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DEVELOPING A METHOD FOR IDENTIFYING AND REDUCING FUNCTIONAL DISCREPANCIES OF INFORMATION SYSTEMS

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Developing a Method for Identifying and Reducing Functional Discrepancies of Information Systems

A

DISSERTATION

Presented to the Faculty of
The University of Texas
School of Health Information Sciences
at Houston
in Partial Fulfillment
of the Requirements

for the Degree of

Doctor of Philosophy

by

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ABSTRACT

Currently more than half of Electronic Health Record (EHR) projects fail. Most of these failures are not due to flawed technology, but rather due to the lack of systematic considerations of human issues. Among the barriers for EHR adoption, function mismatching among users, activities, and systems is a major area that has not been systematically addressed from a human-centered perspective. A theoretical framework called Functional Framework was developed for identifying and reducing functional discrepancies among users, activities, and systems. The Functional Framework is composed of three models – the User Model, the Designer Model, and the Activity Model. The User Model was developed by conducting a survey (N = 32) that identified the functions needed and desired from the user's perspective. The Designer Model was developed by conducting a systemic review of an Electronic Dental Record (EDR) and its functions. The Activity Model was developed using an ethnographic method called shadowing where EDR users (5 dentists, 5 dental assistants, 5 administrative personnel) were followed quietly and observed for their activities. These three models were combined to form a unified model. From the unified model the work domain ontology was developed by asking users to rate the functions (a total of 190 functions) in the unified model along the dimensions of frequency and criticality in a survey. The functional discrepancies, as indicated by the regions of the Venn diagrams formed by the three models, were consistent with the survey results, especially with user satisfaction. The survey for the Functional Framework indicated the preference of one system over the other (R=0.895). The results of this project showed that the Functional Framework provides a systematic method for identifying, evaluating, and reducing functional discrepancies among users, systems, and activities. Limitations and generalizability of the Functional Framework were discussed.

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CHAPTER 1. INTRODUCTION

The advancement of information technology over the past two decades has brought more and more implementations of Electronic Health Records (EHR) in healthcare settings. In spite of what seems to be a positive advance within the healthcare world, more than half of EHR projects fail. This is also true in the dental field where 95% of dental clinics have computers in their offices, but only 30% of dentists use Electronic Dental Record (EDR) (Emmott L, 2004). Furthermore, only 1.8% of dental clinics have gone completely paperless (Schleyer T, 2006). As summarized by Zhang (2005a, 2005b), most of these failures are not due to flawed technology, but rather to the lack of systematic consideration of human issues in the design and implementation processes (Aarts J, 1999; Berg M, 2001; Goddard BL, 2000; Kaplan B 2002; Lenhard J 2000; Southon G 1999; Wager KA 2002). In other words, designing and implementing an EHR system is not as much an IT (Information Technology) project as it is a human project considering human-centered computing such as usability, workflow, organizational change, and process reengineering.

One main goal of designing and implementing an information system is to support the users to do their work in a more efficient way. A user's task is not just to interact with the computer, but to get a particular job done efficiently and effectively. Design of function is a key stage in the design of information systems during which the user accessible functions are chosen and specified. In software engineering, the design of function is traditionally achieved through requirements analysis. This approach is from an engineering perspective and has not systematically integrated human factors from a human-centered, user perspective. In some cases, information systems were designed without a comprehensive requirements analysis. As a result, there are often discrepancies among users' needs, users' activities, and functions provided by the information systems. These discrepancies often contribute to the failure of a system or suboptimal use of the system.

Methods and processes specifically developed for healthcare domains are necessary for the successful development of EHR systems. These systems should increase efficiency and productivity, allow for ease of use and ease of learning, and encourage user adoption, retention, and satisfaction. They should also decrease development time and costs, as well as decreasing support and training costs. A process for identifying and reducing functional discrepancies among users, activities, and systems is an important component of these human-centered methods and processes. The broad and long-term objective of this research was to develop a method for identifying and reducing functional discrepancies found among users, activities, and systems.

To accomplish this objective, the focus of this research was to propose a theoretical framework and then use this framework to develop a method to identify and reduce the discrepancies among the functions provided by systems (Designer Model), desired by users (User Model), and exhibited in the activities of users interacting with systems (Activity Model). We applied the framework and method to analyze the EDR systems in University of Texas Dental Branch at Houston (UTDB) dental clinic. The User Model was developed by conducting a survey that identified the functions needed and desired from the user's perspective. The Designer model was developed by conducting a systemic review of the EDR and its functions. The Activity Model was developed using an ethnographic method called shadowing where EDR users were followed quietly and observed for their activities. These three models were combined to form a unified model. From the unified model the work domain ontology was developed by asking users to rate the functions in the unified model along the dimensions of frequency and criticality in a survey. The functional discrepancies, as indicated by the regions of the Venn diagrams formed by the three models, were consistent with the survey results. The results of this project showed that the functional framework provides a method for identifying, evaluating, and reducing functional discrepancies among users, systems, and activities.

CHAPTER 2. NON-TECHNOLOGY BARRIERS OF EHR ADOPTION

This chapter reviews the studies about the successes, failures, and challenges of designing and implementing EHR systems. The purpose is to show that in addition to technical challenges, human and other non-technology factors play important roles in the success or failure of EHR systems. Among the human factors issues, functional requirements and user interfaces are two major categories. User interface issues have recently attracted increasing attention in the EHR community. However, functional issues from a human-centered perspective have not been well studied yet.

2.1. Challenges in EHR

2.1.1. The Present Status of EHR

To date, the Electronic Health Record system is one of the main research topics and application fields for health information science. The need of EHR has been very clear, not only for individual institutions but also for a cross cooperation and nation-wise implementation. There have been numerous efforts at the national level to improve or set up the standard. The most current Institute of Medicine report on “Key Capabilities of an Electronic Health Record System” (2003) sets the framework for the evaluation of current EHR and the design and development of future EHR. The American Dental Association (ADA) formed a special committee, standard committee on dental informatics, in 1996 to develop a national standard. Furthermore in 2001

ADA and American National Standards Institution have worked on a specific standard for clinical data architecture. In 2004, the American College of Medical Informatics (ACMI) dedicated its symposium's theme to the review of the status of EHR and the development of promotional strategies (Ash 2004, Bates 2004, Detmer 2004). The conference was dedicated to the practical strategies of implementing EHR systems. President Bush's Health Information Technology Plan has targeted the goal of ensuring that most Americans have electronic health records within the next 10 years. Thus the future of health records is very clear; the electronic health record is the future. However, although we have already had so many plans, committees and resources working toward this direction, more than half of the EHR implementation plans have been terminated or failed. What is the reason for these failures?

2.1.2. Barriers to adoption of EHR/EDR

Numerous research papers have shown that Electronic Health Record may contribute positively in a various of aspects namely improvement of the quality of health care, reduction of error, and higher patient satisfaction (Lindberg 1995, Shortliffe 1998).Currently, the deployment of EHR in the United States is less than 10%. Regardless of tremendous effort and money during the past two decades, there are still many barriers that prevent EHR from being accepted by healthcare professionals on a larger scale (Anderson J 1997, Cimino J 1999, Essin D 1990, Kushniruk A 1996, Melles R 1998, Patel V 1998, Tang P 1994, Zhang J 2002). In some cases, institutions implemented EHR systems but later discontinued them (Goddard B 2000, Lenhard J 2000, Wager K 2002). A well known case is the Computerized Physician Order Entry (CPOE) project at Cedars-Sinai medical center in Los Angeles (2003) which was terminated because physicians complained that entering and sending orders using EHR took longer than using paper systems. Additionally, a workflow of the routine was changed and even interrupted. Once users refuse to use a system, it does not matter how good the system is or how much benefit it can bring to the institution, it will be terminated or fail. “ I love it, but I just don’t use it” explained a lot of the users’ real feelings about EHR.

The Electronic Dental Record (EDR) system is a special type of EHR. It is smaller and more limited in function than the EHR for medical care, due to the nature of dental care. To date, available statistics show that only 30% of dental practices in the United States have installed EDR. Very few EDR systems are used on a regular basis. Most EDR systems are used for scheduling (78%), treatment planning (64%), and patient education (61%). Most dentists (58%) do not use EDR for the most basic function performed on paper charts, i.e., progress notes, even if this function is available in EDR. Without a progressive approach, the goal of replacing paper records by EDR will not be achieved. In summary, most dentists do use a computer in their office, but do not use EDR; and those who do use EDR do not take advantage of its full range of function and capacity. It is clear that there is a definite barrier in achieving the adoption of EDR.

2.1.3. Usability Issues: Function Matching

Usability is one of the major barriers to the adoption of EHR in general and EDR in particular. One usability problem is the mismatch among the functions implemented in systems, the functions users want, and the functions exhibited in user activities. Some EHR systems were created by adding patient data on top of an existing system that was designed for different purposes (e.g., clinical data added to financial billing systems). Such systems do not support the tasks that physicians want to perform. Other systems are simply data repositories that collect but do not organize it into usable formats (Cimino J 1999). The cause of this problem is the lack of adequate functional analysis based on human-centered principles. EHR systems have the potential to provide complete, accurate, and timely records at all points of care at all times in a way that maximizes a physician’s time for the care of patients and minimizes time spent on housekeeping activities. However, before this promised function can be realized, the EHR system has to be rendered usable by those implementing the system. Regardless of how superior a system’s functions and technology are, the program is useless if it is not or cannot be successfully implemented. A typical reaction from physicians is that they like the patient results provided by EHR but do not like the extra time required for computerized tasks. Thus, if the functions of EHR do not match the needs of users and the activities they perform, EHR will not be a useful tool. This is clearly demonstrated by an example, which shows that although user interfaces are important, if the functions are irrelevant then the system would not be used even if it has an excellent user interface. Goransson B (1987) showed that a database was considered too difficult to use. They improved the interface to make its use easier. However, after the redesign of the user interface they found no one in the organization needed the data provided by the system. At this point, it appears that the best solution for this problem is to simply remove the database. This example shows that the poor choice of function has wasted time, money, and effort.

Many usability methods focus on optimizing user interfaces for pre-selected functions. However, if the initial requirements and system functions are poorly selected, the rest of the development will probably fail to produce a usable product. If users need the functions, they might be willing to buy and use a clumsy, difficult product with poor user interfaces. However, if the functions are poorly chosen, no matter how easy it is to use the product, it will not be used. Thus, the functions chosen for developing or evaluating any system are extremely important and they should be chosen with care before any other actions are taken.

2.1.4. Human-Computer Interaction Theories

The mismatch among users, tasks, and systems is one of the main problems facing the development of EHR systems. A thorough understanding of the interaction between them is essential for the success of EHR. There are various studies in human-computer interaction (HCI) that examine the relations between users and systems. For example, Norman D (1986), Young R(1983), diSessa A(1983), and Nielsen J(1990) all tried to explain the interaction between computers and humans in terms of models of the systems and models of users. However, these models do not provide any concrete process that specifies how a system can be designed to develop a good match among users, tasks, and systems.

In healthcare IT, there is a tendency to assume that the requirements for a piece of software can and should contain all that is necessary to design and implement the software. The common process of design specifies the requirements by simply generating a wish list of desirable features or functions. However, even if the list of requirements is generated from users, it does not mean that the final product has the right functions to meet the need. This is because even the users sometimes do not know what they want. What the users want may not be what they use, and they may not be aware of some new functions afforded by the system.

Zhang and colleagues (Zhang J, 2005; Zhang J & Butler K, 2007) developed a generate framework called UFuRT (User, Functional, Representational, and Task analyses) for the design of human-centered EHR. This framework combines the user, representation, task, and functional analyses into an integrated framework. Functional analysis is a major component of this framework. However, it is only at an abstract level and is not a process that people can use to generate the functions for system design.

A review of the literature indicates that there is little research on the methodology or process for identifying and reducing functional discrepancies among users, tasks, and systems. There are some attempts, such as the one by Kieras D(1995), that used Goals, Operations, Methods, and Selection rules (GOMS) analysis to analyze a small system for the design of function. Although Kieras mentioned the importance of function in designing a system, his method is not an operational process that can be applied to the design of complex systems such as EHR.

2.2. Summary

In the previous literature review, it was shown that there is a great need for EHR and that a great deal of effort has been put into its design. However, more often than not, the EHR systems do not work well or cannot be easily used because there has been a lack of consideration of the human and other non-technology factors from a human-centered perspective. There are many areas that need to be researched, especially in usability and the interaction among user, system, and the need for the work.

Based on these reviews, we designed this study to try to understand and develop a higher-level method for system design with a focus on function. The broad and long-term objective of this project was to develop a process for identifying and reducing functional discrepancies among users, activities, and systems. This project is significant in the following aspects:

In the theoretical aspect, the process will enhance our understanding of functional requirements of human-centered design and our understanding of why an undisciplined approach to a system design often leads to serious functional discrepancies among systems, users, and activities. In addition, this process ***is*** a method that can be used to identify and reduce functional discrepancies among systems, users, and activities.

In clinical and practical aspects, the results of this study can be directly used to improve the EDR system implemented at the UTDB (University of Texas Dental Branch). The EDR system, Clinical Information System (CIS), is the main model that we used to study since this EDR has been used with paper charting from 1995-2007 at UTDB. The new EDR system, Axium, is another EDR system studied in this project in order to verify the theoretical model. The users are dentists, dental students, assistants, and administrative personnel (front desk, practice care coordinators, cashiers, and schedulers) with UTDB. The activities were the ones observed at UTDB practice. These results can also be applied to similar EDR systems and general EHR systems. In general, this process, with modifications of some domain-dependent factors, is applicable to non-healthcare domains as well.

CHAPTER 3. USER INTERFACE VS. FUNCTION

Chapter 2 gave a broad review of the non-technology factors of EHR barriers. Among them are two major ones: the user interface and the function of an EHR system. This chapter describes two preliminary studies that demonstrated that user interface is only one of the major factors determining a system's usability. The first study is the comparison of EHR and Paper Medical Records, and second one is the comparison of two EHR systems, one with a graphic user interface and one with a text-based user interface. These studies, in conjunction with the literature review, led to the conception and the development of the Functional Framework which is the primary product of this dissertation research.

3.1. Comparing EHR and Paper Records

In this study, we conducted a cognitive task analysis using GOMS to compare the usability of an outpatient EHR (Logician) and paper systems for prescription writing (Chen J-W 2004).

The methodology used for cognitive task analysis identifies the Goals, Operations, Methods, and Selection rules (GOMS) for performing a cognitive task (Card S 1983, Kieras D 1997). The results of GOMS analysis show that the paper record needs 15 steps in order to finish the task of prescription writing, while Logician needs 25 steps to finish the task. We collected preliminary data on the time it takes to write a prescription with paper and with EHR. It took 210 seconds to complete writing an electronic prescription compared to 27 seconds for a paper prescription. Table 1 shows the comparisons between the two methods.

Table 1. Comparison of EHR and Paper- Based Prescription Writing

Paper Record	**EHR**
Total number of workflow steps: 15	Total number of workflow steps: 25
Higher in mental workload	Lower in mental workload
Direct manipulation	Indirect manipulation
The amount of GOMS knowledge is smaller (15 chunks)	The amount of GOMS knowledge is larger (66 chunks)
Learning is harder and requires a larger mental knowledge base	Learning is easier and requires a smaller mental knowledge base
Little technical skill required	Some technical skill required

For each of the steps in the GOMS analysis, we analyzed whether the information needed to carry out a specific action is internal (memorized in the head) or external (perceivable from the environment) (Zhang J 1994). External information can be processed more efficiently than internal information, thus making a product with more external information easier to use than a product with more internal information. The result shows that writing a prescription on paper requires more internal representation than using EHR. More internal representation may cause more medication errors than EHR due to the higher cognitive workload.

In summary (Table 1), the analyses indicate that it is more time consuming and that more steps are needed to complete an e-prescription. On the other hand, there is more internal representation in writing a prescription on the paper pad. The more steps and extra time commitment may contribute to resistance to EHR and prolong the longer learning time. The reduction of internal representation would reduce the possibility of medication errors. Although time consuming, the EHR prescription feature eliminates illegible handwriting and informs the physician of drug interactions. These features reduce medication errors and improve patient safety. Thus in the functional sense, the EHR did provide the function; however there might be some room for improvement.

3.2. Comparing Graphic and Text-Based User Interfaces

In a preliminary study (Chen J-W 2007), we conducted an in-depth cognitive task analysis to compare two isomorphic user interfaces, Graphic User Interface (GUI) and Text-based User Interface (TUI) (Figure 1), in performing a task with an electronic dental record system. In user interface design, GUIs are commonly considered to be superior to TUIs because the former offers direct manipulations. This assumption often leads to blind implementations of GUI for new users, or to replace TUIs. In this study, we used several task analysis techniques (GOMS analysis, hierarchical task analysis, distributed representation analysis) (Table 4,5, Figure 4, 5) to compare the efficiencies of a GUI and a TUI using the same EDR software system. The same task was performed by both novice users and experts user in both GUI and TUI.

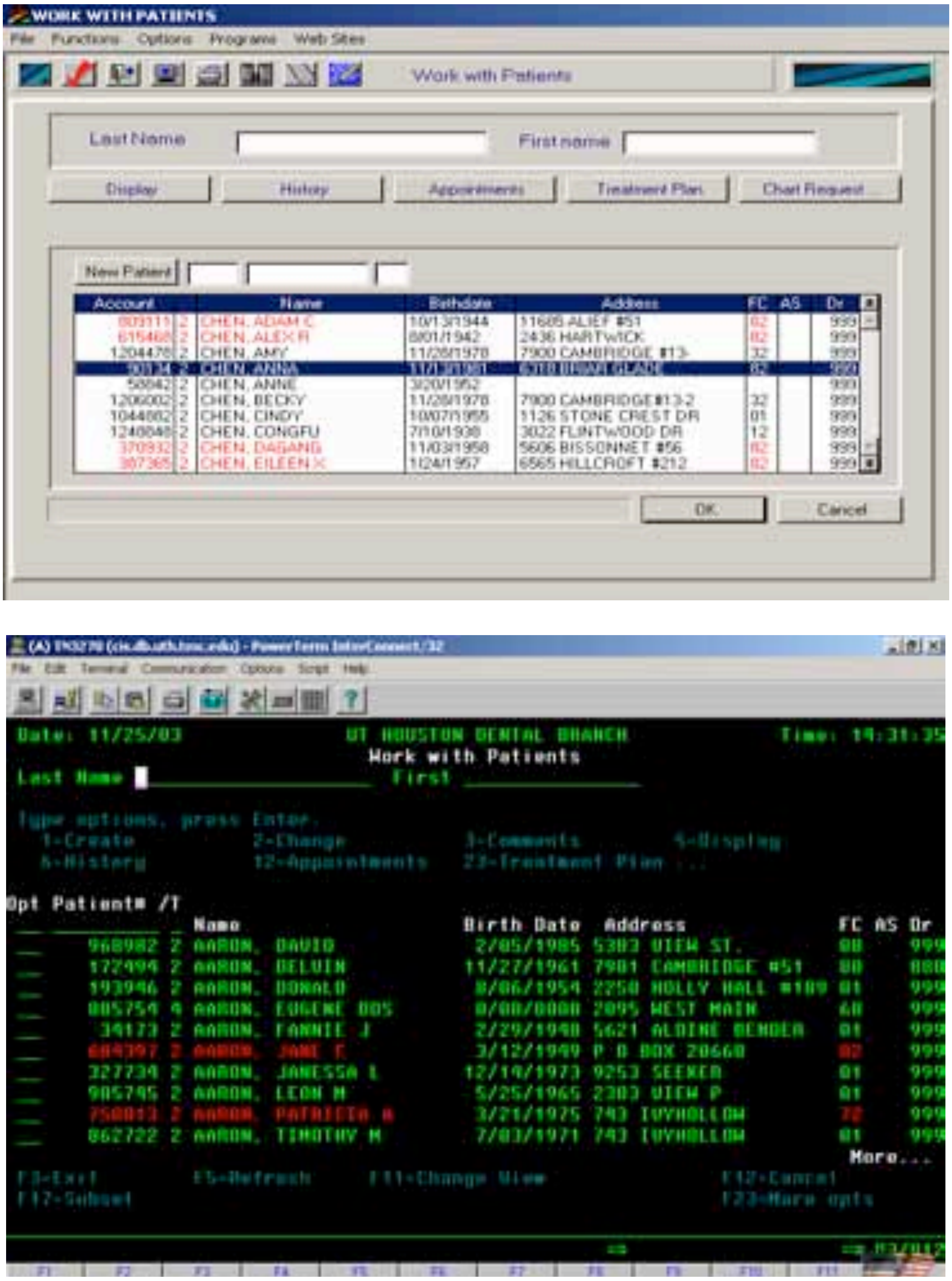


Figure 1. Two isomorphic user interfaces, GUI (top) and TUI (bottom), of the same EDR system (CIS).

3.2.1. Results

Table 2 shows the descriptive result of the average time and external steps taken for task performance by expert and novice users. For the expert user, GUI appears to require more time and more steps, but the difference between text and graphic was not significant (time: $t(8)=0.98$ $p=0.365$, t-test; step: $t(8)=0.526$ $p=0.618$, t-test), probably due to the small sample size (4 per cell).

Table 2 –Comparison of average time (seconds) and steps (number of steps) utilized by experts, novices, and both groups combined using GUI or TUI

	Expert	Novice	Combined
GUI time (sec)	52.5	137.5	113.2
TUI time (sec)	36.5	311.3	232.8
GUI step	12.8	19.2	17.4
TUI step	10.8	30.9	25.1

Table 3 –-Comparison of average time (seconds) and steps(number of steps) utilized by novices using GUI or TUI first in performing the task

	TUI time (sec)	GUI time (sec)	TUI step	GUI step
TUI first	438.8	81.2	38.6	12.6
GUI first	183.8	193.8	23.2	25.8
Overall	311.3	137.5	30.9	19.2

Table 3 shows the descriptive result of the average time and steps used for task performance by novice users only. (Reminder: novice users performed the task with both TUI and GUI). For novice users, interface types made a significant difference in task performance time (dependent variable: GUI time, TUI Time; independent variable: GUI first or TUI first; p=0.024, General Linear Model (GLM) repeated measurement) and steps (dependent variable: GUI steps, TUI steps; independent variable: GUI first or TUI first; p=0.001,GLM repeated measurement). This result shows that for the beginner using GUI, significantly less time is needed to perform a task than when using a TUI. This is also true for the steps needed for this task. This result did demonstrate GUI is an easier interface for a novice user.

Another interesting finding is that there is an interaction between interface type and the order of task (time: p=0.019; steps: p=0.001) (see Figures 2 and 3).

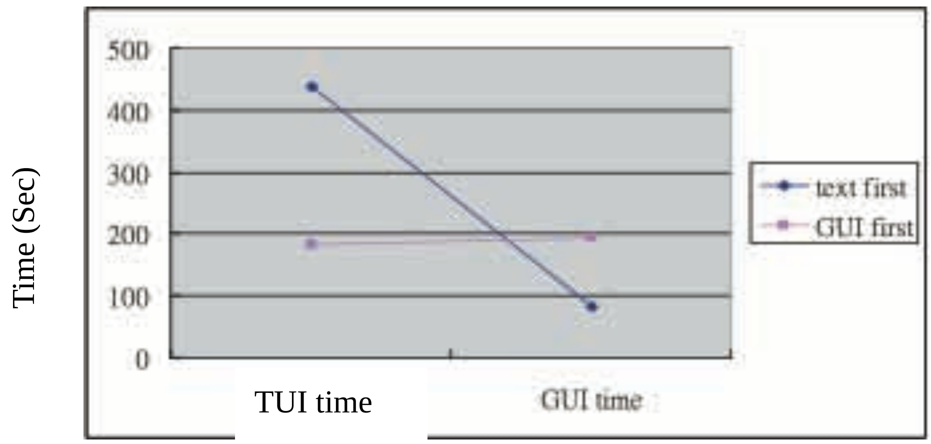


Figure 2 –Time used to perform task by using GUI or TUI with different sequence

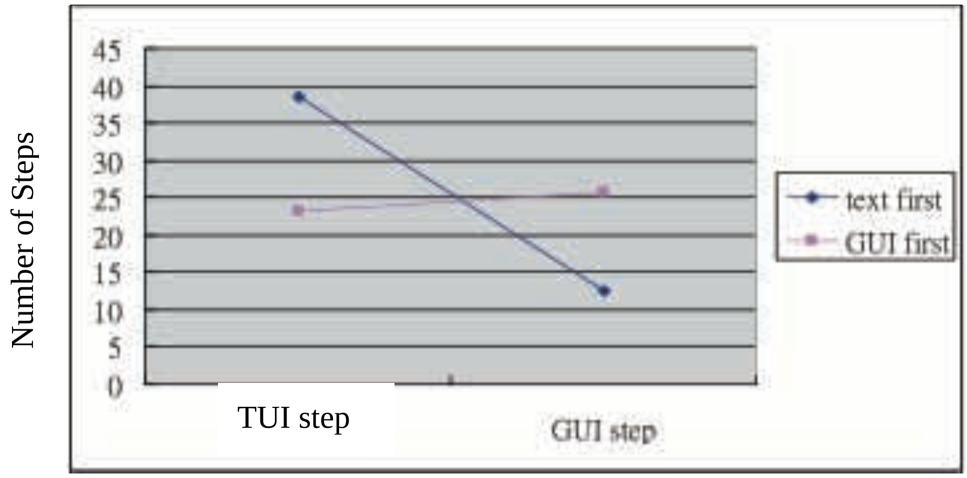


Figure 3 –Steps used to perform task by using GUI or TUI with different sequence

That is, if a novice used a TUI first, his/her performance of the same task using GUI was much better. However, if the novice used the GUI first, there was no improvement when he/she then performed the same task using TUI. This is an asymmetrical learning effect. It also showed that a novice user might spend more time when they use the text interface first. But the TUI learning experience would help novice user learn how to use graphic interface better.

3.2.2 Detailed task analysis result

Table 4 and Table 5 show the case study results of combining GOMS analysis, cognitive distributed representation analysis, and time estimated on each task in either TUI or GUI.

Table 4 –GOMS analysis, distributed representation analysis and time record using GUI to finish a task

Method for accomplishing goal of signing in the system.			
Step #	**Step description**	**Cognitive distribution**	**Time (seconds)**
Step 1	Think of user name	Internal	18 sec
Step 2	Key in user name	External	
Step 3	Think of password	Internal	
Step 4	Key in password	External	
Step 5	Hit "Check Mark" key	External	
Step 6	Hit Enter key (redundant)	External	
Method for accomplishing goal of finding patient			
Step 1	Recognize the blank location	Internal	20 sec
Step 2	Locate cursor at last name blank	External	
Step 3	Look at patient's last name	External	
Step 4	Type patient's last name	External	
Step 5	Look at patient's first name	External	
Step 6	Type patient's first name	External	
Step 7	Hit "Ok" key	External	
Step 8	Recognize patient from the list	External	
Step 9	Double click at patient's name	External	
Method for accomplishing goal of finding specific student			
Step 1	Think which button can list student's name	Internal	17 sec
Step 2	Click treatment plan	External	
Step 3	Look at screen and find student's name	External	
Step 4	Hit back button to go back to menu	External	
Total: 19 steps, 4 internal15 external representations, 55 sec			

The steps are the results of expert performance in each interface. When comparing the number of steps used to accomplish the goal, GUI needed fewer steps than TUI (19: 21 respectively). In cognitive loading, four steps in each interface resulted in internal representation. Therefore, the GUI did not really reduce the cognitive load. Comparing the time spent in accomplishing the goal, users spent more time with the GUI than with the TUI (55 seconds: 47 seconds respectively)

Table 5 –GOMS analysis, distributed representation analysis, and time record using TUI to finish a task

Method for accomplishing goal of signing in the system.			
Step number	**Step description**	**Cognitive distribution**	**Time (seconds)**
Step 1	Think of user name	Internal	20 sec
Step 2	Key in user name	External	
Step 3	Think of password	Internal	
Step 4	Key in password	External	
Step 5	Hit Enter key	External	
Step 6	Hit Enter key (redundant)	External	
Method for accomplishing goal of finding patient			
Step 1	Recognize the location of the blank	Internal	10 sec
Step 2	Hit Shift and Tab key	External	
Step 3	Locate cursor at last name	External	
Step 4	Look at patient’s last name	External	
Step 5	Type patient’s last name	External	
Step 6	Hit Tab key to move cursor to first name	External	
Step 7	Look at patient’s first name	External	
Step 8	Type patient’s first name	External	
Step 9	Hit Enter key	External	
Step 10	Recognize patient in the list	External	
Step 11	Hit Tab key to locate cursor in front of patient’s name	External	
Method for accomplishing goal of finding specific student			
Step 1	Think what key can list student’s name	Internal	17 sec
Step 2	Type 70 in the blank	External	
Step 3	Look at the screen and find student’s name	External	

Step 4	Hit F3 key to go back to Menu External	
Total:21 steps, 4 internal 17 external representation, 47seconds		

Figure 4 and Figure 5 show the case study results of hierarchical task analysis for both GUI and TUI. The expert workflow is in black; the novice's workflow is in red. The goal is on the top, tasks are on the second level, and all other listings are the subtasks. The wave shape denotes the question the user was asked. The diamond shape indicates the decision. In Figure 4, the novice used 10 more actions than the expert to find the correct route. For the task, "sign in the program", both expert and novice did it without problem. But after the user signed in the system, a redundant screen showed up in which the user had only one choice: to click "enter". Another problem of the interface is that the explanation on the screen was not very clear. For example, one function needs to click "F23" key, but there was no "F23" key on the keyboard. The main problem in the TUI was in the task "find the patient". Once the user found the right patient they could easily find the information about the student. In Figure 5, the novice used 10 more actions than the expert to find the correct route. For signing in the program, both expert and novice users did it without any problems.

