

An Activity Theory Evaluation of a User Interface for a Web-based Virtual Research Environment (VRE)

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Declaration

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Abstract

Activity Theory is a framework or descriptive tool which is commonly used in Human-computer Interaction. In particular, it is used more and more in the design and evaluation of some collaborative systems such as a modular object-oriented dynamic learning environment.

Activity Theory offers many advantages to interface design for interactive systems when compared with the traditional cognitive psychology approach. This is because the traditional cognitive method cannot penetrate the human side. Therefore, the thorough analysis of human activities in Activity Theory makes it an effective and efficient method for evaluation and design of a system.

There is currently some ongoing research work on the design or evaluation of interactive systems, in particular commercial information systems. However, none of them are about online virtual research environments.

Therefore, this project aims to evaluate the interface of an online virtual research environment called CRADLE using Activity Theory. We will conduct a humanities study in this project, which seeks to find contradictions between the current interface and user expectations, which will in turn be used to design the next generation of CRADLE. In order to find a better way to represent the human community in CRADLE's digital humanities context, we proposed two candidate proposals and refined them based on participants feedback.

Key Words: Activity Theory; Usability Testing; Interface Design; Virtual Research Environment (VRE).

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Chapter 1 Introduction

1.1 Project Background and Significance

Activity Theory is a framework often used in interaction design and collaborative system evaluation. Currently, some research work has been carried out on both design and evaluation of information systems and it has proved to be quite effective when compared with the traditional cognitive methodology. However, none of the research is about online virtual research environment (VRE). Therefore, this project aims to evaluate an online research software called CRADLE using an analytical framework - Activity Theory. We aim to find contradictions between current interface and users' real needs through a humanities study. Meanwhile, we will propose some ideas on interface updates (human community representation) and also evaluate them in the study, asking for suggestions from real users before further refinement. This project is significant because it provides a new interface with emphasis on human activities. The new design will match more with users' real needs and thus, save time and money before the implementation of next generation of CRADLE. In addition, this project will also validate the usefulness of Activity Theory on the evaluation and design of an online virtual research environment like CRALDE.

1.2 Humanities Scholarship

Humanities Scholarship is concerned with the study of human culture including languages and literature, the arts, history, and philosophy from a multitude of perspectives.

Scholars typically focus on both critical and speculative investigation, interpretation of historical or modern cultural artifacts, for example, historical texts, literary works (prose, poetry, drama), and artistic works (painting, music, performance).

Central to humanities subjects utilizing comparative methods (unlike experimental methods typical in natural sciences) is the use of historical sources, which often require identification and authentication, curation and preservation, archiving and cataloging and translation, and more recently digitization.

Furthermore, scholars engage in scholarly discourse on all aspects of the methods outlined above, and it is normal that contested research deriving from theories, investigations and analyses of single sources co-exist.

CRADLE was developed using Activity Theory to model scholarly activity, and focused on human engagement with source material, utilizing resources for research purposes, and collaborating and debating using vis discourse tools.

1.3 Software User Experience (UX)

According to ISO 9241-210 [1] standard, user experience is a person's perceptions and responses that result from the use or anticipated use of a product, system or service. Therefore, user experience cares about the emotional feelings of users towards the software product. According to [2], there are three main components that constitute user experience:

- User is involved: if the user is not doing something with an interface, there is no experience, for example, we simply show pictures of a software interface to users and ask for their advice. In this context, we just might measure attitudes or opinions.
- The user must interact with software or any system that has an interface. User experience must be measured on an interface where user interaction happens. The interface is the bridge which links users and a software system.
- The experience of the user on that interface can be observed or measured.

A conceptual framework [3] which includes four distinct elements provides a better understanding of user experience particular clarifying its objectives, scope and measurement (figure 1).



Figure 1 Four elements of user experience

- Usability – Is it easy to complete tasks?

As mentioned, usability has a much narrower scope than user experience, in this framework, usability acts only as a subset which cares about how easy it is for users to complete a task.

- Value – Does a product provide value to users?

Usability is not the only important aspect of user experience design. There are a lot of products which have good usability but do not succeed in the market because they failed to bring value to users. The key of achieving high value to users is to meet their real needs. If a product's features are designed in a way that supports user needs, users will consider it to be valuable.

- Adoptability – Will people start using the product?

Adoptability describes if it is easy for users to buy, download, install and start using the product. Sometimes users have problems downloading or installing software even though the software is valuable and has a high level of usability.

- Desirability – Is the experience fun and engaging ?

The previous three elements of user experience focus much on cognitive and rational

aspects, while desirability focuses more on emotion. Some products like traditional MP3 player are easy to use and valuable, but they are not successful like iPod because they are not engaging enough.

1.4 Activity Theory & software dependability

According to Roy Maxion, from MIT's Dependable Systems Laboratory, User Interfaces are the "critical coupling" between humans and computers, and undependable user interfaces, therefore, are considered to be a major obstacle to achieving "overall system dependability" [4]. Even when underlying hardware and software are found to be reliable, errors arising from user interface (UI) usage can cripple, or destroy system activities. The goal of research into user interfaces and dependability, by Maxion and others, is the mitigation of UI errors through careful design of predictable dependable systems, and to provide measurable confidence of the dependability of user interfaces [5]. Current research includes investigation into what kinds of human error and limitations of humans result in making user interfaces undependable, together with work on robust evaluation methodologies, task and user modeling, design and testing of dependable interfaces, fault tolerance and reliability, etc [4]. These include the use of both empirical and experimental methods.

Recently, there have been reports on the use of techniques such as "sub-anchor-based goaling" [7] and "hesitation analysis" [8], specifically for dependability analyses of user interfaces. Typically this research is conducted with small user samples, often analysing an existing interface for errors, and comparing user reaction and error mitigation when using an improved prototype. For example, Maxion and Reeder (2005) found when analysing human error, when using two different pieces of security software, that improved representation of information in the user interface increased performance by 300%, and reduced error by 94% [8].

This project's research, while not conducting a dependability analysis specifically, is also concerned with the representation of information in the user interface of a system (CRADLE) used by humanities' scholars interested in the management of digitized cultural objects. Specifically, we are interested in User Experience (UX) issues, and how they contribute to frustration and misunderstanding of digital objects, their network representation, and ultimately how this leads to usage errors. Our research is concerned,

therefore, with error mitigation arising from poor user experiences, and is directly related to dependable systems research. Our methodology, described later in this thesis, is similar to those described earlier, in that it investigated human usage (using Activity Theory) of the existing interface, and two prototype alternative interfaces (using different information representation systems) with a small user sample. The users' experience was determined by performing a contradiction analysis (from Activity Theory) on the collected data, and a final (third) prototype was developed and analyzed by a user with a view to reporting on the system's dependability.

The use of Activity Theory (AT) has been commonplace within the area of HCI for many years, but an examination of the research literature shows that it has also been utilized in the area of dependability evaluation of IT systems. For example, Sujan et al. (2000), following their research of industrial case studies, criticize dependability evaluation techniques for the assessment of human reliability when using IT systems because many: (i) do not employ sound psychological bases, (ii) restrict user actions, and (iii) often disregard organizational and communication aspects. They argue that an activity theoretic framework may be used as a psychological basis for the modeling of complex systems as it facilitates the unified study of complex interacting elements previously studied in isolation.

More recently, Siti et al (2012) successfully used AT to guide online collaborative learning instructional design. They used AT to provide a descriptive framework to elaborate the process of the various components involved in an online collaborative knowledge building activity. Their study combined both quantitative and qualitative method to collect data from survey, system usage logs and collaborative messages posted in a customized Learning Management System (LMS).

1.5 Project Objectives

There are two primary objectives of this project:

1. Use Activity Theory as the framework for software evaluation together with user experience testing.
2. Present a design and improvement for a new interface which incorporates user and

community presence before the implementation of the next version of CRADLE software.

There are also six key deliverables for this project:

1. Activity Theory analysis of existing CRADLE software (from theory and analysis).
2. Activity Theory model of new feature proposal (from theory and analysis).
3. User study of suitability for humanities scholarship activities (from usability testing workshop).
4. Two candidate proposals for user interface update (proposal A – document focus; proposal B – human focus), representation using html webpage.
5. User study on proposal evaluation and refinement (Human representation and interaction in CRADLE).
6. Thesis and reports on studies.

1.6 Technical Challenges

1. The first challenge is to do with learning Activity Theory and applying it to CRADLE's special context. Currently, the concepts of Activity Theory are still abstract, and need to more clearly defined and operationalized so that researchers can understand how the theory should be applied in concrete cases. CRADLE has a concrete and unique context, which makes it difficult to apply Activity Theory.
2. Conducting User Experience (UX) research is technically challenging, as it requires considerable knowledge in many different areas ranging from psychology to software design. Furthermore, the identification of suitable methodologies that provide meaningful measures of UX is also difficult as it often incorporates "trial-and-error" approaches. There was limited time available for this project, so the challenge was to chose methods carefully and apply them appropriately.
3. Collaborative research has become more and more common due to the rapid development of Human Interaction Design. Scholars are doing research in an

engaging, motivating and collaborative way. Since the online virtual research tool is shaping new forms of learning and research, there is a great need to understand the user experience of VRE. This is challenging due to the lack of canonical UX methodology for VRE.

4. Another challenge is to use Activity Theory to analyze the qualitative data collected from the humanities study. We have to extract useful data from interviews, questionnaires and talks to find the users' real requirements of this software. This will allow us to find the contradictions between the current interface and user expectations and also identify the contradictions between activity system nodes.
5. It is also challenging to represent the human community that users like. We proposed two candidate designs and sought feedback from users. We apply Activity Theory again to identify the contradictions on both designs based on users' feedback so that we can refine the design until users are satisfied. This is a very time-consuming process due to the fact that we have to probe users' thoughts by asking targeted questions.
6. One of the more difficult challenges relates to the study sample size. It takes a lot of time to organize the collection and analysis of HCI-related data, especially for pre-study, study and post-study interviews, etc. It was necessary, therefore, to work with a small sample in order to work through all phases of the AT UX evaluation. This necessitated, for example, only analysing one user's evaluation of the final prototype. A further challenge was extrapolating meaning from a small sample. We found that the process worked, however, and determined that it would be possible to repeat all of the study steps with other sample groups quite easily.

Chapter 2 Overview of Activity Theory

In this chapter we will talk specifically about Activity Theory including its conception, evolution, famous models, principles and how the elements relate to each other in the system. Then we will talk about how Activity Theory is useful for Human Interaction Design and User Experience Design purposes.

2.1 Activity Theory Introduction

Activity Theory is a conceptual framework coming from socio-cultural tradition in Russian psychology. The foundational concept of the framework is “activity”, which is understood as purposeful, transformative, and develops interactions between actors (“subjects”) and the world (“objects”) [11]. The framework was originally developed by the Russian psychologist Aleksei Leontiev (Leontiev 1978; Leontiev 1981).

2.1.1 Activity Theory Principles

There are four basic principles in Activity Theory identified by Kaptelinin and Nardi (2006) [12], building on Wertsch (1981).

- 1) **Object-orientedness:** The nature of activity itself is a relationship of “subject-object” which originates this concept. The world is structured with objects. The subject’s interaction with the world is also structured. The principle of object-orientedness states that all human activities are directed toward their objects and are unique to each other by respective objects. Activities are motivated and directed by objects, therefore, it is very important to analyze objects in order to understand human activities no matter if it is individual or collective.
- 2) **Hierarchical structure of activity:** According to Leontiev, human activities could be specified into three hierarchical layers (figure 2). The first layer is activity itself which has a motive to be achieved by the subject. For example, taking an exam is an activity which aims to get credits for a particular module. Taking an exam itself is a big activity, which can be decomposed into several actions. ‘Action’ is on the second layer of this hierarchical system and it is a conscious process driven by goals. For

example, students may study previous exam papers, have discussions with teachers and other students, finish the exam paper, etc. to complete the activity of taking an exam. In addition to this, an action could be decomposed further into a set of operations when the conditions are satisfied. Operations are initially conscious actions and they will be collapsed into operations which are sub-conscious and automatically performed when the action has been practiced a lot. An operation may return back to the level of action when conditions change.

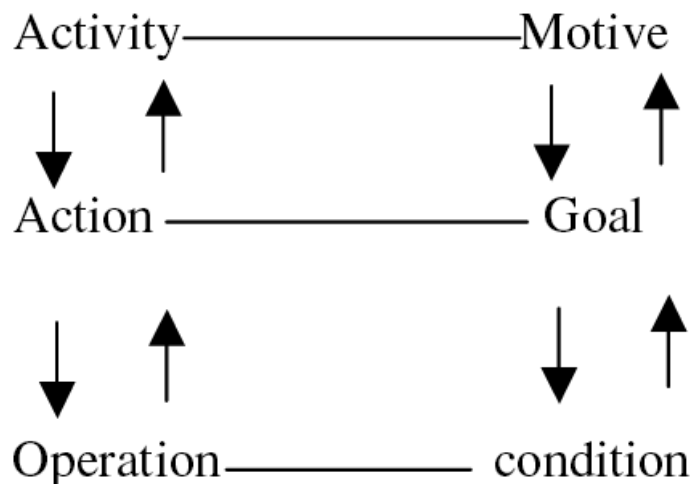


Figure 2 Hierarchical Structure of Activity

- 3) **Mediation:** Human activities distinguish from animals by mediation because their activities are naturally mediated by various types of tools to shape external behavior and also influence mental process. The maps of a city for a car driver and ordinary people will be different because of the tool mediation (car). In ancient society, human's activities are more mediated by simple tools such as hammer, fire and warm clothe. Now with the development of technology, humans are more and more mediated by electronic devices such as computers, mobile phones, cars etc.
- 4) **Internalization and Externalization:** This principle means human activities are distributed by containing both internal and external parts. In Vygotsky's framework, internalization mainly refers to mental development and both internal and external components in activity are becoming increasingly intertwined.

2.1.2 Activity Theory Evolution

Activity Theory has evolved a lot since it was proposed. The most original generation of Activity Theory model is based on the work of Leontiev, Vygotsky and Luria [13][14][15](Figure 3). The two most basic components in the model are subject and object. The relationship between the subject and object is mediated by some tools. This relationship is one of the basic principles as we have stated before.

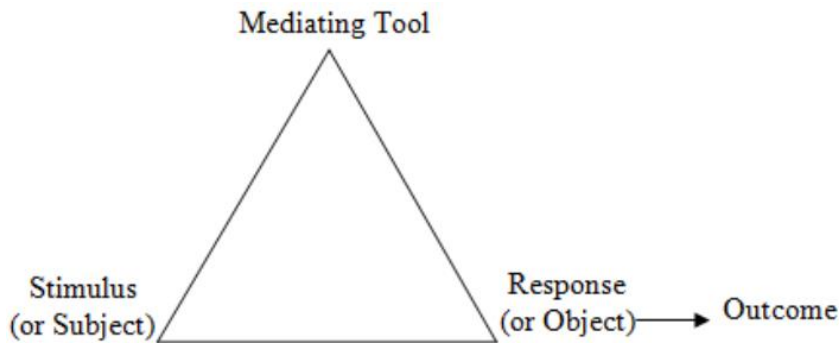


Figure 3 first generation of Activity Theory model

However, this model cannot represent a collection of activities in a community [16]. Therefore, illustrated by Leontiev's work, Engestrom proposed a more specific model (figure 4) which can represent collective human activities using three steps. Firstly, a node called "community" is added to get a structure which has three-way interaction between the subject, object and community. Secondly, all the interactions existing in this structure are mediated by some meditational means. According to Engestrom [16], there are three types of concrete meditational means for these interactions: 1) tools or instruments of the "subject-object" interaction. 2) rules for the "subject-community" interaction. 3) division of labor for the "community-object" interaction. This model also includes the outcome of the activity system which is result of the activity and also a resource for other activity systems.

