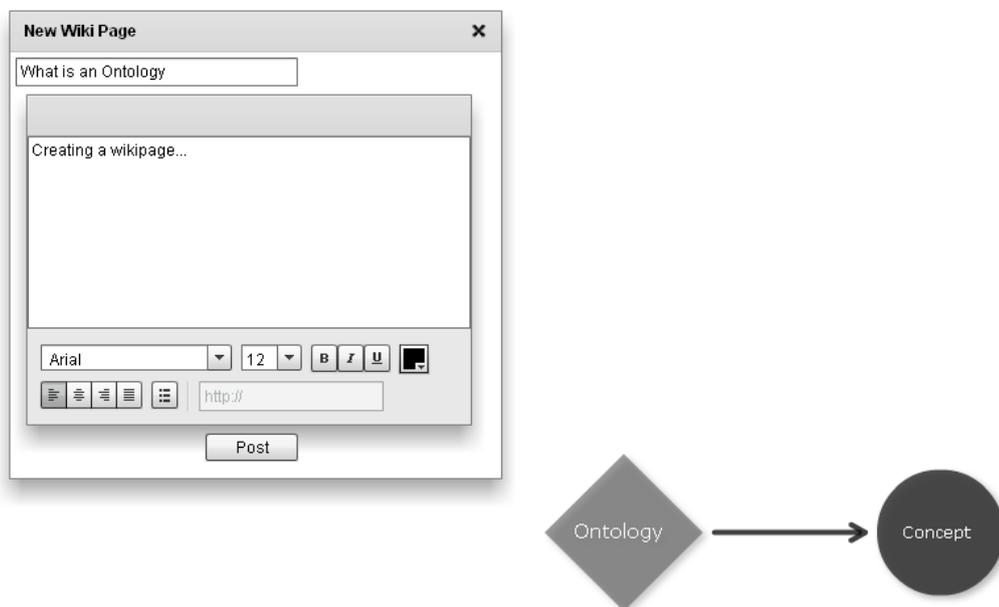Figure 6.5: Add a wiki entry on this platform for a given concept (here "Ontoloy").

Every entry contains some basic information or explanation of the connected concept. Normally, wiki is easily understandable even if the user is not familiar with

the concept/subject. Additionally, the group wikis serve many different purposes, for example: knowledge management or information sharing.

- Other tools, such as scope statements (l'analysis du cahier des charges) or group agenda, can also support group collaboration in different aspects.

6.2.3 History Table

In E-MEMORAe2.0, primarily, two kinds of personal interactions are recorded and presented in the navigation history table as shown in Figure 6.6.
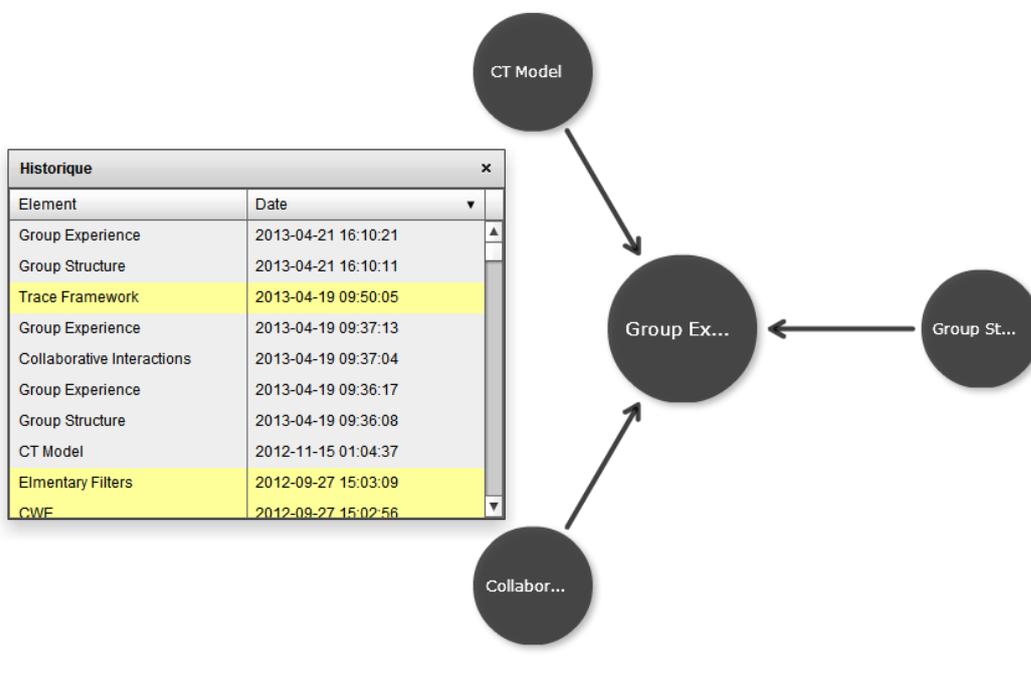
Figure 6.6: Example of user's History Table.