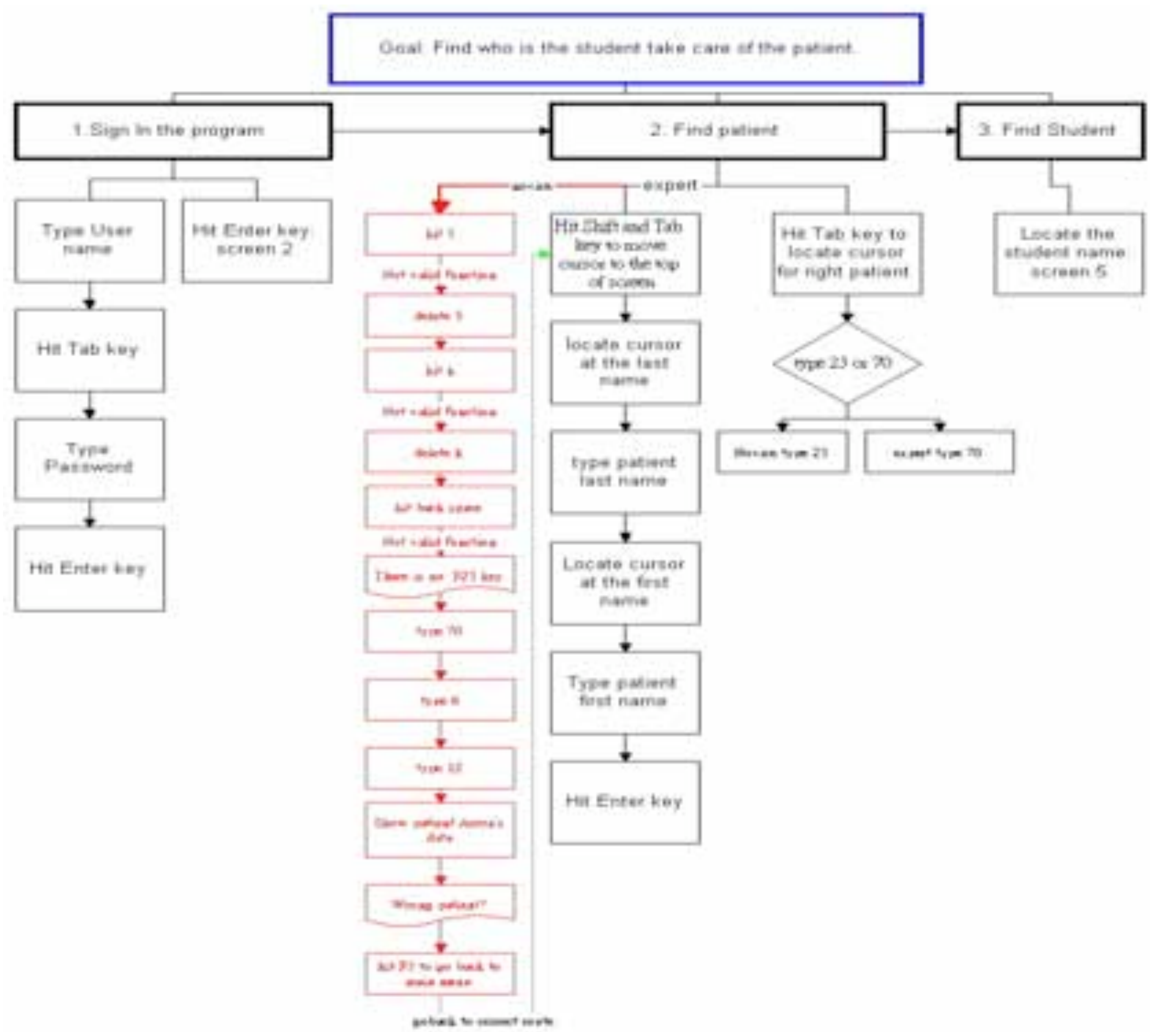


Figure 4- Hierarchical task analysis using TUI to complete the identical task by expert (black) and novice (red)

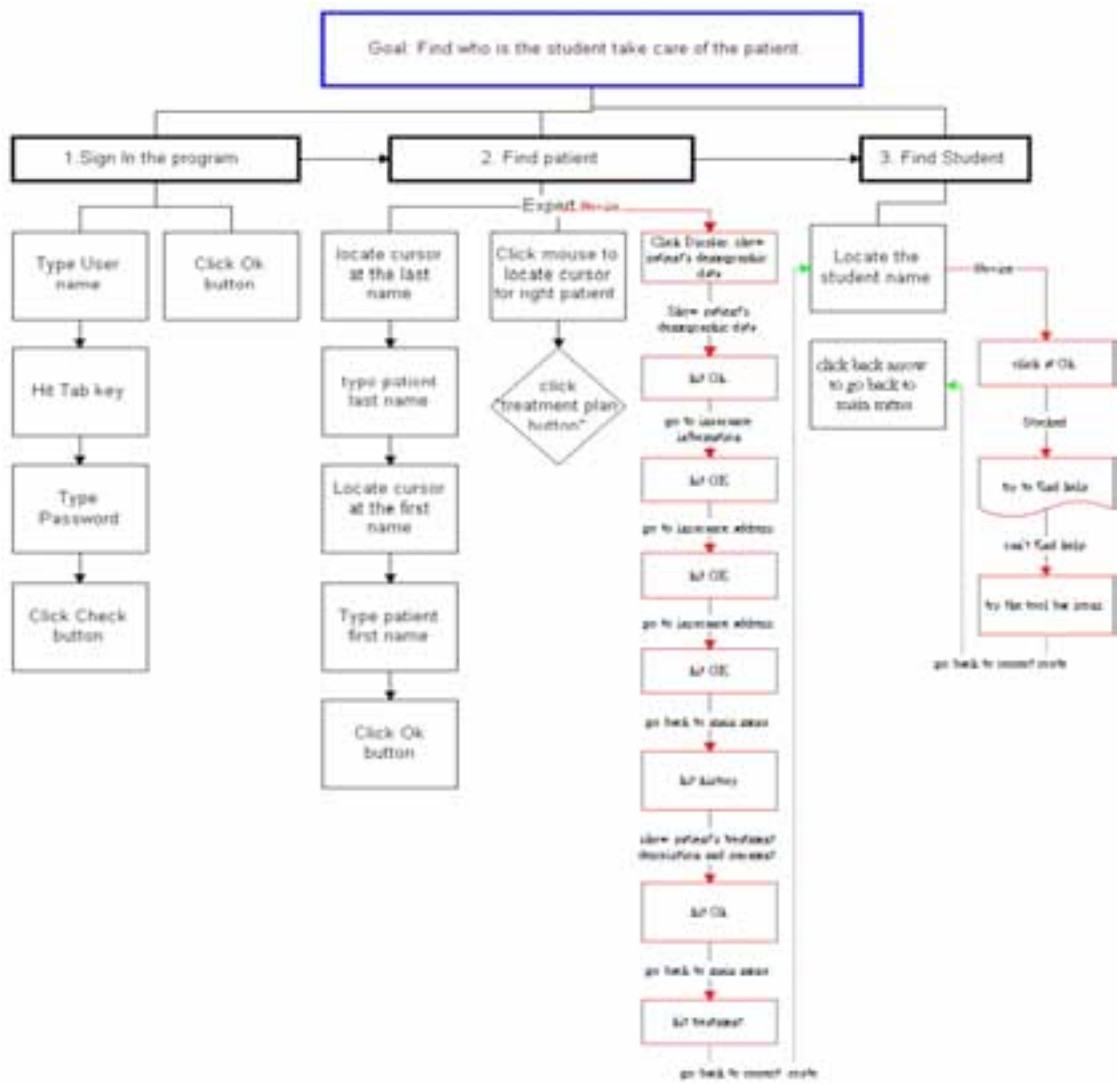


Figure 5 -Hierarchical task analysis using GUI to complete the identical task by expert (black) and novice (red)

The following is a summary of the results in this study:

- GUI requires significantly less time and fewer steps than TUI when used by a novice.
- For a novice, use of TUI or GUI as the first experience makes a difference for

subsequent use of interfaces

- GUI does not reduce cognitive load for either the expert or the novice.

3.2.3. Summary of preliminary studies

Evaluation of these two isomorphic interfaces (GUI and TUI) for the EDR system shows that GUI was not necessarily better than TUI for an expert. They were only better for novice users in this study. For novice users, the first experienced interface made a significant difference in the subsequent use of the interface. When TUI was used first, it had a large learning effect to the GUI. TUI is a valuable tool that should be readily available for training novice users for frequently changing interfaces of software. The task analyses we carried out were, in general, consistent with the empirical findings. One lesson learned from this study is that the interface itself, whether GUI or TUI, does not correlate directly with good or poor user performance. This study demonstrated that the interface itself could not solve all the problems of usability.

A valuable lesson learned from this study is that whether a user interface is user-friendly or not depends on the mapping between the properties of the user interfaces and the proposed tasks. This fact reflects our hypothesis for the functional framework to be developed in the next chapter.

CHAPTER 4. DEVELOPING A THEORETICAL FRAMEWORK FOR FUNCTIONAL DISCREPANCIES

The studies in Chapter 3 demonstrate that good user interface is not sufficient for good usability. In order to achieve good usability, a system should have the essential function as well as good user interfaces. It is the mapping between the function and the interface, in the context of a specific type of users that determines the usability of a system. This chapter is devoted to the development of the key component of this dissertation research: the theoretical framework for identifying and reducing functional discrepancies of information systems. Section 4.1 gives an overview of the theoretical framework and its three component models. The three sections that follow provide the details of how each of the three models was developed and the previous work, both theoretical and empirical, on which each model was based. Chapter 5 will describe how this theoretical framework was used in a real world clinical setting.

4.1. Overview of the Functional Framework

The Functional Framework (FF) was developed to identify and reduce the discrepancies among what users want, what users do, and what functions a system provides. One main problem for many systems is the mismatch among the user needs, user activities, and system functions. For example, a dentist wants to record the progress of a patient's periodontitis. The designer needs to provide a probing depth chart within the EDR system, as well as a place to indicate whether this patient needs the procedure. Thus, a designer needs to know the need for the task and the user's intention. A user needs to know the activity and also how to use the system to carry out the task.

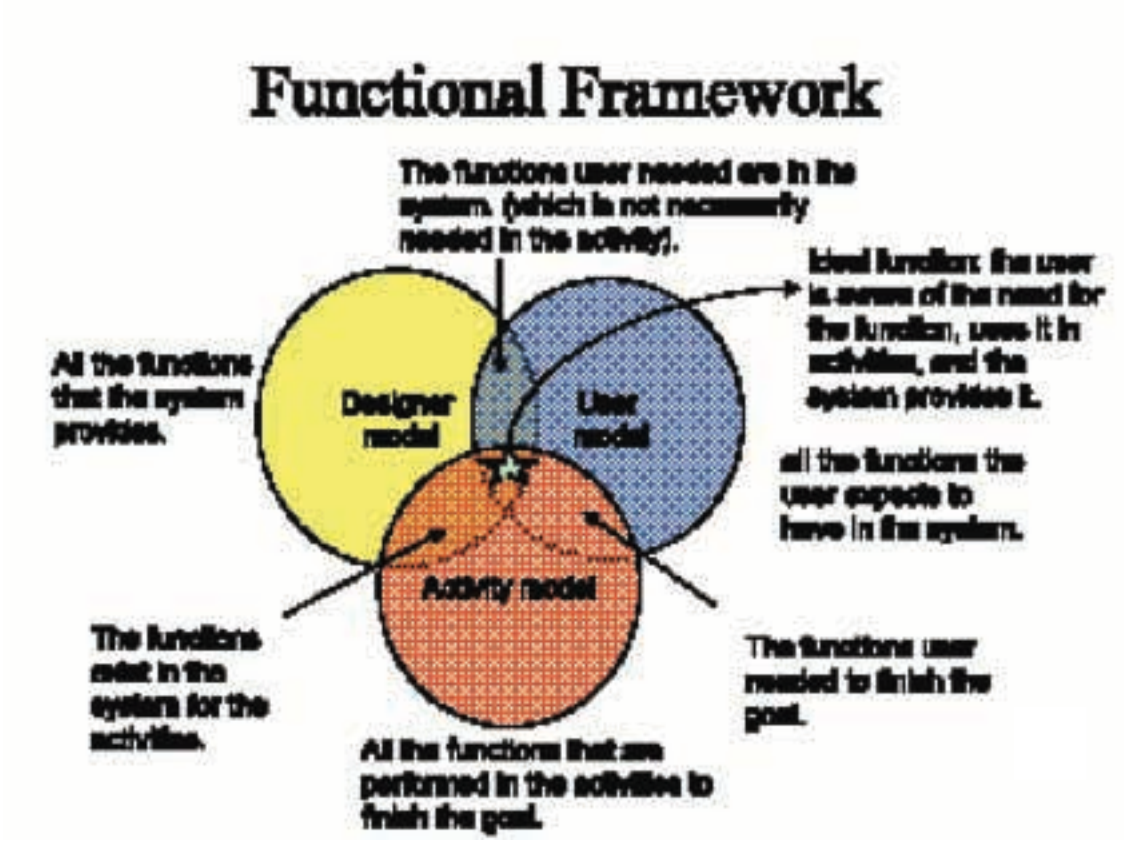


Figure 6. Functional Framework

Figure 6 shows the proposed functional framework. It has three major components: Designer Model, User Model, and Activity Model.

- Designer Model (D): all the functions the EDR system provides.
- User Model (U): all the functions the user expects to have in the EDR system in order to finish the activity.

- Activity Model (A): All the activities for accomplishing the goal.
- U ∩ D ∩ A= ideal function; the function that user want and needed to achieve goal and also provided by the system
- U ∩ D = function that user expects exists in the EDR system but it is not related to activity (MSN messenger)
- U ∩ A = function that user needs for the activity but which is not in the EDR system (automatic caries record)
- D ∩ A = function that designer designed into the EDR system for the activity but which the user was not expecting to have (Thumb print signature)

In my research, a function is defined as "an activity that is inherent in the work domain; performed by a person, a machine, or a person jointly with a machine". For example, cancel an appointment, check insurance claim, and enter a treatment plan are all functions. The function should involve a verb and an object. For example, "make an appointment in schedule" is a function, however, appointment or schedule is not a function. The function should be in the lowest but most descriptive level but not just by verb only such as "delete", "save", or "change" to reduce the confusion and redundancy.

The following sections are the descriptions of preliminary studies, which supported the development of the functional framework and the three main models.

4.2. The User Model

User model is a model that represents the user’s needs and expectations in a system. It appears to be a simple task to develop. However, in reality, to achieve an in-depth and systematic analysis of what user wants is not trivial and sometimes difficult. Not only do humans have the tendency to forget, but also the model is always evolving with different experience and training. The impermanence of user’s need and wish makes development of user model a very tough task. Norman D(1983) mentioned that mental models are usually incomplete, have vague boundaries, tend to be unscientific and contain superstition due to the restrictions of each person’s experience. Norman made very clear that such a model is very unstable and hard to identify. Craik has mentioned very similarly that “a mental model is hard to measure and unstable mental models can make people try out alternatives, conclude which is the best of them, and react to future situations before they arise” (Craik F, 1994). Thus mental model is very important for user to develop new skill and to survive in a new environment. Mental models can help a designer understand what the user needs and how the system interacts with user. The main burden, however, should rest increasingly on system designers to analyze and capture the user's expectations and build that into the system design (Norman D,1988). In Human-Computer Interaction (HCI), mental model has been one of the important topics. The following is a summary of HCI mental models.

Surrogate model (1983 Young) is mechanistic, if highly simplified, accounts of a device (e.g., a computer system). The Young's *surrogate* theory has the hypothesis that the system can be a total replacement of all the functions that the user would like to have, or a perfect ideal system. In the idealistic view, if such a system can be developed that will be in a best situation. However, the problem of this model will be, the design will be very complex and it will be very hard to define the complete functions. Since in this model the goal is to fulfill all the needs from the user, then it will be very time consuming to gather all the functions and also a huge amount of effort will be needed to design the system that can do or even maintain it. The drawback is that for a complex system it would take considerable time and effort to do. And also since we know the user's thoughts keep changing and the need may change real fast, then the problem will be a frequent redesign cycle which may not be able to catch up with what the user needs. Thus *Surrogate models* are more appropriate for the system that is very mature and stable, where the user's need does not require too much change or in the system that fits very specifically to certain specific user.

Task-action mapping model – (1983 Young) is a model that try to simplified the surrogate model and develop a more reasonable and possible to develop kind of system. The tasks-action mapping model has to list the tasks that a user needs to do in the real world situation and then use this list to develop the system that provided these functions. The most important feature in this model is to have the mapping between the task of the user and the action of a computer system. It's not just what the user wishes to have or an aggregation of very abstract thoughts; it is based on a very practical requirement which is the tasks that user needs to perform. For example, if the user needs to fill out a form, then the tasks will be find the information, find the right place to write the information in the form. In the system, then the action of find information, search the cell to enter data will be provided in the system, which is the mapping between tasks and action.

DiSessa A (1986) proposed another model, which is named, distributed models. It has two substructures: *Structural model and functional model. Structural model* is similar to the idea of surrogate models. It is independent of a specific task. It has very detail functions, and the users will have detail functions that the system can be designed for. The drawback of this model is still very similar to surrogate model, too time consuming, a lot of effort, and endless cycle of changing and maintaining of the system. *Functional model*, in the other hand, is more similar to task-action mapping model, which was proposed by Young. (refer to previous 2 paragraphs). The functional model has a list of functions that is mapping with what user needs to perform in a specific task in the real world. One may confuse the functional model and the functional framework as proposed in this dissertation; the main difference between this model and the functional framework is the functional framework includes the activity model and also it integrates the three separate models into one framework with clear and systemic procedures.

Norman (1986) defined user model as “the way the user interprets the system image” and design model as the “conceptual model of the system to be built ”. Thus there are two different models in the conceptual level of user and computer interaction. The user tries to interprets what the system provides and what functions the system can be used for. However what user believes to the system image to be may not match with the real system, the “system image” in the physical level. In the physical level, system image is “the image resulting from the physical structure that has been built” (including the documentation and instructions). The design model is the “conceptual model of the system to be built ”. One may think that the conceptual “design model” should be very close to “system image” in physical level. In fact, due to the limits of designer’s ability, time, financial support, etc, a system image could be very far from the design model. Sasse M(1997) mentioned that if the designer creates the design model correctly and communicates the model successfully through the system image, users interacting with the system would develop an appropriate user model which will then allow them to interact with the system satisfactorily.

After reviewing the theories of human-computer interaction model, we found that most of these models focus on one to one interaction, which means one user interacts with one user. Some models in particular (task-action mapping model, functional model) exclusively focus on the specific task only. These theories are appropriate for a small scale and detail to explain the interaction between the computer (system) and a user. However it will be kind of impossible to apply these to the large scale and complex system such as EHR or EDR.

A summary of the human-computer interaction model theories is shown in Figure 7.

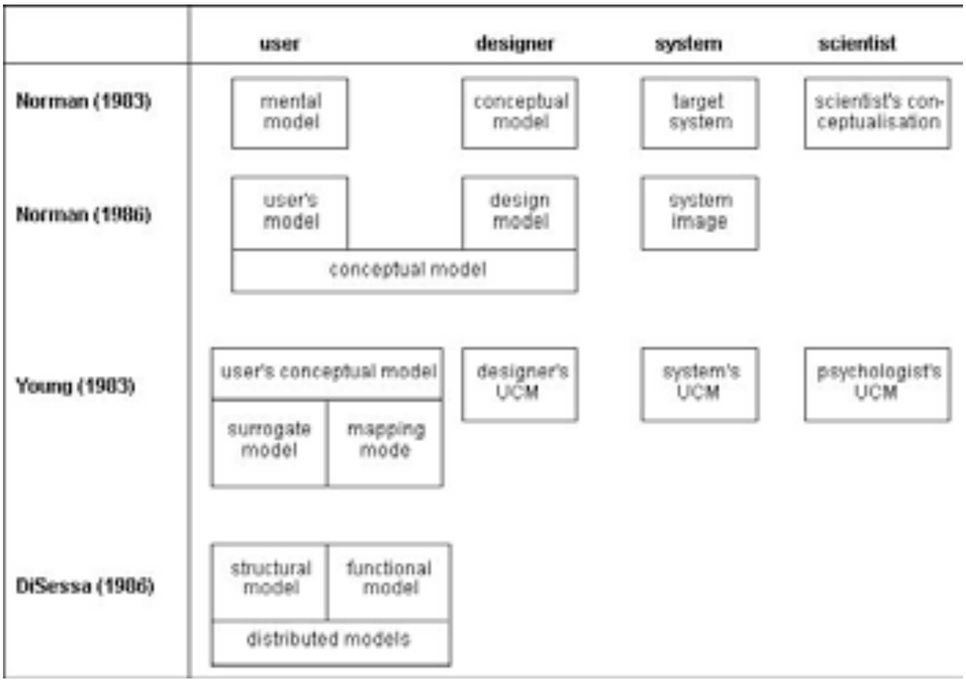


Figure 7. Summary of HCI models. (Sasse, 1997)

For an EHR system, different users, such as installers, maintainers, administrators, nurses, physicians, registration personnel, laboratory technicians, billing staff, and patients use different components of the same system. Different users have different levels of understanding of the same component of the system, such as beginners (medical students), novices (residents), and experts (physicians). Patel V et al(2000) showed that exposure to EHR is associated with fundamental changes in physicians' and trainees' information gathering and reasoning strategies. Differences were found in the content and organization of information, with paper records having a narrative structure, while the computer-based records were organized into discrete items of information. A recent study by Johnson C (2005) shows the importance of proper user analysis for EHR systems. When nurses and physicians, who have partially overlapping, as well as different knowledge bases, skills, experiences, and job responsibilities, are presented with the same medical information about a patient on an EHR, different mental models of this patient were formed that may lead them to different understandings, diagnoses, and subsequent activities.

In my preliminary study, I performed an initial analysis to identify the user model. Since my project was to focus on EDR, this preliminary study focused on EDR users as the target group. The preliminary study was conducted at University of Texas Health Science Center of Houston Dental Branch. The target users were dentists, dental assistants, and administrative staff. A simple e-mail survey with 2 items was used to collect individual's EDR "wish list" via email to all faculty and staff. All the questions were open ended, and responses were free text. Fifty-five response emails were collected. The results were organized into the following 11 categories.

- Registration/screening
- Scheduling
- Patient assignment
- Treatment planning
- Transaction
- Patient accounting and billing
- Insurance
- Recall
- Reports
- Security
- Research and image management

This simple survey gave us information for the future formal survey, because it relayed to us information about the functional elements that users may want. As this was a free text answer questionnaire, its advantage was that the user could express his/her thoughts freely and without any limitations. However the disadvantage of this kind of survey is that the user did not have any hints or reminders, so the user may not remember all his/her needs, especially for a complex EDR system which has a lot of functions. Thus we can expect this survey result may not give us the most thorough results but it gave us the most important functions that users wanted.

4.3. The Designer Model

Designer model in this project is defined as the collection of all the functions that the EHR/EDR system provides. In Norman's model (1986), the system image is in a physical level defined as "the image resulting from the physical structure that has been built" (including the documentation and instructions). But the designer model is the conceptual level object, defined as the "conceptual model of the system to be built". However the designer model needs to be represented by the system image. For example, if the designer has an idea about any new function that should be involved in this system; but did not work on it and program it to become one of the real functions of the system, then it would never be known by anyone beside the designer. Thus, the designer's conceptual model is not an important component in our project.

Another reason that we did not use the similar designer model is that in most cases once a system has been developed, the chance of frequent redesign is very rare. If the function of the system does not meet the user's needs, the users either refuse to use it causing the system to fail (Bardram J 1997) or the user must adjust their workflow and working processes according to the system. The training, learning, and adjusting process all take a long time for each user as well as costing the institution considerable money and time. That is why most EHR systems are relatively stable and can provide long-term use. According to the reasons above we define the designer model by all the functions that an EHR system provides, which is close to the system image but not the same. System image is “the *image* resulting from the physical structure that has been built (including the documentation and instructions)”. According to Norman’s definition, system image changes according to the different user, because each user has a different understanding and perception of the system. In this project we are more interested in the function of the system. Therefore, we included all the functions instead of trying to collect different system images by using different group of images.

Let us consider one of the products that we can get from building a designer model of EHR, basically a collection of ideal and desired properties of an EHR. (1) An ideal EHR should be able to support the following functions: data, alerts, reminders, schedules, clinical decision supports, medical knowledge, communications, and other aids. (2) These functions should be complete, accurate, and timely. (3) These functions should be available for all types of healthcare professionals. (4) These functions should be available at all times and at all points of care. (5) The ideal EHR should include the old yet useful functions and overcome the known problems of paper-based records, provide new useful functions that are not available from paper-based records, and at the same time not generate new problems associated with the electronic medium. The bottom line of an ideal EHR is that it should be able to dramatically improve the quality of healthcare.

4.3.1. Standard Designer Model of EDR

Is there a standard designer model for EDR in functional aspect? The answer is yes and no. In February 2001, the American National Standards Institute (ANSI) and the American Dental Association (ADA) declared the Standards of Clinical Data Architecture for the Structure and Content of an EHR, which provides a standard structure for EDR in functional aspect (Table 6). However, it only gives us a skeletal structure of EDR, giving us a direction but not a clearly defined and detailed function. This guideline is, unfortunately very vague for anyone who would like to use it as a standard by which to develop or evaluate any EDR system.

Table 6. Clinical Data Architecture for the Structure and Content of an EHR

Part number	Content
Part 1000.0	Introduction, Model Architecture, and Specification Framework
Part 1000.1	Individual Identification
Part 1000.2	Codes and Nomenclature
Part 1000.3	Individual Characteristics
Part 1000.4	Population Characteristics
Part 1000.5	Organization
Part 1000.6	Location
Part 1000.7	Communication
Part 1000.8	Health Care Event
Part 1000.9	Health Care Materiel
Part 1000.10	Health Services

Part 1000.11	Health Service Resources
Part 1000.12	Population Health Facts
Part 1000.13	Patient Health Facts
Part 1000.14	Health Condition Diagnosis
Part 1000.15	Patient Service Plan
Part 1000.16	Patient Health Service
Part 1000.17	Clinical Investigation
Part 1000.18	Comments Subject Area

Since we have decided that all the functions of EDR would be included in the model, we have performed a preliminary study to evaluate the feasibility of building a designer model. Three EDR systems (Axium, CIS, and Software of Excellence) were reviewed to understand the basic functions of the systems. The EDR systems are first reviewed by reading their user manuals and instructions. After reviewing the manuals and instructions, the entire drop down menus or buttons or check boxes were clicked and checked to see if any function has been missed in the manual. Missing functions were added to the list of the EDR's functions. The result of all the functions of the EDR systems were recorded and organized into the following 17 categories:

- Patient registration
- Patient financial management
- Patient scheduling
- Patient assignment
- Patient recall

•Patient record tracking

•Student evaluation and grading

•Reporting

•Lab management

•Medical history

•Intra-oral charting

•Extra-oral charting

•Pathology report

•Treatment planning

•Inform consent

•Progress note

•Digital image

In Figures 8, 9, and 10 below are some example interfaces for different functions.

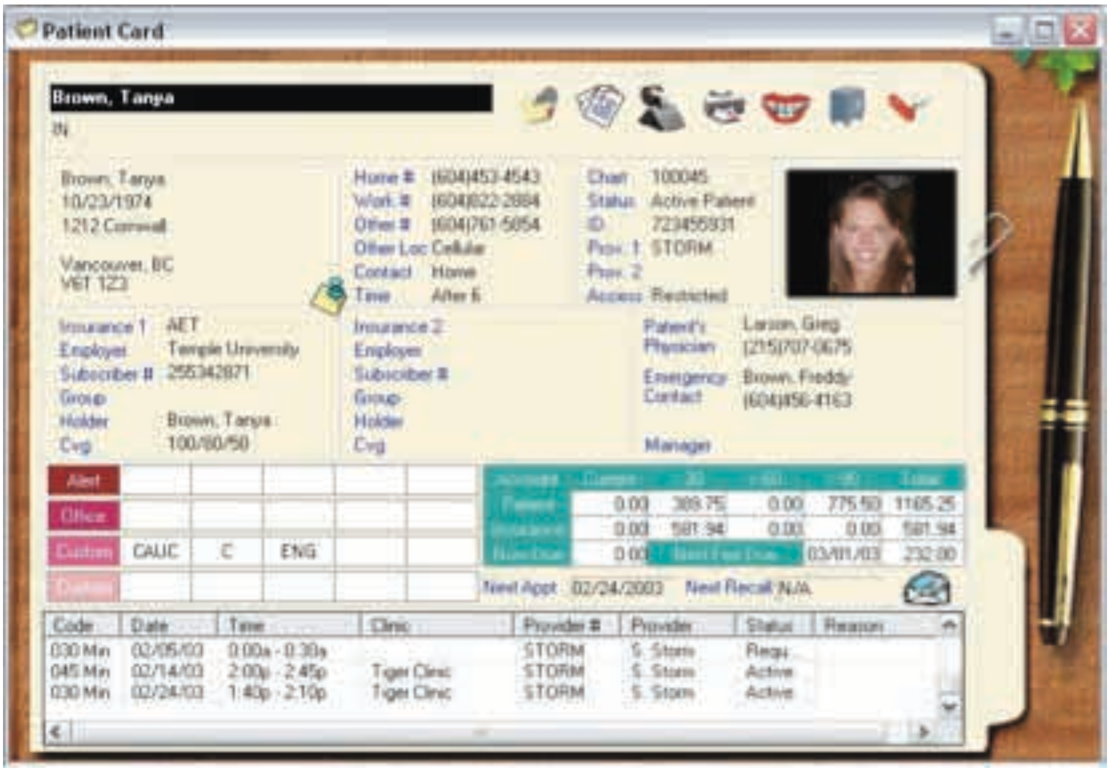


Figure 8. Interface of patient information page of Axium EDR system.

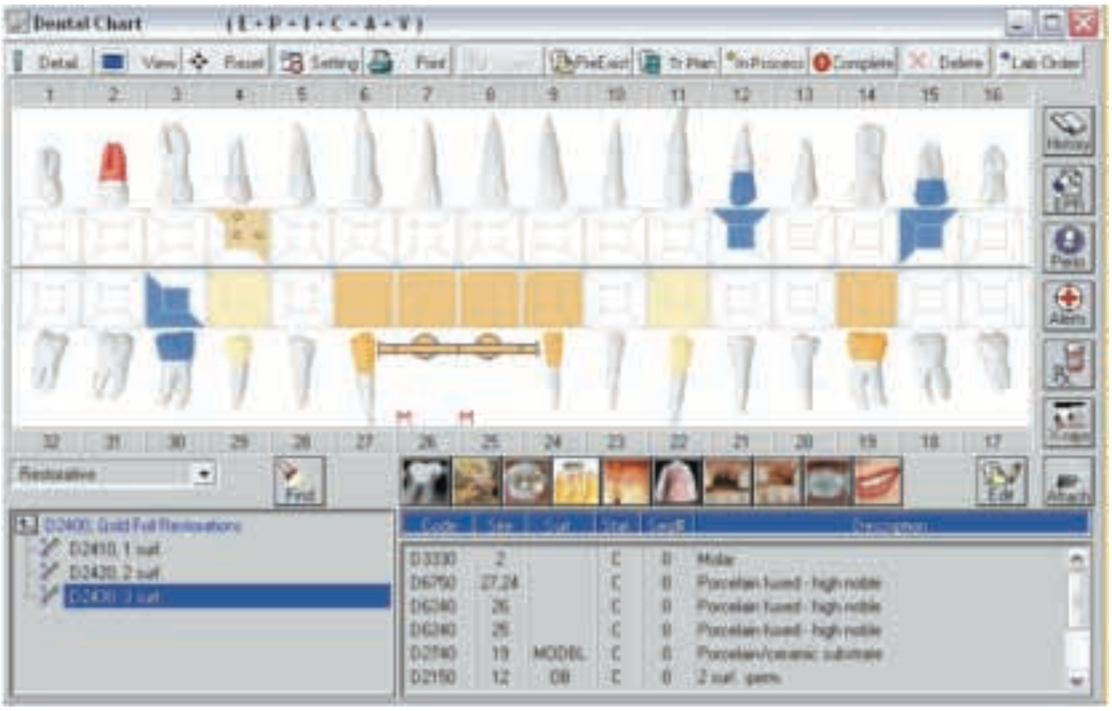


Figure 9. Dental chart of Axium EDR system

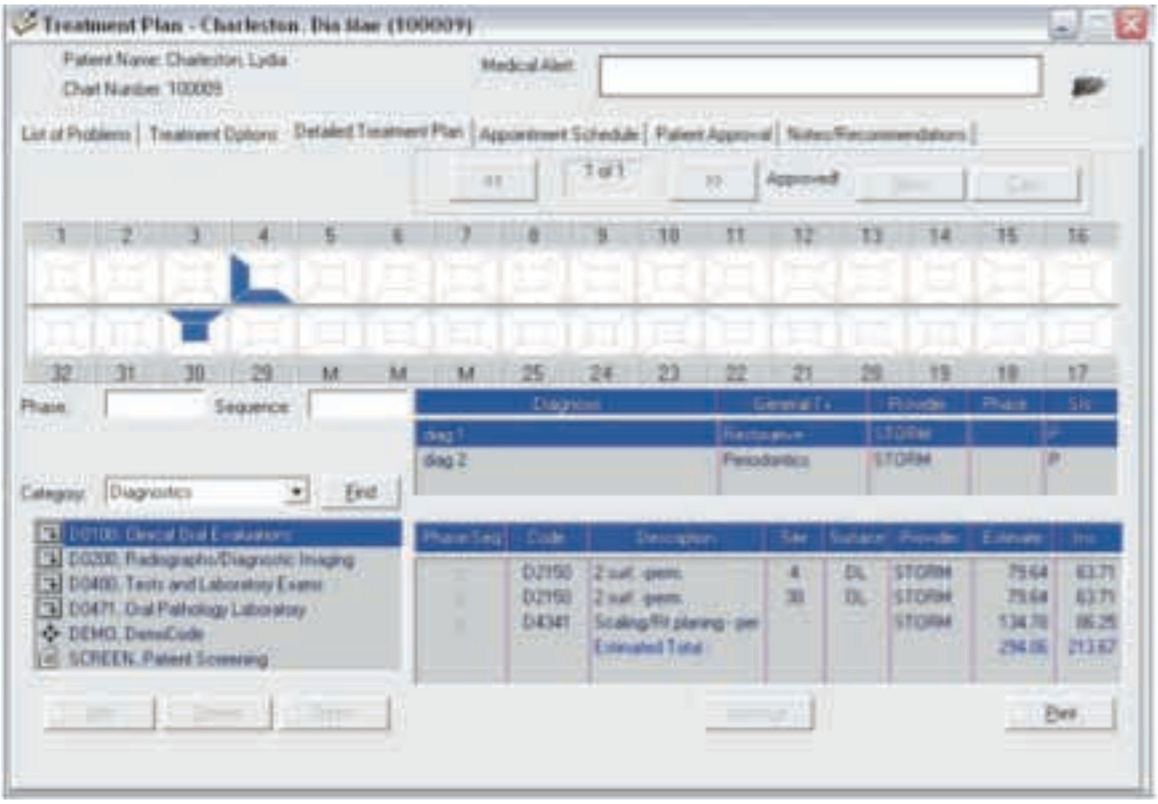


Figure 10. Treatment plan page for Axium EDR system.