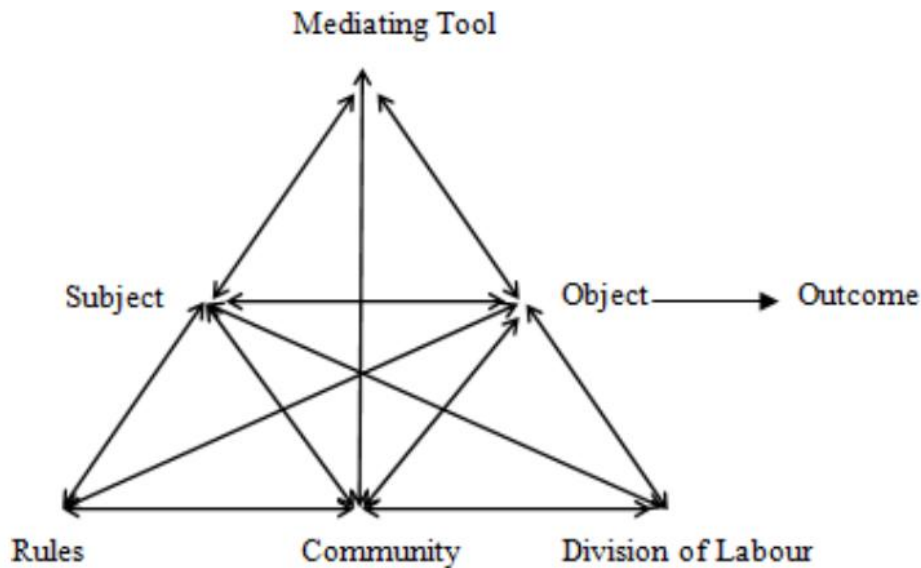


Figure 4 Engeström's model of Activity Theory

2.2 Activity Theory & Human Computer Interaction

Activity Theory is derived from human activities. Our society is a kind of community made of individual humans who perform various activities every day. Activity is a central concept of interactive technology and also one of the most fundamental concepts in Human Computer Interaction (HCI) research. Traditional HCI has cognitive science as the theoretical basis which mostly focuses on the concrete problem of understanding and supporting cognitive processes distributed between people and artefacts [17](Rogers, 2004). Cognitive science is limited to find why a person performs a task and what the task means to them. This is very important for the research of interaction design, especially since modern society is becoming more and more interactive and complex. Therefore, we need another theory which can focus on the analysis of human activities, in particular their motivations, meanings, cultural, social or historical contexts, etc.

Activity Theory is a framework which could fill the gap of cognitive science. It is a framework founded by “activity” and specifies how subjects deal with objects to achieve an outcome by mediating tools, in a community full of rules and division of labor. Activity Theory focuses on some aspects that cognitive science and phenomenology don't emphasize much, such as practice, human consciousness and tool mediation.

Since Activity Theory is capable of addressing current research limitations of HCI, it has

been increasingly used in HCI since the early 1990s. Now Activity Theory, along with cognitive science and phenomenology, has been the leading research framework in HCI and interaction design. Carroll 2011 [18] observes that: “Information processing psychology and laboratory user studies, once the kernel of HCI research, became important, but niche areas. The most canonical theory-base in HCI now is socio-cultural, Activity Theory.”

Activity Theory impacts on HCI, Interaction Design and also User Experience as shown in the following points.

- Activity Theory treats computers as mediating artefacts instead of an activity object, which means that people are interacting with the world through computers, instead of interacting with the computer itself [19].
- Activity Theory decomposes an activity into three hierarchical layers with specific goals or motives on each level. It extends the scope of analysis beyond low-level interaction in HCI and this extension.
- Activity Theory emphasizes the social, historical and cultural contexts where activities are performed [20]. As mentioned earlier, this is the area where current HCI research is missing.
- Activity Theory can be used as the framework for both design and evaluation of interactive systems and now various analytical tools have been proposed to perform this task [21].
- Activity Theory thrives to the implementation of activity-centric computing. Activity-centric systems have some advantages over traditional human-centered systems as proved in some evaluation studies and Activity Theory has positively impact its development during the past decades.
- Activity Theory promises to be good at understanding user experience. According to paper [31], Activity Theory can bring a structure to analyze qualitative data of UX and it helps understand the context under which UX unfolds and prioritizes usability problems based on their impacts on UX.

In conclusion, Activity Theory has established its role as both a design and evaluation

framework in HCI research area. Figure 5 shows the relative popularity of Activity Theory compared with other theoretical approaches like cognitive science and phenomenology which are used in HCI and interaction design. We can see Activity Theory is more combined with HCI research than other approaches. This proves the critical role that Activity Theory is playing in HCI and interaction design. However, Activity Theory is not a panacea. It still needs further development. We will talk about the current weaknesses of Activity Theory later in this report.

Search string	Number of hits	Search string	Number of hits
phenomenology	1,552	phenomenology & HCI	251
"activity theory"	1,496	"activity theory" & HCI	512
"distributed cognition"	1,102	"distributed cognition" & HCI	383
ethnomethodology	621	ethnomethodology & HCI	269
"situated action"	551	"situated action" & HCI	209
"language action"	448	"language action" & HCI	66
"actor network theory"	374	"actor network theory" & HCI	43
"external cognition"	141	"external cognition" & HCI	60

Figure 5 Number of hits in ACM Digital Library for the name of some theoretical approaches searched, January 2nd, 2012

2.3 Summary

In this chapter, we mainly talk about what activity theory is and its application in Human Interaction Design and User Experience Evaluation. Since Activity Theory works well on interactive systems, we are also going to use it for the analysis of an online collaborative system – CRADLE. We will introduce this software in the next chapter.

Chapter 3 Introduction of CRADLE

CRADLE (collaborate, research, archive, discuss, learn, engage) is a virtual research environment, developed at Maynooth University by Dr. John Keating and his colleagues over the past number of years. The project was initially funded by Maynooth University, and later from an IRCHSS & INTEL co-funded project entitled "Delivering a Universal Learning Environment for Digital Humanities Education"(2009-10.€40,656. JG Keating et. al). The software has been the subject of several articles, and presentations.

CRADLE is founded on Scandinavian Activity Theory principles, which describe collaborative objective fulfillment by researchers and learners having distinctive roles, division of labor and community rules. Specifically, it allows users to ingest source material (for example, annotation and mining tools), and facilitate discourse by way of attachment to sources, and other discourses.

CRADLE software was originally designed with the following objectives.

- Reaction to the need to re-focus on resources that support “traditional” scholarly activity, utilizing the publicly funded creation of digital surrogates.
- To not only “manage”, but also to “use” our digital cultural heritage.
- The objective of the research was to create a research & teaching-oriented environment to support scholarly “activity” rather than just “hosting”.
- Two FP7 objectives align with the philosophy of CRADLE:
 1. Technologies for creating personalized & engaging digital cultural experiences.
 2. Open & extendable platforms for building services that support use of cultural resources for research & education.

3.1 Functionality analysis

CRADLE is designed as a general software solution to support the engagement of users

with the multi-modal humanities Source, Discourse and Learning Resources, in a range of research and teaching activities. It allows users to interact with cultural heritage collections in a virtual environment that links cultural objects with learning resources and associated group discussions. CRADLE has a repository called FEDORA which is used to store all supported data (text, image, video etc.). Generally speaking, CRADLE has the following specific functionalities:

1. All digital object resources are managed within collections. A collection has more than one document. Users can search one collection by keyword (figure 6). The left side will show the documents included in the collection and the right side will show its detailed information.

Figure 6 Digital object search

2. Each digital object can be viewed within its relationships, with its metadata, with discussions attached to it, or with learning resources (figure 7).

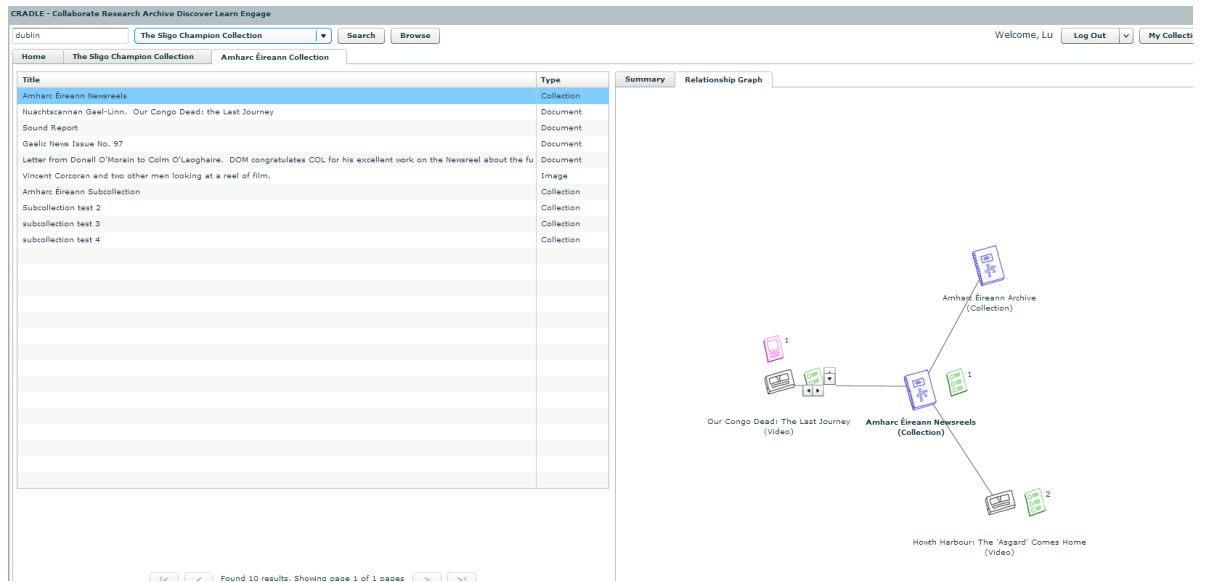
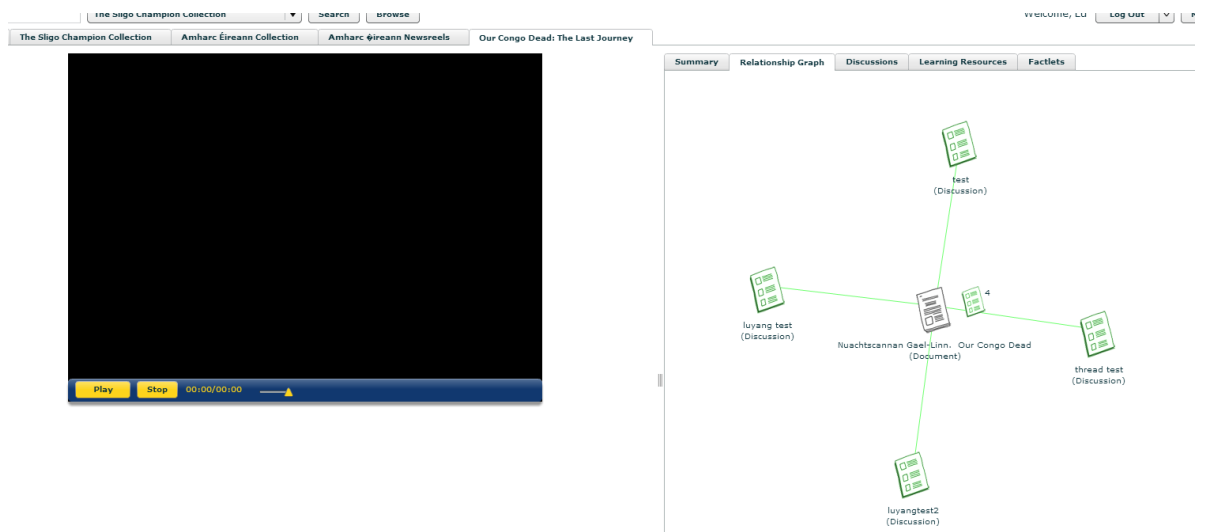


Figure 7 Digital object relationship graph

- Users can create a new discussion based on a document they want to discuss and CRADLE will generate relationship graph for that document and its discussions (figure 8).



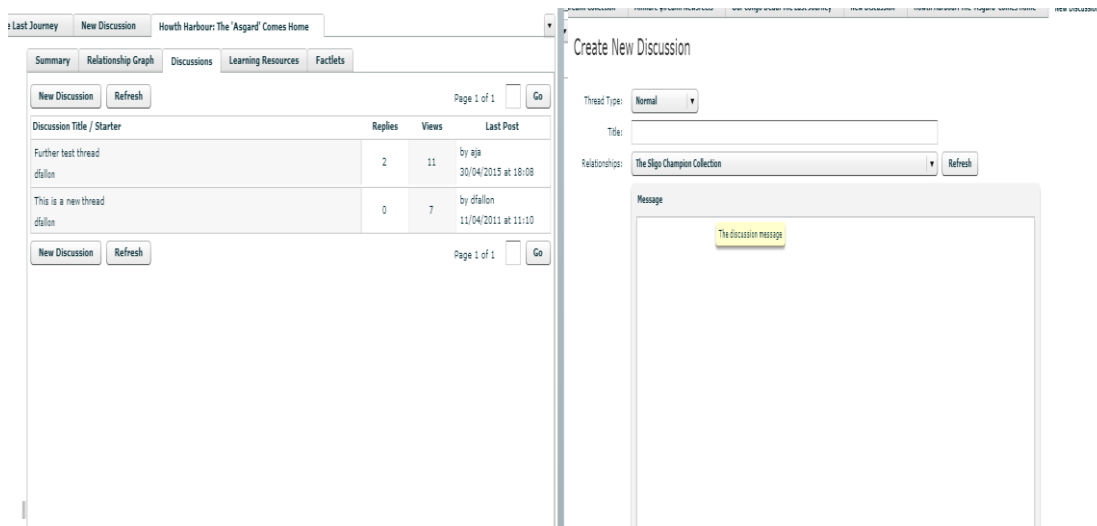


Figure 8 CRADLE discussion on a document

- Users can add learning resources to a digital object they are viewing, CRADLE supports video and images, but as of now the front end doesn't work very well, and resources can only be uploaded from the backend. (Figure 9).

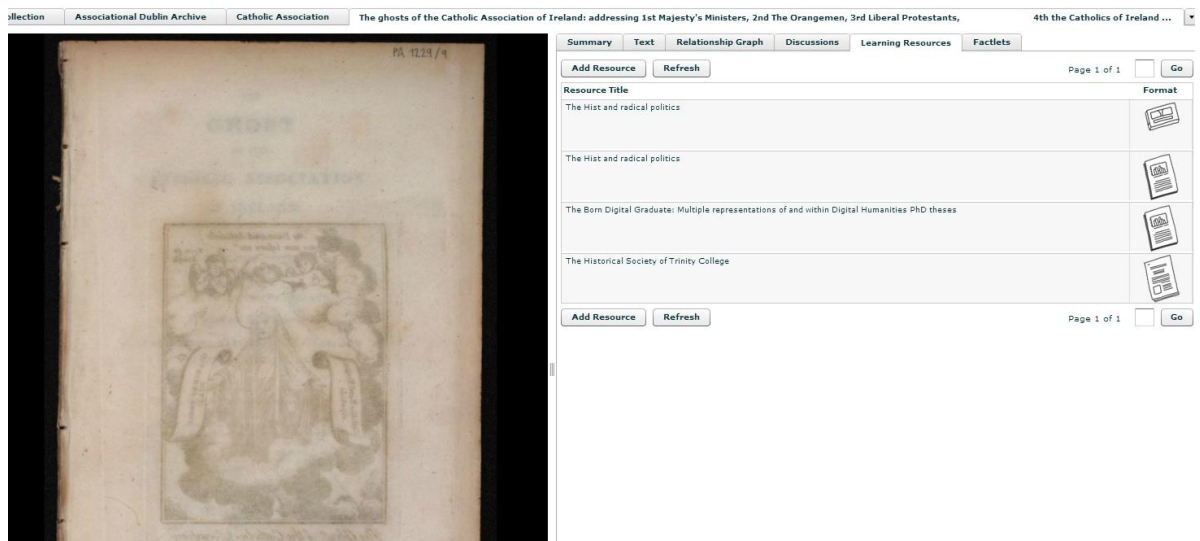


Figure 9 Learning resources management in CRADLE

- CRADLE supports annotations including textual factlets, and, if the digital object is an image, it can also be graphically annotated (figure 10).