This history table respectively contains the examined concepts and resources since they are the most important elements on this platform. The yellow ones are the resources and the others are the concepts.

6.3 Practical cases

In this section, we evaluate our CT model and several complex filters on the web-based collaborative platform E-MEMORAe2.0. As we explained in Chapter 5, three foundational parts constitute a primary framework of trace-based systems: (i) Collection: this process uses diverse sensors and tools to collect primary traces; (ii) Transformation: this

part includes three functions: filtration, calculation and analysis; (iii) Presentation: the last process utilizes the outcomes from the transformation procedure. This core framework is easy to understand and to implement. We naturally apply it on our collaborative platform E-MEMORAe2.0. The exploitation of collaborative traces is principally focused on the transformation and the presentation process. In Figure 5.3, we explained that filtered traces can be used as a flow of IEs (Information Elements) to support traces display and traces based applications, such as CMMI or SWOT analysis. For our practical experiments, we focus on the display process and SWOT Analysis.

6.3.1   Traces Display in CWE

In this case, firstly, the CTs are stored in accordance with the CT model conditions; then the queries are done through the designed complex filters; lastly, the results are presented in a chart or graph. Recall the definition of traces that we explained in Chapter 4: $trace =< \text{Emitter}, \text{Receiver}, < \text{Property}, \text{Value} >>$. In practice the "Emitters" and "Receivers" are defined as the users' ID in the schema of the data base: "per_id" from the table "mem_personne", i.e., the E_i and D_j. The properties are "ontology concepts" and "resources." The corresponding values are: (i) the names of the examined concepts and resources that can be captured from the tables of "concepts" and "resources" in the data base; (ii) the time and date when the users' interactive actions were taken (geographical position could be another choice as the "Index" of CTs). We will examine two cases that are based on the different collaborative group structure and the project issue (Li 2012a, Li 2012c).

- **Case 1**

    In this test, the ontology relates to a lecture on probabilities[4]. Our test group members are: Qiang, Adeline, Marie-Hélène and Jean-Paul, formally, $g_1 = \{u_1, u_2, u_3, u_4\}$. This group is formed by two subgroups: one has three members: Qiang, Marie-Hélène and Jean-Paul; the other one has a single member: Adeline. This group structure is shown in Figure 6.7. The complex filters that we built in our test are of two categories (four types): (i) For private traces: a) the filter that extracts the name of concerned "Concept" and "Resource"; b) the filter that extracts the time and date from the stored actions; (ii) For collaborative traces: a) the filter that analyzes the shared documents situations; b) the filter that analyzes the state of the service for each shared documents. As collaborative traces can be shared in a group (as personal experiences), in our test, we design an interface that allows examining intuitively the state of service of the shared documents in the group.
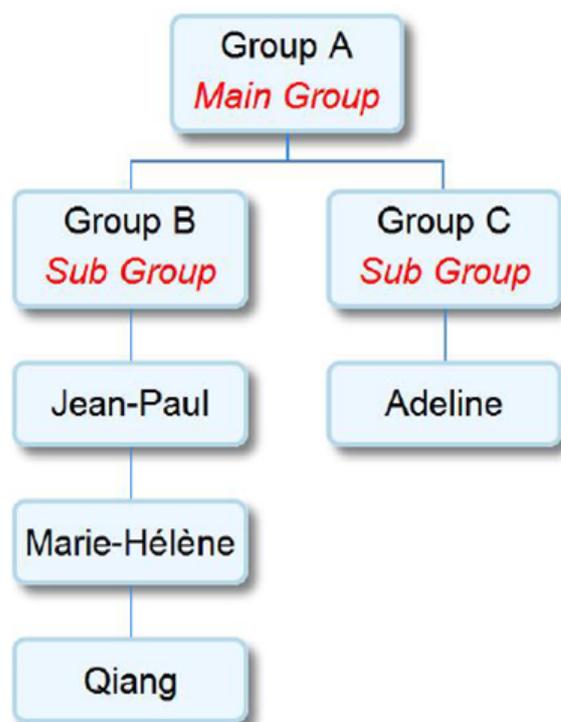
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[4]In the HTML Version