With the illustrations above (Figures 8, 9, and 10), one can see that for each interface, many functions are included. A systematic approach to making sure all functions are recorded is one of the biggest challenges for future studies.

4.4. The Activity Model

Activity model is defined as the collection of all the tasks for accomplishing the main goal. Building the activity model requires not only recording all the tasks one needs to do to accomplish the goal but also the interactions, the dynamics, times, frequencies, and priorities of the tasks. In order to build this model, multiple analyses needed to be performed. The analyses that were used to build the activity model include task analysis (GOMS analysis and hierarchical analysis), workflow analysis, and task priority analysis.

Task analysis is a critical component in cognitive systems engineering and usability engineering (Hackos J 1998, Kirwan B 1992, Rasmussen J 1994). It is the process of identifying the procedures and actions to be carried out and the information to be processed in order to achieve task goals. One important function of task analysis is to ensure that only the necessary task features, those which match users' capacities and are required by the task, would be included in system implementations. Unnecessary luxury features and features that do not match users' capacities or are not required by the task only generate extra processing demands for the user and thus make the system harder to use. This, however, does not exclude mechanisms of adaptation that dynamically adjust the interactions between users and tasks in changing contexts.

For a distributed cognitive system it is important to perform a distributed task analysis that identifies the interactions among human and artificial agents. The theory of distributed representations developed by Zhang J & Norman D (1994, 1998) can be used to analyze the distribution patterns of information among human and artificial agents (Patel V 2000). The information flow analysis (Hutchins E 1995) can be used to analyze how the information is propagated and transformed among human and artificial agents. Distributed task analysis can reveal critical task structures that cannot be identified by conventional task analysis, which focuses on a single individual's interaction with a system. Task analysis can result in the identification of task structures, interactions among procedures, and the information flow of tasks. For example, task analysis can identify overlooked tasks, relative importance of tasks (main vs. peripheral), overlapping of task information, grouping of functions, relation to user analysis, and many other facets. It can also pinpoint the bottlenecks or choking point of the task where special design has to be considered. Another end product of task analysis is taxonomy of tasks based on the types of information processing needs. For example, there are information tasks for retrieval, gathering, seeking, encoding, transformation, calculation, manipulation, comparison, organization, navigation, and others. The identification of different information processing needs is essential for the creation of task specific, context-sensitive and event-related information displays.

4.4.1. GOMS analysis

Cognitive task analysis considers both physical and mental actions. Mental actions include perception, manipulation of mental representations, and generation of motor activities. GOMS analysis (Goals, Operations, Methods, and Selection rules) is one of the best-known models of cognitive task analysis (Kieras D 1997). It consists of descriptions of the methods needed to accomplish specific goals. In this project, GOMS analysis was used to analyze the physical and mental actions step by step. An observer sat by the experiment subject and recorded all the actions the subject performed. For example, if the subject started to ask himself, “Where is the help button?”, the observer wrote the sentence down but did not respond to the question.

4.4.2. Hierarchical task analysis

Hierarchical task analysis (HTA) is one of the most well known forms of task analysis. It constructs a graphic representation of the decomposition of a high level task into its constituent subtasks and operations or actions. It involves an iterative process of identifying tasks, categorizing them, breaking them down into subtasks, and checking the accuracy of the decomposition. Information about tasks is collected from a variety of sources including conversations with users, observation of user activities, job descriptions, and operating manuals.

Performing a hierarchical task analysis to identify the underlying data structure of EHR systems can pinpoint some fundamental problems of EHR. For example, Cimino, Teich, Patel, and Zhang (1999) showed that current EHR systems use two predominant data structures that are not driven by human-centered principles. One uses a hierarchical data model to capture information used by specific applications. It is primarily a patient record system added onto a financial system used for billing purposes. The other data model makes extensive use of an event-based approach in which data are recorded as in a time-oriented view to facilitate their reuse by multiple applications. It is primarily a repository of patient records over time. These two data models revealed by task analysis are not human-centered in that they do not support the tasks that healthcare professionals typically do on a daily basis. A typical daily task, such as making a diagnosis, is better supported by an EHR system that organizes information around problems.

4.4.3. Workflow analysis

A domain expert was recruited and the "think aloud" method was used to record the step-by-step tasks for finishing the goal. After the draft workflow analysis was finished, an observer followed all the human agents who were involved in this work and went through the whole workflow process making sure all the tasks, human agents, and devices were recorded in as detailed fashion as possible. In the workflow analysis we collected tasks, human agents (who may or may not be a user of the EDR system) who were involved, and the devices used to carry and aid in the task. The device in this analysis is not only limited to just computer systems. It can be any physical material that may be used to finish the task, such as phone, fax machine, paper chart, or sticky notes. With workflow analysis, the interrelationship among work, human agents, and devices can be studied. This analysis helps discover for which tasks a user would decline to use EDR and instead use another process device. For example, if a front desk clerk receives a phone call from the patient wanting to make an appointment, and if the clerk uses a sticky note to put the appointment on the scheduling book instead of using the EDR, then this process replaces the EDR for that particular function. This, then, is one of the discrepancies among system, user, and task. With the detailed workflow analysis, the frequency of the function that has been used, the discrepancies between task and user, task and EDR system, system and user would be revealed. Also the frequency of the task would indicate the priority of the function in the EDR system.

In the preliminary study, we did develop a basic structure of workflow analysis which is shown below in Figure 11.

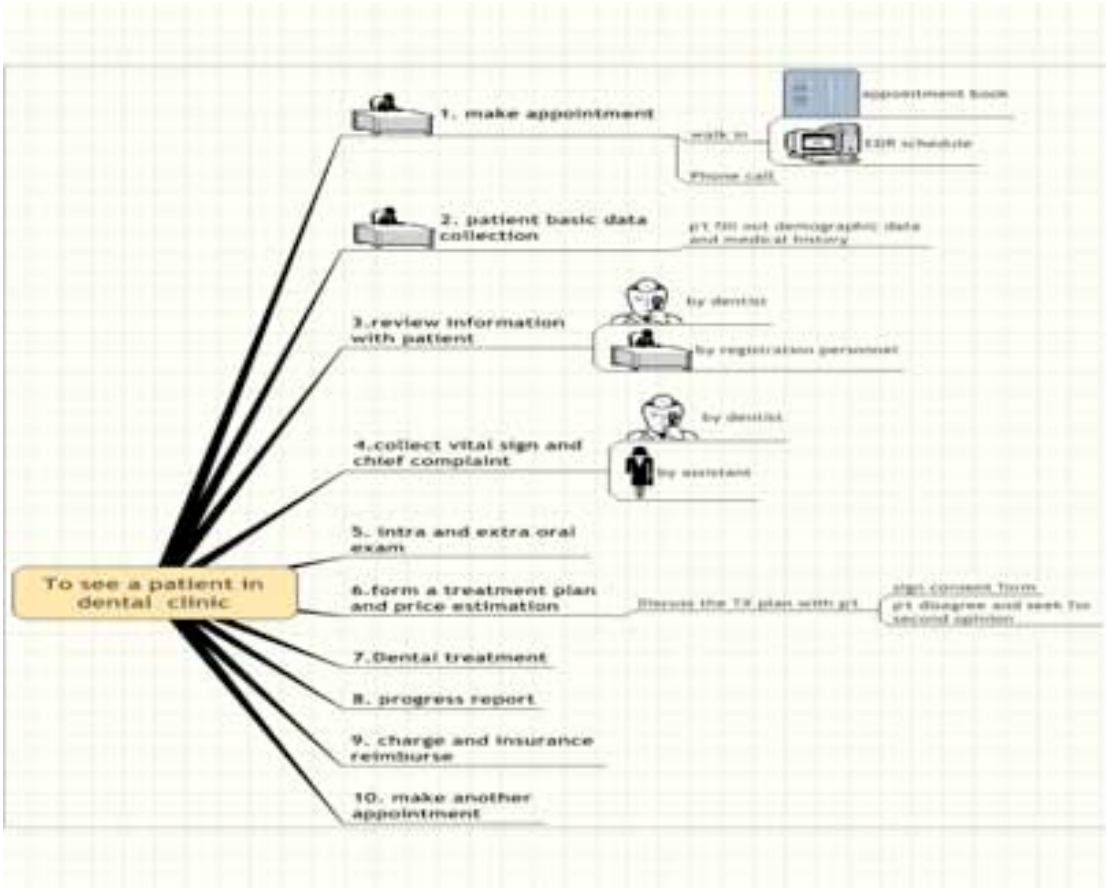


Figure 11. Illustration of Workflow Analysis.

4.4.4. Task priority

A task priority list will also be developed during building of the activity model. The need for the task priority list comes from the need for putting the necessary tasks in the system and for evaluating the EDR system in the future. Because there is no perfect system for every user for every task, such a priority list is important. In the preliminary study, a task priority list was developed and divided according to different users due to the nature of the work. This list is shown in Table 7.

Table 7. Task priority of the primary, secondary, and tertiary duties of dentist, registration personnel and dental assistant

Dentist Activities	**Administrative Personnel**	**Dental Assistant Activities**
Primary Duties (Essential Functions, High Priority) • Perform previous medical and dental history review • Intra-oral, extra-oral, and radiographic examination of patient • Diagnosis and formation of treatment plan(s) • Explain and inform the patient of treatment plan or change the treatment plan according to patient's needs • Perform procedures • Behavior management of the patient • Document all care and services to be provided patients • Refer patient to specialist or transfer to other dentist	**Primary Duties** (Essential Functions, High Priority) • Register patients • Instruct patient on how to complete forms • Check out patient's record • Inform dentist of patient's arrival • Administer and document medication ordered by dentist • Communicate with other healthcare team members • Check out patient's financial situation i.e., set up payment plan, check with insurance, receive payment • Set up patient's next appointment • Remind patient of next appointment (via phone or postcard) • Basic accounting (daily and monthly report)	**Primary Duties** (Essential Functions, High Priority) • Patient and family education • Obtain basic vital signs and help in taking radiograph • Communicate with other healthcare team members • Set up or clean the dental chair and infection control • Assist dentist perform procedure (i.e., suction, retraction, pass instrument, check out instrument) • Help dentist document care • Instrument autoclave and clean up
Secondary Duties (Intermediate Priority) • Checking previous laboratory, x-ray, or medical reports • Transcribing history and physical into chart (documentation) • Documenting phone conversations, transfer reports, and laboratory information when transmitted by phone. • Interfacing with dental assistant	**Secondary Duties** (Intermediate Priority) • Answer phones • Post operation instruction • Patient referral communication and documentation • Data entry and other clerical computer tasks • Food, bathroom, etc	**Secondary Duties** (Intermediate Priority) • Post-operation instruction • Calm patient, if needed, behavior control • Wrap and count all the instruments • Pour model • Contact lab and send out the case • List the order of instruments

regarding direct patient care • Interfacing with physicians, other specialists and consultants • Out of clinic communication with physician, dentists, or staff regarding referral of patients • Performing tasks outside of job description • Food, bathroom, etc.		• Food, bathroom, etc
Tertiary Duties (Non-Essential, Low Priority) • Phone calls not related to patient care • Inappropriate communications with dentists, residents or assistant regarding patient care (i.e., arguing with staff on the appropriateness of admission during active work hours) • Communications with assistant, students, residents, and staff not related to patient care • Out of-hospital communication requesting information of a non-urgent nature (i.e., pharmacy requesting information on a prescription, HMO requesting insurance info) • Interact with staff not directly associated with patient decision-making (i.e., x-ray technician questioning appropriateness of radiograph, calls to housecleaning to clean room) • Quality control initiative • Communications with administrators, media, risk management, business office, etc during work hours • Direct communications to resolve personnel issues (conflict resolution) amongst staff or relating to self during working hours	**Tertiary Duties** (Non-Essential, Low Priority) • Phone calls not related to patient care • Communications with other healthcare professional not related to patient care • Social event	**Tertiary Duties** (Non-Essential, Low Priority) • Phone calls not related to patient care • Communications with other healthcare professional not related to patient care • Social event

4.5. Summary

This chapter gives an overview of Functional Framework. The Functional Framework has three major component models -- user, designer and activity models. A literature review for each model was done in this chapter. This Functional Framework was applied to a real world clinical setting, which is described in the next chapter. In particular, the detailed processes for developing the three models were demonstrated in this application.

CHAPTER 5. DEVELOPING THE COMPONENT MODELS OF THE FUNCTIONAL FRAMEWORK

In Chapter 4 we described the theoretical framework- Functional Framework. The studies described in Chapter 3 demonstrated the importance of identifying functions. This chapter describes the development of the three component models for a real world clinical setting. The following flow chart (Figure 12) illustrates the process of the study.

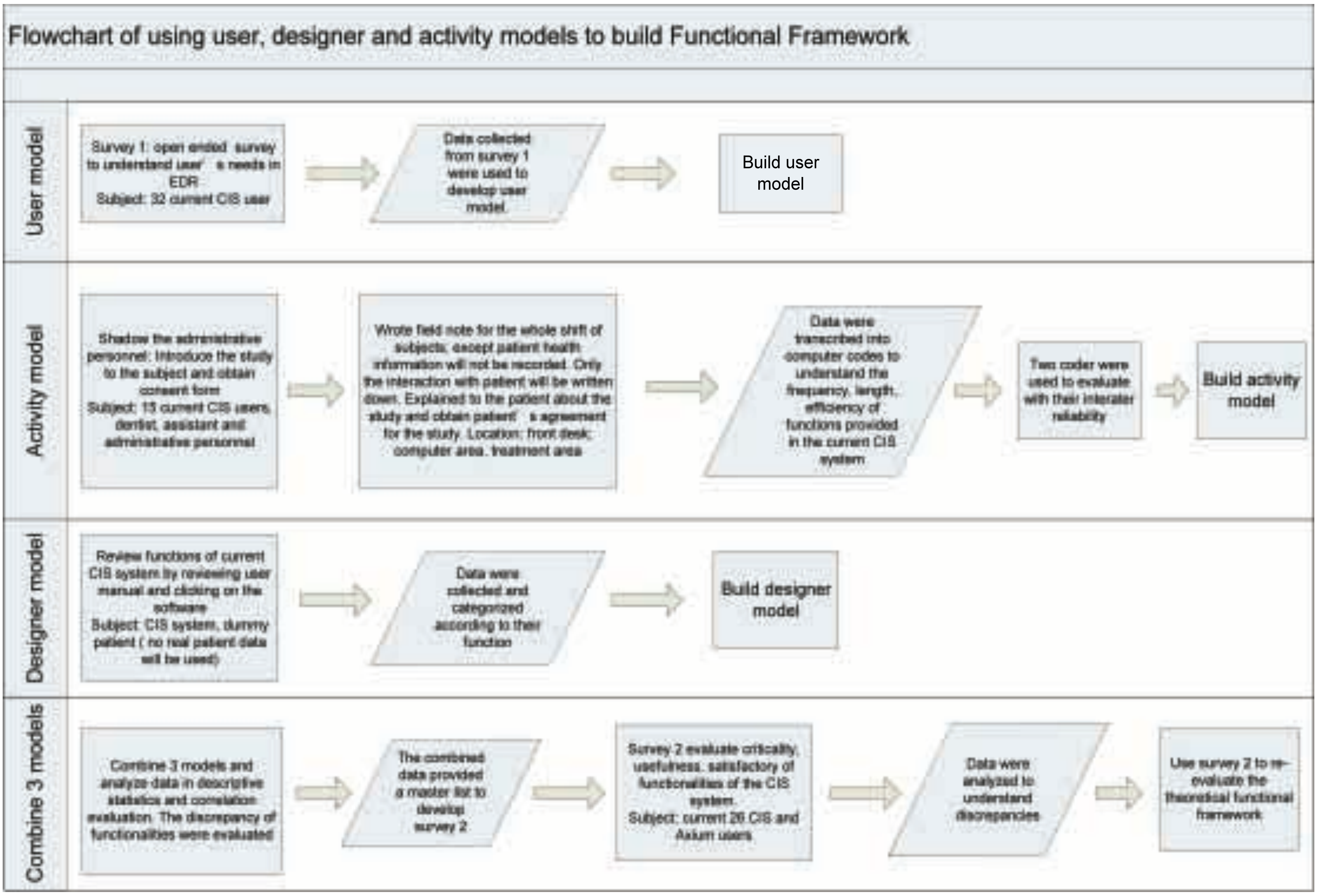


Figure 12. The flowchart of building Functional Framework.

5.1. Institutional Regulatory Board (IRB) Approval

The study was approved by the University of Texas Health Science Center at Houston, IRB # HSC-DB-060066, An Observation of Workflow and Interaction with Electronic Dental Record in Dental Clinic Setting (Appendix 1).

5.2. Building User Model

The basic rationale and preliminary information collection of user mental model has been described in Section 4.2. However, a more detailed and concise mental model will be needed. Since mental models are abstract, incomplete, and vague, the challenge was how to build a model which comes close to the user model. According to a previous study (Laerum 2004) in EHR, similar questions were raised about how to develop a task list for EHR. If it is done by listing all the low-level tasks, the collection would be too big for use in a questionnaire. In that study, the lower level tasks were merged to a high-level task list. In this current study, a different approach would be used to try to obtain a list that is concise but comprehensive enough to include most of the important tasks that users expect.

5.2.1. Methods of building user model

An open-ended survey with 7 items was used to collect what functions were used in the current EDR system (CIS) and what functions users would like to have incorporated to produce an ideal EDR system.(Appendix 2) All questions were open ended. All responses were free text. The survey took approximately 20 minutes to complete. A convenient subject sampling method was used. The investigator walked in to UTDB clinics and randomly asked who were users of current EDR system. The chosen subjects were then assigned by computer a unique code number and his/her personal survey data was identified only through this number. The subject's individual responses remained confidential.

5.2.2. Result of user model survey

A survey was given to sixty (60) CIS EDR users; 40 surveys were returned and completed (66% response rate). Thirty-two (32) surveys (53%) were included in the final analysis. The exclusion criteria are: the user never used the system before survey (6) or the user did not answer any function-related questions (questions 3-7). The subjects included were 23 dental students, (72%); 4 staff members, (13%); 2 faculty members, (6%); 1 resident, (3%); 1 office manager, (3%); and 1 patient care coordinator, (3%). The majority of the subjects were dental students, but the other subjects included all different kinds of employees who used EDR. The amount of time the subjects had used the EDR system (CIS) varied from 1 year to 15 years; 4 subjects did not give an exact length of time they had used the EDR system (Table 8).

Table 8. Length of Time Subjects Had Used CIS System

Duration of CIS use	Number of subjects	Percentage %
< 4 years	24	75
4-8 years	3	9.4
> 8 years	1	3.1
Unknown	4	12.5

All responses to this survey were entered and coded by using NUD*IST Vivo 1.0 (Qualitative Solutions and Research Pty Ltd). Two three-tiered hierarchy of user and function was formed through the systematic study of data collected in all surveys. The categories had been developed using a bottom-up, which is an inductive approach found in Grounded Theory. A partial list of coding is shown in Fig. 13. There are a total of 302 passages and 118 code nodes recorded and coded. The first level nodes in the coder are user and status. User node is basic information about the user, such as role and usage of EDR in daily work.

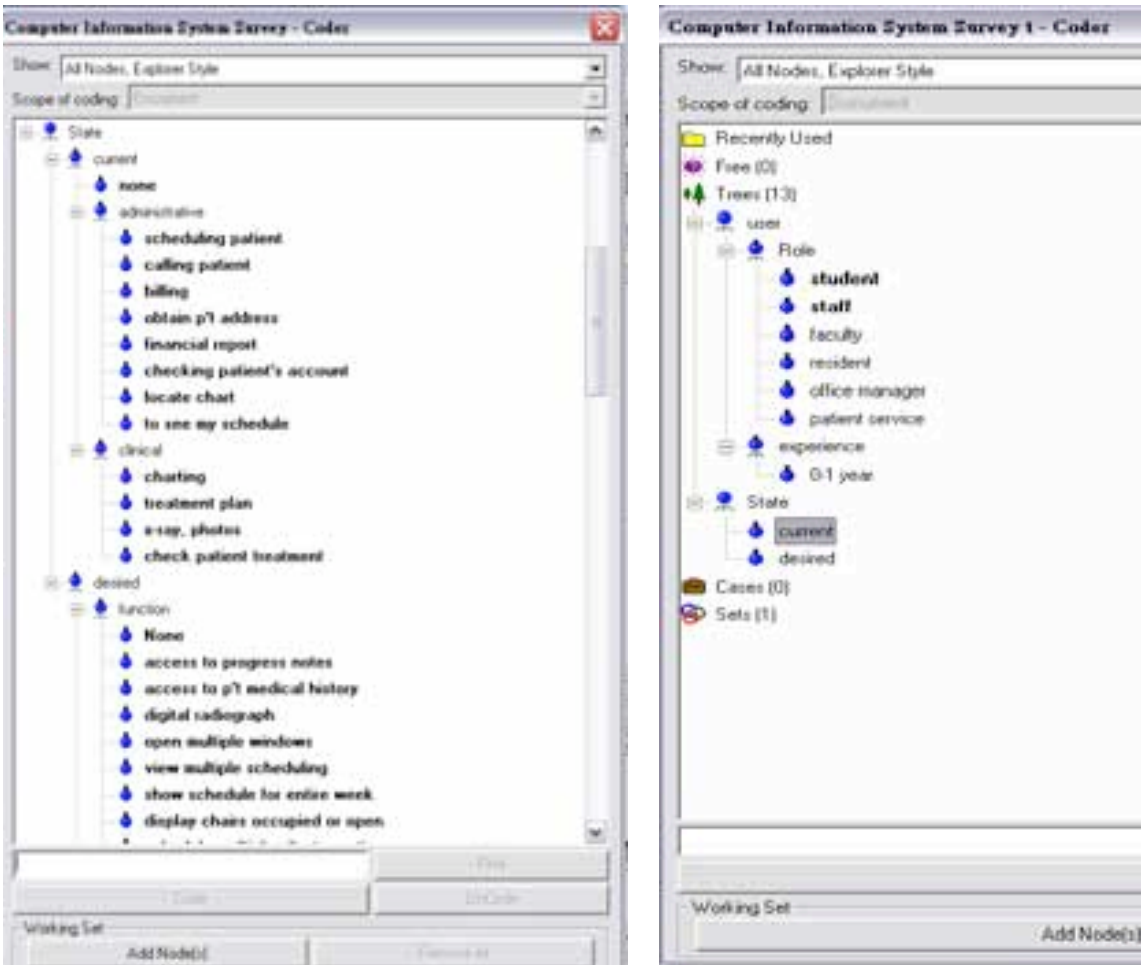


Figure 13. The coding structure of the survey showing NUD*IST Vivo coder

Under the state node are the nodes related to function of the EDR. The highest level of hierarchy are the nodes of the existing function in the EDR. They are divided into current and desired EDR functions. There are 12 total functions listed by the users for current EDR's functions (8 administrative and 4 clinical functions, Figure 13). The most often-used administrative function in the current EDR system is "scheduling"(27 subjects, 84%). The second and third most used functions are "calling patient" (15 subjects, 47%) and "billing" (11 subjects, 34%). The top three are all administrative functions in current EDR. The most often used clinical function in the current EDR system is "charting" (10 subjects, 31%), which is a lower percentage than the top 3 functions in the administrative area. This result shows much lower recognition in EDR's function than the EDR provided.

A desired function, defined as a function not available in current system and one which a user would like to have without having to consider any limitation; i.e., money, equipment, etc. The subjects were encouraged to list as many of the possible functions they would like to have in a ideal situation. The desired functions were categorized in the following 4 categories, ranging from very specific to very general. The 4 categories and their definitions are:

- **Functionality:** self-contained software routine that performs a task, example: delete information
- **Task**: piece of work assigned or done, example: delete patient's phone number
- **Feature**: prominent or distinctive aspect, quality, or characteristic, example: delete patient's old phone number when new phone number is provide
- **Character**: combination of qualities or features that distinguishes the EDR, example: Automatically update information

A partial list of coding is shown in Fig. 14 and Fig 15.

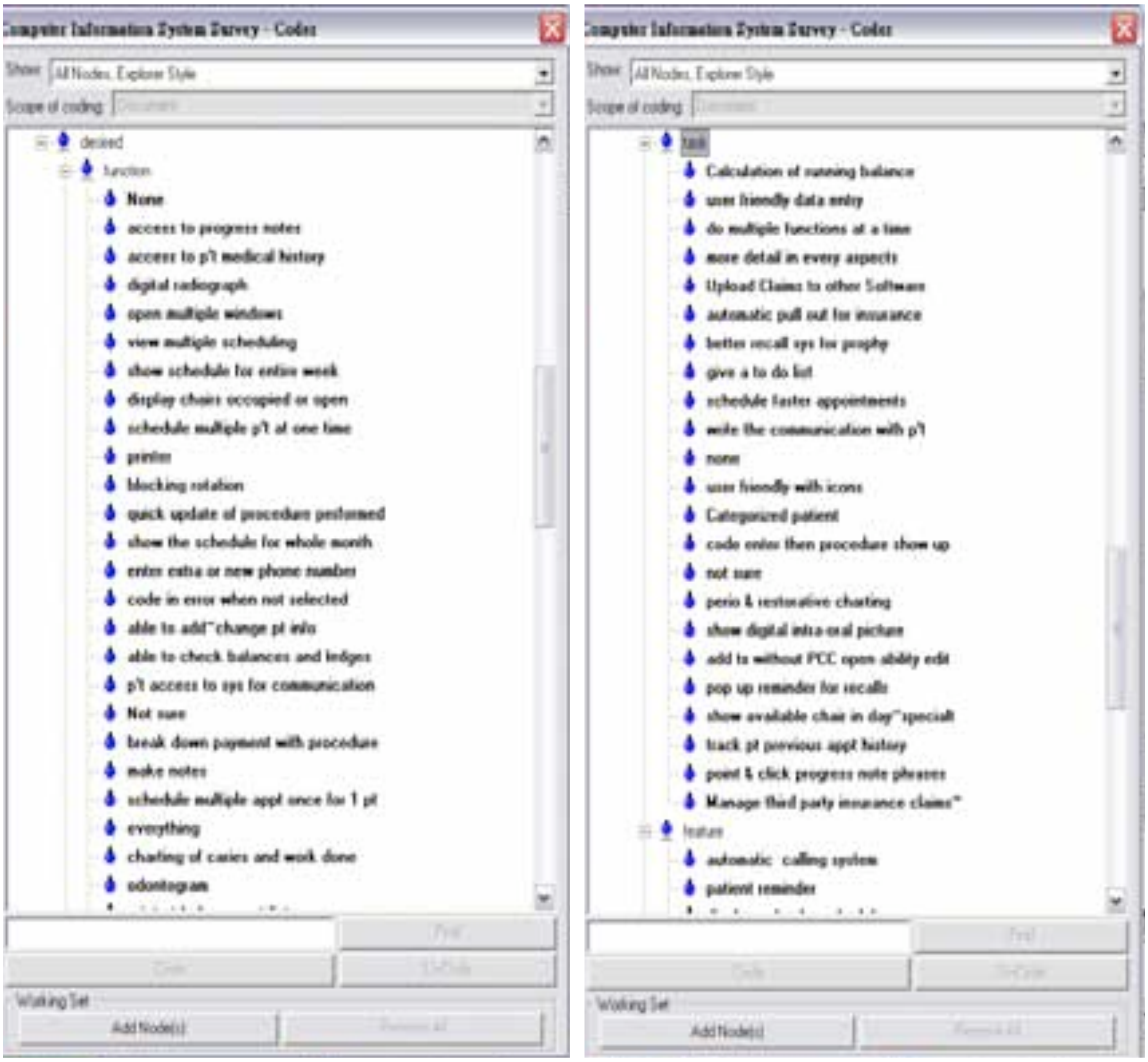


Figure 14. Coding structure of desired function

There were 28 functions, 23 tasks, 21 features, and 8 characters categorized in the whole coding process (Figure 14). The functions are very detailed and specific, but the characters are very general, such as “convenient”, “user friendly” “keep up with latest technology”, “faster”, “easier to operate” (Figure 15). These general characters, seen in the survey, very often give short answers. There are two possibilities which can be drawn from these users: they are either satisfied with the functions provided or they are dissatisfied with so many of the functions, they have a difficult time answering the survey questions so they often tend to generalize. Thus the only complaint is over all. The result of this survey was used to develop user model for the final survey.

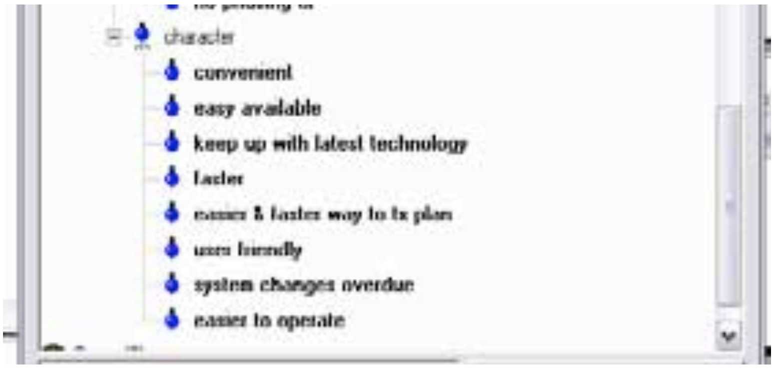


Figure 15. "Characters" code nodes

5.2.3. Discussion of user model survey

An open-ended survey was the method used to try to understand what users want and what functions users believe they are utilizing in the EDR. The advantage of this method is that the user can express their thoughts freely and without any limitations. However, the disadvantage of this kind of survey is that the users do not have any hints or reminders, so they may not remember all their needs for a complex EDR system which has a lot of functions. The result of functions listed in current and desired (12: 80) indicated this. Thus, the results from this type of survey may not be the most thorough, although it may give us the most important functions that users want. With the data collected, we can build the draft user model which has important and detailed functions. There is one item in this open-ended survey which had a very low response rate. Fifty-six (56%) percent of subjects did not respond to the item, “If there is any other feature that you would like have for the new electronic dental record system, please let us know.” This response was predicted when we designed the survey. The survey was trying to remind users to think of all the functions in different situations in order to avoid the forgettable effect found in open-ended surveys; so the assumption was the last question may have the lowest response rate since, based on Grounded Theory, that the information reaches the saturation point for the subject, usually at the point where the subject has answered most of the questions to the best of their possible ability. At this time, the subject may simply not answer the question. Thus, questions 3-7 are very similar in meaning and therefore we believe the last question is the one that would probably have the lowest response rate. The results showed that to be the case. This result also indicates that the data was exhausted after being repeated. And, finally, we must consider the possibility that the subjects truly do not know what they really want.