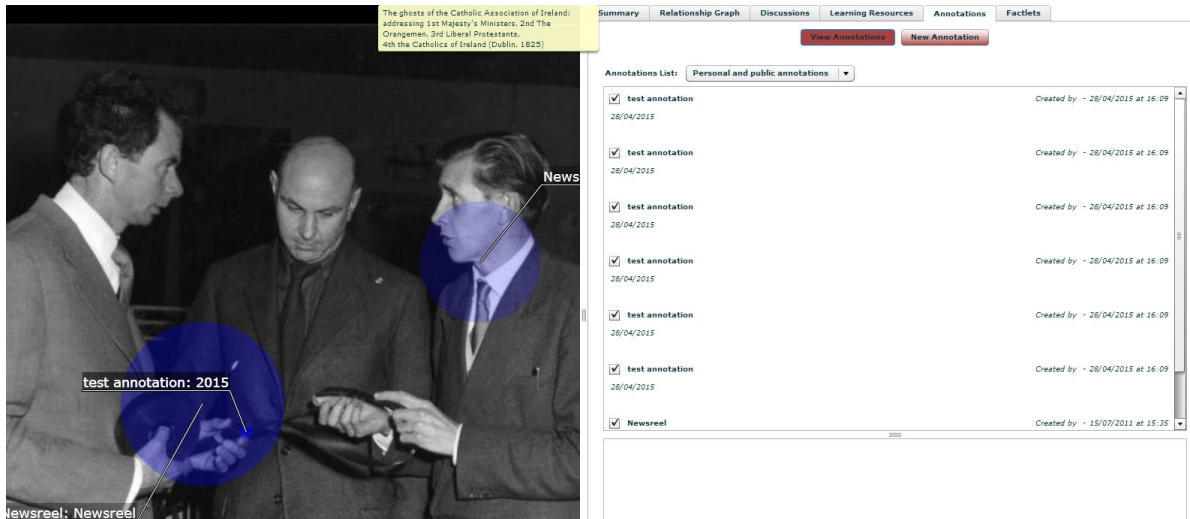


Figure 10 Annotation management in CRADLE

6. CRADLE supports the creation of factlets which work as text annotations for documents and factoids which work as attachments for factlets (figure 11).

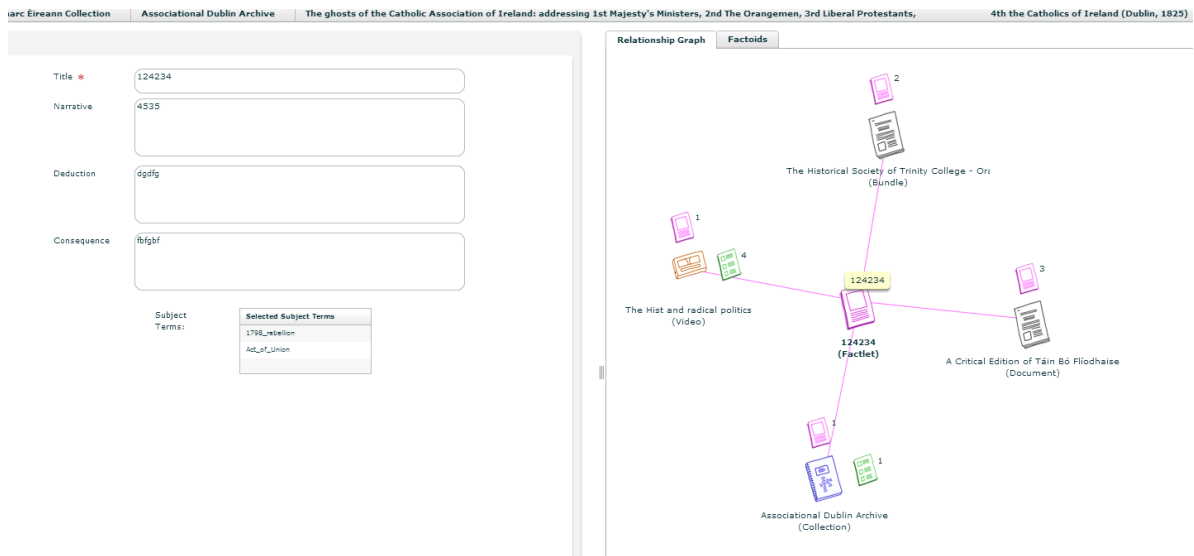


Figure 11 Factlets management in CRADLE

7. CRADLE also supports the comparison of image views and text views of an image document (figure 12).

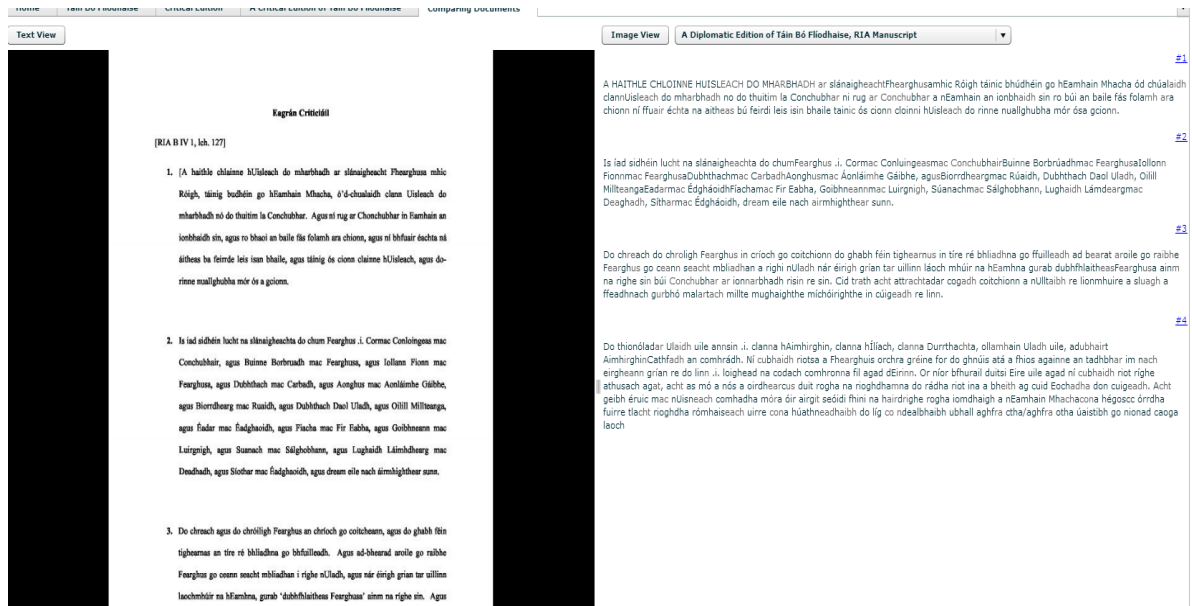


Figure 12 Document comparison in CRADLE

3.2 Activity Theory analysis

CRADLE is short for collaborative, research, archive, discuss, archive, learn and engage. They are the six key activities identified in virtual research environment like CRADLE. Figure 13 is an activity model for humanities education and research which integrates and relates all the key activities in the context of CRADLE.

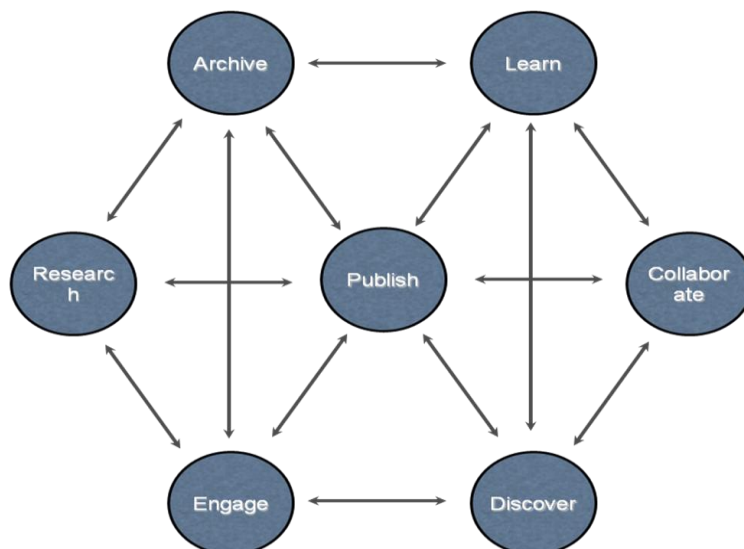


Figure 13 An activity model for humanities education and research

3.2.1 Activity Theory elements analysis

We are going to give a detailed analysis of CRADLE software using Activity Theory. As illustrated in figure 13, we know there are six elements in an activity system: subject, object, mediating tool, rules, community and division of labour. We have identified these elements in the CRADLE software as follows:

- Subject: Humanities scholars
- Objects: The digital object resources, source or discourse manipulated by scholars in humanities research.
- Tool: Online virtual research environment which is CRADLE software in this case.
- Rules: Institutional, humanities education and research rules, guidelines or any other norms, habits, etc. There is a set of rules on humanities research set by law, norms, governments or research institutions. In humanities scholarship, one of the most important rules is copyright, for example, a scholar is permitted to upload or share a document only if he has the copyright or he is the owner. An archive may be available to be uploaded or viewed, but may not be available for download.
- Community: Humanities researchers or scholars group.
- Division of labor: discussion group on a document, document edition group.

In addition, we also care about other unique aspects of Activity Theory in system analysis such as context, and outcome. The context of CRADLE is quite clear, which is the social, historical and cultural humanities research environment. The outcome produced by using CRADLE software is the digestion, management and engagement of humanities digital objects. Figure 14 is a diagram which shows the Activity Theory specifications of CRADLE.

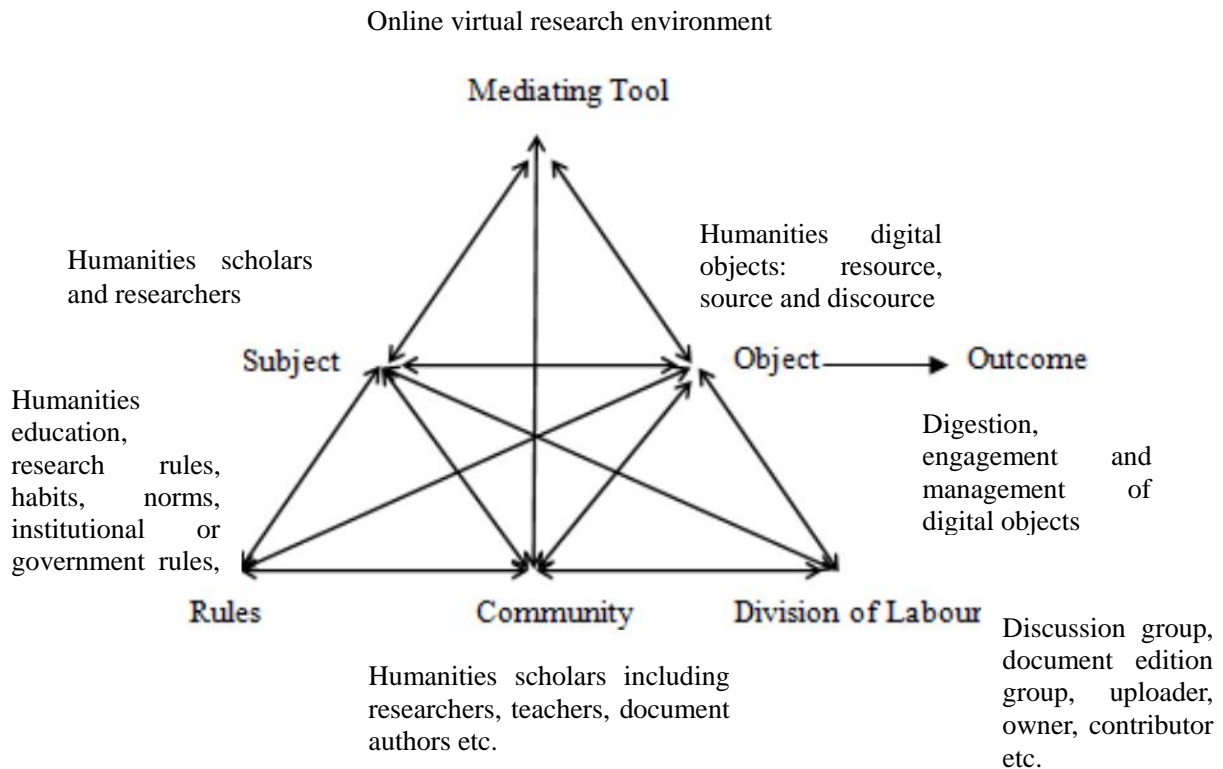


Figure 14 Activity system for CRADLE humanities research

3.2.2 Activity structure analysis

As mentioned before in 1.1.1, one of the most significant characteristics of Activity Theory is that it has a hierarchical structure of activity. This characteristic is also one of the four principles of Activity Theory. According to this principle, an activity could be decomposed into actions with goals and an action could be decomposed further into operations when conditions are met. We already identify six activities in CRADLE software, which are collaborate, research, archive, discuss, learn and engagement. Since there are overlaps among these activities and some activities haven't been supported by the current version of CRADLE, we will only analyze the research activity in this system. Research is the core activity in the context of CRADLE because CRADLE is developed for humanities scholarship research. Activities like the study of documents, discussion, annotation, factlets etc. are all in the scope of research. As illustrated from figure 15, in order to research a digital object, users must search it first before they can study it. Actions are known as a conscious process while operations are unconscious. For inexperienced users, the operations identified are still actions while experienced users who practice a lot will do them in an unconsciously way. Therefore, the operation layer will be deeper (under dash line in figure

15) for an inexperienced user.

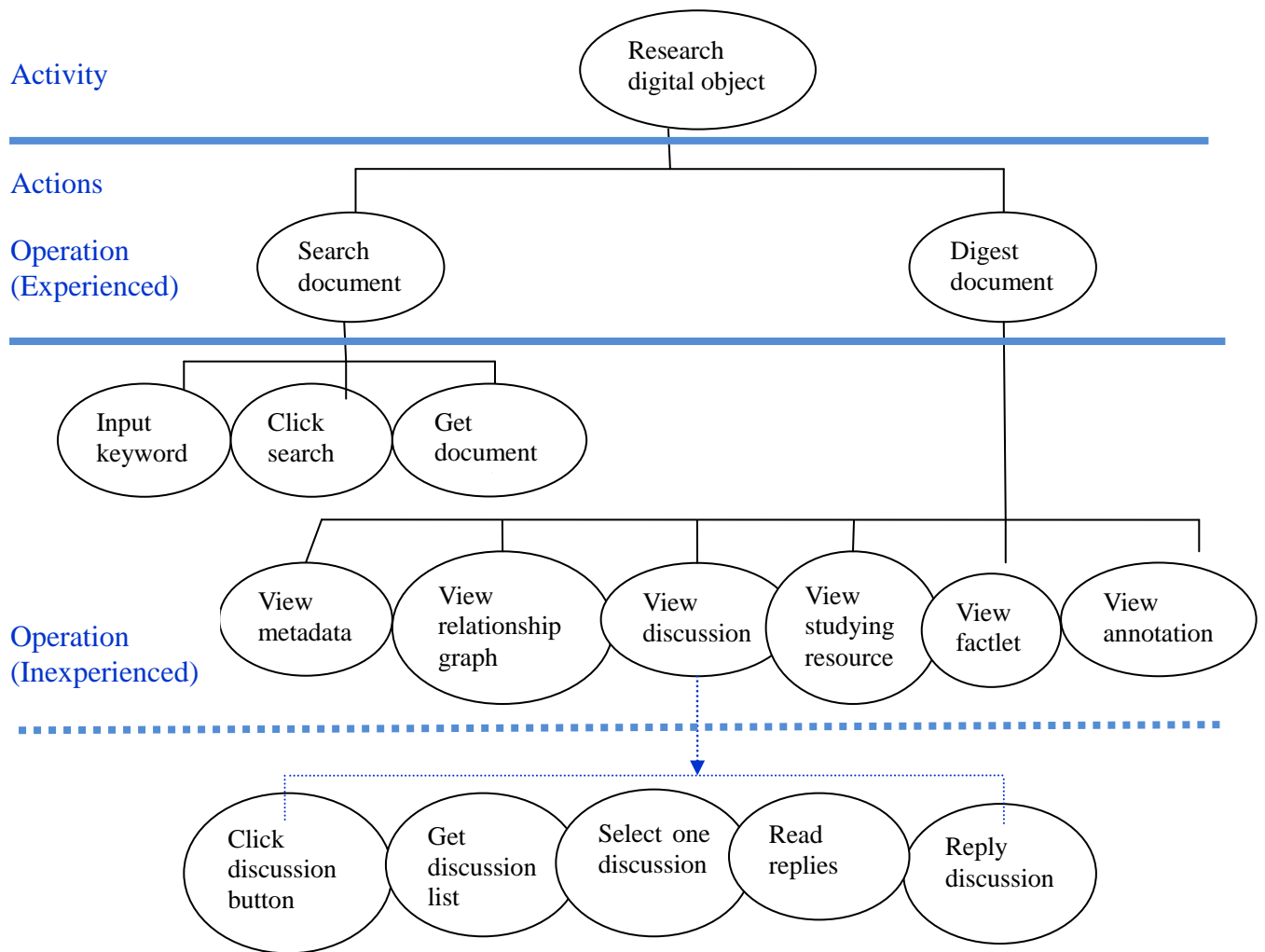


Figure 15 Hierarchical analysis of CRADLE research activity

3.3 Summary

We give a very specific introduction of CRADLE in this chapter both on functionality analysis and Activity Theory analysis. The Activity Theory analysis is performed on two aspects: identification of activity system elements and activity structure analysis. Next chapter we are going to talk and criticize the application of Activity Theory methodology on software design and evaluation.