Figure 6.7: The Group Formation (a lecture on probabilities).

In the case of "Concepts", for private traces, (i) the "Emitter (E_i)" is the "Receiver (D_j)" who built and managed all the concepts in the knowledge map (e.g., the administrator); (ii) The property (p_1) is "the concepts". For the values, one (v_1) is the name of the concept and another (v_2) is the frequency/times of the service situation for this concept. As shown in Figure 6.8, private traces are filtered into two parts: the upper figure presents the four most consulted concepts during a month period (from 12/12/2011 to 01/12/2012); and the lower chart shows the matching service conditions. In Figure 6.8, one can easily find that the most consulted or interesting concept is "Loi Normale" (Normal Distribution), and in Jan/06, the user examined this concept three times. From the private trace, this user could obtain his preferences/attentions and the relevant details that are based on the timeline. It is almost the same for "Resources," while the private traces of "Resources" aim at the private document service condition.

For collaborative traces, in the case of "Resources," (i) the "Emitter (E_i)" is any member in the group who shared a file that concerns the concepts in the knowledge map; (ii) "Receiver (D_j)" is "All the group members" (g_1), e.g. every member can view and check the shared documents in the group workspace; (ii) The property (p_2) is "the shared files" in the group workspace. Besides, for the values, one (v_3) is the situation of shared files (the file name, type and quantity) and another (v_4)

Figure 6.8: An example of Private Trace.

is the frequency/times of the service situation for each file.

Figure 6.9: An example of Collaborative Trace.

We captured two categories of shared files: one including PDFs and doc documents, the other involving videos and images. In the test, personal collaborative traces are integrated together and compared in detail. In Figure 6.9, the upper presents the quantity of every type file that has been shared during one month

(from 12/12/2011 to 01/12/2012) for the three most concerned concepts. One of the concepts "Probabilité" (Probability) is associated with some files: three PDFs, three DOCs, one video and three images. The lower chart shows that the state of service for the three shared pdf documents about the concept "Probabilité" (Probability) in the group. The "frequency" means the number of times: "open the document." It is clear to see that the PDF2: "Note I de Probabilité" (Note I of Probability) was of no interest and had never been opened by Adeline, however, it was indeed read several times by Qiang and Jean-Paul.

Apparently, group knowledge is enriched by the shared files. Furthermore, with the collaborative traces, the group's preferences (as part of their experiences) can be regularly compared and observed (the most relevant problems or the concepts of highest interest). As a result, some potential relations of collaboration within members strongly depend on their shared preferences (for instance, we could propose a communication between Qiang and Jean-Paul about the PDF2 in a next step). On the other hand, from the outcomes of the filtered collaborative traces, it is not difficult to note the affinities (the service state) between group knowledge and group experience. From the group experience, we can reconsider whether our knowledge is fully used or not. For instance: PDF1 (Introduction aux Probablités) is less used than the others. Every member can distinctly know his contributions to the group and also know the needs of other members during a certain period.