5.2.4. Summary of user model survey

This qualitative research used an open-ended survey to study the user model of EDR. The purpose of this survey was to understand what functions users are implementing right now and what function functions would be desirable to add to the present EDR system. The result showed that the user may not list all the functions they used in EDR and also, that they may not be aware of what functions they might like to have. Also, when users are not conscious of the wide range of possible new functions or they do not know what functions could be requested, they may use very vague terminology to describe their needs.

5.3. Building Designer model

In this section we focused on the collection of all functions of each EDR system. One EDR system (Clinical Information System (quick recovery)) was selected based on its accessibility and on the fact that most users have had experience with this system. This system is the one which has been used by the UTH Dental Branch from 1995 until the present time. It has two isomorphic interfaces, graphic user interface and text user interface. Although the two interfaces are different, their functions are the same. In the preliminary study mentioned in Section 3, we showed that the interface does not make a significant difference when performing tasks. We now chose only one interface for our project. Because the other EDR system (Axium) uses GUI for control and consistency we have chosen the GUI version of this system as our designer model subject.

To build the designer model, two methods were used: document analysis and direct interface check.

Document analysis: we analyzed the manuals, handbooks, practice protocols, guidelines, and other training materials to indirectly obtain knowledge about the functions of the EDR systems. We managed to obtain the original hard copy training book manual. We also used the help manual, which is included in the software. We followed the hierarchical structure of the help manual to record all the functions provided by the EDR (Figure 16).

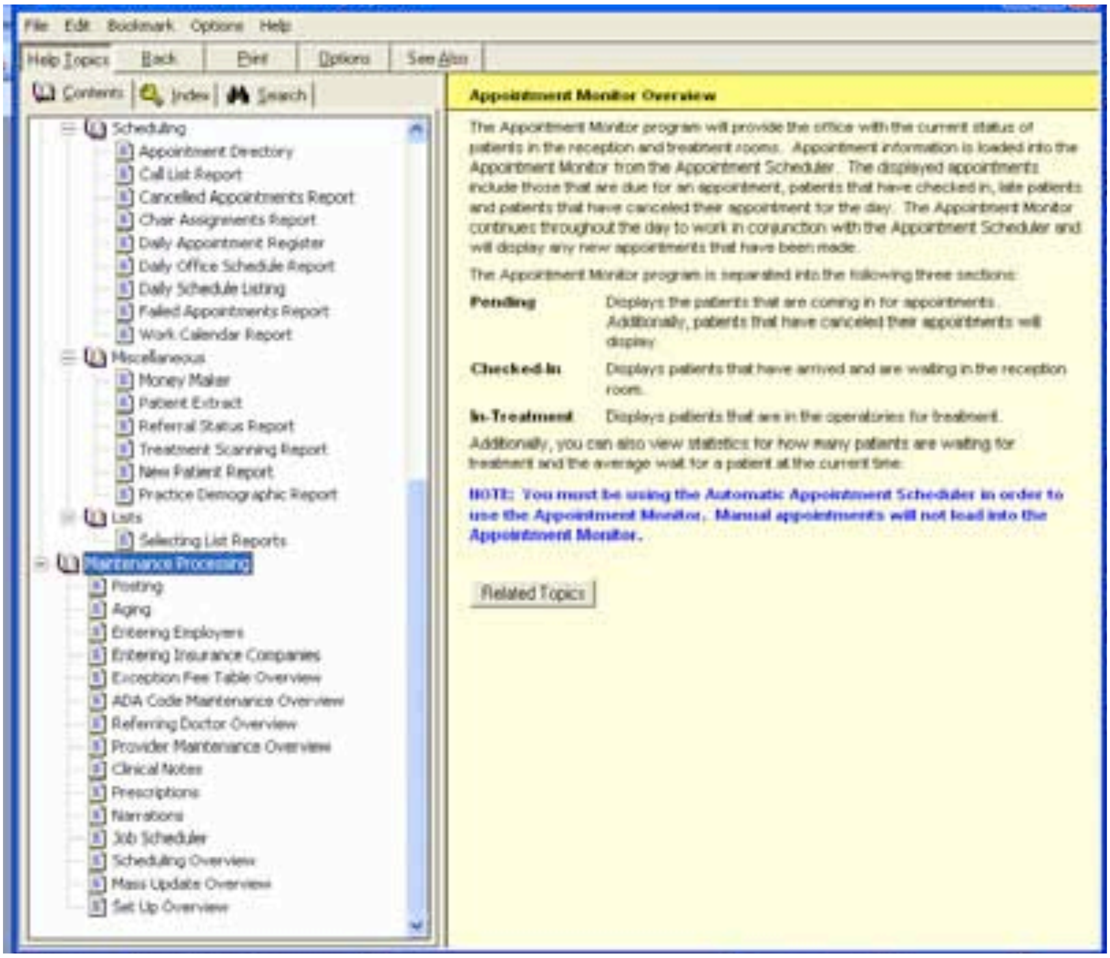


Figure 16. The help manual of the EDR

Direct interface check(system walk through): the observer went through the whole system and clicked on every drop down menu and button. Data were collected which included the functions from document analysis and direct interface check (Figure 17). The result showed that the functions of two different methods are highly consistent. The data was used in the development of working domain ontology in the next chapter.

Figure 17. Direct interface click on EDR to obtain designer model

5.4. Building Activity Model

The design for this section is based on a qualitative design known as ethnography. Emerson, Fretz, and Shaw (1995) described ethnographic field work as “the study of groups and people as they go about their everyday lives”. Ethnography involves the discovery of what people actually do and the reasons why. In this study, an observer viewed dentists, dental assistants, and administrative personnel working at UTH dental clinic in order to build the activity model.

5.4.1. Participants

The 5 dentists, 5 dental assistants, and 5 administrative personnel participating in this study are from a convenience sample of oral healthcare professionals working in the University of Texas Health Science Center Houston Dental Branch. These 15 individuals were observed during their daily working activity for an entire shift. Participation was voluntary and written consent was obtained prior to the observation sessions. The subjects had to be at least 21 years of age to participate. They also had to have worked at the UTDB for at least 12 months and be familiar with the clinical EDR system.

5.4.1.1. Setting

The observation is performed in the UTDB pediatric dental clinic. It is a specialty clinic and also a resident training program. The clinic is about 3000 square feet. It closely resembles a regular private clinic setting instead of a dental school setting. The clinic includes a waiting area, front desk, open bay, quiet operatory room, sterilization area, x-ray room, dark room, lab, resident room, lounge, director's office, and restroom. (See Figure 18)

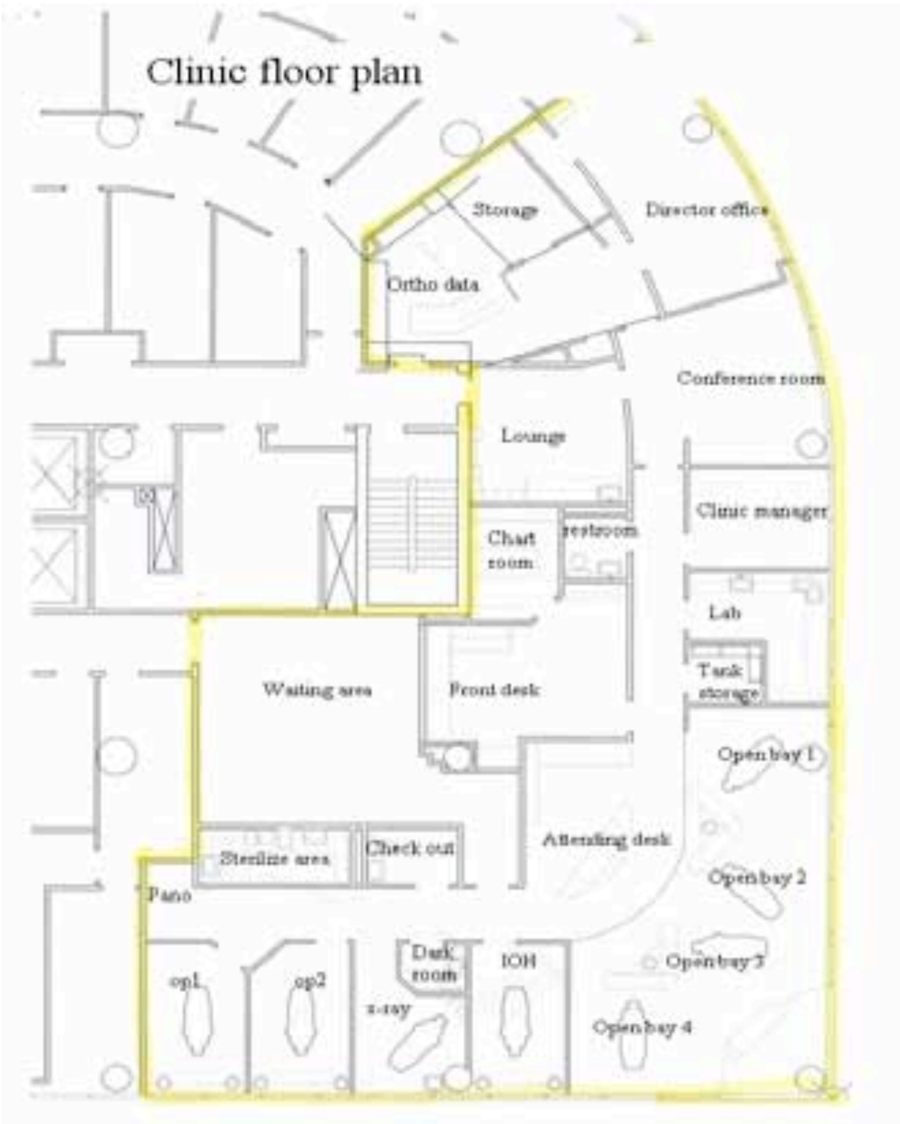


Figure 18. The floor plan and setting for the observation site

5.4.2. Data collection

The observer, who is a dentist with more than 10 years experience, is familiar with the observing site working environment. The observer also has a health informatics background and has been trained and participated in shadowing before. All data were collected in one tablet PC.

5.4.2.1. Shadowing

In this specific study, we limited shadowing to routine sessions of dentists, dental assistants, and administrative personnel who have completed the informed consent process and signed the consent form. The observer employed direct observation with note-taking for activities and interaction with EDR system between routine dental visits. All the notes were written into a tablet PC. We shadowed dentists, dental assistants, and administrative personnel for a total of 15 sessions (5 for dentists, 5 for dental assistants, and 5 for administrative personnel) with each session lasting at least one shift (3 hours). The observers focused on shadowing that started when a patient walked in and continued until the patient walked out of the office. Within the 3-hour period, the number of patients observed was determined by the schedule of the day.

Shadowing is a qualitative technique that does not necessarily involve the use of statistical analysis of data. A total of 15 sessions provided sufficiently rich data for the analysis of workflow processes and the interaction between users and EDR systems in performing different tasks. After each session, we conducted post-session interviews with each participant. These interviews served to inquire into the nature of the interactions observed or any unclear interaction with EDR system. Each post-session interview lasted for up to 30 minutes.

After the signing of the consent form and before the observation and hand note taking of each session, the participants (person to be shadowed and other surrounding staff) were informed regarding the start of the observation. They were told to perform their usual tasks and to ignore the observer. They are also told that the observer would in no way interfere with their activities. After each session, the participants were asked to clarify questions the observer may have in a post-session interview during which voice taping was used to supplement field notes.

Each shadowing session lasted from several hours up to an entire morning or afternoon and the post-session lasted up to 30 minutes. The subject could also withdraw their data for any reason at any time by calling the Principal Investigator. No patient's data was collected or recorded; the only data recorded was the activity itself and the EDR functions which had been used.

5.4.2.2. Descriptive Statistics Results of Shadowing

There were a total of 15 subjects and 1590 minutes involved in the observation of the clinical activity model. The average observation time was 160.1 minutes per subject (Range 114-220 minutes; SD=34.72).

Each observation period was based on the whole shift. But if there was no more activity or if the subject was going to leave, the observation was ended. There is a significant difference in observation time among the 3 different kinds of users (ANOVA, $p=0.037$). The dental assistant's observation time (mean=181.8 min) is significantly longer than that of administrative personnel (mean=130.2 min) (post-hoc test LSD, $p=0.014$); but there is no significant difference when comparing the dental assistant's time to that of the dentist (mean=168.2 min, $p=0.465$). This may only indicate that the dental assistant may have the longest shift in the clinic. (Figure 19).

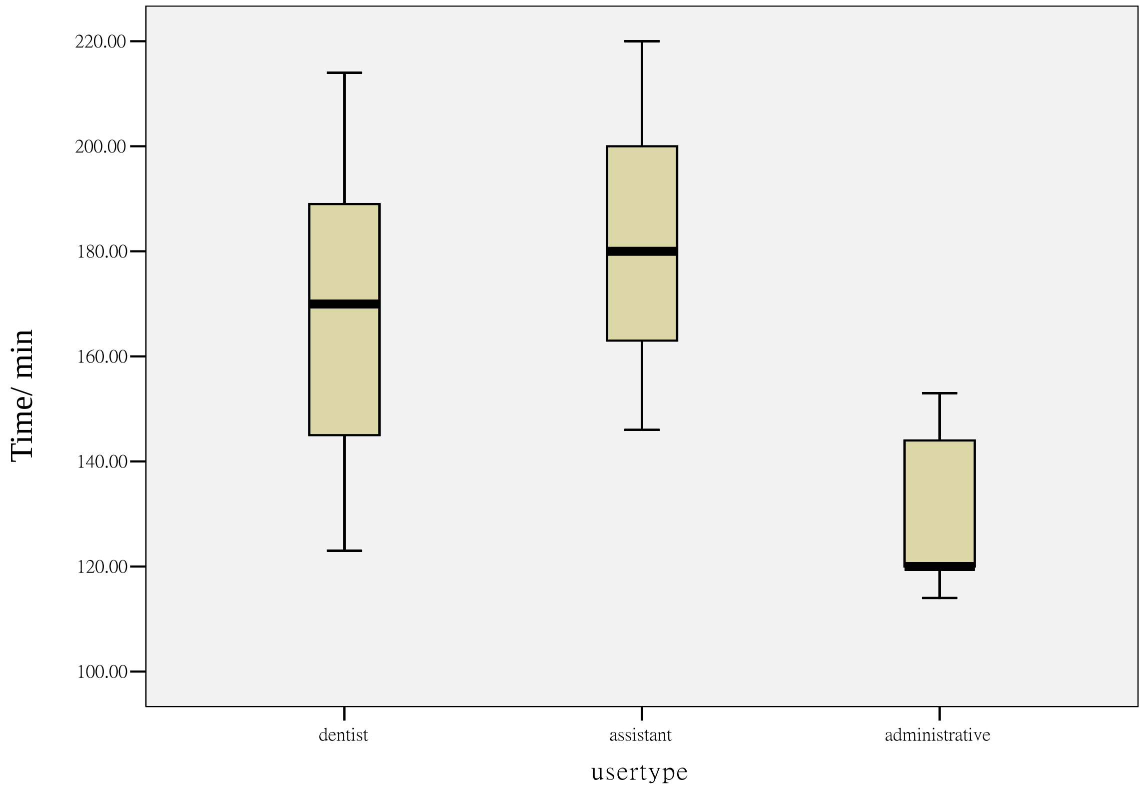


Figure 19. Box plot of the observation duration among 3 user types

5.4.2.3. Developing a Coding System for Data Analysis

Development and refinement of the coding scheme was based on Grounded Theory. Grounded Theory is an inductive process developed by Glaser and Strauss. They introduced the theory as a research methodology in 1967. The methodology depends on an inductive process grounded in the systematic analysis of the data. The primary purpose of Grounded Theory is to develop theories in order to understand phenomena. The theories that arise from this process are middle-range theoretical frameworks that explain the collected data. The strength of Grounded Theory techniques is found in a set of methods from which one may build explanatory frameworks that identify relationships among concepts.

The Functional Framework coding system was developed by the author. It was designed by using the activity coding system as a reference. This coding system was developed by Juliana Brixey as part of her PhD dissertation and has been modified by the author for the EDR setting of my project. The coding of an activity was to provide an explicit and structured description of the activity in a specific temporal and spatial environment. In general, an activity contains the following components:

- Actors: physicians, nurses, patients, family members, lab technicians, etc.
- Content: details of the activity
- Location: place where an activity occurs
- Status: status of the activity
- Time: start, end, duration

The coding system shown below is a top-level description of an activity. It does not show the microstructure of the "content" variable. In our project, we decomposed "content" into identified components such as goal of the action, devices, and media types. Examples of coded activities are listed below:

Assesses(<Dr X>, <ED resident>, <assesses the condition of new admission by taking a history and performing a physical assessment of the patient>, <major trauma room>, <ongoing>, <4:25pm, 4:30pm>)

The functional framework coding system was modified from the activity coding system. On the other hand, this study focused on the function that has been used in the clinical setting, so the actor and the content are not that critical. Thus, the component of this coding system is different from Brixey's system. A task generally has the following components:

1. What kind of task is it? Administrative, clinical or general (it does not belong to either administrative nor clinical; example: answer personal cell phone)
2. In which category is it based within the Functional Framework? In Chapter 3 we proposed 3 models, but the areas of intersection can be designated as categories as shown in the illustration (Figure 20). Category 1 is the function which is included in all 3 models. Categories 2,3, and 4 are the functions which are included in only 2 of the 3 models. Category 5,6, and 7 are the functions which are included in only l model.
3. Is it a multiple or single task?
4. What is the content of the tasks, listing of the task
5. What object was involved in performing this task (such as EDR, paper chart, phone, etc)?
6. Where was this function performed (location)?
7. What are the details? List the detail information for future reference.

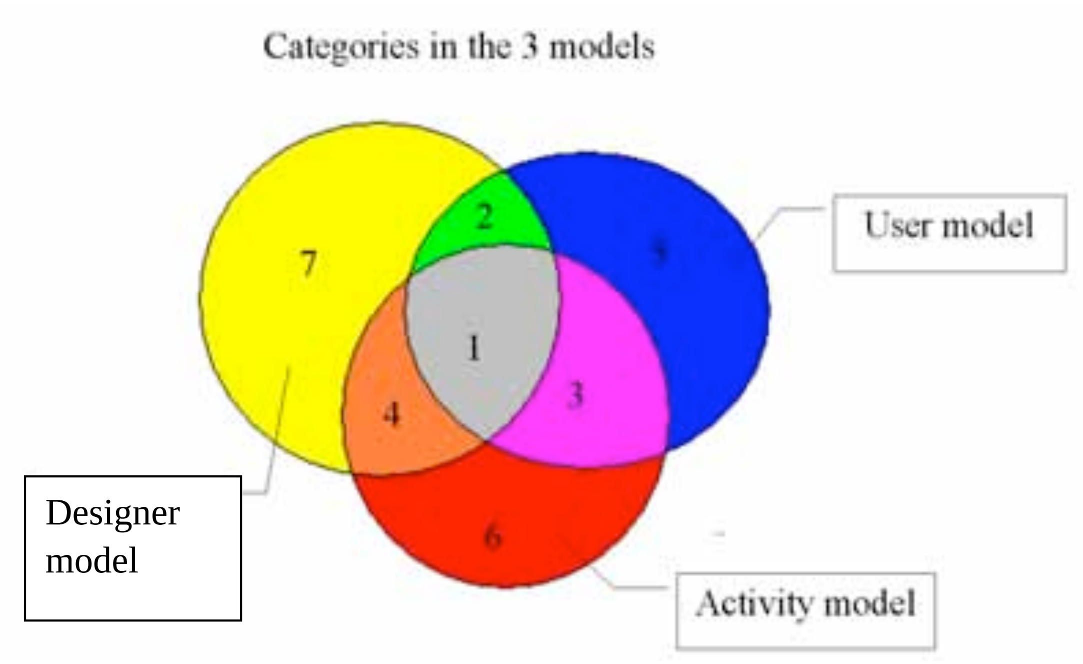


Figure 20. Categories within the Functional Framework differentiated by color.

The codes were implemented as predicates in MacShapa. MacShapa is a Macintosh-based qualitative data analysis software application for sequential data. It was designed to assist researchers engaged in observing human operators interacting with complex systems and with each other in laboratory simulators or in the field. MacShapa supports both qualitative and quantitative statistical analyses of the data. It includes various visualization tools such as a timeline report and tree outputs and can carry out various statistical analyses for temporal data. It is easy to modify or change coding syntaxes and vocabulary. The MacShapa variable we used to implement the codes of activities is called predicate, which is a function with a set of parameters.

Once the predicates are defined and implemented, an activity can be entered by filling the parameters of the predicate corresponding to the activity.

Example of a predicate: Operation (<adm/clinc/gen>, <Category>, <multiple /single task>, <task>, <multiple/single object>, <object>, <location>,<detail>)

Examples of coded function: The person at the front desk answered a phone call from someone wishing to make an appointment.

Operation (<administrative>, <cat 3 >, <multiple tasks> <make appointment>, <multiple objects>, <Phone, EDR> <front desk>, <detail>)

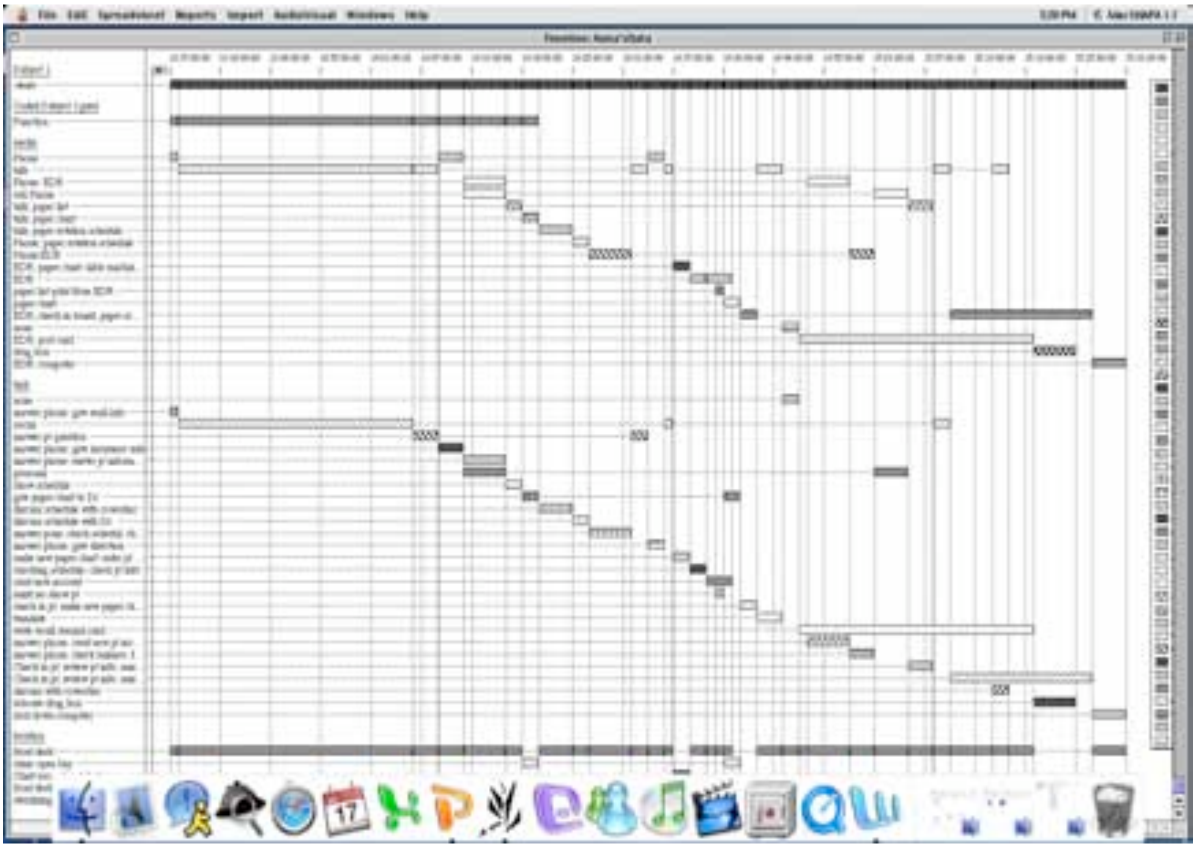


Figure 21. Macshapa timeline report of subject 1

Figure 22. MacShapa content report of subject 1 with all predicates

5.4.2.4. Inter coder reliability and validity

Two coders were used to code all the field notes. The field notes have a good deal of information, so it was saved in the computer and gone over line by line. After the field notes had been organized, the two coders performed the coding using MacShapa. The two coders were tested in their inter-rater reliability, revealing that the reliability is very high. The following table (Table 9) shows the descriptive results of the coding. The designations ‘C1’and ‘C2’ indicate coder 1 and coder 2. The following box plot shows the comparison of all the predicates in pairs of coder1 and coder 2 (Figure 23). Table 10 shows the code result comparison between coder1 and coder 2 in every predicate by using pair sample t-test. There are only 2 predicates with a significant difference, i.e., clinical and use of paper chart. The term “clinical” predicate is coding denoting whether or not this specific task is a clinical one. The “paper chart” indicates whether or not the user employed paper chart in the task.

Table 9. Descriptive Statistics of Coding Results

	Minimum	Maximum	Mean	Std. Deviation
c1task	24.00	106.00	53.3333	19.85183
c1admin	.00	41.00	20.2667	14.34009
c1clinic	.00	47.00	22.4667	19.05206
c1gen	2.00	23.00	10.6000	5.44846
c1opcat	.00	5.00	1.8667	1.92230
c1oc3	.00	19.00	7.6667	6.33208
c1oc4	.00	10.00	1.2000	2.78260
c1oc6	22.00	82.00	42.6000	15.83306
c1single	8.00	46.00	20.6000	10.30811
c1mult	13.00	73.00	31.6667	14.46013
c1edr	.00	16.00	3.8667	5.75533
c1paper	2.00	37.00	13.2000	11.79709
c2task	24.00	103.00	52.8000	19.04206
c2admin	.00	43.00	21.5333	14.04517
c2clinic	.00	48.00	20.5333	17.48006
c2gen	2.00	26.00	10.7333	6.09996
c2opcat	.00	6.00	1.4667	1.95911
c2oc3	.00	21.00	7.8667	6.57774
c2oc4	.00	10.00	1.1333	2.77403
c2oc6	24.00	81.00	42.3333	15.36074
c2single	8.00	46.00	21.6667	10.25160
c2mult	13.00	69.00	31.1333	13.46884

c2edr	.00	16.00	3.8667	5.79244
c2paper	2.00	36.00	12.8667	11.66721
avgtask	24.00	104.50	53.0667	19.44394
avgadmin	.00	41.50	20.9000	14.13986
avgclinic	.00	47.50	21.5000	18.23458
avggen	2.00	24.50	10.6667	5.74042
avgoc1	.00	5.50	1.6667	1.84842
avgoc3	.00	20.00	7.7667	6.44999
avgoc4	.00	10.00	1.1667	2.77532
avgoc6	23.00	81.50	42.4667	15.59243
avgsingle	8.00	46.00	21.1333	10.09326
avgmult	13.00	71.00	31.4000	13.95426
avgedr	.00	16.00	3.8667	5.77082
avgpaper	2.00	36.50	13.0333	11.72980

Table 10. Comparison of coding results between the 2 coders

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	c1task - c2task	.53333	1.06010	.27372	-.05373	1.12040	1.948	14	.072
Pair 2	c1admin - c2admin	-1.26667	2.46306	.63596	-2.63066	.09733	-1.992	14	.066
Pair 3	c1clinic - c2clinic	1.93333	2.65832	.68638	.46120	3.40546	2.817	14	.014
Pair 4	c1gen - c2gen	-.13333	1.40746	.36341	-.91276	.64609	-.367	14	.719
Pair 5	c1opcat - c2opcat	.40000	1.18322	.30551	-.25524	1.05524	1.309	14	.212
Pair 6	c1oc3 - c2oc3	-.20000	.56061	.14475	-.51046	.11046	-1.382	14	.189
Pair 7	c1oc4 - c2oc4	.06667	.25820	.06667	-.07632	.20965	1.000	14	.334
Pair 8	c1oc6 - c2oc6	.26667	.88372	.22817	-.22272	.75605	1.169	14	.262
Pair 9	c1single - c2single	-1.06667	3.89994	1.00696	-3.22638	1.09305	-1.059	14	.307
Pair 10	c1mult - c2mult	.53333	1.45733	.37628	-.27371	1.34038	1.417	14	.178
Pair 11	c1edr - c2edr	.00000	.37796	.09759	-.20931	.20931	.000	14	1.000
Pair 12	c1paper - c2paper	.33333	.48795	.12599	.06312	.60355	2.646	14	.019

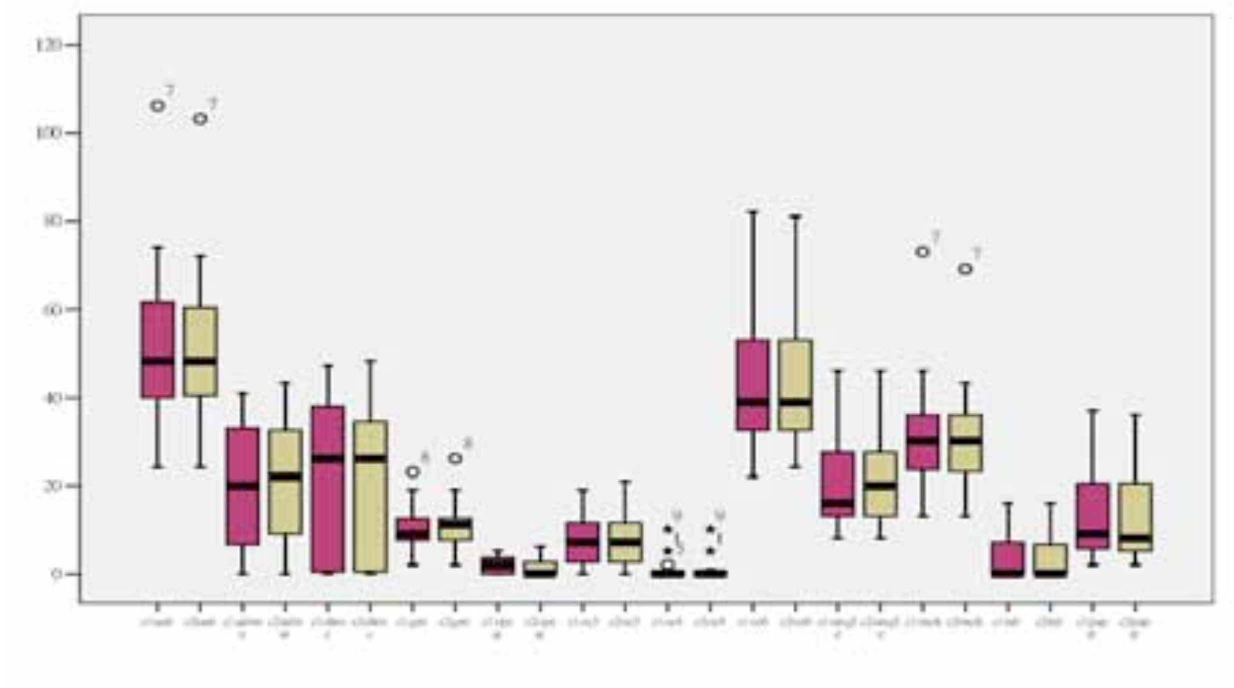


Figure 23. Box plot of all the predicates by coder1 and 2 (Coder 1Purple;Coder 2 Gray)

5.4.3. Results of shadowing

After testing the coder's inter-rater difference, the two coders were determined to have very similar and comparable coding results. The results of the two coders were combined and the following table shows the results of the observation of the 15 subjects. The average task number for a shift is 53, the range of task is very wide (minimum 24 tasks, maximum 104 tasks). In the function category section, category 6 (42.47) is much higher than category 3 (7.76), category 4 (1.16), or category 1(1.67) thus indicating that most of the operations performed in the clinical routine are not supported by EDR nor considered by the user. Use of paper chart (13.03) is much higher than the use of EDR (3.87); showing that paper charting is still being used much more often in the real world than is EDR. With the nature of occupation responsibility, different users were expected to perform different tasks. The following table (Table 11) shows the descriptive results for all the predicate value during observation performed by different users.