Chapter 4 Methodology Review

As mentioned earlier, Activity Theory has been a landmark and acts as a leading theoretical framework in HCI and interaction design research. Particularly, it works very well on both interactive system design and their evaluation. In this section, we are going to view some methodologies or approaches used in these two categories.

4.1 Activity Theory on Software Design

Lorna Uden, Neil Willis [22] uses Activity Theory as the framework for both design and evaluation of a tourism information kiosk instead of using traditional cognitive psychology. The design starts from requirements elicitation by using Activity Theory to identify activities, objects, subjects, outcome, community, activity motive and rules. In order to capture the required domain knowledge and activities needed for this information kiosk, this paper uses a method called Acquired Cognitive Task Analysis (ACTA) by conducting three types of interviews. It also uses an activity checklist to evaluate the design. This paper proves the advantages of Activity Theory in HCI design, but it didn't consider that activities may differ among various users. Therefore, more analysis should be done with the consideration of various users, especially when evaluating using activity checklist. H. Jonassen, Lucia Rohrer-Murphy [23] describes a process of using Activity Theory to analyze the needs, tasks, and outcomes to design a constructivist learning environment (CLE). This paper identifies several interdependent components in constructive learning environment and it describes how Activity Theory can be used as a design framework to determine components of the activity system in any CLEs components through six steps. Morten Fjeld, Kristina Lauche etc. [24] employed both Activity Theory and a recent technology called Augmented Reality as the design philosophy to develop a groupware called BUILD-IT system which enable users to cooperate in as virtual environment for planning a real-world object (such as rooms or schools). They also conducted an evaluation of this system using an Activity Checklist through three types of users. The Augmented Reality used in this paper is an approach to bring the virtual world of computers into physical world of everyday human activity. The whole design process is divided into two

aspects: physical and handling (virtual). This paper also distills a set of design guidelines from the experience gained in using Activity Theory. However, Activity Theory was proved to be limited in mental activity design, in particular it is difficult to figure out what kind of virtuality is still perceived as exteriorization rather than disconnected outer world – or “just one more environment [25]”.

4.2 Activity Theory on Software Evaluation

Activity Theory has also proved to be a powerful and effective framework for software evaluation. In paper [26], Jyoti Laxmi Mishra, David K.Allen and Alan D.Pearman use Activity Theory as a methodology and analytical framework to study information practices in the context of Emergency Management and it proves that Activity Theory helps a lot in achieving a holistic approach to understanding the work activities context better than some other analytical methodology. This paper focuses on finding tensions and contradictions among different components in an activity (this case is emergency management) system by conducting interviews and several issues have been identified which might not be visible if using other analytical framework. However, distinguishing between action and operation in this case is difficult because the interviewees did not normally talk about operations (unconscious actions). Also, it is not feasible to observe commanders in action in real emergency situations. Therefore, future work needs to be done to figure out this problem. Mohd Nihra Haruzuan Mohamad Said, Lokman Mohd Tahir [27] etc. recently employed Activity Theory as the analytical framework to evaluate contextual online collaborative learning through three different levels. The higher contextual level (class) is to analyze in a broader cultural institutional context where the intervention happens. The middle contextual level (group) is to analyze the intervention with regard to students’ distributed online interactions to the course and the lower level (outcomes) tries to discuss intervention’s outcome and constrains on students’ participation. This three level framework based on Activity Theory has proved to be quite useful to evaluate online collaborative learning outcomes followed by the identification of constraints. However, this methodology focuses much on analyzing only activity outcomes, and thus is not enough to analyze the system in a more thorough way, particularly when it comes to identifying contradictions between real needs of users and current design. Lejia Vrazalic [28] proposes a new summative website usability testing methodology based on the notion of distributed usability and Activity

Theory to overcome the problems in traditional laboratory based usability testing methodology. This paper first identifies a set of problems of traditional usability testing by conducting a study and then proposes an Activity Theory based usability testing methodology which consists of four steps: defining user activity, activity scenario development, usability testing and analysis. This methodology focuses on real user activities and mediating role of software interface instead of discrete interface elements. This way is more efficient to identify design contradictions, which can be referred to as re-design ideas in the future. However, this paper didn't provide results on using this methodology. In paper [29], Helen Hasan discussed the limitation of cognitive psychology on system development which involves user interactions and how Activity Theory works well as a framework to understand this phenomenon. This paper also describes how Activity Theory works well as the principles for software usability testing. Mark A. Spasser [30] presents a social realist evaluation framework for an activity theoretic case study of North America digital library and it proves that Activity Theory supplies a conceptually and substantively rich vocabulary for explanatory reasoning about technologically mediated social practices, such as digital library assemblage and use. Lately, Effie Lai-Chong Law and Xu Sun [31] used Activity Theory to evaluate user experience of adaptive digital educational games. They proposed a four dimension evaluation framework (gaming experience, learning experience, adaptivity and usability) and applied it to an empirical study with a digital educational games on teaching geography. They identified a set of contradictions or breakdowns between activity elements (e.g. subject-rules, subject-tool and tool-object etc.) and cross activities. These contradictions are very useful implications of software redesign. However, the evaluation setting was in boys school instead of mixed gender school and they are missing co-experience due to constrains regarding videotaping.

4.3 Summary

In conclusion, Activity Theory has been used widely and effectively in both information system design and evaluation, especially systems with various activities and interactions. The papers discussed above introduce various methodologies used in software design or evaluation and we have criticized some of them in terms of their advantages and limitations. Though the usefulness of Activity Theory on both software design and evaluation has been proved by various research work, there is less work on using Activity Theory on evaluation

or design of online virtual research environment like CRADLE software. CRADLE's special domain (humanities scholarship management) also indicates the suitability of Activity Theory as the analytical framework. Therefore, in this project, we are going to use Activity Theory as both an evaluation and a design framework to identify current interface problems before the implementation of next generation of CRADLE software. In the next chapter, we will talk about the evaluation framework we are going to use in this project, and how we design, conduct and analyze the results of the humanities study.

Chapter 5 Software Evaluation

5.1 Software Evaluation Framework

It is important and necessary to evaluate software before it is released. These days there is an increasing need of more reliable, high-quality software from the software industry. In order to evaluate one software more efficiently and effectively, an evaluation framework is usually adopted to provide a basic set of attributes which will characterize important aspects of software systems.

5.1.1 Traditional Usability Testing

Usability testing is a technique used in user-centered interaction design to evaluate a product by testing it on users. This can be seen as an irreplaceable usability practice, since it gives direct input on how real users use the system.[13] This is in contrast with usability inspection methods, where experts use different methods to evaluate a user interface without involving the users.

Laboratory based software usability testing is the classic methodology where users physically go to a lab and they are observed by a group of researchers when doing some tasks using the software. This approach focuses mainly on software interfaces. Evaluators can get data about the interface and the cognitive processes involved in the direct interaction between users and the interface. Laboratory usability is useful in the following aspects:

- It helps to identify design or redesign problems.
- It confirms the assumptions made during the design.
- It gets lots of data which reflects software attributes. For example, we know how difficult it is to use the software by measuring the time user takes to complete a task and the number of mistakes they make. This kind of laboratory based usability testing is good to test software performance.

- Evaluating proprietary applications or prototypes that cannot be accessed outside the organization.
- Convincing product designers and developers about software problems by watching real users doing tasks instead of getting opinions from usability experts.

However, it also has some weaknesses. Laboratory based usability testing tries to relate internal cognitive processes and perceptions of the individual to discrete interface components like website structure, content, etc [32]. Therefore, it doesn't take account the physical, social or historical context where the interaction happens. Cognitive science is the theoretical basis of laboratory based usability testing which has been outdated because of its inability of penetrating human activities. CRADLE is a software which aims at conducting types of activities in humanities scholarship. Thus, its evaluation needs to be human penetrated instead of just checking software elements.

5.1.2 Activity Theory based Usability Testing Methodology

Activity Theory has been used as a methodology and analytical framework for a long time in information systems study. It is also widely used in Human Interaction Design. Activity Theory has proved to be useful because human activities could be structured in relation to computers in a particular situation. In the context of online virtual research environment like CRADLE, Activity Theory is also useful to analyze the various research activities in humanities scholarship.

Activity Theory based usability testing methodology offers some benefits when compared with traditional laboratory based usability testing.

- Activity Theory allows context (human activities) to be studied and the goal for every action is also checked for a better understanding of user activities.
- Not only does Activity Theory illustrate user activities, but it also identifies the motive for each activity. Each activity can be further decomposed into actions which have goals and actions may transfer to operation when conditions change. Therefore, Activity Theory offers a very detailed multi-level analysis of human activities which cannot be achieved using other theories.

- Activity Theory provides a framework to empower users with some tools to work through the interface to achieve desired outcomes.

Activity Theory can be combined with cognitive science as the theoretical basis for a new advanced usability testing methodology. The methodology will focus the role of interface as the mediating tool for user activities instead of a set of discrete interface elements. In addition, various changing social, physical or historical contexts where user interaction happens will also be considered.

Currently, some work has been done using Activity Theory based methodology for interface usability testing. [22] conducts a series of traditional UT on a website and finds user-related and process-related shortcomings of traditional UT method. Then the paper describes the standard steps of the new Activity Theory based methodology. [23] also discussed the limitations of traditional UT and then gives a brief description of how Activity Theory is adopted in the Activity Theory Usability Laboratory (ATUL) to test software prototypes and information systems. [31] uses a four dimension framework based on Activity Theory to evaluate the user experience of adaptive digital educational games. Similarly, [26] performs a set of interviews and studies to analyze the information practices in emergency management based on Activity Theory as well. All of the above papers aim to identify the contradictions or breakdowns within the activity systems.

Therefore, we can see that this evaluation framework has been used as an effective interface usability testing methodology based on Activity Theory. However, none of these papers gave a very detailed case of using this framework to explore its efficiency and effectiveness. In this project, we are also going to adopt this methodology to evaluate CRADLE software with the goal of verifying this framework at the same time. Figure 16 shows a working model of this methodology.

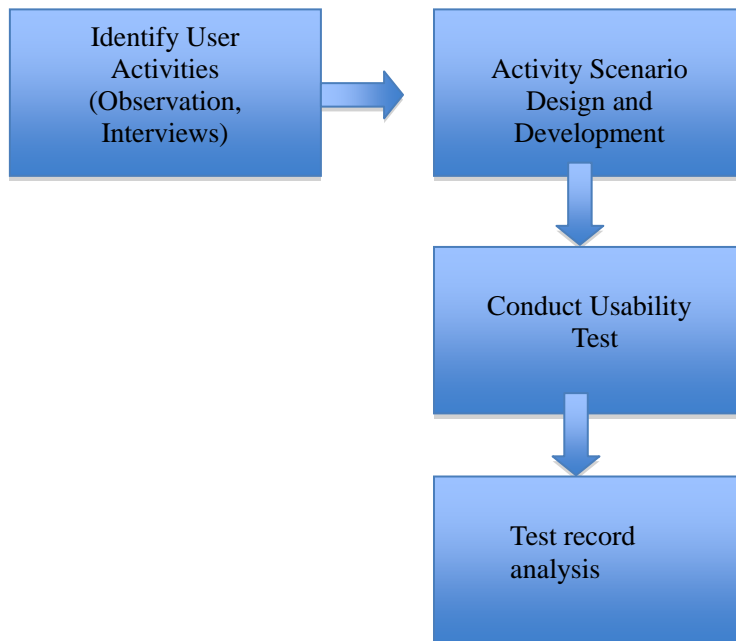


Figure 16 Workflow of Activity-Theory based usability test framework

As it is shown from figure 16, there are four key steps in this framework.

1. Identify user activities

This stage needs identify real user activities by observing or interviewing users to gain an understanding of the primary user activities supported by the tool. The four principles discussed in 1.1 can be used as guideline for the better understanding of the information gathered. Generally speaking, this stage should generate the following information:

- Real needs of user, what users want to do with the software.
- Current activities supported by the software including user motives and activity object.
- Actions required to carry out the activity. Since each activity can be decomposed further into a set of actions, this phase aims at analyzing each activity on action level.

- Various other online software or physical tool that can support the activity and the mediating effects of those tools.
- The rules of the community engaged in the software context.
- How the activities were carried out prior to the existence of the CRADLE.

2. Test Scenario design and development

This step aims to design scenarios which test whether the software does what the users want it to do. Scenarios have proven to be very useful in understanding human activities, especially for evaluation task design. The second phase is based on the information gathered on first stage to test how well the software does what users really want to do based on the understanding of real users requirements. Sometimes, users may still have a positive view of the software even if they come across some difficulties, as long as the software does what they want it to do. This is different from traditional usability testing which only cares about how well the website does what it does.

3. Usability testing

After the scenario design is complete, users will be invited into a contextual laboratory where they are asked to test the software based on the scenarios. Since we want to know if the software is doing what users really want it to do, the software is not being evaluated on its content, navigation, structure etc. The laboratory will be set up to support the essential activities in that software. After the scenarios, a questionnaire will be conducted to collect data on usefulness, satisfaction and ease of use of the software.

4. Test record analysis

Loads of data will be collected after the previous three steps and the final step aims to identify the contradictions between what the software does and what it should do (mapping between primary and current activities). The contradictions are the problems of the software interface and solutions should be proposed. If there is no contradiction, it means that the interface is successful in supporting users' real needs.

5.2 User study of suitability for Humanities Scholarship Activities

5.2.1 Study Design and Process

5.1.2 outlines an evaluation framework based on Activity Theory. According to this framework, the first step is to identify user activities. This step can be done by observations or interviews. In our study, we design a pre-study questionnaire which includes a set of targeted questions illustrated by Activity Theory (see table 1).

Number	Pre-study Questions
1	What purposes or activities would you want software tool to support?
2	What do you expect from CRADLE? Which of your scholarly activities would you perform using CRADLE?
3	What are your motivations (objectives) for these activities?
4	How are these activities currently carried out?
5	What actions are required for the activities you mentioned above and what goals achieved by each action?
6	CRADLE is designed for scholars to manage cultural heritage and digital objects. What rules should scholarly users follow when performing these activities?
7	As a scholarly user, are there any social or cultural norms or habits that will affect your decisions regarding the management of digital objects?
8	In what conditions might you deviate from the normal cultural/operational rules?
9	Are the rules you mentioned above sufficient to perform the task effectively?
10	What research questions would you like to answer using CRADLE?

Table 1 Pre-study questionnaire questions for CRADLE evaluation

We made these questions into formal questionnaire using Google forms and invited 5 scholars (who are potential users of CRADLE) to participate in our workshop. Table 2 shows the background of all the participants in this workshop.

We held a workshop in the Royal Irish Academy in Dublin. The workshop lasted for two hours. Firstly, we gave a brief presentation of our project and the workshop to all the participants. We introduced the concepts of Activity Theory, humanities scholarship and user experience etc. so that participants could have a general knowledge of the project background. Secondly, we asked all the participants to watch a video which talks about how

CRADLE software works. Since all the participants have some background of humanities scholarship research, they will have their own expectations, opinions and needs about an online virtual research environment. After the video, all participants were invited to fill the pre-study questionnaire which is used to collect real user activities before experiencing CRADLE.