- **Case 2**

  In this scenario[5], the collaborative group is formed by four members: Qiang, Étienne, Marie-Hélène and Jean-Paul, formally, $g_2 = \{u_1, u_5, u_3, u_4\}$. They cooperate in a project called "Trace". The group has two subgroups: one has two members: Marie-Hélène and Jean-Paul; the other one has two other members: Qiang and Étienne. It is clear to see the group relation in Figure 6.10.

  For the case: "Resources", (i) the "Emitter" (E_i) is any member in the group who shared a file that concerns the concepts in the knowledge map; (ii) "Receiver (D_j)" is the whole group (g_2), e.g. every member can view and check the shared documents in the group workspace; (ii) The property (p_3) is "the shared files" in the group workspace. Besides, for the values, one (v_5) is the situation of shared files (the file name and quantity) and another (v_6) is the frequency/times of the service situation for each file.

  As shown in Figure 6.11, the upper chart demonstrates the quantity of each type file that has been shared in group workspace during three month (same as the case "Concepts": from 01/9/2012 to 01/12/2012). The user can select the different collaborative group which he belongs to. We can see that a total of seven files is shared in the group workspace. Besides, every member's contribution is clear, e.g.,

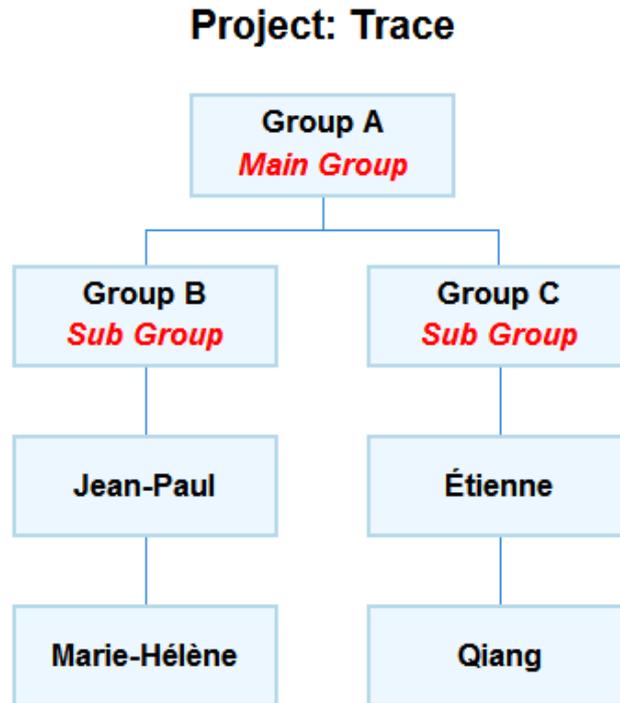---

[5]The E-MEMORAe2.0 Flash Version

Figure 6.10: The Group Formation (project "Trace").

Qiang shared most of the files (three). The lower figure presents the state of service for the shared files that is associated with the concepts in the group's knowledge map. The "frequency" signifies the number of times the file has been opened ("open this file"). For three of the files ("CT Definition", "CWE" and "Trace"), it is obvious to see that all group members had a lack of interest and have never opened these files. However, the group pays more attention to the file "CT Exploitation" that was shared by the member Qiang. In this case, the complex filter (ζ_1) is used to help observe, compare and analyze the group's preference and members' contributions in collaborative workspace.

As a consequence of the filtered CTs, some potential collaborative relations that tightly rely on their "preferences" and "contributions" will be recommended within group members, for example: the group members collaborate with the subject of "CT Exploitation". Furthermore, the competence or knowledge background within group members can be identified with more complex filters, e.g. from the similarity of the shared files. It is helpful to allocate the tasks or replace a member in some particular situations. For instance if we are missing an expert in a group, we could propose another expert for this task. Without a doubt, the group's knowledge is enriched by these shared files and the ontology in the group workspace. Using the filtered CTs, we could understand the service state of the shared knowledge, e.g.