Table 11. Descriptive statistics result of all the predicate value of the observation

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
timemin	15	106.00	114.00	220.00	160.0667	34.72024	.356	.580	-1.011	1.121
avgtask	15	80.50	24.00	104.50	53.0667	19.44394	1.245	.580	2.505	1.121
avgadmin	15	41.50	.00	41.50	20.9000	14.13986	.025	.580	-1.461	1.121
avgclinic	15	47.50	.00	47.50	21.5000	18.23458	-.053	.580	-1.754	1.121
avggen	15	22.50	2.00	24.50	10.6667	5.74042	.925	.580	1.322	1.121
avgoc1	15	5.50	.00	5.50	1.6667	1.84842	.742	.580	-.664	1.121
avgoc3	15	20.00	.00	20.00	7.7667	6.44999	.550	.580	-.736	1.121
avgoc4	15	10.00	.00	10.00	1.1667	2.77532	2.807	.580	7.946	1.121
avgoc6	15	58.50	23.00	81.50	42.4667	15.59243	1.018	.580	1.382	1.121
avgsingle	15	38.00	8.00	46.00	21.1333	10.09326	1.067	.580	1.138	1.121
avgmult	15	58.00	13.00	71.00	31.4000	13.95426	1.592	.580	4.012	1.121
avgodr	15	16.00	.00	16.00	3.8667	5.77082	1.223	.580	.005	1.121
avgpaper	15	34.50	2.00	36.50	13.0333	11.72980	1.043	.580	-.516	1.121
Valid N (listwise)	15									

Table 12. Comparison of different roles in task performance and ANOVA result

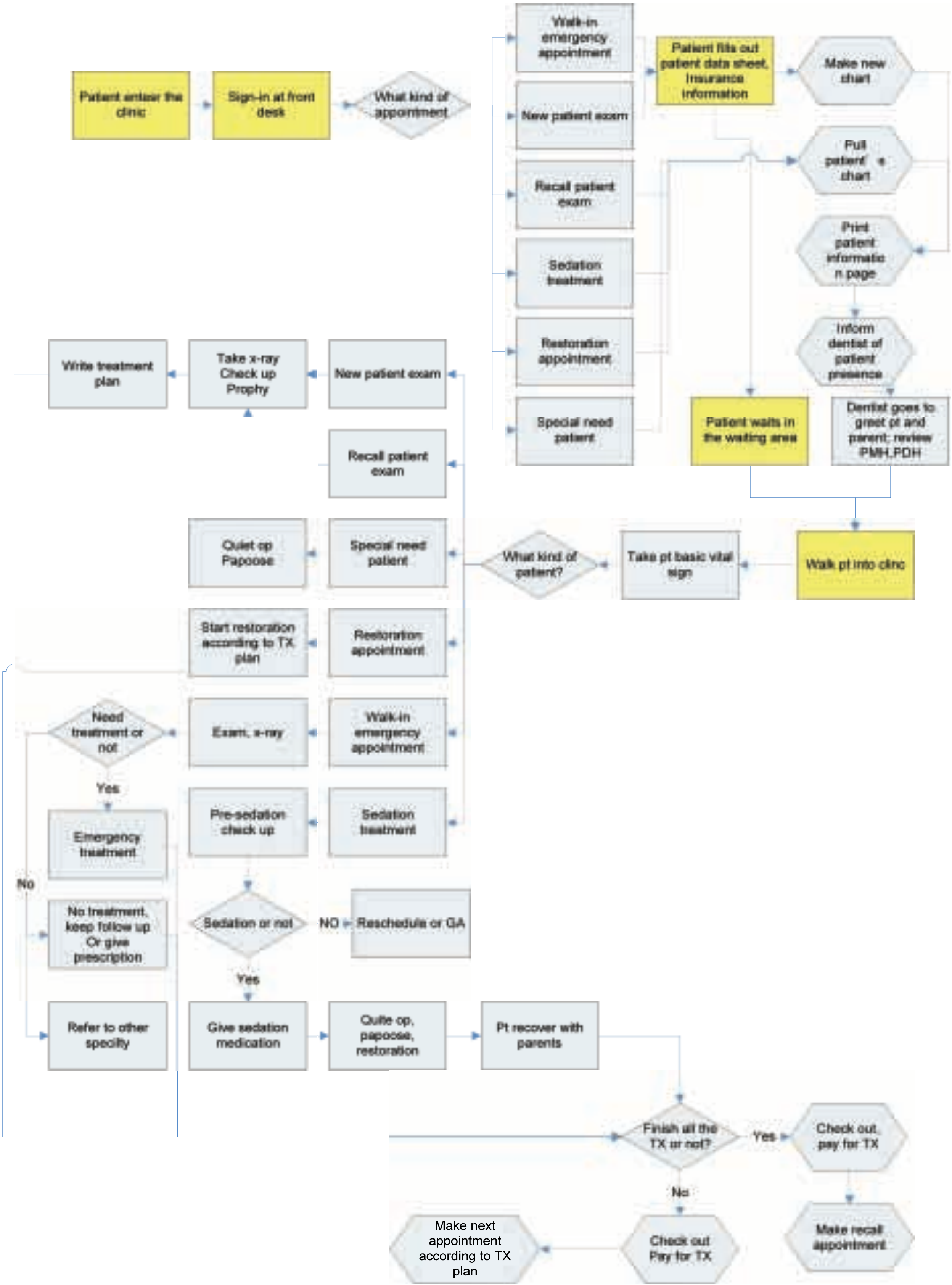
		Mean	Std. Deviation	Minimum	Maximum	ANOVA
						p-value
avgtask	dentist	61.7000	29.89900	24.00	104.50	0.289
	assistant	55.3000	11.38859	41.00	69.50	
	administrative	42.2000	7.25086	36.00	54.00	
	Total	53.0667	19.44394	24.00	104.50	
avgadmin	dentist	21.7000	14.87279	.00	41.50	0.002*
	assistant	7.2000	2.61247	3.00	10.00	
	administrative	33.8000	5.32212	27.00	41.00	
	Total	20.9000	14.13986	.00	41.50	
avgclinic	dentist	29.6000	11.45862	13.00	44.00	0.000*
	assistant	34.7000	12.85788	13.50	47.50	
	administrative	.2000	.44721	.00	1.00	
	Total	21.5000	18.23458	.00	47.50	

avggen	dentist	10.4000	6.18870	2.00	19.00	0.383
	assistant	13.4000	7.02140	5.50	24.50	
	administrative	8.2000	3.27109	4.00	13.00	
	Total	10.6667	5.74042	2.00	24.50	
avgoc1	dentist	1.5000	1.41421	.00	3.00	0.054
	assistant	.4000	.89443	.00	2.00	
	administrative	3.1000	2.13307	.00	5.50	
	Total	1.6667	1.84842	.00	5.50	
avgoc3	dentist	12.2000	8.19756	.00	20.00	0.174
	assistant	5.6000	5.17687	.00	12.00	
	administrative	5.5000	3.84057	1.00	11.00	
	Total	7.7667	6.44999	.00	20.00	
avgoc4	dentist	.0000	.00000	.00	.00	0.058
	assistant	.0000	.00000	.00	.00	
	administrative	3.5000	4.09268	.00	10.00	
	Total	1.1667	2.77532	.00	10.00	
avgoc6	dentist	48.0000	22.00852	23.00	81.50	0.084
	assistant	49.3000	7.56307	39.00	57.50	
	administrative	30.1000	4.64220	24.00	35.00	
	Total	42.4667	15.59243	23.00	81.50	
avgsingle	dentist	20.1000	10.77845	8.00	33.50	0.375
	assistant	26.2000	12.76029	13.50	46.00	
	administrative	17.1000	4.87852	12.50	24.00	
	Total	21.1333	10.09326	8.00	46.00	
avgmult	dentist	40.0000	20.18353	16.00	71.00	0.228
	assistant	29.1000	10.67357	13.00	38.50	
	administrative	25.1000	3.39853	21.50	30.00	
	Total	31.4000	13.95426	13.00	71.00	
avgedr	dentist	.6000	1.34164	.00	3.00	0.000*
	assistant	.0000	.00000	.00	.00	
	administrative	11.0000	4.37321	5.00	16.00	
	Total	3.8667	5.77082	.00	16.00	
avgpaper	dentist	25.9000	11.87118	5.50	36.50	0.002*
	assistant	5.9000	3.24808	2.00	11.00	
	administrative	7.3000	4.29535	3.00	13.00	
	Total	13.0333	11.72980	2.00	36.50	

5.4.4. Workflow Analysis and Process Flow

Beyer & Holtzblatt (1998) define workflow analysis as how work is distributed across people and how people coordinate the work to accomplish a goal. During this analysis, the following were identified: job responsibilities, roles that dentists, dental assistants, and administrative personnel assume, delegation of tasks, and the use of physical places and artifacts used to coordinate work. Workflow analysis was used to identify the informal structure of the dental office or how the work was actually carried out. Work models were generated for dentists, dental assistants, and administrative personnel. Sequence models were prepared to depict the patient flow for different dental patients. A physical model was completed to illustrate the physical layout (exam room, computer location, reception desk) of the dental office. The physical model provided important information about how the environment affects the way people perform in the dental office. In future studies a more detail workflow analysis can be done to fully elaborate and help to understand the activity model in depth. Figure 24 illustrates the basic workflow analysis result. The yellow color indicates patient movement, diamond shape is the decision making point, and the hexagon shape is the tasks performed by either dentist, assistant or front desk.

Figure 24. Workflow analysis of the clinic



5.4.5. Data Security

The investigators transcribed the audiotapes into a password-protected personal computer (PC), which was kept in a locked office. No identifiers of participants were kept in the transcribed data. This PC was not used by anyone other than study personnel. The notes were stored in locked file cabinets, and the data were analyzed on a password-protected computer that was only used by study personnel to analyze study data. These personnel were named and cleared through the IRB. All other study-related data (e.g., shadowing notes, processed data, etc.) were kept on the same computers. The transcribed data without identifiers on CD ROM and computers will be kept for two years for reanalysis of data and audit of research results for future publications.

5.4.6. Summary of Activity Model

In the process of building the activity model, we used the shadowing ethnographic study method to collect data. Data was transferred from field notes to quantified data by applying the functional coding method. This has helped us understand the nature of functions and tasks that are needed in a real world dental clinic. Additionally, we have utilized the data to understand the task and its category, which is very helpful for building the overall Functional Framework.

5.5. Summary

In this chapter, the data collection and analysis of user, system, and activity models were described in detail. The results gave us a basic understanding of the complexity and details of each of the models. The data collected in these three models were used to develop the unified model from which the work domain ontology was developed; the details of which will be described in the next chapter.

CHAPTER 6. INTEGRATING AND EVALUATING THE FUNCTIONAL FRAMEWORK

Chapter 5 described the process of how to build separate user, system, and activity models. This chapter shows how to combine the three separate models and how to evaluate the Functional Framework (Figure 25).

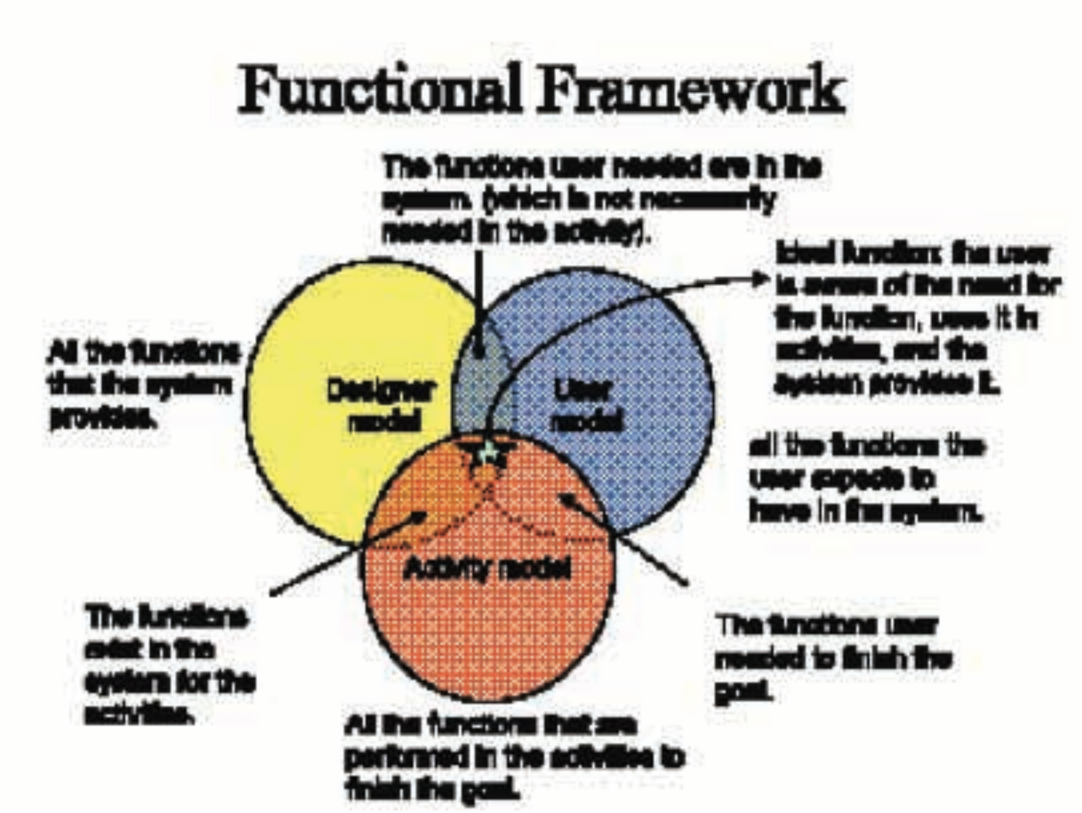


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Figure 25. Functional Framework (Venn diagram). This figure is identical to Figure 6 in Ch 3; it is inserted here for ease of reading.

6.1. A Work Domain Ontology

A Work Domain Ontology (WDO) is an abstract, declarative characterization of the work domain in terms of goals, objects, operations, and constraints. It allows us to describe essential requirements of work in an abstract model. It tells us the inherent complexity of the work, and it supports identification of overhead actions that are non-essential for the work. The objective of this part of the study is to identify the functional discrepancies among system, user, and activity models and to develop a WDO by consolidating the discrepancies.

6.1.1. User Model

We used the data that was collected from the user model survey to develop the user model. The data was coded and analyzed by using Nvivo(Chapter 4.2). After the data was coded, it was used to build a user model ontology. To build the ontology, Protégé version 3.2 was used to categorize, analyze, and visualize the data. The URI of the user ontology is: http://www.shis.uth.tmc.edu/Anna/userEDR.owl .The user model top-level classes are object, object property, operation, and user. User is the data related to user's role and experience. The object property was used to classify the data collected in the survey because the data "feature" and "character" is very vague and somewhat separated from the original goal—to identify functions. Thus, we put them into the class "object property". Figures 26 and 27 showed the overall hierarchical and radial layout of the structure of the user model.

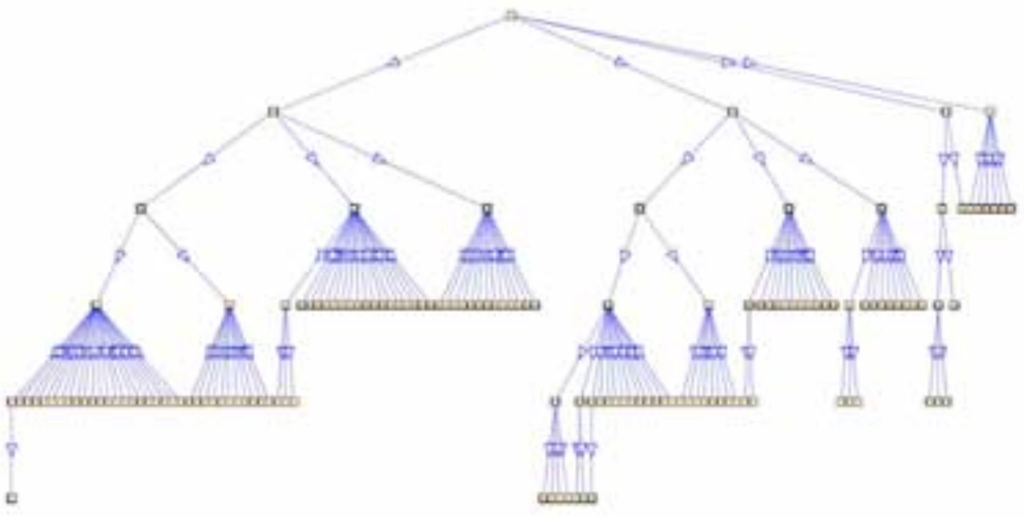

Figure 26. Overall Structure of User Model Ontology (Hierarchical view).

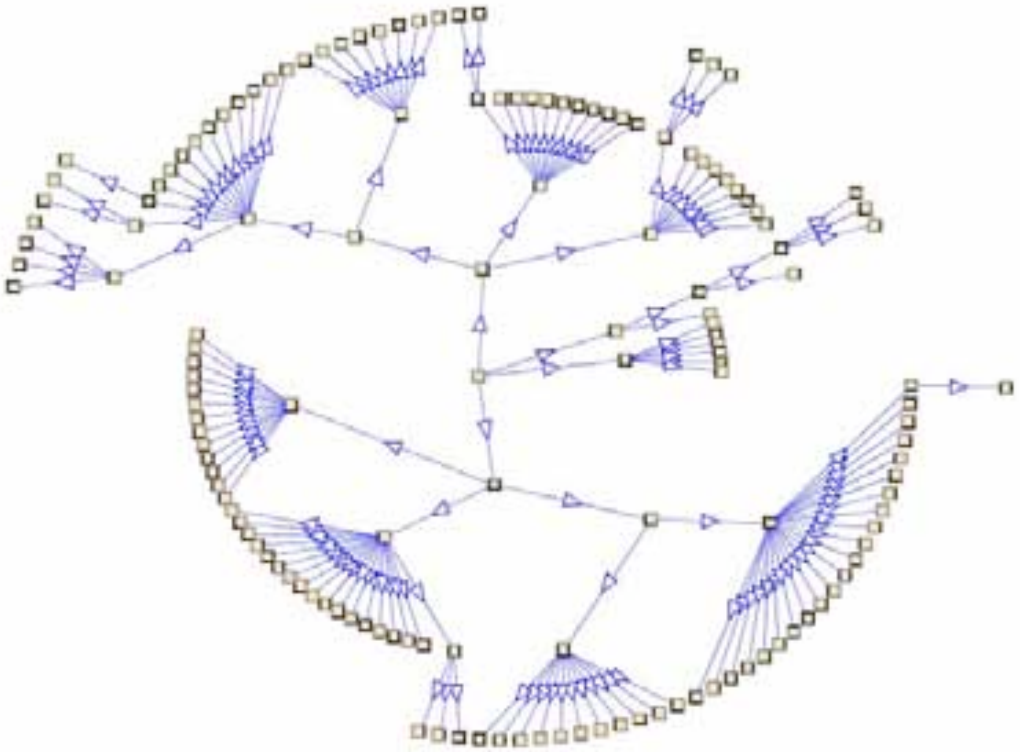

Figure 27. Overall Structure of User Model Ontology (Radial layout view).

In user model, the users only recognized 13 different kinds of operations provided by the present EDR system. However, the users would like to have 28 functions, 23 tasks, 21 features, and 8 characters in the ideal EDR. This shows that the user does have considerably more needs than the EDR system provides. In addition, the users do not even know all the functions that the current EDR has. The user model ontology did help clean out the data in order that the real functions could be seen more clearly.

6.1.2. Designer Model

The data collected in the designer model by directly click and systematic review of manual were used to develop the designer model. The top-level classes are EDR objects and EDR operations. There are 5 levels of the subclasses (Figure 28; Figure 29).

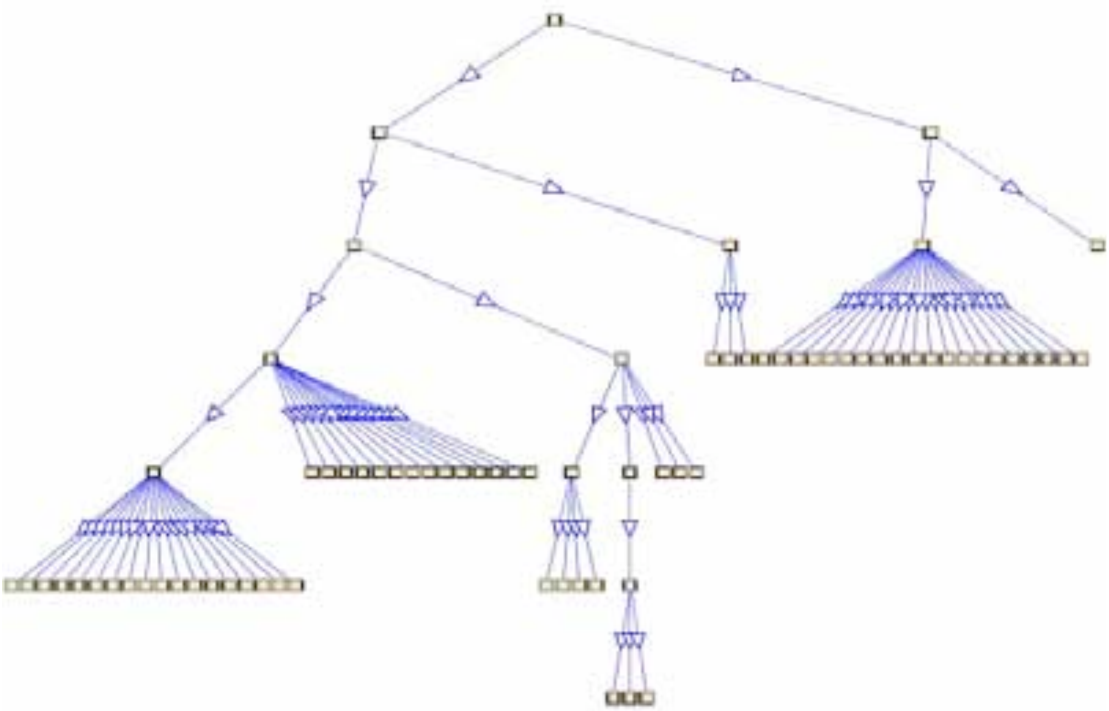

Figure 28. Overall Structure of Designer model Ontology (Hierarchical view)

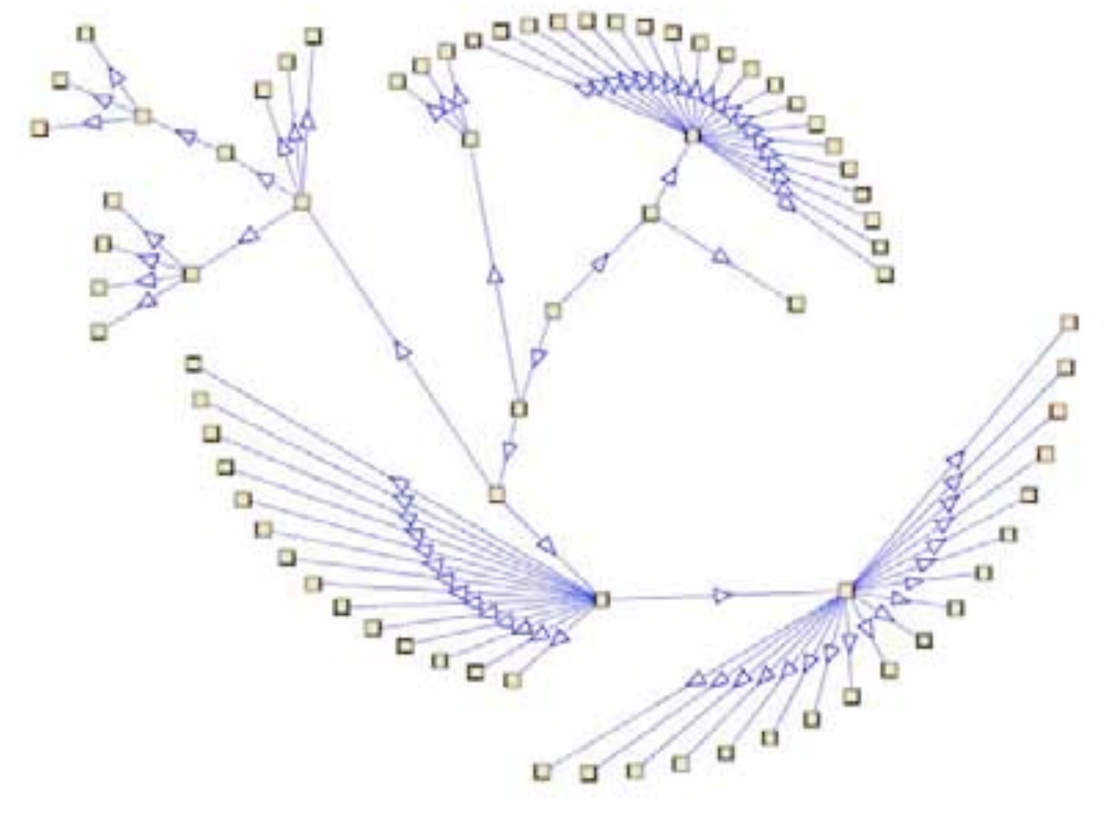

Figure 29. Overall Structure of Designer model Ontology(Radial Layout view)

Figures 28 and 29 show the general structure of the designer model.

6.1.3. Activity Model

To develop the activity model ontology, we used the data collected during shadowing. All the data were categorized into a hierarchical ontology structure. The analysis strategy is top down, so within in the highest level of classes is: locations, objects, operations, personnel, and time. Figures 30 and 31 show the overall hierarchical and radial layouts of the structure of the user model ontology. Figure 32 shows the overall nested tree map of the entire activity ontology.

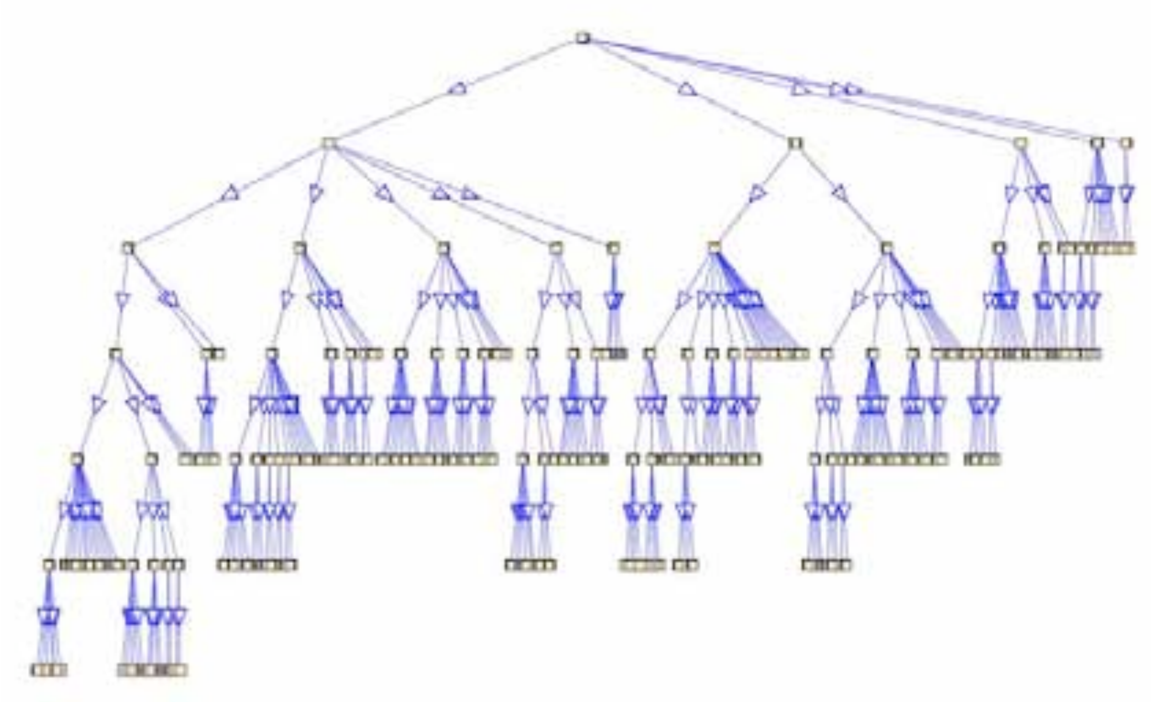

Figure 30. Overall Structure of Activity Model Ontology (Hierarchical view)

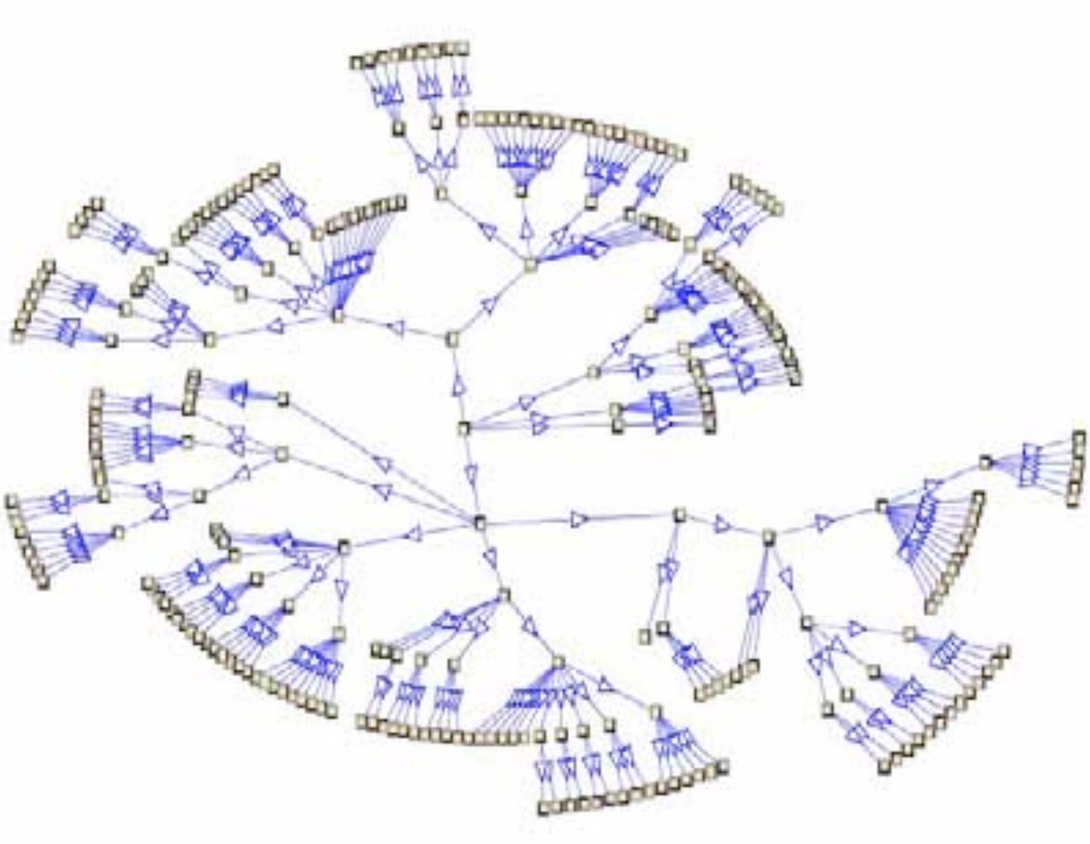

Figure 31. Overall Structure of Activity Model Ontology (Radial Layout view)

Figure 32. Overall Activity Model Ontology in Nested Tree Map View.