Participant number	Background
P₁	This reviewer has a background in humanities and archival studies. She works with both print and digital archival material. She is involved in several funded research projects where she has responsibility for digitization.
P₂	This reviewer has a background in humanities, media and archival studies. She works primarily with digital archival material. She is involved in several funded high-profile research projects where she has responsibility for digitization. She is actively engaged in research and pursuing a doctoral degree in digitization and archival studies.
P₃	This reviewer has a background in science and digital humanities. She has previously taught digital humanities and currently works, as part of a funded research project, on requirements verification for digital humanities software.
P₄	This reviewer has an undergraduate background in humanities (history) and computer science and doctorate in digital humanities. She has developed digital humanities software, and contributed to the development of CRADLE. She is actively engaged in research in digitization, requirements modeling and digital repository development. She is active in publication in digital humanities and has previously used CRADLE for her research.
P₅	This reviewer has an undergraduate background in humanities, postgraduate qualifications in computer science, and is currently pursuing a funded doctorate in data analytics. She has considerable experience in the design of digital humanities software systems, and contributed to the design of CRADLE. She is actively engaged in research in digitization, textual modeling, activity theory and digital repository development. She has previously taught and supervised postgraduate theses in the area of digital humanities.

Table 2 Background of participants

Then we asked all the participants to perform some tasks using CRADLE so that they can gain some user experience with CRADLE. We designed a set of scenarios according to activities supported by the current version of CRADLE and each test scenario included one or more test cases (see table 3).

During the workshop scenario, we continually observed and asked participants questions about what they are doing, how do they feel and what they like or dislike about the design and functionality. Table 4 describes some sample feedback received from workshop participants.

Test Scenario	Test Cases
Search digital objects (collection/document etc.)	Search without keyword Search with matching results Search with invalid keyword
View Digital objects (metadata, relationship graph, content etc.)	View text documents/slideshow View images/video View collections/bundle View links
Relationship graph management	View the graph Manipulate graph by dragging, clicking Editing graph by adding/removing discussions, factlets
Document discussion management	Create/delete a discussion Reply a discussion View discussion on relationship graph and its details
Document factlet management	Create/delete a new factlet View factlets on relationship graph and its details or on tab
Document annotation management	Create/delete new annotation View annotations on text view or on image view
Document comparison (text view, image view)	Text view and text view Image view and image view Image view and text view
Study resources management	Adding new study resource (currently doesn't support frontend)

Table 3 Test scenarios and test case for CRADLE workshop.

Design/ Functionality	Like	Dislike
Collection/ document search	The color code of documents, lines support dropdown and keyword search	<ol style="list-style-type: none"> 1. The search of using Irish language is not accurate enough and instructions about how to search with irish language should be provided. 2. Should have text when there are no matched results.
Relationship graph	Comprehensive representation; nice drag functionality; star structure	<ol style="list-style-type: none"> 1. Some icons look similar. 2. Numbers attached with small green icon (discussion) are not clear. 3. Factlet and discussion icon are not clearly labeled. 4. Bigger and small icons of discussions in discussion relationship graph are confusing. 5. When there are a large number of related documents, the relationship will be super huge. 6. It is better too resize the left and right side of document index and its relationship graph. 7. Can only go further, not possible to go back previous layer. 8. Zoom out doesn't work well without mouse.
Discussion	/	<ol style="list-style-type: none"> 1. Mixed size of discussion icon in the relationship graph is too confusing 2. When create a new discussion, there are two "new discussion" buttons. 3. Don't understand the three optional thread types of discussion: normal, sticky and announcement. 4. The relationship options in the dropdown list sometimes are confusing and the relationship should be attached automatically between the object under view and the creating discussion. 5. The new created discussion cannot be synchronized right away on relationship graph. If refresh, all sessions will be lost. 6. Support selections about discussion visibility.
Document comparison	<ol style="list-style-type: none"> 1. Image view and text view at the same time, good for learning 2. Good zoom in and zoom out of images. 	<ol style="list-style-type: none"> 1. The left side should also have a dropdown list to support more combinations of editions. 2. The paragraph number sometimes is not clear enough. 3. Comparison button is hidden at the bottom.
Factlets	<ol style="list-style-type: none"> 1. Clearly labeled sections: title, narrative, deduction and consequences. 2. Users can create relationships on this factlet with other documents and It can be viewed in tab to show the relationship 	<ol style="list-style-type: none"> 1. Instructions about how to use factlets are not enough. 2. The factlets is too specific based on only historical research, it should be more general so that more users can use it. 3. Confusing with Factoids and factlets.

	graph.	
Image annotation	1. Differentiation between annotation and caption	1. Too simple structure of annotation text
	2. Zoom in and zoom out is good	2. Only support one shape (circle)
	3. Support overlapping between annotations.	3. Cannot export annotation for other usage.
	4. Can be public or private	4. Takes time to figure out how it works the first time.

Table 4 Sample feedback from participants during workshop scenarios

After the workshop, all participants were invited to fill the post study questionnaire for usability evaluation. There are four sections in the questionnaire we think are important for usability testing. We designed a set of questions in each section, and each question could be answered with a range from 0 to 9 (strongly disagree to strongly agree). Table 5 is a list of all the post study questions.

Usability Aspects	Questions
CRADLE Learnability	I think that learning to operate CRADLE is: difficult to easy (0-9).
	I think that exploring CRADLE features by trial and error is: difficult to easy (0-9).
	I think that remembering CRADLE functionality or the use of CRADLE functions is difficult to easy (0-9).
	I think that performing tasks using CRADLE is straightforward: never to always (0-9)
	I think that the CRADLE help messages on the screen are unhelpful to helpful (0-9)
	I think that learning the graphical representation of different elements is: difficult to easy (0-9).
	I think that learning the CRADLE network structure representing document relationships is: difficult to easy (0-9).
	I think that learning how to use CRADLE’s discussion system is difficult or easy (0-9).
	I think that learning how to use CRADLE’s factlet system is: difficult to easy (0-9).
	I think that learning to use CRADLE’s image annotation system is: difficult to easy (0-9).
	Any comments on CRADLE learnability (the reasons for rating any areas as "difficult").
CRADLE Usefulness	CRADLE would help me be more effective for collaborative archival and digital texts: strongly disagree to strongly agree (0-9)
	CRADLE would help me be more productive for collaborative archival and digital texts: strongly disagree to strongly agree (0-9)
	CRADLE would be very useful for collaborative engagement with digitized historical texts: strongly disagree to strongly agree (0-9)
	CRADLE makes it easier to complete my research activities: strongly disagree to strongly agree (0-9)
	CRADLE would save time when I use it: strongly disagree to strongly agree (0-9)

	CRADLE would meets my needs for collaborative digital text management.: strongly disagree to strongly agree (0-9)
	CRADLE does everything I would expect it to do: strongly disagree to strongly agree (0-9)
	Additional comments on CRADLE usefulness , give more details for areas where you disagree that CRADLE is useful.
CRADLE Ease of use	CRADLE is simple to use: strongly disagree to strongly agree (0-9)
	CRADLE is simple to use: strongly disagree to strongly agree (0-9)
	CRADLE can be used without written instructions: strongly disagree to strongly agree (0-9)
	CRADLE does not appear to have any inconsistencies: strongly disagree to strongly agree (0-9)
	Using CRADLE you can recover from mistakes or errors quickly and easily: strongly disagree to strongly agree (0-9)
	Additional comments on CRADLE ease of use, the questions you are disagree, tell us the reasons.
CRADLE Satisfaction	I am satisfied with CRADLE: strongly disagree to strongly agree (0-9)
	I would recommend CRADLE to a friend: strongly disagree to strongly agree (0-9)
	CRADLE is fun to use: strongly disagree to strongly agree (0-9)
	CRADLE works the way I want it to work: strongly disagree to strongly agree (0-9)
	I feel that i could use CRADLE in the future: strongly disagree to strongly agree (0-9)
	Additional comments on CRADLE satisfaction, give more details for areas where you are unsatisfied with CRADLE.

Table 5 CRADLE usability testing questionnaire

Before the workshop, we designed two alternative proposals (A & B) to address the inability of human representation in the current CRADLE interface (We will talk more about this in chapter 5). After the workshop, we gave a short presentation of two proposals to all the participants and we also designed a questionnaire for each of them in order to collect users' opinions. We expected users to decide which proposal is better so that we can refine our design in the future.

5.2.2 Study Result and Analysis

Illustrated from the Activity Theory based evaluation framework in section 5.1.2, the first step should generate some information, especially the real need of users (expected activities). By summarizing the pre-study questionnaire, we identified the following essential information.

- Real needs of users (expected activities)

Table 1 lists the 10 questions we used in pre-study questionnaire. We extracted the following real user activities by quoting original thoughts from participants.

- 1) Querying or accessing a primary source, its metadata and leading me to other related sources and studies, viewing sources in CRADLE from the library even though CRADLE does not actually hold the original source. Ability to handle multiple metadata standards.

“P₁ question 2: I expect CRADLE to be able to give me access to primary source documentation and lead me to other related sources and studies.”

“P₅ question 1: Querying of document contents. Querying of document metadata. Querying of document element metadata (mark-up). Allow me to view sources in CRADLE from the library (ones which I have permission to view), annotate them and keep the annotations (even though CRADLE does not actually hold the original source.”

“P₃ question 7: A metadata standard for capturing descriptive metadata would be chosen in accordance with the digital object type, therefore CRADLE should have the capability to handle multiple metadata standards.”

- 2) Individual source management and examination with visibility control.

“P₄ question 2: I would use it for individual source management and examination. To help with the first step of research, this however is dependent on the functionality of CRADLE in terms of who sees what content. See everything publicly available? If I load primary documents that I have gathered for my research will everyone see these documents?”

- 3) Collaborate with others on documents.

“P₂ question 2: I imagine that it would be most useful for collaborative research and teaching in its current format, or for sharing content which I own the copyright of.”

- 4) Sharing content which I own the copyright of.

“P₂ question 2 I imagine that it would be most useful for collaborative research and teaching in its current format, or for sharing content which I own the copyright of.”

“P₄ question1: The important research activities that I require support are primary source (document) access, annotation, sharing, and dissemination.”

- 5) Discussions within a group and setting restrictions on these discussions.

“P₃ question2: I expect CRADLE could support discussions within a group, and setting restrictions on these discussions.”

- 6) Private annotations and factlets, (for literature view) provide a way to make and save structured annotations that are linked directly to either certain words or classes of words, or certain areas of the physically represented document and support exporting those in an ordered format. Also annotate from external libraries.

“P₃ question2: It is better to have private annotations and factlets”

“P₅ question1: For my literature review, provide me with a way to make and save structured annotations that are linked directly to either certain words or classes of words (as I’ve defined classes), or certain areas of the physically represented document. Allow me to export those in an ordered format. Show me which sources I have finished examining (annotating) for my literature review.”

- 7) Generate descriptive relationships between digital objects.

“P₃ question2 & question6: I want descriptive relationships between objects, Have rich descriptive metadata. Have comprehensive relationships between objects in place.”

- 8) Upload a digital object easily or embed link to the primary document.

“P₃ question2: I hope uploading objectives could be easy.”

“P₄ question1: It is important that I have the ability to either embed a link to that primary source within the software or upload a document (provided I have permission).”

- 9) Annotate images, timecode audio with publication control.

“P₄ question1: Depending on where I am on the research life-cycle, the ability to take notes or annotate objects is important, specifically to be able to highlight pieces of important text or sections of an image or time-code an audio file or moving image. However, it is important that annotation can be hidden from other viewers until that research is either complete or required to support scholarly publications.”

- 10) Reference management: support reference across other objects, save my references in a structured manner and export them to a bibliographic reference system.

“P₂ question1: I am currently working on a PhD (but in archivistics - social sciences rather than humanities). I imagine the most useful software tool would allow me to store and cross-reference publications as I do not currently use archival objects in my research.”

“P₄ question1: Some sort of analysis of data is al so important and the ability to cross reference other digital objects or resources that is either within the system or outside.”

“P₅ question: Allow me to save my references in a structured manner and export them to a bibliographic reference system.”

11) Provide an examinable record of the evolution of my sources.

“P₅ question1 Provide me an examinable record of the evolution of my thought with regard to my sources.”

12) Organize sources in structured hierarchies for example: traditional folders.

“P₅ question1: Allow me to organize those sources in structured hierarchies (traditionally, folders). Allow me to implicitly describe the reason for the structure I have chosen (for instance, by typing the links, or naming the folders, etc).”

13) Document comparison.

“P₄ question2: You might need to compare documents side by side - e.g. a primary document and a dissemination document.”

- Current activities supported by CRADLE

The original design of CRADLE is inspired by Activity Theory and six primary activities are identified in this software which are collaborate, research, archive, discuss, learn and engage. Since there are some overlaps among these activities and current version of CRADLE still has some uncompleted implementations, we identified the following activities in the current version:

- 1) Digital object search
- 2) Digital object content (text, relationship graph, metadata etc.) study
- 3) Generation of relationships between digital objects in star structure (with colored lines).
- 4) Hierarchical organization of documents in collections/bundle
- 5) Discussion management
- 6) Document annotation management
- 7) Document factlets management
- 8) Learning resources management

9) Document comparison

10) My collection management

- Various other online software or physical tools that can support the activity and the mediating effects of those tools.

Currently, there are a number of humanities research tools [33] by which scholars can do annotations, citations, library references etc. For example, Pundit [34] is a semantic annotation tool by which users can annotate web pages in Linked Open Data – whether working on texts, graphics, pictures, or maps. The Quick Start Guide is a site that hosts useful material for building your own digitization, semantic digital library & Open Access publishing platform. MONK [35] is a digital environment designed to help humanities scholars discover and analyze patterns in the texts they study. However, none of these tools can generate relationship graph between documents and manage them as collections like CRADLE does. Therefore, CRADLE is unique on helping researchers to focus on document relationships and boost their research by exploring deeper.

- The rules of the community engaged in the software context.

We collected the following rules that real users think are important:

- 1) Ownership and copyrights. Scholars must be clear on what they do and do not have the right to upload to the system. Right to share/download documents.

“P₂ question 6: I think that the most important rules relate to ownership rights and copyrights. Scholars must be clear on what they do and do not have the right to upload to the system (eg. do they own the right to disseminate a paper if it has been published in a traditional, non-OA journal?) Also, just because a scholar has access/permission to use a digitized archival object it does not mean that they have permission to share it. Furthermore an archive may give permission for their content to be uploaded and viewed by others, but not for others to download it - this needs to be controlled/monitored by the system.”

- 2) Objectivity – bias created by users in their collection management or any selection process.

“P₄ question 6: Objectivity - scholars should be aware that their selection process

automatically brings in bias. What bias are they creating through their collections?"

- 3) Openness, transparency and accuracy in scholarship for example: data, digital objects should be updated and true, metadata should be descriptive, relationship graphs should be comprehensive etc.

"P₁ question 6: Responsible for and ensuring the data and objects are true and up to date."

"P₃ question 6: Have rich descriptive metadata; Have comprehensive relationships between objects in place."

"P₄ question 6: Openness, transparency in scholarship."

- 4) Any rules laid out by university ethics statement and employment or academic contracts. Any rules laid out by users' own moral judgment or other legal agreement, e.g. with external collaborators, etc.

"P₅ question 6: Any rules laid out by their university ethics statement and employment or academic contracts. Any rules laid out by their own moral judgment. Any rules laid out in other legal agreements, e.g. with external collaborators, etc. Any rules implied by agreements the scholar has otherwise entered e.g. departmental collaboration. As a rule, they should also consider, but not necessarily follow, stakeholder preferences as outlined in, for instance, university-defined, prioritized research areas. I suppose this generalizes out to considering the preferences, expectations and obligations of communities or groups to which the researcher has pledged some belonging (department, collaborative group, class, research group, funded project, etc)."

- How the activities were carried out prior to the existence of CRADLE.
- 1) Marking up or creating metadata for the components of the interested sources.