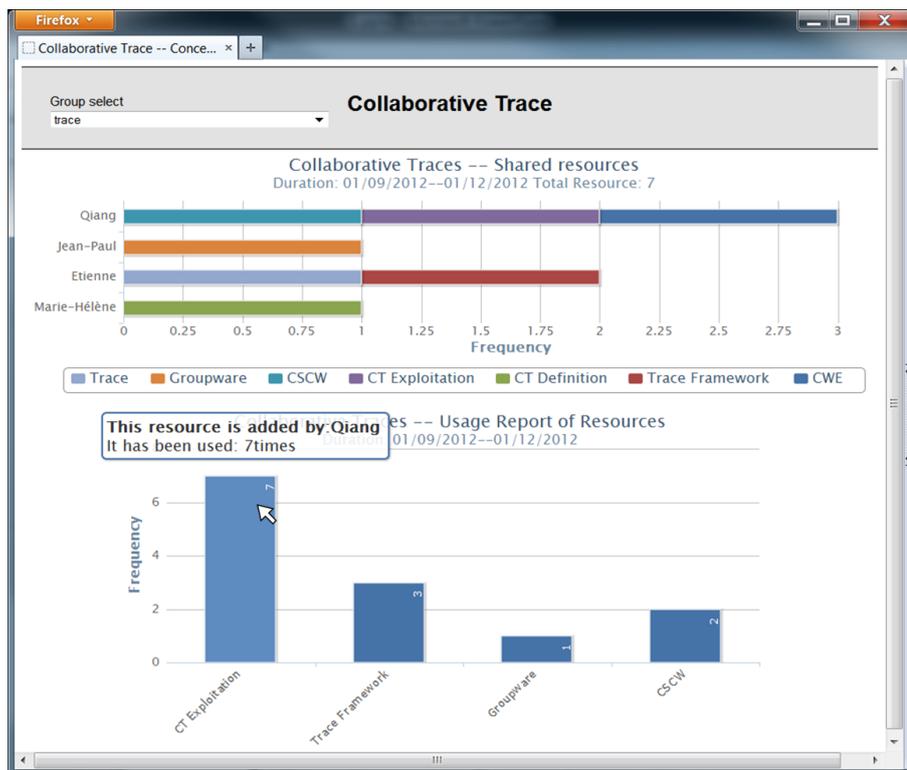the level of knowledge usage and the type of knowledge requested in the group.

Figure 6.11: An example of Collaborative Trace (project "Trace").

In Chapter 4, we explained that three types of traces can be distinguished from different situations of "Emitter" and "Receiver". Respectively, they are "Collaborative Trace", "Collective Trace" and "Private Trace". The above test is about the group collaborative traces. For the private trace, the times of login times were collected. As shown in Figure 6.12, this user can view his personal usage of this platform, e.g., 26 login times on 2012-11-01. This user may not be the administrator but he can know his general activity on this platform (e.g., the active degree).