Locations are the physically existing areas where the operation occurred. Locations were then categorized into administrative, clinical, and facility areas. (Please refer to Chapter 5.4.1.1 setting.)

The objects are more complicated. The second-level of classes include: administrative objects, CIS objects, clinical objects, communication objects, and paper charts. The definition of object is “something perceptible by one or more of the senses, especially by vision or touch”. In this class we include both physical objects and computer objects. For example:

“High speed hand piece”: categorized as Objects/Clinical objects/Hand piece/High speed hand piece.

“Print manager icon”: categorized as Objects/CIS objects/ Computer software / EDR system components/ Print Manager.

In operations class, the operations were divided into administrative and clinical operations. The operation has a total of 5 levels of hierarchical structure (Figure 33) and 93 operations in the activity ontology.

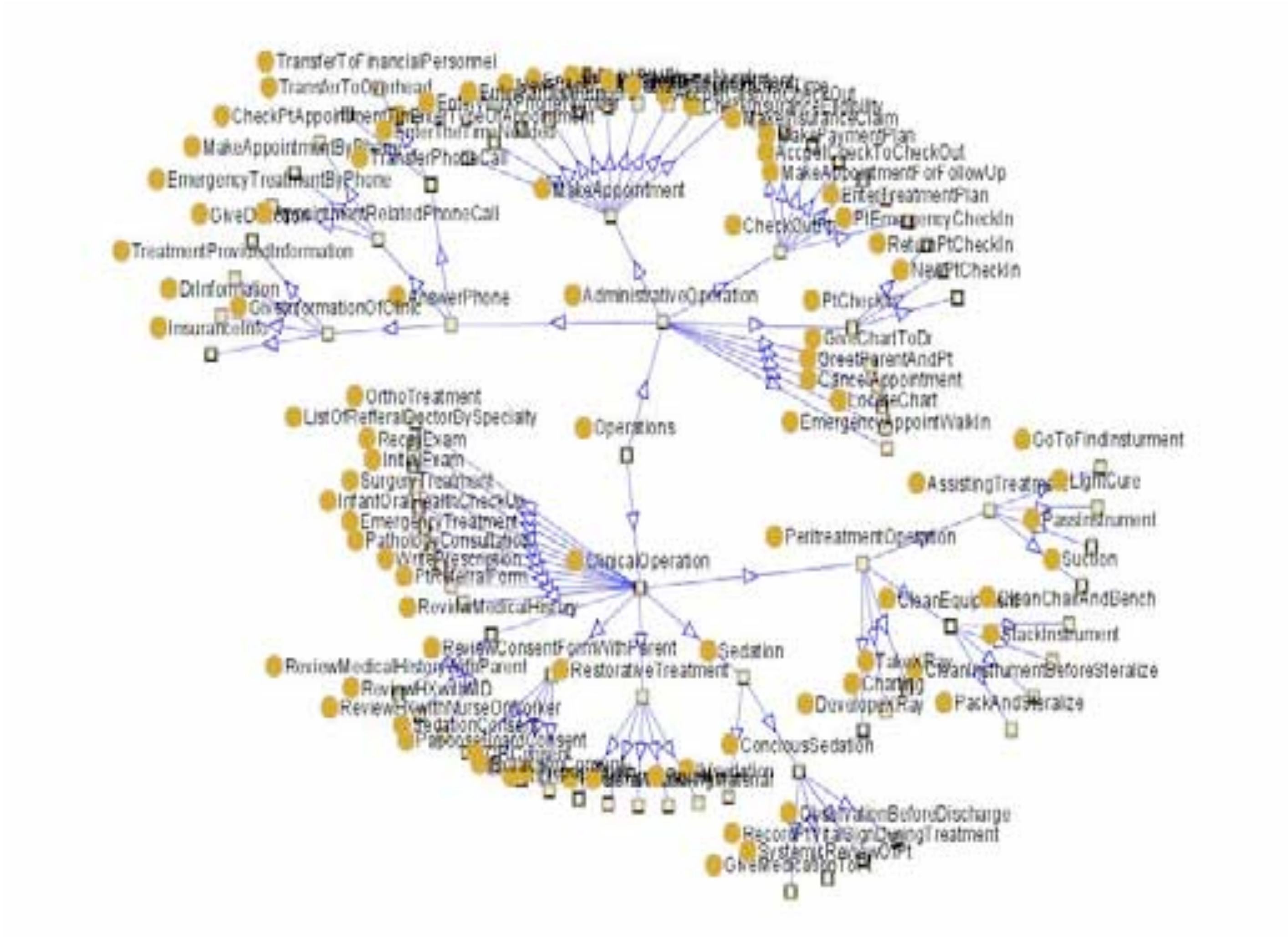

Figure 33. Radial Layout of the Operation Class and its Nodes in Activity Model.

In “Personnel”, we categorized all the personnel involved in this clinic. In “Time”, we were simply listing the different working times. These two classes were not used extensively in this study.

In the user model ontology section, the data present that the users do have more needs than the EDR system provides. However, as previously stated, the users do not know all the functions that the current EDR has (because the user only listed very limited functions in the user model survey). In the activity model there are many times when the user was employing traditional methods (paper, x-ray) instead of the EDR system. Dentists (2%), and dental assistants (<1%), spent little time with the EDR even though the EDR system has functions supporting some of the operations.

The discrepancies among the 3 models show the gaps among what the EDR system offers, what users want, and what happens in the real world. A WDO, implemented in Protégé-OWL, was developed by combining the 3 models.

6.2. Categorization of Function by Combining the Three Models

Figure 34 is the Functional Framework we have proposed. It has been studied in depth in the previous sections.

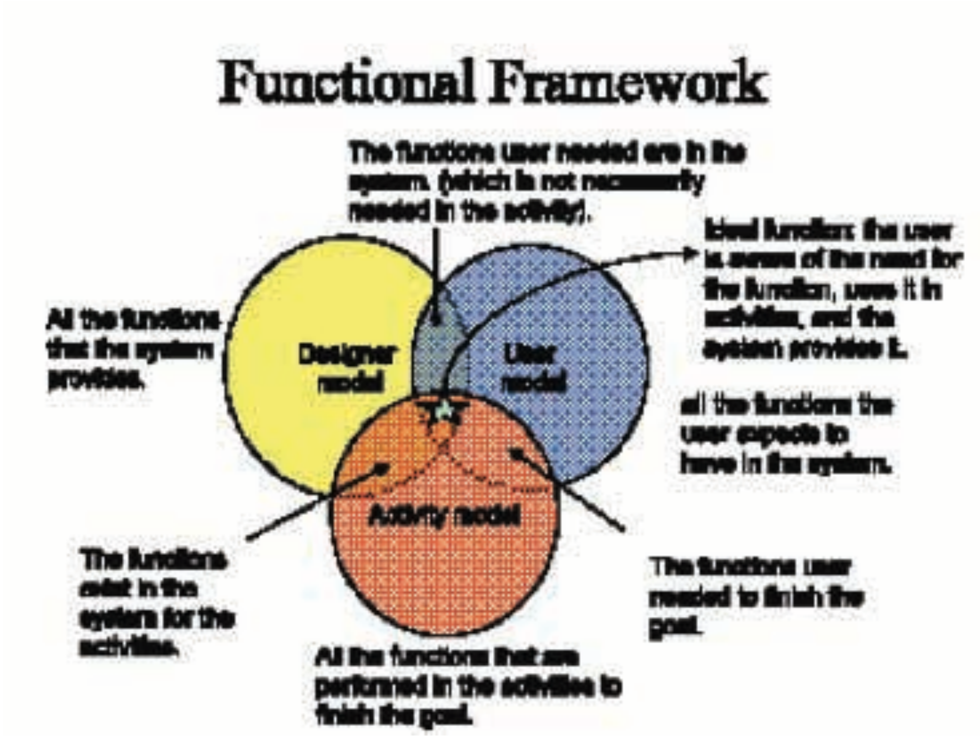

Figure 34. Functional Framework (identical to Figure 6)

- $U \cap D \cap A$ = ideal function

- $U \cap D$ = functions user expects exist in the system (MSN messenger)
- $U \cap A$ = functions that user needs for the activity (automatic caries record)
- $D \cap A$ = functions that designer designed for the activity (thumb print signature)

Now having developed the 3 models and their ontology, it is now very important to separate and understand each area. In Section 5.4.4., we have categorized each area; after having built the 3 models, we are able to know precisely where each function is located (Figure 35).

- Area 1 = $U \cap D \cap A$
- Area 2= $U \cap D -$ Area1
- Area 3= $U \cap A -$ Area1
- Area 4= $D \cap A -$ Area 1
- Area 5=$U -$ (Area1+Area2+Area3)
- Area 6=$A -$ (Area1+Area3+Area4)
- Area 7=$D -$ (Area1+Area2+Area4)

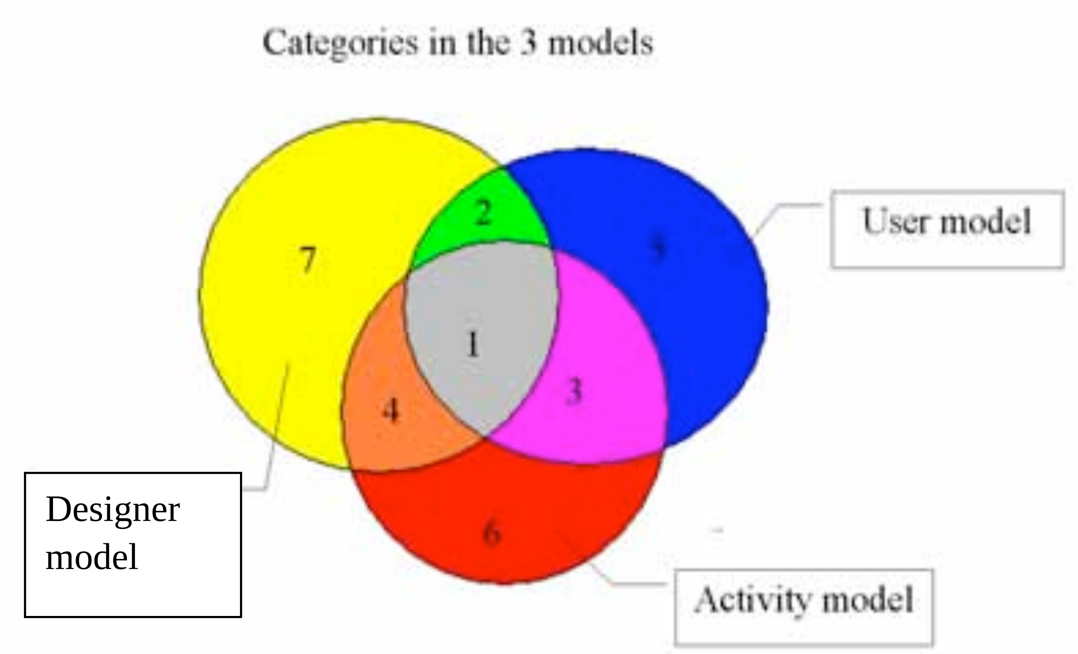

Figure 35. Areas of Functional Framework (identical to Figure 20)

6.3. Identifying the Functional Discrepancies

Since in this study, we were only interested in functions, we extracted all the functions that were identified in the three models. There are 54 functions in the designer model, 74 functions in the user model, and 93 functions in the activity model (Appendix 4). After all the functions were listed, a color-coding was applied to the summary table to help identify the functions that are in the same area (Figure 36). The green color indicates area 1; yellow indicates area 2, purple indicates area 3, and aqua indicates area 4. The color gray indicates the functions that are clinical operations only at the present time, the EDR system cannot perform those functions, those such as ‘pass instrument’, ‘clean chair’, etc. Only the exact same words of the functions were identified as a match, for example, “Check canceled appointment” $\neq$ “Cancel appointment”.

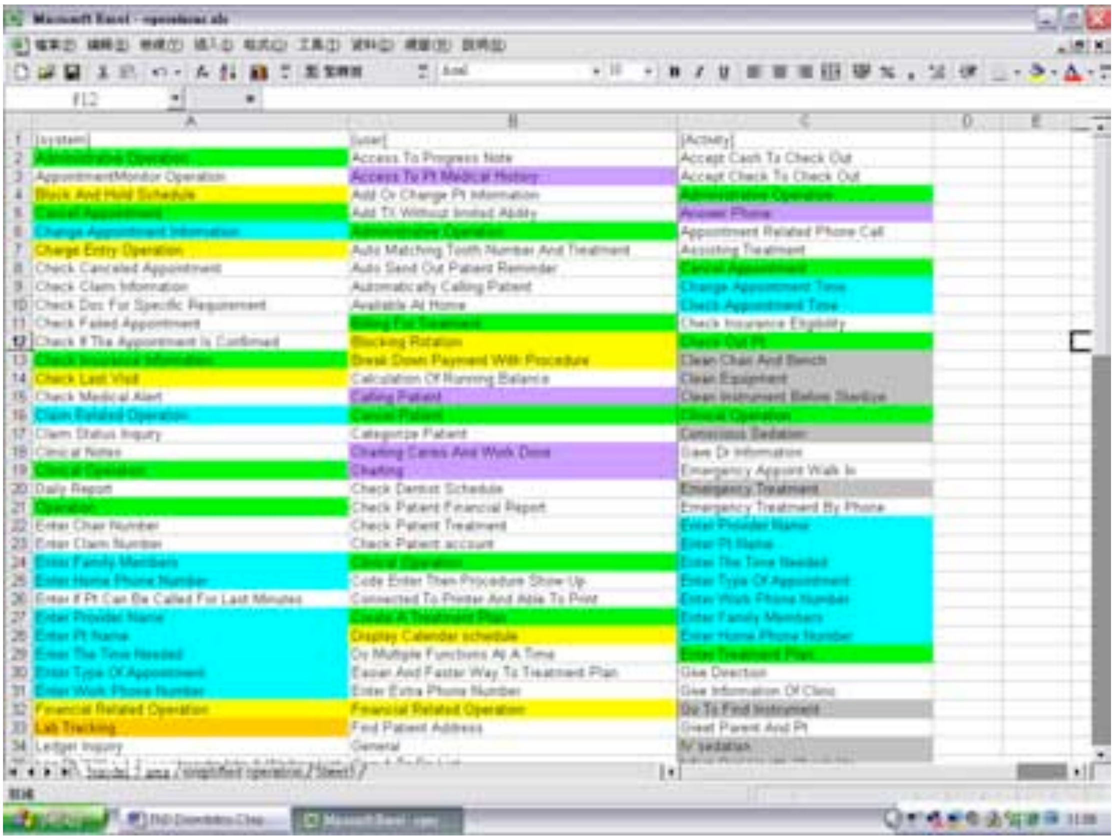

Figure 36. The Color Code Applied on the Functions of the three Models

The results for the numbers of functions are listed in the Table 13. The result for all functions located in the different areas can be illustrated in the following graph as a proportion to the number of functions (Figure 37).

Table 13. Number of Functions and Percentages for Each Area of Functional Framework

Area of Functional Framework	Number of functions	Percentages (%)
1	11	5.8
2	12	6.3
3	10	5.3
4	11	5.7
5	50	26.3
6	69	36.3
7	27	14.2

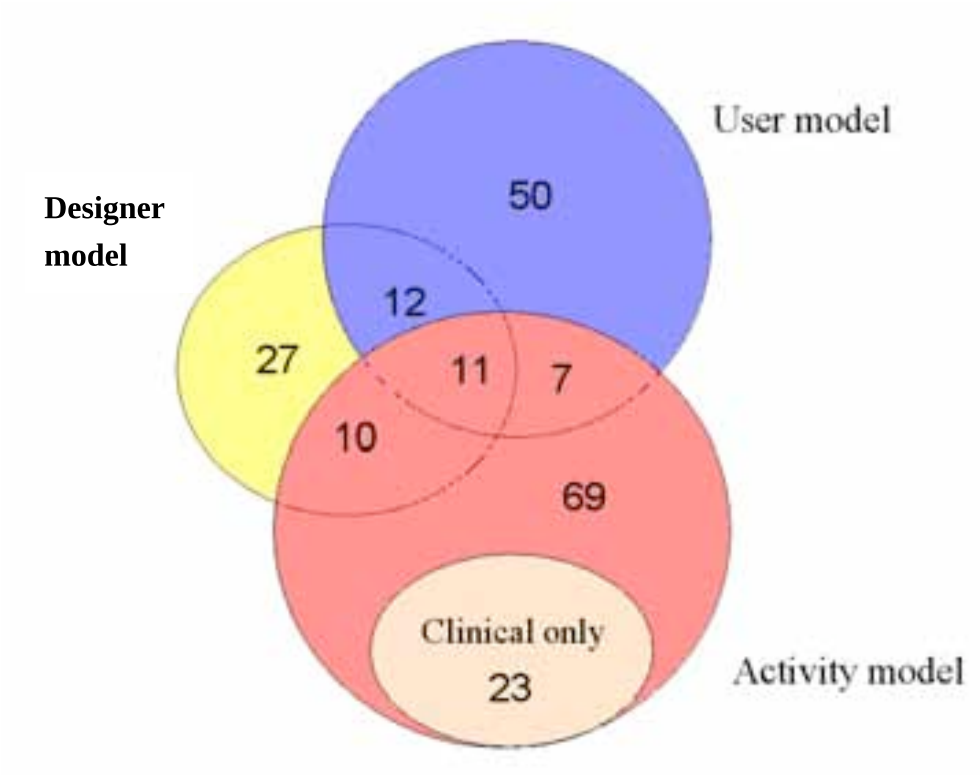

Figure 37. Number of Functions in Each Area

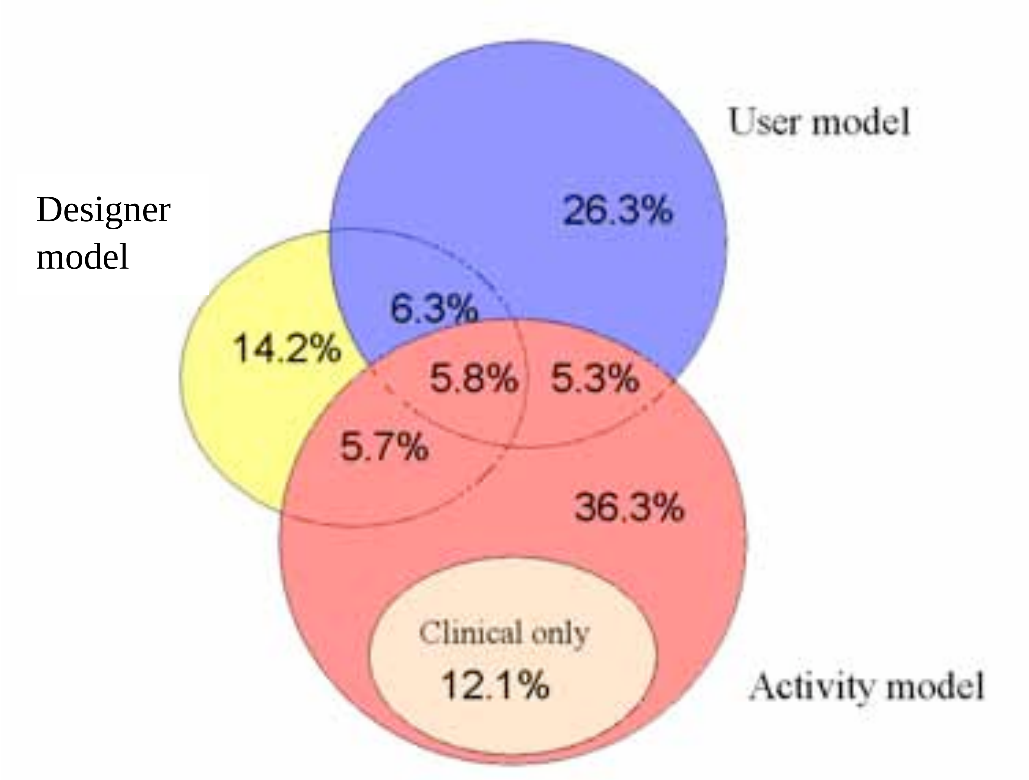

Figure 38. Percentage of Functions in Each Area.

According to the results (Figure 38) we found that there are very few matching functions in area (11, 5.8%). This result indicates that the ideal function percentage is extremely low in comparison with other areas. We can also see that, in the activity model, only 16.8% of functions were supported by EDR. It is a startling result. Even though the EDR was available for use in the clinic, the percentage of using it in the activities of the daily health care routine was extremely low. One may argue that this occurred because most of the EDR functions supported administrative work. However, in the functions identified as clinical only, the percentage is only 12.1%. This means that currently the computer systems are still unable to do those kinds of tasks. Even when subtracting them from area 6, there is still 24.2% of functions that were not supported. This certainly demonstrates that the EDR system still has significant room for improvement.

6.4. Evaluation of the Functional Framework

We already collected data for the three models (user, system, and activity) and identified the Functional Framework by using EDR as the working domain. Now an evaluation of this proposed framework is needed. We used a close ended survey to evaluate this functional framework. It evaluated not only the validity of the Functional Framework, but also its reliability by comparison to the second EDR system (Axium).

6.4.1. Instrument

A user's feedback survey was conducted to evaluate the user's satisfaction regarding the functions of the two EDR systems used before. All users were those who used both systems in the care of patients.

From 1995 until 2006, CIS was the EDR used in the University of Texas Health Science Center at Houston Dental Branch. CIS was also the system we used to build the designer model. In September 2006, Axium began to be used at UTDB at Houston, replacing the CIS system. This gave us the opportunity to allow users who used both EDR systems to evaluate the validity and accuracy of our framework. In Section 6.3, Figure 36 lists all the functions from user, activity, and designer models. We added all the functions together and deleted the repeated functions. For example, 'make treatment plan' is listed in area 1, indicating that this function was included in all 3 models. We then deleted the 2 repeated functions so that it was listed only one time. After the review and the deletion of the repeated functions, the end result is a list with 190 functions from the three models. These 190 functions were the items used in the survey to obtain information about the users' satisfaction and perception.

The 7 questions we listed on the survey were:

1. "How useful is this function to you?" (Rates your opinion of usefulness of each function; 5 indicating that it is very useful, 1 that it is not very important at all.)
2. "How critical is this function to you?" (Rates if this function is critical for you in your work; 5 being very critical and 1 not critical at all.) For example, of functions in outlook 'send email' is a critical function; without it the system does not work. However the 'search for email address' function is not critical; even without the function, the user can still type in the email address or go through other ways to finish the goal and send the email.
3. Did this function exist in the old system? (Yes/No)
4. Does this function exist in the current system? (Yes/No)
5. Rate the old system in this function. (1=not satisfied at all, 5=very satisfied)
6. Rate the new system in this function. (1=not satisfied at all, 5= very satisfied)
7. Which system do you prefer to use? (1=old system; 2= current system)

This final survey has 190 rows of functions and 7 columns of questions for each function. There are a total of 1330 cells on this survey (Appendix 5).

6.4.2. Subjects

Eighty (80) surveys were handed to the users who had experience in using both CIS and Axium systems and using them in the care of patients for more than 6 months. Twenty-six (26) surveys (32.5%) were returned. The response rate was not very high. One of the major reasons for this low response rate was the length of the survey. Of the 26 returned surveys, missing data fields and percentages were calculated (Figure 39). Only surveys with less than 20% missing data fields were used in the final analysis. Final inclusions of subjects for detailed statistic analyses were 15 due to the missing data exclusion criteria.

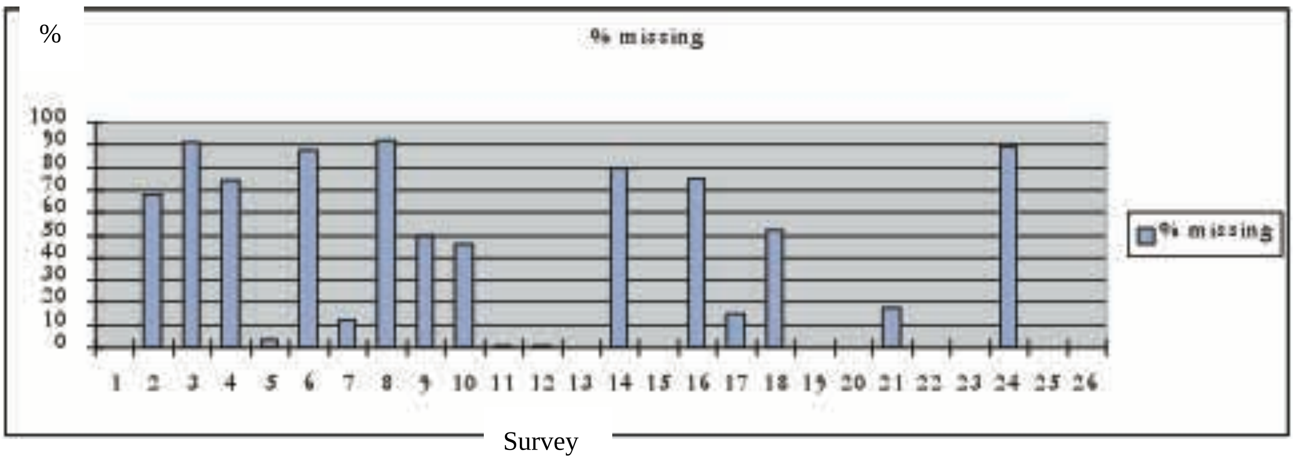

Figure 39. Percentage of Missing Data of Each Survey

6.4.3. Statistical Analyses

The data that was included in this statistical analyses section were the 15 subjects with their survey results. The survey results include 190 functions, and 7 questions for each function(Ch 6.4.1). Every subject's answer for the same question was summarized and a average value was calculated for each question for each function (Appendix 6). After the spreadsheet was formed an average value of each of the 7 questions over all the functions was calculated. An average value of each question for each subject was calculated and formed another spreadsheet (Appendix 7). A descriptive statistic result was calculated for the average of all the functions of the survey (N=15). The average result of every question was tested to correlated with each other to test if there is a correlation between questions (Pearson correlation, N=15). A linear regression test was performed by using the preference as the dependent variable with all other questions as the independent variables to test if the preference can have a linear regression model by combining the survey questions. A paired t-test was performed to compare the user's satisfaction in both systems. The average result for survey questions 5 and 6 were the dependent variables, the group was defined as the new system and old system. Since the same user used both systems we choose paired t-test.

In section 6.4.5. we used the average of all the subjects' responses to each function as the dependent variable. The independent variable was the 7 areas based on the Functional Framework. The other independent variable is the number of models that overlap in the area (1-3). Descriptive statistics including mean, standard deviation, confidential interval, maximum and minimum were reported presented by different overlap. Box plots were formed based on these data. A One Way ANOVA was performed on the average result of all subjects' response (190) on each question with between subject factor as overlap (N=3). A post-hoc test, LSD test, was performed to compare each within subject difference. Spearman Rho correlation was tested between the overlap correlated to usefulness, criticalness and user's satisfaction. This test is trying to find out if there is any correlation between our overlap and user's response. All data were analyzed with SPSS 13.0.

Table 14 shows the basic descriptive statistic results for all the survey questions. There is very similar average value in usefulness and criticalness. Comparison of the two systems will be discussed in the following section.

Table 14. Descriptive Statistics of all Questions in Final Survey

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
usefulness	15	1.48	5.00	2.9708	.31557	1.22221	.568	.580	-1.284	1.121
criticalness	15	2.00	5.00	2.9640	.28409	1.10027	.036	.580	-.893	1.121
existold	15	.00	.61	.1612	.04373	.16937	1.435	.580	2.406	1.121
existnew	15	.36	1.00	.7248	.06117	.23691	-.328	.580	-1.253	1.121
satisfyold	15	.00	4.97	1.5374	.29367	1.13739	2.186	.580	5.967	1.121
satisfynew	15	1.48	5.00	2.9006	.34092	1.32037	.625	.580	-1.159	1.121
preference	15	1.69	2.00	1.9570	.02333	.09036	-2.354	.580	5.257	1.121
preference2	15	.69	1.00	.9570	.02333	.09036	-2.354	.580	5.257	1.121
Valid N (listwise)	15									

In Appendix 6, a table of the average score of all the questions for each function can be found. This table gives us information about the user's perception of each function.

Table 15 is the Pearson correlation table for correlation between questions to each other. The data is from the average of all functions in each question (Appendix 7). The purpose for the Pearson correlation test is to test whether there is a correlation between the question results. Since the data is the average result they are not rank order data instead of measure data. Usefulness and criticalness are highly correlated (r=0.956; p<0.001). This is not difficult to understand since, for most people, usefulness and criticalness go together. Usefulness is highly correlated to satisfaction of the new EDR(r=0.68; p=0.005). This means that when the user rated the system high in usefulness, they also had higher satisfaction. Satisfaction of the new or old system is positively correlated with the presence of functions in the new system (r=0.533 p=0.041); usefulness and criticalness (r=0.627, p= 0.012). This maybe due to the fact that when a function exists in the new system, its presence increases the possibility of preference; and the usefulness and criticalness can be identified more easily.

Table 15. Pearson correlation Test the Correlations Between Questions.

Correlations

		usefulness	criticalness	existold	existnew	satisfyold	satisfynew
usefulness	Pearson Correlation	1	.956**	.366	.044	-.097	.680**
	Sig. (2-tailed)		.000	.180	.877	.730	.005
	N	15	15	15	15	15	15
criticalness	Pearson Correlation	.956**	1	.272	.190	-.136	.627*
	Sig. (2-tailed)	.000		.326	.498	.630	.012
	N	15	15	15	15	15	15
existold	Pearson Correlation	.366	.272	1	-.262	.237	.035
	Sig. (2-tailed)	.180	.326		.346	.394	.901
	N	15	15	15	15	15	15
existnew	Pearson Correlation	.044	.190	-.262	1	.208	.533*
	Sig. (2-tailed)	.877	.498	.346		.457	.041
	N	15	15	15	15	15	15
satisfyold	Pearson Correlation	-.097	-.136	.237	.208	1	.363
	Sig. (2-tailed)	.730	.630	.394	.457		.183
	N	15	15	15	15	15	15
satisfynew	Pearson Correlation	.680**	.627*	.035	.533*	.363	1
	Sig. (2-tailed)	.005	.012	.901	.041	.183	
	N	15	15	15	15	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Upon looking at the correlations between the questions, we must ask an important question. Can any of these questions help us predict which system a user is going to prefer? To answer this question, we ran a linear regression analysis in order to predict the preference. The dependent variable is the average of the surveys preference of all the functions(Appendix 7). The model summary is in Table 16. The answer is positive. With usefulness, criticalness, existing old, existing new, and satisfaction in both systems as predictors, we can now state the user's preference in the EDR system is

80.1% (R= 0.895; p=0.017; R-square=0.801). This means that the combination of answers to the survey questions will be a very good predictor of the user's preference.

Table 16. Linear Regression Model Summary Table

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.895[a]	.801	.651	.05338	.801	5.351	6	8	.017

a. Predictors: (Constant), satisfynew, existold, satisfyold, existnew, criticalness, usefulness

b. Dependent Variable: preference2

6.4.4. Comparison of the Two EDR Systems

Paired sample t-test was used to compare user satisfaction and user recognition of function between the two EDR systems: CIS (old) and Axium (new). After comparing the existence of functions in these two systems, it was found that in the old system only 16% were recognized, whereas in the new system 72% were recognized. There was a significant difference in the user's perception of the existence of functions in the system ($p<0.001$). This means that, from the user's point of view, there was a significant difference in the functions these two systems provided. The new system provides more than the old. A similar result was obtained for user satisfaction; there was a significant difference in the user's satisfaction between the old and new systems ($p=0.002$). The new system had a significantly higher satisfaction rate (2.9 $\pm$1.3) than the old system (1.53 ± 1.1).

6.4.5. Categorized Zone Related to User Satisfaction

In our proposed Functional Framework, the framework was used to identify the match and discrepancy among user, system, and activity. The hypothesis was that the EDR system with greater functional discrepancies among User model, Designer model, and Activity model was the one with less user satisfaction. The following graphs shows the results. EDR system with the greater functional discrepancies among user model, designer model, and activity model was the one with the less user satisfaction. The graphs in Figures 40, 41, 42 and 43 show the results for each question by Functional Framework category area.