"P₅ question 4: By marking-up, or creating metadata for, the components of the sources that I considered to be markers indicating mentions of women. And then subsequently running x-queries on the to answer questions such as 'on average, how many women are mentioned per source.'"

- 2) Moodle or Google documents, with links to the resources. Or simply using highlighter and pen on a printed page.

"P₃ question 4: 1. Tutorials on Moodle; 2. Google documents, with links to the resource. Or a plain old highlighter and pen on a printed page."

- 3) Custom XML and related technologies for analysis: BibTex, Delicious. Other programming languages like R or Processing – depending on the activity (e.g. data

analysis or viz).

“P₄ question 4: Custom XML and related technologies for analysis, BibTeX, Delicious. Other programming languages like R or Processing - depending on the activity (e.g. data analysis or viz).”

- 4) Face to face/Skype meeting with collaborative work on Google Drive or Dropbox.

“P₂ question 4: Generally via face to face/Skype meetings with collaborative work on Google Drive or Dropbox”

- ✚ Contradiction analysis by mapping primary and current activities:

The core goal of our evaluation is to seek the contradictions between what the software does and what it should do. We collected a number of primary activities expected by real users and also identified the activities supported by the current version of CRADLE. Therefore, we are going to find the contradictions by mapping between primary and current activities (Table 6).

Number	Primary activity	Current activity	Contradiction analysis
1	Querying or access primary source, its metadata and lead me to other related sources and studies, view sources in CRADLE from the library even though CRADLE does not actually hold the original source. Ability to handle multiple metadata standards.	Digital object search and Digital object content (text, relationship graph, metadata etc.) study.	Doesn't support source view from external library. Only support one metadata standard.
2	Individual source management and examination with visibility control.	My collection management	Current CRADLE includes this feature, but it is not implemented yet. Now the upload function can only done from backend and all the collections are public visible.
3	Sharing content which I own the copyright of.	/	Not available in current CRADLE
4	Discussions within a group and setting restrictions on these discussions	Discussion management	Doesn't support setting restrictions
	For literature view, provide a way to make and save structured	Documents annotation management and	Text annotation is not structured, factlets structure

5	annotations that are linked directly to either certain words or classes of words, or certain areas of the physically represented document and support exporting those in an ordered format; private annotation and factlets both in comprehensive structure; annotate in external library	Document factlets management	is too specific and not user friendly; no link to primary documents; no support for data exporting and external library annotation.
6	Generate descriptive relationships between digital objects	Generate relationships between digital objects in star structure (with colored lines).	No description of relationships (how documents are related)
7	Upload a digital object easily.	Learning resources management	CRADLE has its own special way to upload digital object, scholars must have good knowledge of XML, TEI and VRA. Therefore, it is not easy to upload digital objects in CRADLE.
8	Reference management: support reference across other objects, save my references in a structured manner and export them to a bibliographic reference system.	/	Not available in current CRADLE
9	Provide examinable record of the evolution of my sources	/	Not available in current CRADLE
10	Organize sources in structured hierarchies for example: traditional folders.	Hierarchical organization of documents in collections/bundle	Support hierarchical organization in relationship graph, but not in a folder and it is hard to rename
11	Annotate images, timecode audio with publication control.	Documents annotation management	No support for video annotation and no control for publication when annotation is not completed.

Table 6 Contradictions between primary activities and current activities in CRADLE

 Contradiction analysis between activity system nodes:

Activity Theory also works as an effective way to identify the contradictions between system nodes (see figure 14). Contradictions may happen between different nodes within the system, which will be the source of future innovation and development. In this section, we

find some contradictions (shown as dashed line with lightning bolt in figure 17) illustrated from both pre-study and post usability study questionnaires.

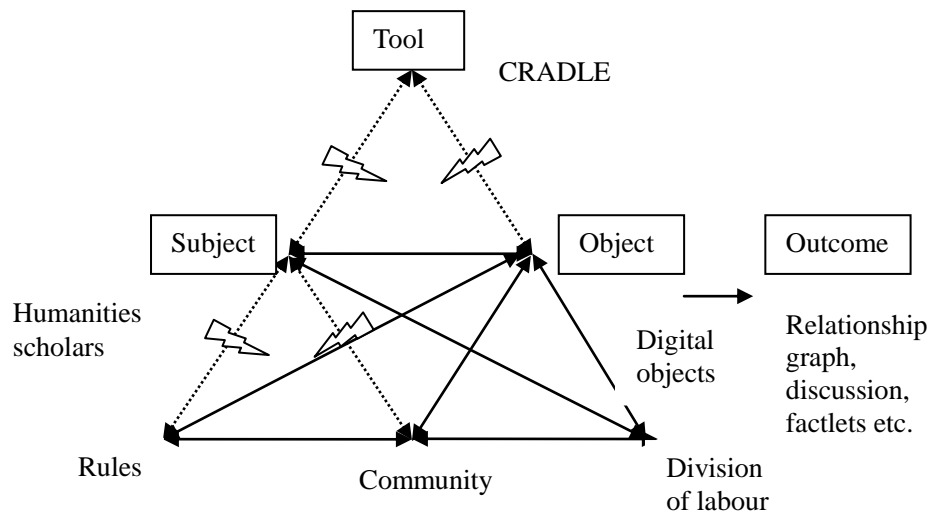


Figure 17 Activity system model for CRADLE showing Contradictions

- Contradiction between Subject (Humanities Scholars) and Tools (CRADLE)

CRADLE is created as a tool to manage humanities scholarship, but there are difficulties identified about this technology because of CRADLE’s special domain. As talked by P₅ who has rich experience on humanities research.

It is kind of hard to use CRADLE, even you are a humanities scholar. Because CRADLE has its only working style and context. Some tutorial needs to be provided especially for novices on generating TEI (Text Encoding Initiative) and VRA (Visual Resource Association) metadata. (P₅)

Besides, half of the participants voted that learning to operate CRADLE is difficult in usability study, meaning CRADLE is not particularly user friendly (Figure 18).

1. I think that learning to operate CRADLE is:

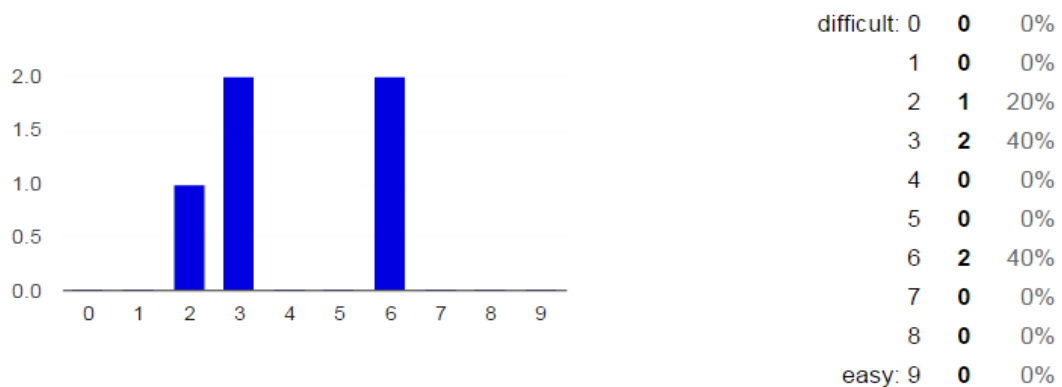


Figure 18 CRADLE learnability response graph

We also got some more comments about the learnability of CRADLE from users:

I found using the factlets and the factoids to be very confusing. The explanation text needs to be more generic, and the inclusion of hover text help on the different parts of a factlet would be useful.(P₁)

It seems that the interface is easy to use, but I was not sure which features exist in the system so there may have been areas that I missed. For example I didn't see any "on screen help messages", except for an explanation of factlets in the factlet tab, so it was difficult to know whether it was my own fault for missing the help messages, or whether there weren't any. Also I was not able to figure out how to add objects to "My Collection" - are these objects I upload myself, or should I be able to bookmark/store content from existing collections? If I start a discussion/add an annotation etc are these objects added to My Collection?(P₂)

I think that trial and error is a good way to find your way around CRADLE but I imagine that there is a lot more to do on it and for this reason I think that there should be some instructions, just to get you started and comfortable with the tool.(P₃)

Learning to operate cradle: I think that the metacognition required to operate CRADLE is quite high (P₅).

- Contradiction between Object and Tool

We got lots of feedback from both the talk during the workshop and the post usability study. The generation of the relationship graph among documents is the most important feature in CRADLE. However, most participants said that they got lost easily in the graph when they clicked deeper and deeper, and there is no explanation of the lines between documents. Therefore, the outcome from this activity system is confusing.

- Contradiction between Subject and Community

Humanities cross many disciplines such as language, literature, philosophy and musicology etc. This means CRADLE users have various backgrounds. Therefore, documents uploaded by some users may be hard for others to understand.

Sometimes, discussions on a digital object can be hard and time consuming because different users have different level of understanding. If a group is collaborating on a same document, misunderstanding will delay work progress. (P₂)

Besides, different users have different requirements with regards to collaboration. Some scholars mainly do their research individually while others collaborate a lot. Therefore, for scholars who consider CRADLE as a pure research tool, too much community representation will be annoying. This is also a contradiction between subject and community.

I don't know if CRADLE would save time: it would definitely allow me to 'go deeper' into my research when I was using it for collaborative philology, but I would probably not engage in the activities that it supports, at that deeper level, if it wasn't available to support me in them. (P₃)

CRADLE would be a great resource for collaboration. Especially, as a distance learning resource where are class could work together using CRADLE to have discussions and share knowledge about a resource. (P₄)

- Contradiction between Subject and Rules

As illustrated from the pre-study questionnaire, most participants agreed that ownership rights and copyrights are the most important rules in humanities research. Scholars must be clear on what they do and do not have the right to upload, share or copy from the system. However, it is kind of difficult for scholars to be absolutely clear about their rights, meaning that a violation of the rules is possible. As for the metadata representation, all scholars have their own preference of the metadata format while CRADLE currently supports only one type. However, rules of research can be flexible depending on the founded project, research group, department, stakeholders, institution etc.

A metadata standard for capturing descriptive metadata would be chosen in accordance with the digital object type, therefore CRADLE should have the capability to handle multiple metadata standards.(P₂)

Any rules laid out by their university ethics statement and employment or academic contracts. Any rules laid out by their own moral judgment. Any rules laid out in other

legal agreements, e.g. with external collaborators, etc. Any rules implied by agreements the scholar has otherwise entered e.g. departmental collaboration.(P₅)

5.3 Summary

In conclusion, we identified a number of contradictions through two different methods: mapping between primary and current activities, and contradictions between activity system nodes. The contradictions identified in the first method are more representative and specific on the activity level while the second method places more emphasis on activity system elements. Both of them will be valuable for future redesign. As mentioned earlier, we acquired some feedback from users after the release of CRADLE. They suggested that the inclusion of user and user-community representation within the system would enhance the user experience significantly. Both the pre and post study questionnaire also indicated that users need community representation to collaborate with each other. Currently, CRADLE doesn't support collaborative activities very well, except for discussions. That is also why many participants get confused about the community mechanism in CRADLE. We will give two candidate proposals which represent the human community and ask users to evaluate them in Chapter 6.

Chapter 6 Solutions

6.1 Current CRADLE software interface

3.1 has introduced the functionality supported by the current version of CRADLE. One of the most important functionalities is that CRADLE can generate the relationship graph between documents and its attachments like discussions, factlets, and annotations. Figure 19 shows a typical example of the relationship graph.

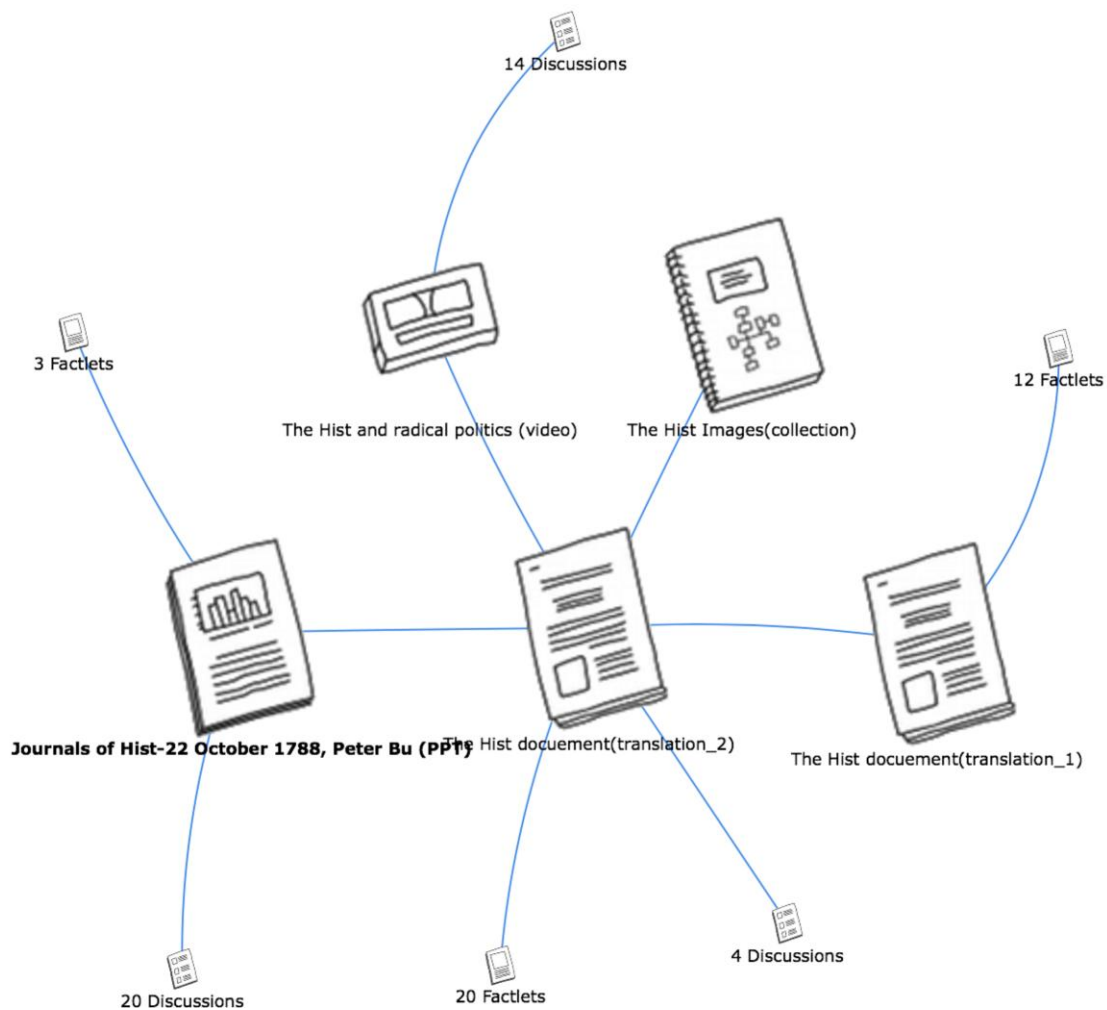


Figure 19 Current CRADLE software interface

Obviously, the current version of CRADLE focuses too much on document representation. When a user clicks on a document, the relationship graph of this document and its related documents and attachments will be presented. However, according to Activity Theory, we can not see any human interactions in this graph. We have no idea how CRADLE users

interact with each other. In addition, even the lines between documents are not comprehensive. We don't know how those documents are related to each other. Therefore, the current version of CRADLE doesn't support participating humans in its collaborative work place. We have to change the current interface so that the people involved in all aspects of the activity are presented. We propose two possible interfaces that would facilitate this request and prototype, and use a workshop to test user response to each proposal.

6.2 Two candidate proposals for User Interface Update

6.2.1 Document focused

The current version of CRADLE doesn't have any human representation. Research and discussions are two primary activities in CRADLE and users have the motive to interact with other users for better study and research. Therefore, if one user is studying a document and they also wants to study with the owner or someone who is engaging in discussion of that document, they have to explore and click until the very end to check participants in the discussion forum or to find document owners on its metadata. It is not convenient, especially when scholars are interested in the owner of document they are researching or discussion participants. Therefore, proposal A addresses this problem (Figure 20) by including some human representation in a document focused model.