6.3.2   Exploiting CTs to Support SWOT Analysis

In general, SWOT Analysis is a kind of strategic tool that focus on the various internal (Strengths and Weaknesses) and external factors (Opportunities and Threats) that may affect the group's final decisions or future plans. A SWOT Analysis is usually generated from answering a series questions for a given specific objectify. As we explained in Section 5.3.1, this process is formed by two levels: (i) the retrieval of IEs from the Data Base and the set of traces; (ii) the implementation and formating the IEs into a SWOT Matrix. For our practical test, we just introduce a simple example because of some features and challenges of CTs based approaches, such as cold starting. The SWOT
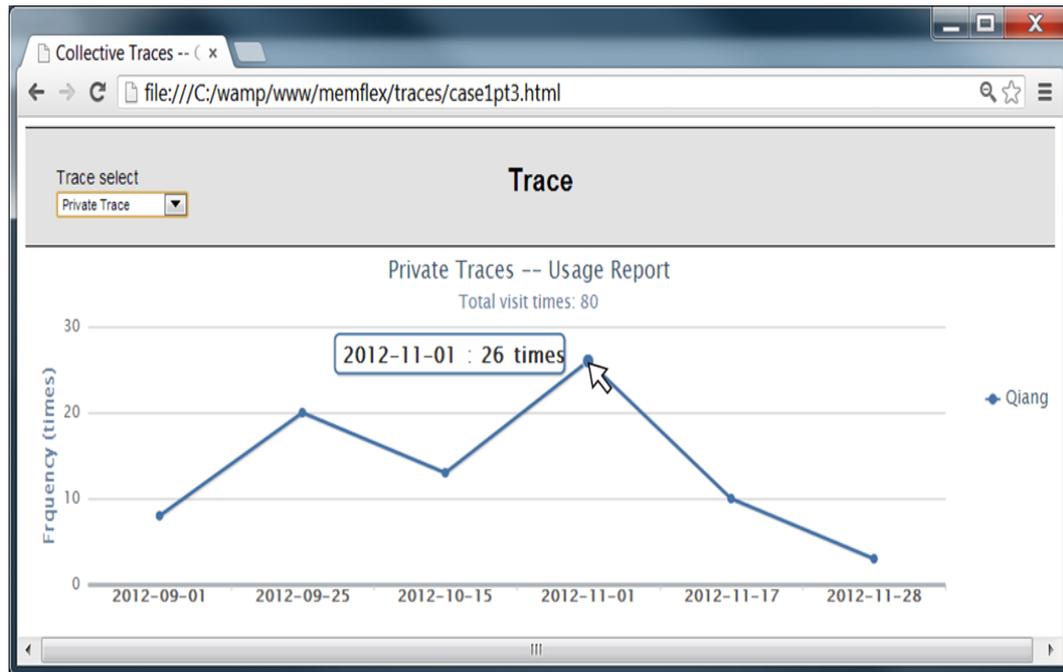
Figure 6.12: An example of Private Trace (project "Trace").

Analysis is to evaluate the group members' competences for a new related sub project: Trace Exploitation. It contains several basic tasks, for example: build a knowledge map for this topic or share some files for the related concepts. The group is formed by four members that are same as the above case2. First, we use online survey and questionnaire tool to specify the target, i.e., to start a new project: Trace Exploitation. The Data Base and the set of traces are based on the project "Trace". Once the group (or the team leader) completes these questions and chooses the SWOT Factors (several indexes, e.g., resources or experts), we could build a few complex filters to extract a specific set of IEs that would be used for generate a SWOT Matrix.

As shown in Figure 6.13, we need two members for the project "Trace Exploitation". Based on our previous project "Trace", we know that there are four members (Figure 6.11) and seven resources (Figure 6.12). Two members (Qiang and Étienne) shared some files ("CT Exploitation" and "Trace") that relate to the "keywords" of our SWOT Analysis object ("Trace" and "Exploitation"). Compare to other members, they have more competences for this new issue. Naturally, they would be ideal candidates for our new project. Moreover, this can be considered as one of our strengths since we have enough experts.

The above simple test is mainly about the factor "strengths". The other factors can be extract from their CTs (e.g., the exchanged messages or shared resources) and Data Base (e.g., personal information such as name or age). Actually, any CTs based SWOT Analysis requires domain ontologies (i.e., SWOT Factors' indexes) and clear object description

Figure 6.13: An example of SWOT Analysis Factor (the project "Trace Exploitation").

(e.g., start a new project or a complex task). Besides, the group can add some special indexes that would be independent of IEs from the CTs or Data Base, e.g., Innovations or Creations that are stimulated from the group brainstorming.

In E-MEMORAe2.0, through the application of the collaborative trace, the collaborative working experiences are modeled and exploited to enrich the group experiences. These applications can also be used to other ends, like in another application supporting the organizational Content Management (Deparis 2011b) and the Tendering process (in railway transport) (Penciuc 2011b, Penciuc 2011a). Actually, in the Tendering process, different teams collaborate for finding and recommending the best solution to their customers. For example: one situation that collaboration occurs during Tendering is the analysis of customer RFP (Request For Proposal) documents. To face such challenges, the collaborative trace model and the exploitation framework could be an efficient solution, for instance: short time, distributed teams, or making the right decisions. Furthermore, our model and framework can be expanded and easily ported, for instance: in an agent-based CWE, filters can be implemented and designed as various agents.