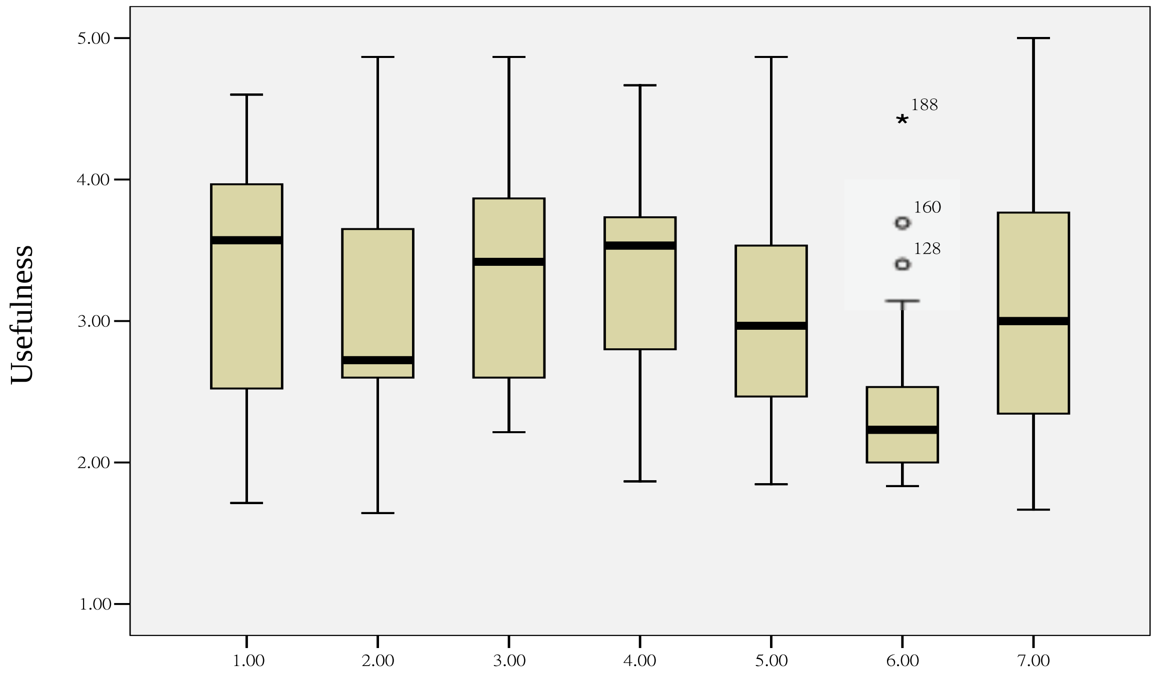

Figure 40. Mean usefulness value for each area of the Functional Framework

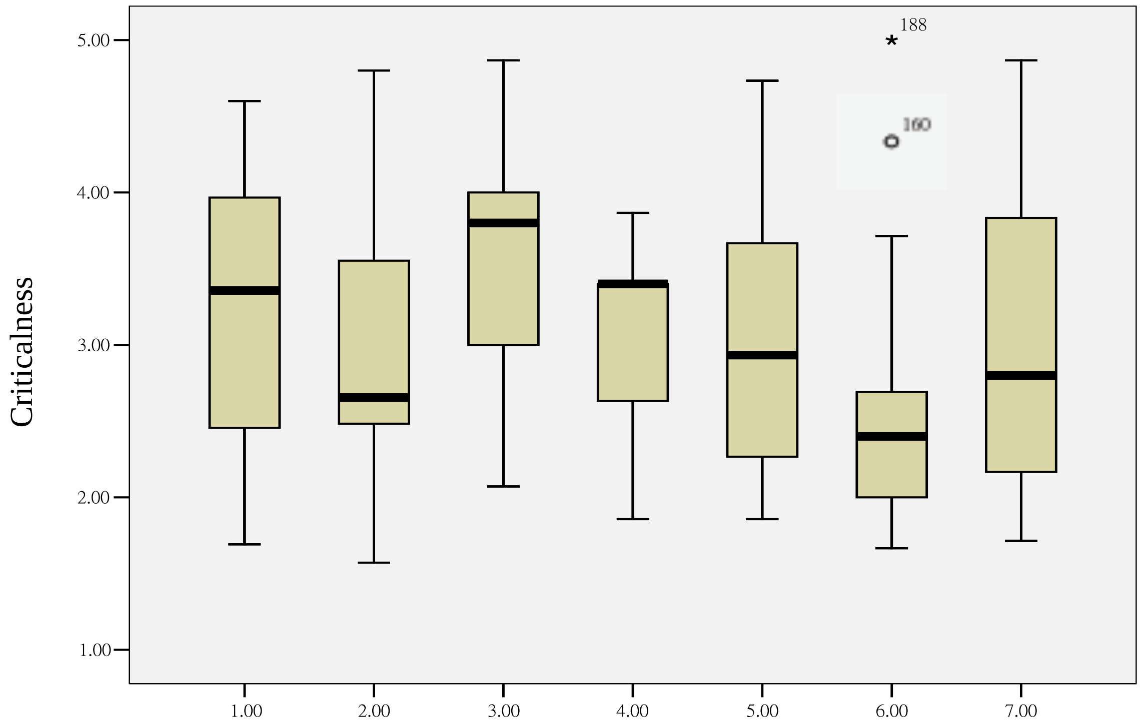

Figure 41. Mean Criticalness value for each area of Functional Framework

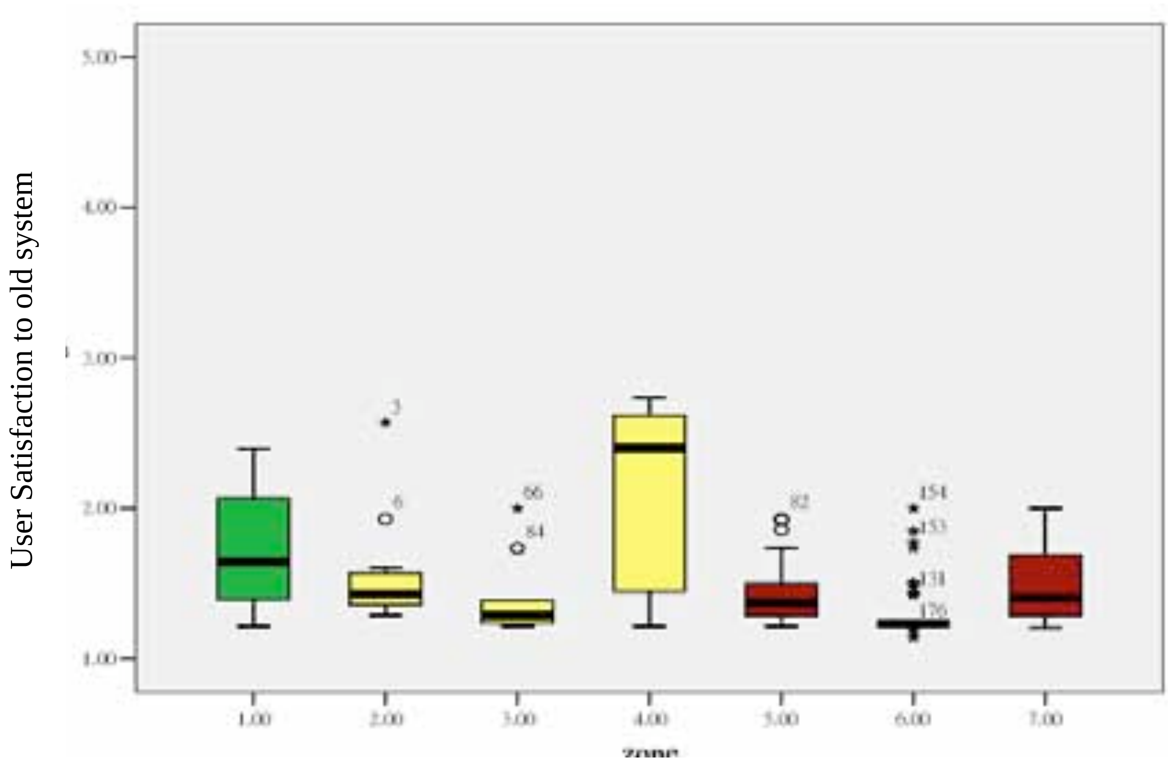

Figure 42. Mean User Satisfaction of the old EDR system for each area of Functional Framework

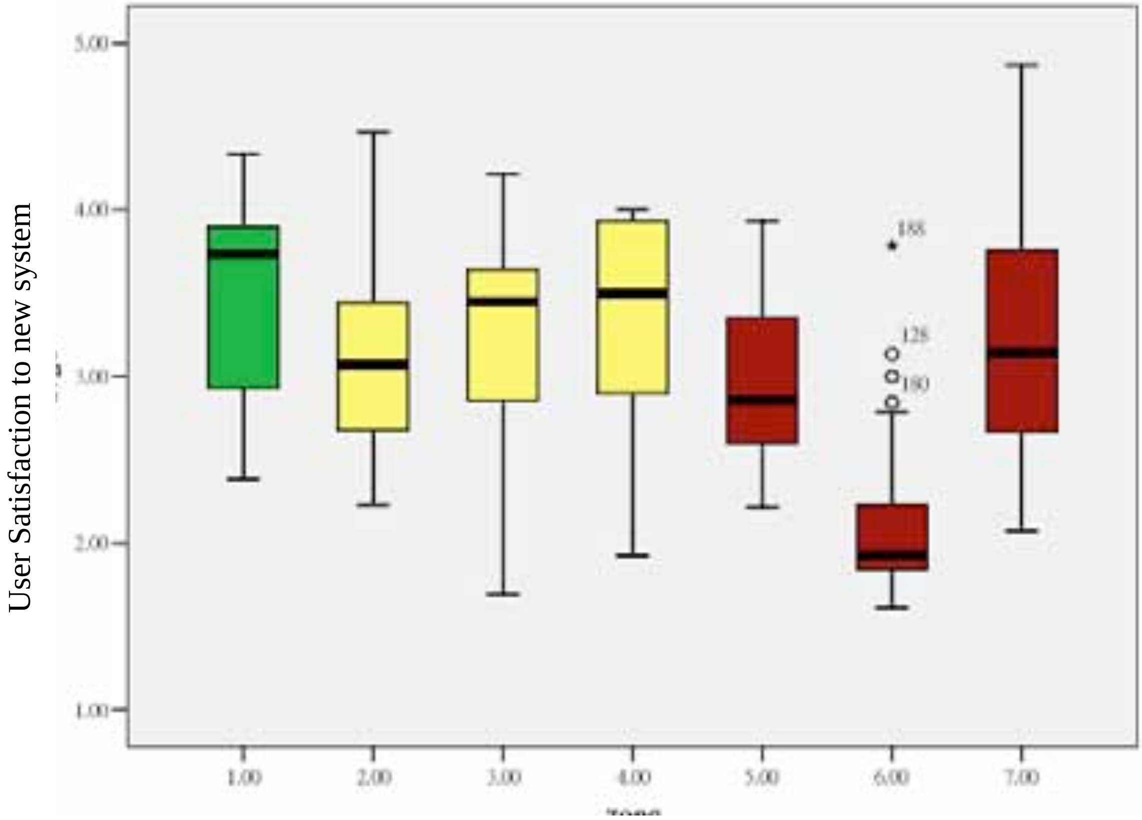

Figure 43. Mean User Satisfaction of the new EDR system for each area of Functional Framework

Box plots in Figures 44 and 45, as well as Table 17 and 18, show that as functions are contained or overlapped by increasing number (1,2 or 3) of models (user, designer and activity model) user satisfaction increases. In the graph we can see very clearly that more overlap does provide more satisfaction whether in the old system or in the new. The following table (Table 17) presents one-way ANOVA test results. Table 18 presents the post-hoc test comparing overlaps. It shows a significant difference in every question, (usefulness, criticalness, satisfaction in old or new, and preference). The standardized effect sizes for functions contained by three overlapping models versus those contained by only one model range from approximately 0.54 to 1.30

standard deviations, which are in the large range of standardized effect sizes (Cohen, 1988).

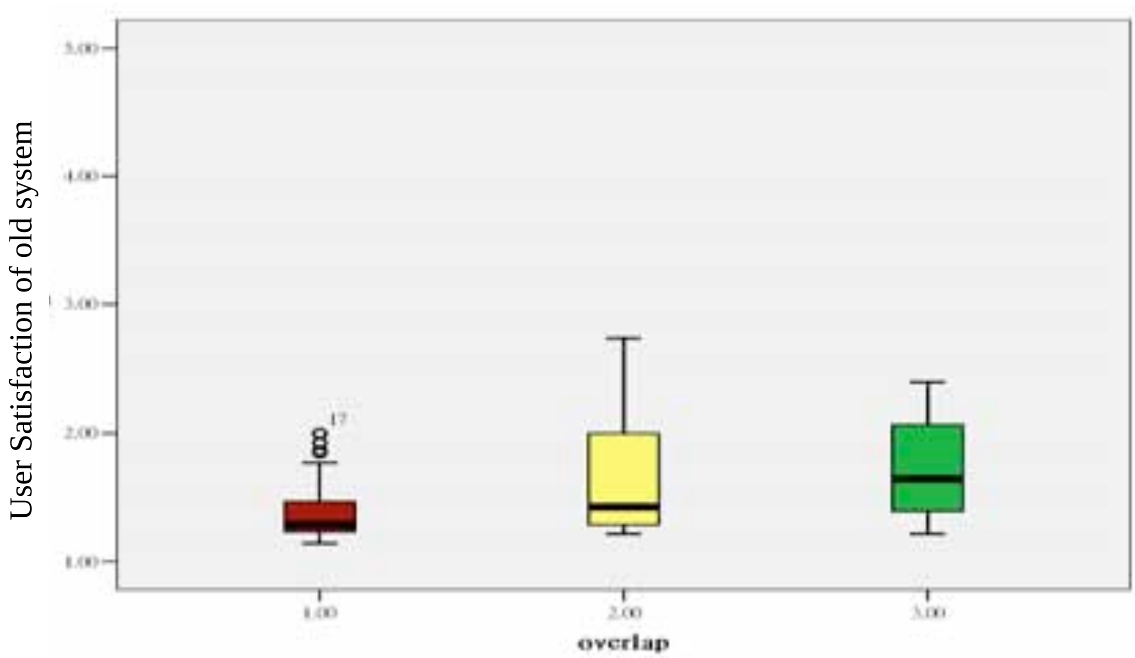

Figure 44. User Satisfaction of Old System by Overlap

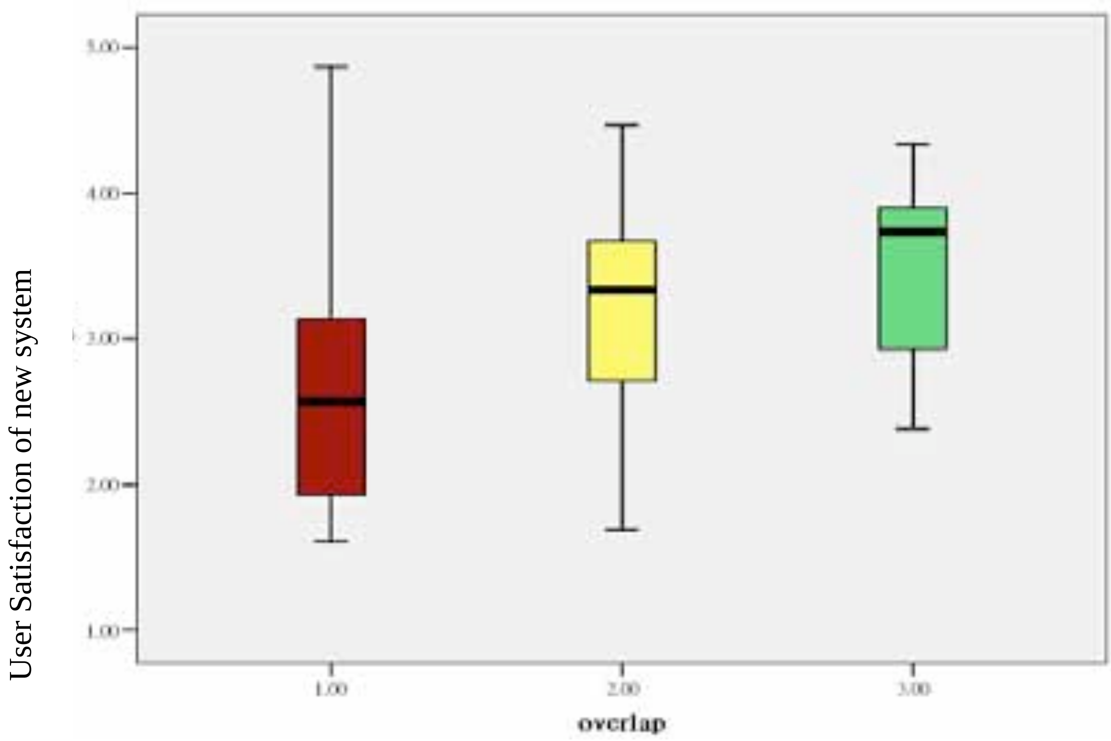

Figure 45. User Satisfaction of New System By Overlap

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
avg1	1.00	146	2.7322	.77312	.06398	2.6057	2.8586	1.67	5.00
	2.00	33	3.2477	.88670	.15435	2.9332	3.5621	1.64	4.87
	3.00	11	3.2768	1.02820	.31001	2.5860	3.9675	1.71	4.60
	Total	190	2.8532	.83459	.06055	2.7338	2.9727	1.64	5.00
avg2	1.00	146	2.7548	.81862	.06775	2.6209	2.8887	1.67	5.00
	2.00	33	3.1694	.87129	.15167	2.8605	3.4784	1.57	4.87
	3.00	11	3.2312	1.06509	.32114	2.5157	3.9467	1.69	4.60
	Total	190	2.8544	.85787	.06224	2.7316	2.9771	1.57	5.00
avg3	1.00	146	.1910	.18924	.01566	.1600	.2219	.00	.93
	2.00	33	.2671	.23610	.04110	.1834	.3508	.00	.67
	3.00	11	.2948	.19559	.05897	.1634	.4262	.00	.53
	Total	190	.2102	.20051	.01455	.1815	.2389	.00	.93
avg4	1.00	146	.7372	.20016	.01657	.7045	.7699	.23	1.21
	2.00	33	.8921	.14507	.02525	.8406	.9435	.40	1.23
	3.00	11	.9013	.10815	.03261	.8286	.9740	.71	1.00
	Total	190	.7736	.19835	.01439	.7452	.8020	.23	1.23
avg5	1.00	146	1.3789	.19657	.01627	1.3467	1.4110	1.14	2.00
	2.00	33	1.6936	.53687	.09346	1.5032	1.8840	1.21	2.73
	3.00	11	1.7390	.43574	.13138	1.4462	2.0317	1.21	2.40
	Total	190	1.4544	.32802	.02380	1.4075	1.5013	1.14	2.73
avg6	1.00	146	2.5980	.71669	.05931	2.4808	2.7152	1.62	4.87
	2.00	33	3.2351	.69934	.12174	2.9871	3.4831	1.69	4.47
	3.00	11	3.4614	.65850	.19855	3.0190	3.9038	2.38	4.33
	Total	190	2.7586	.76690	.05564	2.6489	2.8684	1.62	4.87
avg7	1.00	146	1.8743	.13165	.01090	1.8528	1.8959	1.60	2.20
	2.00	33	1.9339	.11210	.01951	1.8941	1.9736	1.60	2.14
	3.00	11	1.9381	.08392	.02530	1.8817	1.9945	1.79	2.00
	Total	190	1.8884	.12828	.00931	1.8700	1.9067	1.60	2.20

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
avg1	Between Groups	9.247	2	4.624	7.064	.001
	Within Groups	122.399	187	.655		
	Total	131.647	189			
avg2	Between Groups	6.286	2	3.143	4.425	.013
	Within Groups	132.807	187	.710		
	Total	139.092	189			
avg3	Between Groups	.240	2	.120	3.043	.050
	Within Groups	7.359	187	.039		
	Total	7.599	189			
avg4	Between Groups	.836	2	.418	11.843	.000
	Within Groups	6.600	187	.035		
	Total	7.435	189			
avg5	Between Groups	3.612	2	1.806	20.191	.000
	Within Groups	16.725	187	.089		
	Total	20.336	189			
avg6	Between Groups	16.692	2	8.346	16.521	.000
	Within Groups	94.465	187	.505		
	Total	111.157	189			
avg7	Between Groups	.124	2	.062	3.892	.022
	Within Groups	2.986	187	.016		
	Total	3.110	189			

Multiple Comparisons

Table 17 ANOVA Test Results in Each Survey Question by Overlap
Avg1=usefulness, Avg2=criticalness; Avg3=function exist in old system; Avg4=function exist in new system; Avg5=satisfaction to old system; Avg6=satisfaction to new system; Avg7=which system was preferred

Dependent Variable	(I) overlap	(J) overlap	Mean Difference (I-J)	Std. Error	Sig.
avg1	1.00	2.00	-.51550(*)	.15594	.001
		3.00	-.54464(*)	.25296	.033
	2.00	1.00	.51550(*)	.15594	.001
		3.00	-.02914	.28167	.918
	3.00	1.00	.54464(*)	.25296	.033
		2.00	.02914	.28167	.918
avg2	1.00	2.00	-.41464(*)	.16244	.011
		3.00	-.47643	.26349	.072
	2.00	1.00	.41464(*)	.16244	.011
		3.00	-.06179	.29340	.833
	3.00	1.00	.47643	.26349	.072
		2.00	.06179	.29340	.833
avg3	1.00	2.00	-.07611(*)	.03824	.048
		3.00	-.10384	.06203	.096
	2.00	1.00	.07611(*)	.03824	.048
		3.00	-.02773	.06907	.689
	3.00	1.00	.10384	.06203	.096
		2.00	.02773	.06907	.689
avg4	1.00	2.00	-.15486(*)	.03621	.000
		3.00	-.16410(*)	.05874	.006
	2.00	1.00	.15486(*)	.03621	.000
		3.00	-.00924	.06540	.888
	3.00	1.00	.16410(*)	.05874	.006
		2.00	.00924	.06540	.888
avg5	1.00	2.00	-.31472(*)	.05764	.000
		3.00	-.36008(*)	.09351	.000
	2.00	1.00	.31472(*)	.05764	.000
		3.00	-.04535	.10412	.664
	3.00	1.00	.36008(*)	.09351	.000
		2.00	.04535	.10412	.664
avg6	1.00	2.00	-.63712(*)	.13700	.000
		3.00	-.86337(*)	.22222	.000
	2.00	1.00	.63712(*)	.13700	.000
		3.00	-.22625	.24745	.362
	3.00	1.00	.86337(*)	.22222	.000
		2.00	.22625	.24745	.362
avg7	1.00	2.00	-.05954(*)	.02436	.015
		3.00	-.06377	.03951	.108
	2.00	1.00	.05954(*)	.02436	.015
		3.00	-.00423	.04399	.924
	3.00	1.00	.06377	.03951	.108

* The mean difference is significant at the .05 level.

Table 18 Post Hoc Test (LSD) Results in Each Survey Question by Overlap Avg1-7the same to Table 17.

The results showed that more overlap correlated with better user satisfaction and recognition. This indicated that our framework is very helpful in predicting results.

Table 19 is the Spearman's Rho correlation test result R values testing correlation between overlap and usefulness, criticalness, and satisfaction to both the old and the new EDRs. There are only 14 subjects because for one of the subjects all the answers for the new system were 5 and for the old system were 1. With the unified answer it is not possible to have any correlation calculated. Therefore this subject's response was excluded. Table 19 clearly shows that most of the subjects' satisfaction with the EDR was indeed related to the overlap.

Table 19. R value of Spearman's Rho Test correlation with Overlap (yellow color indicates p<0.05)

Subject #	usefulness	criticalness	satisfaction old	satisfaction new
5	-0.122	-0.155	N/A	0.255
7	-0.181	-0.187	0.124	-1.08
11	0.215	0.213	0.29	0.193
12	0.155	0.155	-0.87	N/A
13	0.239	0.238	0.384	0.331
15	0.145	0.209	0.314	0.314
17	0.144	0.072	0.197	0.252
19	0.298	0.238	0.384	0.331
20	0.298	0.238	0.384	0.331
21	0.133	0.156	-0.46	0.214

22	0.145	0.209	0.314	0.314
23	0.31	0.238	0.384	0.331
25	0.11	0.012	0.184	0.075
26	0.11	0.012	0.184	0.248

6.5. Summary

In this chapter, we described how to develop a work domain ontology by integrating the 3 models. After using the ontology to organize all the functions, we identified the functional discrepancy in 7 different areas. We measured the quantity of functions located in the different areas. Then we used a close-ended survey to evaluate our hypothesis that less functional discrepancy produced higher user satisfaction. We ran statistical analyses to evaluate the two EDR systems and also to test the overlap areas' relationship to user satisfaction. The results told us that Axium had more function than CIS and higher user satisfaction. It shows that the overlap was related to usefulness and satisfaction. This Functional Framework also provided a method to predict which EDR system the users preferred.

CHAPTER 7. DISCUSSION AND CONCLUSION

There are many different brands of EDRs and many of them have nice looking user interfaces. This may lead people to think that wide adoption of EDRs is simple and straightforward. However the statistics do not show this trend. In the United States, only 1.8% of dentists actually use an EDR system (paperless) on a daily basis, although 95% of them have computers in the clinic. As indicated by the reviews in the initial chapters, usability and other non-technology factors were among the major factors affecting the adoption of EDR. This dissertation research attempts to demonstrate that user interfaces and function were both important for the usability of EDR systems. The importance of user interfaces has been getting increased recognition and human-centered design of user interfaces has been increasingly integrated in EDR designs. In contrast, although function has been an important consideration for information system design in software engineering, it has not been well integrated into practice from a human-centered perspective. In a typical design and development project, a designer tries to formulate the specifications of a system by doing an analysis informally and on an ad hoc basis. This is not sufficient for the design for any enterprise system for real world applications. Kieras' functional GOMS analysis was an early attempt to develop functional needs from a human-centered perspective. However, this method does not provide a proceduralized process to develop the functional needs systematically, and it is often at a level too low to be applicable for large systems. The objective of this dissertation research was to fill the gap and develop a human-centered functional framework for large systems.

7.1. Summary of Main Findings

We proposed the development of the Functional Framework and it was used to identify and quantify functional discrepancies of information systems. Four major steps are required to apply the Functional Framework to identify functional discrepancies. First, a user model must be developed. The method we used to develop the user model was through user surveys. The results of the surveys were coded as functions that reflect what the users want. Second, the designer model must be identified. In this study, the designer model was developed by a thorough walk-through of the current system's features and functions. Third, the activity model must be developed. In our study, it was developed through an ethnographic method called shadowing. After the three models were developed, the fourth step was to integrate them into a combined single model. Once the three models were integrated, it was possible to identify the discrepancies between systems and users, between systems and activities, and between users and activities by analyzing the regions of the Venn diagrams formed by the three models.

We validated the Functional Framework by doing a survey to find out the criticality, frequency, and user satisfaction for each function in the integrated model. We found positive correlations between the overlapping functions and user satisfaction, that is, the more overlap, the higher user satisfaction. In addition, by using this survey, which was developed according the Functional Framework, one can predict the user's preference in the EDR.

This framework can be used to propose guidelines and recommendations for the modification of current systems and the design of new systems. It can also be used for customers in their purchasing decisions. For example, customers can compare different EDR systems for the functions they provide and compare their system functions to the functions desired by the users and carried in the activities by the users. By doing this, the users will not only be able to evaluate the user interfaces but also the function of the systems, both of which are crucial for the system's overall usability. This framework was developed in the context of EDR. However, the methodology and the process are general enough to be applicable to other domains.

7.2. Limitations

The process of applying the Functional Framework is very thorough and detail-oriented. A lot of time and manpower is required and thus these will be the main limitations for using the Functional Framework. The coding of survey results and the coding of shadowing field notes is another factor that may affect the efficient use of this framework. These limitations reflect the limitations of qualitative research. In this research we attempted to transfer the qualitative data into quantitative results to make it easily understood.

The number of subjects for the second survey was somewhat low. One of the main reasons for this was the length of the survey: it is very long, with 190 items with 7 questions for each item. It was a challenge to finish it within one hour. Some of the users who took the survey never finished it. Others finished it but with a very low response rate (80-90% missing data). We may have gotten less information than we hoped to have because we included subjects who submitted surveys with a low response rate. One suggestion to ameliorate this problem would be to select some functions in each of the major sections (1/10, or 1/5). A shorter survey may encourage the user to finish.

Another limitation in this study was that it was very hard to find users who had knowledge of both EDRs. Most of them were fourth year dental students. Once they graduated it became difficult to keep contact with them and ask them to fill out any additional paper work because the survey was no longer related to their grade or current practice.

7.3. Future Directions

In the process of developing the Functional Framework, there are many issues that need to be studied. In shadowing, the workflow analysis could be analyzed in greater detail by user types and tasks performed. With these extra details, it would be easier to find the most effective manner of practice. The functional efficiency of a workplace or travel and movement of users could be another parameter with which to evaluate users' effectiveness and the whole environment of effectiveness. During shadowing, time spent on and frequency of use of the function could be studied in greater detail to know not only if the function was used, but also the length of time and how often it was used.

This Functional Framework can be useful not only in EDR and EHR; it can also be applied to other software designs. It is a theoretical work that can be used in other fields. Additionally, it is a framework that not only may be used at the initial design phase of the product but also during the iterative design phrases. One major challenge which is worthy of future research is to simplify and even automate the process to make it widely usable and available.

7.4. Conclusion

For an information system to be successful, it has to be usable and useful. "Usable" is linked to the user interfaces and "useful" is linked to function. Because "usable" and "useful" are both in the context of human users, they should be designed from the human-centered perspective. Human-centered design of user interfaces has been well developed. Human-centered design of function, however, has not been well developed.

The Functional Framework developed in this dissertation research offers one step towards a comprehensive framework for designing human-centered functionality.

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APPENDIX 1 IRB APPROVAL

THE UNIVERSITY *of* TEXAS

HEALTH SCIENCE CENTER AT HOUSTON

The Committee for the Protection of Human Subjects
Office of Research Support Committees

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NOTICE OF APPROVAL TO BEGIN RESEARCH March 02, 2006

HSC-DB-06-0066 - AN OBSERVATION OF WORKFLOW AND INTERACTION WITH ELECTRONIC DENTAL RECORDS IN DENTAL CLINIC SETTING

PROVISIONS: This approval relates to the research to be conducted under the above referenced title and/or to any associated materials considered by the Committee for the Protection of Human Subjects, e.g. study documents, informed consent, etc.

APPROVED: By Expedited Review and Approval

APPROVAL DATE: 03/02/2006

EXPIRATION DATE: 02/28/2007

CHAIRPERSON: Anne Dougherty, MD

Subject to any provisions noted above, you may now begin this research.

CHANGES: The principal investigator (PI) must receive approval from the CPHS before initiating any changes, including those required by the sponsor, which would affect human subjects, e.g. changes in methods or procedures, numbers or kinds of human subjects, or revisions to the informed consent document or procedures. The addition of co-investigators must also receive approval from the CPHS. **ALL PROTOCOL REVISIONS MUST BE SUBMITTED TO THE SPONSOR OF THE RESEARCH.**

INFORMED CONSENT: When Informed consent is required, it must be obtained by the PI or designee(s), using the format and procedures approved by the CPHS. The PI is responsible to instruct the designee in the methods approved by the CPHS for the consent process. The individual obtaining informed consent must also sign the consent document. Please note that only copies of the stamped approved informed consent form can be used when obtaining consent.