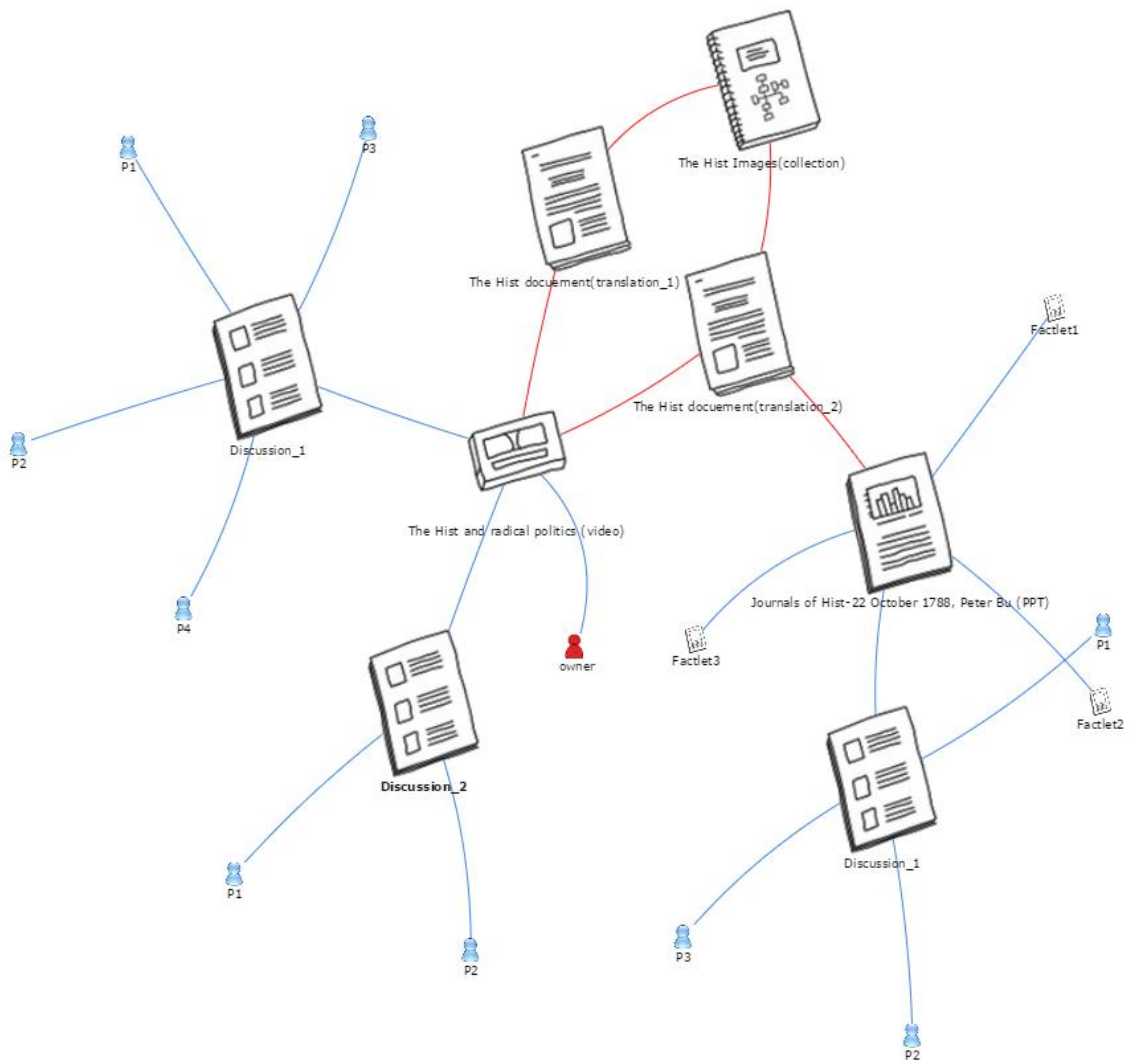


Figure 20 CRADLE Interface update – Proposal A

Figure 20 describes a typical case of proposal A. The Hist and redial politics (video) is the document under research. The software will generate a relationship graph of this document with other related documents. The Hist document (translation_1) and The Hist document (translation_2) are two different translation versions by two different translators. For the discussions attached with The Hist and redial politics (video), all the participants are presented and the document owner is also shown. In addition, proposal A differentiates relationship types between document relationship (red) and human association (blue).

6.2.2 Human focused

As mentioned previously, activity is understood to be interactions between subjects and objects. In the context of CRADLE, the subjects refer to system users (researcher and

scholars) and objects refer to digital objects (resources, source and discourse manipulated by users). Proposal A chooses objects (documents) as the point to start relationship together with some human representation. However, if we are particularly interested in a scholar who has similar research interests, we would like to retrieve their documents even though some documents are contributed to by other scholars as well. Taking this into account, proposal A will be useless in this case.

As discussed before, collaboration is one of the primary activities in the context of CRADLE which involves a group of people working on the same document. This mechanism is especially effective for cultural heritage translation, which sometimes needs a group of scholars to contribute.

The cases discussed above are more human focused than proposal A. Therefore, proposal B which is created to address the above problems is human focused with the addition of some document representation. Figure 21 shows how a typical case of proposal B.

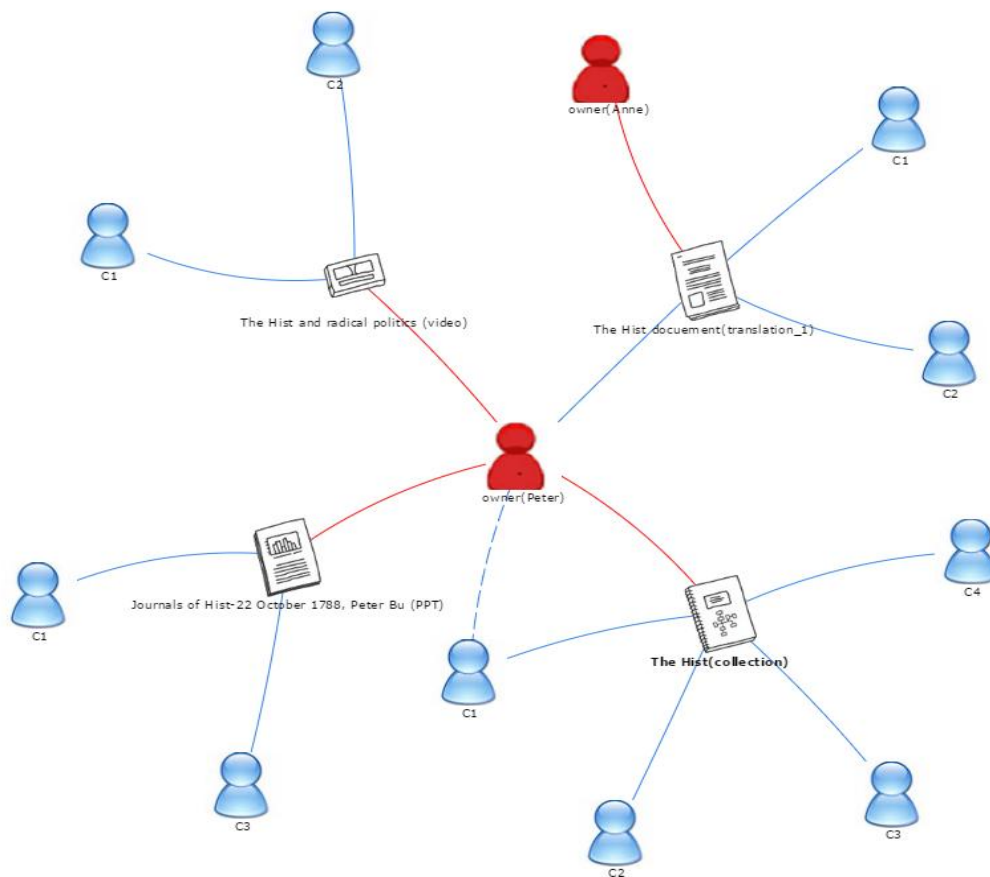


Figure 21 CRADLE Interface update – Proposal B

In figure 21, suppose we get a scholar called Peter, who has a similar research area as me. I presume that Peter may have other documents, which will help my research or study. Proposal B could generate a relationship graph which refers to Peter as the center. All the documents will be connected with their owner and contributors. Therefore, there are also two types of relationships in this interface: ownership (red) and contribution (blue).

6.3 User study on proposal evaluation

6.3.1 Study Design

In 6.2, we introduced the two alternative interface update proposals. Proposal A is good at relating documents, but has too little human representation while proposal B includes human representation, but is missing document relationships. Besides, in proposal B, we have no idea if it is better to include human-human relationships (dash line) as well. Therefore, in order to know if users are satisfied with one of, or both, or none of the two proposals, we have to ask real users to evaluate them. As mentioned in 5.2.1, we also designed questionnaires for each proposal to collect user's opinions and suggestions. We invited all participants to fill the form after the workshop. Table 6 is a list of the questions in proposal A&B questionnaires.

Proposal	Questions
A	The representation of human association with documents etc. is clear and understandable: strongly disagree to strongly agree (0-9).
	It is better to associate humans with documents than including human-networks in the interface: strongly disagree to strongly agree (0-9).
B	The representation of human- and document- network are clear and understandable: strongly disagree to strongly agree (0-9).
	It is better to include human networks alongside document networks rather than associating humans with documents: strongly disagree to strongly agree (0-9).
A&B	The network diagram is a easier to read than the original CRADLE: strongly disagree to strongly agree (0-9).
	Users should be able to select separate interface views showing document-networks, human-networks, or both, in the CRADLE interface: strongly disagree to strongly agree (0-9).
	Please provide a description of what you think this network represents.
	Please provide further comments on what you like about this proposal.
	Please provide further comments on what you dislike about this proposal.

Table 6 Questionnaire of CRADLE interface update proposal A & B

6.3.2 Study Result and Analysis

- Proposal A

Four of five participants think that the network diagram of proposal A is easier to read than the original CRADLE (figure 22), while the representation of human association with documents etc. is not clear and understandable enough (figure 23).

The network diagram is a easier to read than the original CRADLE

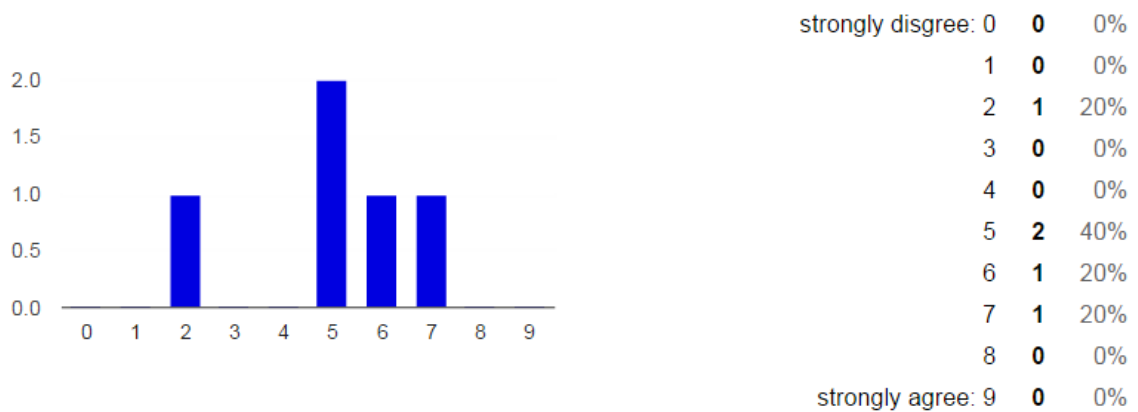


Figure 22 User attitude upon proposal A

The representation of human association with documents etc. is clear and understandable.

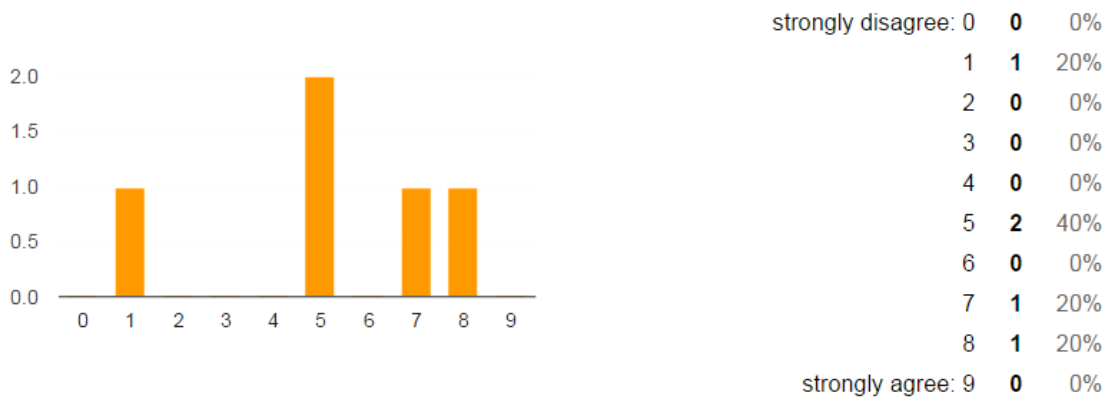


Figure 23 Feedback of clarity and understandability of Proposal A

All the users like the inclusion of human into document focused representation without interfering too much with digital objects.

I like that the human is being captured. I think that the human is being captured to an appropriate degree by not interfering too much with the digital objects. (P₁)

I like that different relationship types are being expressed in different colors, but I think there still needs to be more description on the type of relationship that these colors signifies. (P₁)

Contradictions in Proposal A (figure 24):

- Contradiction between subject and objects

The roles of humans introduced in this network are not clear enough. Scholars would like to

study them like other digital objects instead of useless icons. Like P₅ said:

I don't like the way that the relationships aren't typed, and I don't like that I don't know what role the people are playing, or if they are not people at all but rather roles. I would also like to be able to arrange people as sources within the system so that I could study them as objects in the same way that I can study a book or a collection as an object. (P₅)

- Contradiction between tool and object:

Not enough description on image icons in the network. Participants care about the description of various relationships.

I cannot remember what each image is. I know that there is a small description at the bottom but I think that the images need to be more distinctive. Images can convey messages quickly but the writing underneath defeats the purpose of them.

The links between each of the documents are not that clear. I would assume that these items are related as they are on the same page so the connections also need to be clearer. (P₄)

- Contradiction between community and object:

The representation of human community was confusing for some participants. They didn't know what their relationship is to the digital objects.

It is not clear who the humans are in the current data model, and what their relationship is to the digital objects. If the purpose of Cradle is collaborative work in Digital Humanity, perhaps a human-centric approach would be better. (P₃)

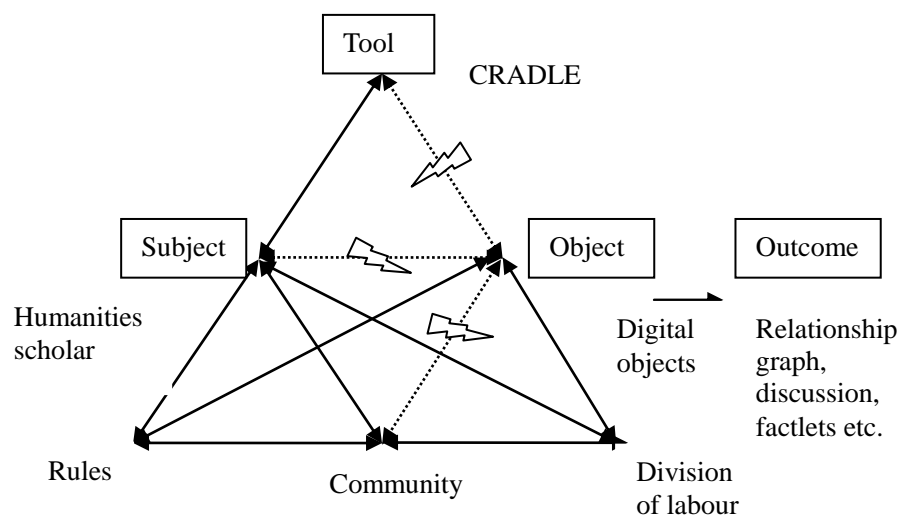


Figure 24 Contradictions identified in proposal A

- Proposal B

The feedback from proposal B was more negative than proposal A. All of the participants didn't feel that proposal B was easier to read than the original CRADLE and the representation of human- and document- network were not clear and understandable (Figure 25). However, some participants liked this proposal when it is used for collaborative document translation.