6.4   Conclusion

In this chapter, we presented two practical cases that are based on the CTs exploitation framework on the collaborative platform E-MEMORAe2.0: traces display and SWOT

Analysis. For the first case, we performed two tests that each contained four users with different group structure and belonged to different project. The results we obtained are encouraging users have recognized the contribution of such a tool in the analysis of their collaborative and private activities in the certain workspace, i.e., the private and the group shared workspace. The examined subjects contained the shared files and the concepts in the knowledge map. For the second case, we performed a very simple test that relied on the CTs of our previous project.

These practical tests allow us to see the possible traces based tools/applications with respect to the improvements for facilitating collaboration in CWE: e.g., we collaborated with whom and what kind of knowledge we used. Some of these improvements have been previously identified but some others have not been implemented since we are lack of rich data and traces. We should perform additional testings in different collaboration scenarios from the frequent collaborative interactions between group members. Furthermore, it would be particularly interesting to build and design other applications that are based on our proposed CTs exploitation framework (e.g., CTs based group recommendation) and to test these tools in more practical scenarios to get more feedbacks.

CHAPTER 7

Conclusions, Contributions and Perspectives

Contents

7.1 Conclusions and Contributions

This thesis is part of the wider context of trace research in a Collaborative Working Environment (CWE). The objective of this thesis was to define, model and exploit the various traces in CWE, in particular Collaborative Traces (CTs) left in the shared/collaborative workspace.

Collaboration is the action of working jointly with someone to produce something. For humans, we could not live without collaboration since it is one of the most important and basic collective relations in human societies. As a kind of survival skill, people always need to collaborate for accomplishing complex projects or difficult tasks in the real world as well as in the virtual world. In fact, Collaboration is greatly affected by the tool that the collaborators may use, the group that maintains collaborative relations and the environment/space where they can work together.

With the fast development of Internet (e.g., wireless techniques) and the quick popularity of smart-devices, collaboration becomes much more flexible and effortless, for example: people can work together using various devices (e.g. tablets, laptops, smart phones, or PCs) with less restriction of time, language, or geographical position. In a Web-based Collaborative Working Environment (CWE), traces are always produced by activities or interactions and can be recorded. The modeled traces not only represent knowledge but also experience concerning the interactive actions among the actors or between an actor and the system. With the increasing complexity of group structure and frequent collaboration needs, the existing interactions become more difficult to grasp and to analyze. In

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a CWE, actually, the different types of traces can be divided into four categories: Private Trace, Collaborative Trace, Collective Trace and Personal Trace. The past collaborative activities in the group shared/collaborative workspace could be recorded and represented by collaborative traces.

In this thesis, from analyzing different types of traces and collaboration group structure in CWE, we proposed a definition of Collaborative Trace and built a corresponding model. This model is meant to analyze users' private interactions but also to pay more attention to the relationships among members who had previous collaborative activities. In fact, when group members work together for a common objective, their connections deserve to be studied more carefully. Additionally, we proposed a CTs based exploitation framework that can be applied in different collaborative applications to support group work, for instances: project planning, information sharing and so on. Three CTs based approaches/applications were introduced: SWOT Analysis, CMMI and Group Recommendations. The primary part of this framework is to build a series of Complex Filters to retrieve a particular set of CTs. Generally, the complex filter is not simple to define but with some rules from our collaborative goal and the application formalism, it should require less efforts and be more comprehensive in practice. Furthermore, in order to verify and to examine the model and the framework, some typical tests based on the E-MEMORAe2.0 platform were introduced and compared with practical cases: traces display and SWOT Analysis.

The CT model and the exploitation framework were introduced to meet several critical research issues both in Experience Management and CWE which can be summarized as four key points:

- *Store and organize users' a posteriori interactions as traces.* Such traces are based on information and knowledge. They represent a kind of experience from their interactions being indexed by time or by some other index. Naturally, from the most basic functions of Web-based CWE, information and knowledge sharing and communication can be supported by the modeled traces;

- *Share working experiences with the group*: with the modeled and filtered collaborative traces, the flow of experience circulates from collaborating actions with time variation. Without doubt, "sharing" is the fundamental features of collaboration, thus the group can take advantage of these modeled traces. Moreover, with the complex filters, the user and the group can identify and look back at their interactive activities for their practical needs (traces display). The influence from the group model and structure on the collaborative trace can be reduced by some proper filters;

- *Facilitate the exploitation of traces*: normally, it plays a role like an assistant in CWE that involves techniques from various domains: e.g., artificial intelligence or

information science. The traces based approach/application depends on certain types of traces and filters, for example: personal usage analysis (private traces) or group collaboration analysis (collaborative traces);

- *Support information retrieval process*: i.e., more potential or implicit collaboration information can be collected by complex filters. As a series of Information Elements (IEs), the extracted traces can assist group collaboration in various aspects, as well as SWOT Analysis, other tools, such as group recommendation or CMMI can also benefit from the trace-based exploitation process.

There are some remarks for all the CT-based approaches: i) cold start: requires a large amount of traces, i.e., frequent use of the corresponding CWE; ii) group oriented: almost every element of group will affect the exploitation process in different degrees: e.g., group size or structure; iii) fallibleness for the new and independent issue, i.e., CTs strongly depend on our previous collaborative activities. In practice, the more traces we can store and model, the more difficult our exploitations will be. In implementing this process, we must take a particular care of the user interface.

7.2 Perspectives

A number of perspectives, in our opinion, represent a natural continuation of this work. We dedicate this section for a description of different aspects of such perspectives.

- Our proposed approach can apply not only to Collaborative Working Environment but also to other collaboration systems, e.g., collaborative learning platforms. For the trace formal definition, the relations between "Emitters" and "Receivers" will always be the same as in CWE. However, the "Properties" and the "Values" may change according to certain characteristics of this collaborative system. And the main difficulty/challenge is to design a particular set of complex filters for the user or the group. Meanwhile, both techniques and strategies from various domains would be required in different processes (e.g., the collection or the transformation of traces), such as Artificial Intelligence (e.g., Web Data Mining strategies for collection or analysis), Linguistics (e.g., Natural Language Processing for transformation or implementation) or Semantic Web (e.g., Resource Description Framework for collection), since the more traces we can collect, the more complex our implementation and exploitation process will be;

- In our practical tests, we principally focused on the "Concepts" and "Resources" ("Properties") on the collaborative platform E-MEMORAe2.0. This is the core part of their collaborative activities but not the only one. Other activities from

their communications or coordinations would also be helpful and valuable: e.g., the group discussion issues/topics may imply/involve some potential information about the external opportunities or threats. Definitely, it is not necessary to record every past action of the actor in the system but the chosen ones should be strongly related to the purpose of traces exploitation. For example, for Group Recommendation, the CTs of group preferences are very important because that is the basis of prediction. Nevertheless, for SWOT Analysis, the CTs of group communications may be more important and more suitable.

- Other kinds of trace-based applications or tools should be considered in CWE, e.g., personal trace-based knowledge management tools. In this thesis, we analyzed different types of traces in CWE and concentrated on "Collaborative Trace." As a matter of fact, collective traces and private traces should be given more attentions, especially, in the exploitation process. As we mentioned above, any trace-based applications/tools will be confronted to the "cold star" challenge. We need to be patient and to examine more scenarios and different kinds of trace-based applications in the long term. Besides, our proposed CT definition revealed a kind of social relationship/connection (i.e., "collaboration") that will be a significant reference for other research areas: such as social networking or online game systems.

Publications

Journal

Q. Li, M.-H. Abel and J.-P. A. Barthès. *Modeling and exploiting collaborative traces in web-based collaborative working environment.* Computers in Human Behavior, vol. Accepted, page In Press., 2013

Lecture Notes

Q. Li, M.-H. Abel and J.-P. A. Barthès. *Exploiting and reusing Collaborative Traces to facilitate sharing experiences in groups.* series Communications in Computer and Information Science, vol. Revised Selected Papers in IC3K 2012, page In Press., 2013

Q. Li, M.-H. Abel and J.-P. A. Barthès. *Facilitating Collaboration and Information Retrieval: Collaborative Traces Based SWOT Analysis and Implications.* series Studies in Computational Intelligence, vol. Accepted, page In Press., 2013

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