I like that the Activity of collaborative translation of an original collection is modeled here and that CRADLE can be used for this. (P₁)

I think this is a clearer representation of what Cradle can be used for (if its purpose is to allow collaboration.) (P₄)

The network diagram is a easier to read than in the original CRADLE



The representation of human- and document- network are clear and understandable.



Figure 25 User feedback of proposal B

Contradictions in Proposal B (figure 26):

- Contradiction between subject and objects, tool and object

In Proposal B, humans are presented more as objects than documents which turns CRADLE into a social tool instead of research tool. Scholars want to see more on the relationship between documents.

I don't like it for any other activity. It seems more like a project management tool than a research tool. (P₁)

I think that with humans being the focus, the software is becoming less about the document altogether. I think that it is difficult to see the relationships, if any, between the documents. (P₂)

- Contradiction between community and division of labor

The network in Proposal B includes two types of roles: creator and contributor. However, in humanities research, the author is the more important role rather than creator. Therefore, some participants suggest that the network should include the document author instead of the creator.

I do not think that having the owners displayed is particularly useful information. Author information is good to have but I do not think that owner information is necessary. (P₅)

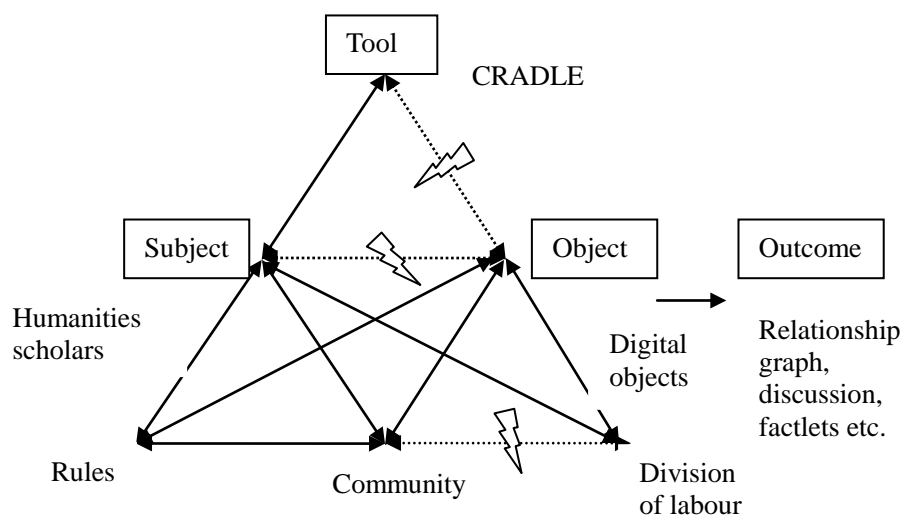


Figure 26 Contradictions identified in Proposal B

6.4 Proposal Refinement

Concluded from 6.3.1, participants put forward both the advantages and disadvantages of proposal A & B. Users liked proposal A more than B because it was more document focused with a little bit of human representation. For proposal B, all participants thought it would be a good feature to include document collaborative activity but not for other activities. We also identified a set of contradictions for each proposal. Based on this analysis, we have summarized the following tips for further refinement.

1. Many participants want a detailed explanation of the lines between documents.
2. Human representation is good, but not too much, for example, in proposal A, it is enough to just attach document author/owner, and numbers of participants in a discussion (don't present all of them (presume it is a very huge discussion)).
3. Most participants think proposal B focuses too much on the human aspect which is not good for humanities research because CRADLE is a humanities research tool and not a social tool. But proposal B is perfect to act as a mechanism for collaborative activities such as document translation.
4. Proposal B works as a description for collaboration. The author should always be attached (not the owner), and there may be a lot of contributors which should normally just be represented by a number. However, when the contributors are small group, it can be more specific.
5. If CRADLE is going to include both proposals, it is better to represent them in separate windows, for example, when users are interested in the author of a document in a document relationship graph, they can click the author and then they will be directed to another page which generates all the documents owned by the author and the contributors attached.
6. It is important to manage the scale of the relationship graph when the document/discussion participants/ document contributors are large. One alternative option is to just attach the number or attach top three active participants, with the others represented as a number.

In conclusion, the refined idea of proposal A&B is to combine document and human representation in a clear way. The document representation should focus mostly on documents, which is good for research, while human representation should focus more on humans which is just for collaborative activities. Thus, for proposal A, we can remove the human representation from discussion when the group size is larger than 5 and present them further in discussion graph. Attaching the author to each document from which users can be directed to the human centered relationship graph (Figure 27).

As shown in figure 27, when a document is selected (e.g. The Hist and Radical Politics (video)), a relationship graph between documents will be generated with its author, discussions, and factlets attached. Discussions whose size is larger than 5 will be presented with only the group size and that discussion will be clickable so that users can view all the participants. If the user is interested in the author of any document in that graph, they can click the author (e.g. Peter) and they will be directed to a human-centered graph, which shows all the documents owned by the author and the contributors. In the same way as the discussion group, when the contribution group is larger than 5 it will also be presented with a number which represents the size. We also provide a detailed explanation on the relationship lines so that users won't become confused by them.

We think this proposal combines proposal A&B in a proper way. If scholars care only about research, they can just focus on the document relationship graph and don't need to click any further. If scholars are doing collaborative activities such as group translation, a human-centered graph would help a lot. We showed this to some of participants and received some positive feedback. However, this proposal still has some problems such as: How do we make sure that 5 is the appropriate threshold of group size? What if there are many discussions on a document and how to present them? The same way as discussion members? What if there are more than one (perhaps five) authors in a document? In order to address these questions we will seek more advice from users and iteratively refine the design in the future.

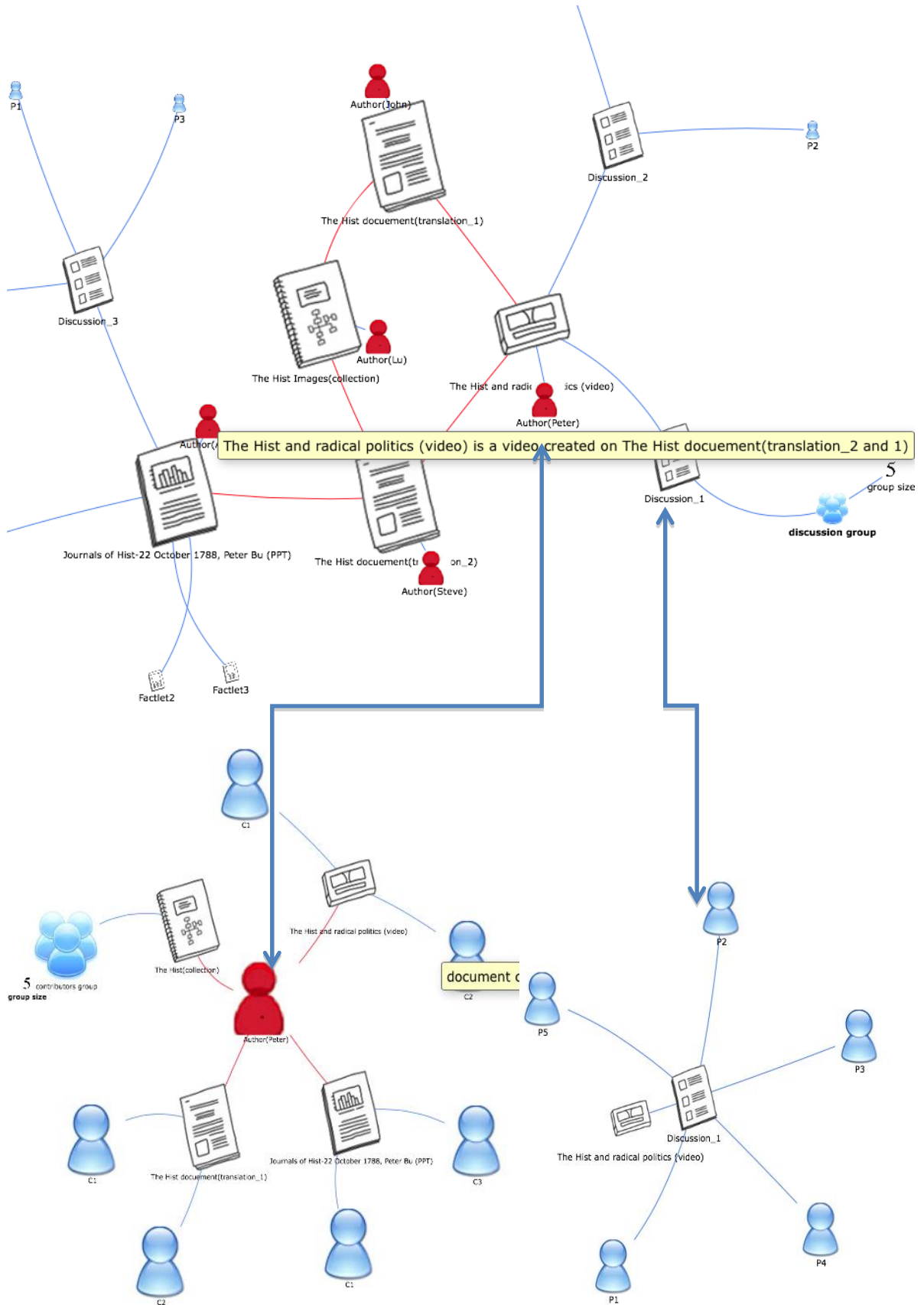


Figure 27 Refined proposal

6.5 Summary

In this chapter, we talked about how current CRADLE represents relationships in humanities scholarship research and what is missing there (human community). Then we introduced two candidate proposals on presenting human community. One is document focused, the other one is human focused. Feedback from real users shows that they both have advantages and disadvantages and we should combine them in a proper way. We refine the prototype according to users' suggestions and got some positive feedback. However, more iterations should be done in the future until users are satisfied with the design.

Chapter 7 Conclusion

This project uses Activity Theory for the evaluation and design of software. We proposed an evaluation framework which includes four steps, which tries to find the contradictions between the real needs of users and the current interface. We identified a number of contradictions using two different methods which proves the effectiveness of this framework.

7.1 Project evaluation and impact

1. CRADLE interface evaluation

Part 4 introduced the Activity Theory based framework used in the CRADLE interface evaluation. This framework has more or less been talked about or used in other research work, but none of them are about online virtual research environment. The special context and activities in CRADLE (humanities scholarship) indicates the usefulness of Activity Theory as the evaluation framework, as opposed to the use of other theories. We used two different methods to identify contradictions. By conducting a humanities study (which included interviews and questionnaires), we collected lots of useful data from real users and identified a number of contradictions between the current version of CRADLE and the expected version of CRADLE. We also found some contradictions between activity system nodes. These contradictions will be very useful in the design of the new version of CRADLE to avoid the similar problems.

2. Evaluation of two candidate proposals (A&B)

Based on the previous user feedback, we proposed two candidate proposals to represent the human community in CRADLE. Proposal A is document-centered with human representations and proposal B is human-centered with document representations. We sought feedback for these two proposals by interviewing workshop participants. Inspired by their feedback, we identified a set of

contradictions in both proposals and proposed some suggestions for further refinement. We redesigned the prototype and sent them back to some participants, seeking further feedback. They suggested that the new design was better but still identified some problems. As mentioned previously, this design is an iterative process and it will be addressed as part of future work on the project.

3. Dependability of the CRADLE User Interface

Although this research project was concerned with evaluating the usability experience of the CRADLE user interface, and not explicitly a dependability analysis, we can also consider the implication of our results for system dependability. Specifically, we can consider the results of the contradiction analysis, as we believe that emergent contradictions will lead to various forms of user error and lack of confidence when conducting certain activities.

For example, users can only go further and further on the relationship graph, but can't go back. If they refresh or click back on browser, they will lose all sessions.

Given the short timescale associated with this project, it was not possible to measure whether contradiction removal (using a new prototype interface) assists with error mitigation, but our observations of user usage together with feedback would indicate that may be the case.

7.2 Successful deliverables

We successfully achieve the following deliverables:

1. Activity Theory analysis of existing CRADLE software. Chapter 3 gives both functionality and Activity Theory analysis of CRADLE. Especially, we identify the six critical elements in AT model and we decompose the central research activity into three levels according to AT hierarchical principle.
2. Activity Theory model of evaluation framework. 5.1 talks specially the AT based usability testing framework we use in this project.
3. User study of suitability for humanities scholarship activities. As mentioned in the

usability testing framework, one of the core steps is the user study workshop. 5.2 gives a very detailed description on how the study is designed, processed and analyzed.

4. Two candidate proposals for user interface update (proposal A – document focus; proposal B – human focus). Chapter 6 introduces the two candidate proposals and how they work to present human community on humanities scholarship context and we already present them using html webpage.
5. User study on proposal evaluation and further refinement. In order to evaluate the two proposals and select the better one, we also conduct user study on these two proposals (talked in 6.3). We got some feedback from users and did some refinement before seeking for second time feedback.
6. Thesis and reports on studies.

7.3 Project limitations & Future work

The overview of Activity Theory in part 1 has talked much about the leading role that Activity Theory has on HCI and interaction design, especially with regards to software evaluation and design. This project further proves its effectiveness to evaluate and design an online virtual research software such as CRADLE. However, Activity Theory still has some weaknesses which need to be overcome in the future. We identified the following problems with both Activity Theory and the framework we used in this project.

- The concept of Activity Theory needed to be more clear and operationalized so that researchers can know how the theory should be applied in concrete cases [10]. For example, in the case of CRADLE, we found it is difficult to use and understand the context using Activity Theory because the theory just explains the general activity model of the human being and community. As we all know, each case has its unique context. Therefore, it would be better if Activity Theory can give more guidelines when dealing with concrete cases.
- It was difficult to collect actions, not even operations using questionnaires or interviews. We asked participants about what actions each activity needed. Unfortunately, none of them were able to provide us with useful feedback for this

question. One good solution is to ask probing questions during the workshop. However, this does not work as well as we would like because participants become confused on how to answer these questions and cannot give answers in a short amount of time. The future work for this problem is to design targeted questions which could help participants to understand what actions and operations are, which in turn will encourage them to give useful answers to the question.

- The questionnaire has limitations in collecting loads of data because users normally won't type too many words. Some participants give very short answers for each question which reduces its value. Also, collecting data using the questionnaire is very time-consuming. It took more than one month to get completed responses from the participants.
- The evaluation framework we used in this project works well to identify the contradictions which might not be visible if we were to use other analytical methods. But this methodology is time consuming because of the extensive nature of questionnaires, focus groups and observations, and therefore it may be expensive. In this case in particular, the potential users are humanities scholars, who were difficult to coordinate with a suitable time to conduct the workshop and it takes quite a lot of time to get all responses.
- We invited 5 participants to our workshop and got five replies for each questionnaire. In particular, the pre-study questionnaire contained all open questions which meant we had to extract useful answers from lots of text. It was a very time-consuming and difficult process because some replies were controversial and unclear. 5 participants are still feasible and not difficult to analyze. However, more accurate software evaluation and design should include more than 5 participants. Assuming we had 100 participants, the data would have been too much to analyze and it would have taken too long to collect all the responses.
- As discussed previously, this workshop only invited 5 participants. To make the result more convincing, more participants should be included to achieve a greater breadth of data. This will be part of the future work on the project.

- Some parts of the questionnaire need to get responses from participants in an iterative way. For example, the learnability of CRADLE in the usability questionnaire should get responses each time the participants used or practiced CRADLE for one week, one month or two months. Using these we can summarize the learning curve. But due to the time limitation of this project, this should be included in future work on the project.
- We have identified a number of contradictions with the current CRADLE interface. The next step is to propose solutions to solve these problems and present them to users for evaluation and seek feedback. This process will be iterative until users are satisfied with the design. The same process will be used in the refinement of proposal A & B as well. Currently, we just perform a first refinement and get feedback on this from users. But there are still some problems that need to be addressed in the future.
- Another future work is about dependability analysis of CRADLE interface. As mentioned before, the contradictions we identified are important sources of CRADLE undependability. Therefore, we are expecting to see whether the removal of contradictions can improve system dependability in future work.

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