HEALTH INSURANCE PORTABILITY and ACCOUNTABILITY ACT (HIPAA):
The study must meet all HIPAA research requirements. For compliance guidelines see details on the Committee for the Protection of Human Subjects website at:
http://www.uth.tmc.edu/ut_general/research_acad_aff/orsc/cphs/guidelines/hipaa.htm

UNANTICIPATED RISK OR HARM, OR ADVERSE DRUG REACTIONS: The PI will immediately inform the CPHS of any unanticipated problems involving risks to subjects or others, of any serious harm to subjects, and of any adverse drug reactions.

APPENDIX 2 USER MODEL SURVEY

Survey for the new computer information system in UTDB.
As everyone knows there will be a new electronic dental record system (EDR) to be installed in the dental branch. We would like to know everyone's opinion about the CIS system that you are using now and expectation on the new EDR system. Thank you for you time to fill out this survey.

What position you are holding now in dental school? (Staff, student, patient coordinator, faculty, administration)

Do you use CIS in your daily work? How many years?

What do you use the CIS for? (scheduling patient, calling patient, charting, billing,….etc)

What are the function(s) that you need which are not in the current CIS system?

What tasks you would like the new electronic dental record system to be able to perform in the future?

Can you give us an example of the task that you want the new electronic dental record system to perform? (Case scenario)

7. If there is any other feature that you would like have for the new electronic dental record system, please let us know.

APPENDIX 3 THE CODING RESULTS OF USER MODEL SURVEY CODED BY NVIVO (EXAMPLE)

NVivo revision 1.0.118 Licensee: anna

Project: User model 1 User: AdministratorDate: 24/7/2007 - 0:02:52

DOCUMENT CODING REPORT

Document: Computer Information System Survey

Created: 9/5/2006 - 0:21:58

Modified: 23/7/2007 - 23:59:43

Description:

Description could not be read from file

Nodes in Set: All Nodes

Node 1 of 118 (2 1 14 4) /State/current/administrative/billing

Passage 1 of 11 Section 0, Para 14, 8 chars.

14: billing

Passage 2 of 11 Section 0, Para 26, 8 chars.

26: billing/

Passage 3 of 11 Section 0, Para 36, 7 chars.

36: billing

Passage 4 of 11 Section 0, Para 58, 8 chars.

58: Billing

Passage 5 of 11 Section 0, Para 78, 7 chars.

78: billing

Passage 6 of 11 Section 0, Para 96, 7 chars.

96: billing

Passage 7 of 11 Section 0, Para 148, 7 chars.

148: billing

Passage 8 of 11 Section 0, Para 179, 15 chars.

179: patient billing

Passage 9 of 11 Section 0, Para 200, 18 chars.

200: history of billing

Passage 10 of 11 Section 0, Para 219, 16 chars.

219: patient payments

Passage 11 of 11 Section 0, Para 269, 7 chars.

269: billing

Node 2 of 118 (2 1 14 3) /State/current/administrative/calling patient
Passage 1 of 15 Section 0, Para 14, 18 chars.

14: calling patients,

APPENDIX 4 FUNCTIONS FROM USER, DESIGNER AND ACTIVITY MODELS

[Desidner]	[User]	[Activity]
Administrative Operation	Access To Progress Note	Accept Cash To Check Out
AppointmentMonitor Operation	Access To Pt Medical History	Accept Check To Check Out
Block And Hold Schedule	Add Or Change Pt Information	Administrative Operation
Cancel Appointment	Add TX Without limited Ability	Answer Phone
Change Appointment Information	Administrative Operation	Appointment Related Phone Call
Charge Entry Operation	Auto Matching Tooth Number And Treatment	Assisting Treatment
Check Canceled Appointment	Auto Send Out Patient Reminder	Cancel Appointment
Check Claim Information	Automatically Calling Patient	Change Appointment Time
Check Doc For Specific Requirement	Available At Home	Check Appointment Time
Check Failed Appointment	Billing For Treatment	Check Insurance Eligibility
Check If The Appointment Is Confirmed	Blocking Rotation	Check Out Pt
Check Insurance Information	Break Down Payment With Procedure	Clean Chair And Bench
Check Last Visit	Calculation Of Running Balance	Clean Equipment
Check Medical Alert	Calling Patient	Clean Instrument Before Sterilize
Claim Related Operation	Cancel Patient	Clinical Operation
Claim Status Inquiry	Categorize Patient	Conscious Sedation
Clinical Notes	Charting Caries And Work Done	Gave Dr Information
Clinical Operation	Charting	Emergency Appoint Walk In
Daily Report	Check Dentist Schedule	Emergency Treatment
Operation	Check Patient Financial Report	Emergency Treatment By Phone
Enter Chair Number	Check Patient Treatment	Enter Provider Name
Enter Claim Number	Check Patient account	Enter Pt Name
Enter Family Members	Clinical Operation	Enter The Time Needed
Enter Home Phone Number	Code Enter Then Procedure Show Up	Enter Type Of Appointment
Enter If Pt Can Be Called For Last Minutes	Connected To Printer And Able To Print	Enter Work Phone Number
Enter Provider Name	Create A Treatment Plan	Enter Family Members
Enter Pt Name	Display Calendar schedule	Enter Home Phone Number
Enter The Time Needed	Do Multiple Functions At A Time	Enter Treatment Plan
Enter Type Of Appointment	Easier And Faster Way To Treatment Plan	Give Direction
Enter Work Phone Number	Enter Extra Phone Number	Give Information Of Clinic

- Financial Related Operation
- Lab Tracking
- Ledger Inquiry
- Log Pt Without Appointments Into A Waiting List
- Monthly Report
- Payment Check Out Operation
- Phone Mate Operation
- Print Appointment Card
- Quick Phone Inquiry Operation
- Report Analysis
- Report And Listing Operation
- Rescheduling An Appointment
- Schedule An Appointment
- Schedule Related Operation
- Schedule The Time And Provider
- Search Available Appointment Time
- Search Patient Number
- Treatment Plan
- View Calendar
- View Dentist Schedule For 7day
- View Family Member Appointment
- View Multi-dentists Schedule
- View Upcoming Appointment
- Weekly Report

- Financial Related Operation
- Find Patient Address
- General
- Give A To Do List
- Keep Connect At All Time
- Keep Up With Latest Technology
- Locate Chart
- Manage Third Party Insurance Claim
- No Phasing Treatment
- Notify Sent Out Restoration Ready
- Open Multiple Window
- Operation
- Password Do Not Require Change Often
- Periodontal And Restorative Charting
- Point And Click Progress Note Phrases
- Pop Up Reminder For Recall
- Print Pt Ledger On Pt List
- Pt Access To Enter Chief Complaint For Assess
- Pt Access To System For Communication
- Pull Out Master Check Out Chart
- Pull Out Pt Insurance Information Automatically
- Quick Update Of Procedure Performed
- Read and take X-Ray
- Recall Pt For Prophy Automatically
- Record Odontochart
- Retain Pt Previous Address And Tel
- Schedule Multiple Appointment Once For One Patient
- Schedule Multiple Pt At The Same Time
- Schedule Pt With Appointment

- Go To Find Instrument
- Greet Parent And Pt
- IV sedation
- Infant Oral Health Check Up
- Initial Exam
- Check Insurance Info
- Light Cure
- Make Appointment
- Make Appointment By Phone
- Make Appointment For Follow Up
- Make Insurance Claim
- Make Payment Plan
- Make New Pt Appointment
- New Pt Check In
- Operations
- Ortho Treatment
- Pack And Sterilize
- Pass Instrument
- Pathology Consultation
- Peri-treatment Operation
- Pt Check In
- Pt Emergency Check In
- Recall Exam
- Restorative Treatment
- Return Pt Check In
- Returned Pt Appointment
- Review HX with MD
- Review HX with Nurse Or Worker
- Review Medical History

	Schedule Related Operation	Review Medical History With Parent
	Show Available Chair Daily By	
	Specialty	Sedation
	Show Cancel Appt On Screen	Stack Instrument
	Show Digital Intra-Oral Picture	Suction
	Show Popup Screen For Update	Surgery Treatment
	System Chang Overdue	Transfer Phone Call
	Track Pt Previous Appt History	Transfer To Financial Personnel
	Upload Claim To Other Software	Transfer To Overhead
	User Friendly Icon	Treatment Provided Information
	User Friendly Data Enter	Take x-Ray
	Verbal Communication	Develop x-ray
	View Multiple Scheduling	Charting
	Voice Active Data Entry	Locate Chart
	Write the Communication With Pt	Give Chart To Doctors
	X-Ray Keep Track Of Recall Appt	Prepare tooth
		Restore with filling material
		Impression for preparation
		Pour impression model
		Send model to the Lab
		Give Medication to Pt
		Record Pt Vital Sign During
same for user, designer, activity=9		Treatment
The same in user and designer=7		Systemic Review Of Pt
same user and activity=7		Observation Before Discharge
same designer and activity=10		Review Consent Form With Parent
Designer only=27		Papoose Board Consent
user only=50		Sedation Consent
Activity only=69		Extraction consent
		OR Consent
		Pt referral Form
Clinical operations=23		Write Priscription
		List Of Refferal Doctor By Specialty
		Write Progress Note
		Date The Xary taken Date
		Chatting

APPENDIX 5: THE USER FINAL SURVEY

This is a survey to understand your opinion of the new and old clinical information system. Your answer will be very helpful for the future of improving the system. “How useful this function is to you?” rates your opinion of usefulness of each function, 5 is very useful, 1 is not important. “How critical is this function to you?” rates if this function critical for you to your work; 5 is very critical and 1 is not critical at all. For example of functions in outlook; send email is a critical function without it the system doesn’t work; however search for email address function is not critical; without the function user still can type in the email address or go through the other ways to finish the goal of sending email. Rate the old system and current system in the specific function is rating your opinion in the system’s performance and your satisfactory to this function. The last question is asking which system do you prefer to use in the specific function. Thank you for your help.

	How useful this function is to you? (1:not useful at all. 5:Very useful)	**How critical is this function to you?** (1: not critical at all, 5:very critical)	**Did this function exist in the old system? (Yes/No)**	**Does this function exist in the current system? (Yes/No)**	**Rate the old system in this function.** (1:not satisfied at all, 5: very satisfied)	**Rate the new system in this function.** (1:not satisfied at all, 5: very satisfied)	**Which system do you prefer to use?** (1: old system; 2: current system)
Administrative Operation							
Appointment Monitor Operation							
Block And Hold Schedule							
Cancel Appointment							
Change Appointment Information							
Charge Entry Operation							
Check Canceled Appointment							
Check Claim Information							
Check Doc For Specific Requirement							

Check Failed Appointment							
Check If The Appointment Is Confirmed							
Check Insurance Information							
Check Last Visit							
Check Medical Alert							
Claim Related Operation							
Claim Status Inquiry							
Clinical Notes							
Clinical Operation							
Daily Report							
Operation							
Enter Chair Number							
Enter Claim Number							
Enter Family Members							
Enter Home Phone Number							
Enter If Pt Can Be Called For Last Minutes							
Enter Provider Name							
Enter Pt Name							
Enter The Time Needed							
Enter Type Of Appointment							
Enter Work Phone Number							
Financial Related Operation							
Lab Tracking							
Ledger Inquiry							
Log Pt Without Appointments Into A Waiting List							
Monthly Report							
Payment Check Out Operation							
Phone Mate Operation							
Print Appointment Card							
Quick Phone Inquiry							

Operation							
Report Analysis							
Report And Listing Operation							
Rescheduling An Appointment							
Schedule An Appointment							
Schedule Related Operation							
Schedule The Time And Provider							
Search Available Appointment Time							
Search Patient Number							
View Calendar							
View Dentist Schedule For 7day							
View Family Member Appointment							
View Multi-dentists Schedule							
View Upcoming Appointment							
Weekly Report							
Access To Progress Note							
Access To Pt Medical History							
Add Or Change Pt Information							
Add TX Without limited Ability							
Auto Matching Tooth Number And Treatment							
Auto Send Out Patient Reminder							
Automatically Calling Patient							

Available At Home							
Blocking Rotation							
Calculation Of Running Balance							
Calling Patient							
Categorize Patient							
Charting Caries And Work Done							
Charting							
Check Dentist Schedule							
Check Patient Financial Report							
Check Patient Treatment							
Check Patient account							
Code Enter Then Procedure Show Up							
Connected To Printer And Able To Print							
Create A Treatment Plan							
Display Calendar schedule							
Do Multiple Functions At A Time							
Easier And Faster Way To Treatment Plan							
Enter Extra Phone Number							
Find Patient Address							
General							
Give A To Do List							
Keep Connect At All Time							
Keep Up With Latest Technology							
Locate Chart							
Manage Third Party Insurance Claim							
No Phasing Treatment							
Notify Sent Out Restoration Ready							

Open Multiple Window							
Password Do Not Require Change Often							
Periodontal And Restorative Charting							
Point And Click Progress Note Phrases							
Pop Up Reminder For Recall							
Print Pt Ledger On Pt List							
Pt Access To Enter Chief Complaint For Assess							
Pt Access To System For Communication							
Pull Out Master Check Out Chart							
Pull Out Pt Insurance Information Automatically							
Quick Update Of Procedure Performed							
Read X-Ray							
Recall Pt For Prophy Automatically							
Record Odontochart							
Retain Pt Previous Address And Tel							
Schedule Multiple Appointment Once For One Patient							
Schedule Multiple Pt At The Same Time							
Show Available Chair Daily By Specialty							
Show Cancel Appt On Screen							
Show Digital Intra-Oral Picture							
Show Popup Screen For							

Update							
System Chang Overdue							
Upload Claim To Other Software							
User Friendly Icon							
User Friendly Data Enter							
Verbal Communication							
View Multiple Scheduling							
Voice Active Data Entry							
Write the Communication With Pt							
X-Ray Keep Track Of Recall Appt							
Accept Cash To Check Out							
Accept Check To Check Out							
Answer Phone							
Appointment Related Phone Call							
Assisting Treatment							
Check Insurance Eligibility							
Clean Chair And Bench							
Clean Equipment							
Clean Instrument Before Sterilize							
Conscious Sedation							
Gave Dr Information							
Emergency Appoint Walk In							
Emergency Treatment							
Emergency Treatment By Phone							
Give Direction							
Give Information Of Clinic							
Go To Find Instrument							
Greet Parent And Pt							
IV sedation							

Infant Oral Health Check Up							
Initial Exam							
Light Cure							
Make Appointment By Phone							
Make Appointment For Follow Up							
Make Insurance Claim							
Make Payment Plan							
Make New Pt Appointment							
New Pt Check In							
Ortho Treatment							
Pack And Sterilize							
Pass Instrument							
Pathology Consultation							
Peri-treatment Operation							
Pt Check In							
Pt Emergency Check In							
Recall Exam							
Restorative Treatment							
Return Pt Check In							
Returned Pt Appointment							
Review HX with MD							
Review HX with Nurse Or Worker							
Review Medical History							
Review Medical History With Parent							
Sedation							
Stack Instrument							
Suction							
Surgery Treatment							
Transfer Phone Call							
Transfer To Financial Personnel							
Transfer To Overhead							

Take x-Ray							
Develop x-ray							
Give Chart To Doctors							
Prepare tooth							
Restore with filling material							
Impression for preparation							
Pour impression model							
Send model to the Lab							
Give Medication to Pt							
Record Pt Vital Sign During Treatment							
Systemic Review Of Pt							
Observation Before Discharge							
Review Consent Form With Parent							
Papoose Board Consent							
Sedation Consent							
Extraction consent							
OR Consent							
Pt referral Form							
Write Prescription							
List Of Referral Doctor By Specialty							
Write Progress Note							
Date The X-Ray							

APPENDIX 6 ALL FUNCTIONS WITH AVERAGE RESULT FOR EACH QUESTION

Function	usefulness	critical ness	exist old	exist new	satisfaction old	satisfaction new	preference
Administrative Operation	3.57	3.36	0.36	0.93	1.64	3.5	2
AppointmentMonitor Operation	4.47	4.2	0.43	1	1.71	3.93	2
Block And Hold Schedule	2.73	2.47	0.33	0.93	2.57	3	2
Cancel Appointment	4.6	3.73	0.33	1	2.4	3.8	2
Change Appointment Information	4.67	3.87	0.4	1	2.4	3.33	2
Charge Entry Operation	3.5	2.64	0.36	1	1.93	2.71	1.87
Check Canceled Appointment	3.73	2.87	0.2	0.86	1.4	2.67	2
Check Claim Information	2.29	2	0.21	0.85	1.21	2.5	1.87
Check Doc For Specific Requirement	2.36	2.36	0.21	1	1.43	3	2
Check Failed Appointment	2.6	2.53	0.27	0.86	1.4	2.87	2
Check If The Appointment Is Confirmed	2.2	2.2	0.13	0.93	1.2	2.67	2
Check Insurance Information	1.71	1.71	0.21	0.83	1.21	2.38	1.87
Check Last Visit	3.8	3.53	0.33	1	1.53	3.29	1.87
Check Medical Alert	4.8	4.47	0.13	1	1.73	4.27	2
Claim Related Operation	1.87	1.87	0	0.8	1.47	2.47	1.87
Claim Status Inquiry	1.87	1.93	0.33	0.8	2	3.13	1.87
Clinical Notes	5	4.87	0.33	1	2	4.87	2
Clinical Operation	4	4.2	0.47	1	2.33	4.07	2
Daily Report	3.8	3.87	0.2	1	1.47	4.07	2
Operation	3.67	3.67	0.53	1	2.33	3.73	2
Enter Chair Number	2.6	2	0.27	0.87	1.67	2.6	1.93
Enter Claim Number	1.67	1.73	0.13	0.73	1.4	2.14	1.87
Enter Family Members	2.2	2.13	0.13	0.93	1.27	2.43	2
Enter Home Phone Number	3.53	3.4	0.67	0.93	2.73	3.5	2
Enter If Pt Can Be Called For Last Minutes	2.73	2.73	0.07	0.67	1.21	2.15	1.93
Enter Provider Name	3.53	3.13	0.67	1	2.4	3.87	2
Enter Pt Name	3.8	3.4	0.67	1	2.67	4	2
Enter The Time Needed	3.67	3.27	0.6	1	2.57	4	2
Enter Type Of Appointment	4.07	3.67	0.67	1	2.53	4	2
Enter Work Phone Number	3.53	3.4	0.67	0.93	2.67	3.71	2
Financial Related Operation	2.64	2.5	0.14	0.79	1.43	3.08	1.93

Lab Tracking	1.64	1.57	0.07	0.71	1.29	2.23	1.93
Ledger Inquiry	2.33	2.13	0.4	0.93	1.87	2.64	2
Log Pt Without Appointments Into A Waiting List	1.79	1.71	0.07	0.64	1.29	2.08	1.93
Monthly Report	3.21	2.86	0.14	0.79	1.43	2.86	1.93
Payment Check Out Operation	3.07	3.07	0.47	0.87	1.8	3.87	2
Phone Mate Operation	1.93	1.79	0	0.71	1.29	3.07	1.93
Print Appointment Card	3.33	2.8	0.07	0.8	1.36	3.8	1.93
Quick Phone Inquiry Operation	2.79	2.79	0	0.67	1.29	3.2	1.93
Report Analysis	3	3	0.07	0.71	1.36	3.79	1.93
Report And Listing Operation	2.85	2.85	0.07	0.71	1.43	3.21	1.93
Rescheduling An Appointment	4.47	4.6	0.4	1	1.73	4.4	2
Schedule An Appointment	4.6	4.6	0.47	1	1.73	4.33	1.93
Schedule Related Operation	3.43	3.57	0.07	0.8	1.36	3.14	1.93
Schedule The Time And Provider	3.67	3.8	0.27	1	1.6	3.53	1.93
Search Available Appointment Time	3.4	3.4	0.2	0.93	1.43	3.47	2
Search Patient Number	4.5	4.5	0.47	0.93	1.4	3.4	2
View Calendar	4.87	4.8	0.07	1	1.4	4.4	2
View Dentist Schedule For 7day	3.14	3	0	0.87	1.29	3.6	1.93
View Family Member Appointment	2.57	2.64	0	0.6	1.29	3.14	1.93
View Multi-dentists Schedule	2.71	2.64	0.13	0.87	1.43	3.6	1.93
View Upcoming Appointment	3.93	3.87	0.53	0.93	1.71	3.73	1.93
Weekly Report	3.62	3.77	0.21	0.86	1.5	3.5	1.93
Access To Progress Note	4.87	4.33	0.13	1	1.5	3.93	2
Access To Pt Medical History	4.87	4.87	0	1	1.21	3.6	2
Add Or Change Pt Information	4.71	4.71	0.2	0.8	1.4	3.47	1.93
Add TX Without limited Ability	3.8	4.07	0.07	0.8	1.47	3.27	1.93
Auto Matching Tooth Number And Treatment	4.38	4.38	0	0.71	1.21	3.79	1.93
Auto Send Out Patient Reminder	2.47	2.27	0.07	0.36	1.33	2.62	1.6
Automatically Calling Patient	2.6	2.33	0	0.33	1.21	2.54	1.6
Available At Home	2.64	2.5	0.14	0.36	1.5	2.23	1.67
Blocking Rotation	2.6	2.93	0.07	0.8	1.36	3.07	1.6
Calculation Of Running Balance	3	2.93	0.43	0.79	1.43	3.07	1.73
Calling Patient	2.6	3	0.07	0.4	1.23	3.55	1.85
Categorize Patient	3.71	4.69	0.31	0.64	1.92	3.42	1.85
Charting Caries And Work Done	3.57	4	0.43	0.93	2	4.21	1.93
Charting	3.71	4	0	0.93	1.29	3.64	2

Check Dentist Schedule	3.67	3.67	0.21	0.87	1.43	3.57	2
Check Patient Financial Report	2.47	2.47	0.4	0.87	1.36	2.57	1.87
Check Patient Treatment	4.27	4.6	0.93	1	1.53	3.67	2
Check Patient account	3.13	4.2	0.13	0.8	1.6	3.13	1.87
Code Enter Then Procedure Show Up	3.4	3.53	0.27	0.87	1.73	3.43	1.93
Connected To Printer And Able To Print	4.2	4.2	0.13	0.87	1.6	3.4	1.86
Create A Treatment Plan	3.93	4.6	0.33	1	1.6	3.93	2
Display Calendar schedule	4.73	4	0.27	1	1.6	4.47	2
Do Multiple Functions At A Time	4.07	4.07	0	0.93	1.36	3.21	2
Easier And Faster Way To Treatment Plan	4.2	4.73	0.07	0.73	1.33	3.5	1.87
Enter Extra Phone Number	3	2.73	0.47	1	1.47	2.73	2
Find Patient Address	3.13	3	0.33	0.93	1.73	3.36	1.93
General	3	3	0.15	1	1.38	2.85	2
Give A To Do List	2.27	2.07	0	0.71	1.29	2.4	1.79
Keep Connect At All Time	2.93	2.79	0.14	0.71	1.93	2.71	1.71
Keep Up With Latest Technology	2.86	2.86	0	0.79	1.5	2.79	1.8
Locate Chart	3.87	3.8	0.27	0.93	1.73	3.67	1.79
Manage Third Party Insurance Claim	1.85	2.07	0.07	0.77	1.29	2.5	1.71
No Phasing Treatment	2.64	2.21	0.21	0.93	1.36	2.57	1.86
Notify Sent Out Restoration Ready	2.21	2.07	0	0.79	1.29	2.64	1.73
Open Multiple Window	2.93	2.93	0	1	1.29	3.13	2
Password Do Not Require Change Often	3.53	3.53	0.2	0.87	1.6	2.87	1.93
Periodontal And Restorative Charting	2.6	2.93	0	0.8	1.29	2.67	1.73
Point And Click Progress Note Phrases	3.53	3.13	0	0.87	1.29	2.73	1.79
Pop Up Reminder For Recall	3	2.33	0.13	0.93	1.5	3	1.93
Print Pt Ledger On Pt List	2.47	2.33	0.13	0.8	1.43	2.6	1.79
Pt Access To Enter Chief Complaint For Assess	2.87	2.6	0	0.79	1.36	2.64	1.86
Pt Access To System For Communication	2	2	0	0.71	1.36	2.57	1.79
Pull Out Master Check Out Chart	2	1.86	0	0.71	1.36	2.57	1.79
Pull Out Pt Insurance Information Automatically	1.85	1.69	0	0.79	1.36	2.6	1.79
Quick Update Of Procedure Performed	2.2	2.07	0	0.79	1.29	2.64	1.8
Read X-Ray	2.71	2.43	0	0.73	1.29	2.86	1.87

Recall Pt For Prophy Automatically	2.8	2.2	0	0.8	1.29	2.57	1.8
Record Odontochart	3.27	3.8	0.13	0.93	1.21	3.36	2
Retain Pt Previous Address And Tel	2.93	3.27	0.33	0.87	1.86	3.79	1.93
Schedule Multiple Appointment Once For One Patient	3.27	3.6	0.13	1	1.5	3.93	2
Schedule Multiple Pt At The Same Time	2.6	2.4	0	0.8	1.36	3.53	1.8
Show Available Chair Daily By Specialty	3.27	3.8	0.2	0.93	1.43	3.36	1.8
Show Cancel Appt On Screen	3.6	3.47	0.13	0.87	1.29	3.33	1.87
Show Digital Intra-Oral Picture	3.27	3.27	0	0.93	1.29	2.93	2
Show Popup Screen For Update	3	2.93	0.13	0.93	1.43	2.79	1.93
System Chang Overdue	2.07	2.14	0	0.79	1.29	2.64	1.8
Upload Claim To Other Software	2.07	2.14	0	0.79	1.29	2.64	1.8
User Friendly Icon	2.73	2.6	0.07	1	1.43	3	2
User Friendly Data Enter	3.6	3.67	0.2	1	1.5	3.13	2
Verbal Communication	2.43	2.21	0	0.71	1.23	2.85	1.79
View Multiple Scheduling	2.6	2.67	0.13	0.93	1.43	2.64	1.93
Voice Active Data Entry	2.2	1.93	0	0.67	1.29	2.21	1.79
Write the Communication With Pt	2.33	2.2	0.07	0.87	1.36	2.5	1.93
X-Ray Keep Track Of Recall Appt	2.33	2.07	0	0.67	1.36	2.29	1.64
Accept Cash To Check Out	2.6	2.47	0.07	0.79	1.43	2.36	1.64
Accept Check To Check Out	2.6	2.4	0.07	0.79	1.43	2.36	1.64
Answer Phone	2.21	2.07	0	0.71	1.36	2.29	1.64
Appointment Related Phone Call	2.53	2.2	0.07	0.79	1.43	2.36	1.64
Assisting Treatment	2	1.86	0	0.77	1.23	2.23	1.64
Check Insurance Eligibility	2.2	2.2	0.13	0.53	1.21	2.07	1.71
Clean Chair And Bench	2.4	2.8	0	0.4	1.23	2	1.71
Clean Equipment	3	2.87	0	0.4	1.23	2	1.71
Clean Instrument Before Sterilize	3	2.87	0	0.4	1.23	2.62	1.79
Conscious Sedation	2.07	1.93	0	0.43	1.23	2	1.79
Gave Dr Information	3.4	3	0.07	0.8	1.5	3.13	1.67
Emergency Appoint Walk In	1.93	2.14	0.36	0.64	1.21	2.29	2
Emergency Treatment	1.93	1.79	0.36	0.79	1.14	1.86	2
Emergency Treatment By Phone	2.29	1.79	0	0.71	1.43	1.86	1.67
Give Direction	2.47	2.33	0	0.4	1.43	2.14	1.67
Give Information Of Clinic	2.27	2.27	0.27	0.4	1.14	2.21	2
Go To Find Instrument	2	1.86	0	0.38	1.23	2	2

Greet Parent And Pt	2.43	2.43	0.07	0.71	1.5	1.93	1.73
IV sedation	2.07	1.93	0	0.36	1.43	2.14	1.67
Infant Oral Health Check Up	1.93	2.14	0.36	0.43	1.21	2.21	2
Initial Exam	2.93	2.43	0.36	0.71	1.21	2.79	2
Light Cure	2.29	2.43	0.07	0.71	1.43	1.93	1.73
Make Appointment By Phone	2.6	3	0.07	0.4	1.5	2.21	1.73
Make Appointment For Follow Up	2.47	3	0.53	0.6	1.47	2.67	2.2
Make Insurance Claim	2	1.86	0.36	0.71	1.21	1.93	2
Make Payment Plan	2.4	2.53	0.07	0.67	1.5	1.93	1.73
Make New Pt Appointment	3	3.4	0.33	0.93	1.73	2.67	1.93
New Pt Check In	2.53	2.53	0.33	0.67	1.21	2.67	2.2
Ortho Treatment	3	2.86	0.36	1.21	1.21	2.21	2
Pack And Sterilize	1.83	2.5	0.38	0.69	1.23	1.62	1.69
Pass Instrument	1.83	1.83	0.31	0.62	1.23	1.62	1.69
Pathology Consultation	2	2.67	0.38	0.69	1.23	1.62	1.69
Peri-treatment Operation	1.83	1.83	0.38	0.69	1.23	1.62	1.69
Pt Check In	2.15	2	0.36	0.71	1.21	1.79	1.69
Pt Emergency Check In	1.83	1.83	0.38	0.69	1.23	1.62	1.69
Recall Exam	2.83	2.83	0.69	1	1.77	2.15	1.64
Restorative Treatment	3	3.54	0.85	1.15	2	2.54	1.93
Return Pt Check In	1.92	1.83	0.38	0.69	1.23	2.23	1.64
Returned Pt Appointment	2.69	2.83	0.69	1	1.85	2.23	1.64
Review HX with MD	2.23	2.83	0.38	0.69	1.23	1.62	1.86
Review HX with Nurse Or Worker	2.46	2.17	0.38	0.69	1.23	1.62	1.86
Review Medical History	4.15	4.83	0.54	1.23	1.38	2.92	2
Review Medical History With Parent	3.69	4.33	0.38	1	1.23	2.54	2
Sedation	1.85	2.33	0.38	0.69	1.23	1.62	2
Stack Instrument	1.85	1.67	0.38	0.69	1.23	1.62	2
Suction	1.85	2.33	0.38	0.69	1.23	1.62	2
Surgery Treatment	2.15	2.67	0.38	0.69	1.23	1.62	2
Transfer Phone Call	2	1.83	0.38	0.69	1.23	1.62	2
Transfer To Financial Personnel	2.15	1.83	0.38	0.69	1.23	1.62	2
Transfer To Overhead	2	1.83	0.38	0.69	1.23	1.62	2
Take x-Ray	2.46	3	0.38	0.77	1.23	1.69	2
Develop x-ray	1.85	2.33	0.38	0.69	1.23	1.62	2
Give Chart To Doctors	2.15	2	0.38	0.69	1.23	1.62	2
Prepare tooth	2.07	2.54	0.36	0.64	1.21	1.86	2
Restore with filling material	2.21	2.69	0.36	0.64	1.21	1.86	2

Impression for preparation	2.07	2.54	0.36	0.64	1.21	1.86	2
Pour impression model	2.07	2.54	0.36	0.64	1.21	1.86	2
Send model to the Lab	2.21	2.69	0.36	0.64	1.21	1.86	2
Give Medication to Pt	2.07	2.54	0.07	0.43	1.21	1.86	2
Record Pt Vital Sign During Treatment	2.21	2.69	0.33	0.69	1.19	1.84	1.92
Systemic Review Of Pt	2.62	3.05	0	0.69	1.23	2.54	1.85
Observation Before Discharge	1.92	1.92	0	0.31	1.23	1.92	1.85
Review Consent Form With Parent	2.85	2.69	0	0.85	1.23	2.85	2
Papoose Board Consent	1.92	1.92	0	0.31	1.23	1.92	1.85
Sedation Consent	2.23	2.08	0	0.38	1.23	1.92	1.85
Extraction consent	2.23	2.08	0	0.38	1.23	1.92	1.85
OR Consent	2.08	2.08	0	0.38	1.23	1.92	1.85
Pt referral Form	2.23	2.08	0	0.38	1.23	1.92	1.85
Write Prescription	3.14	3.71	0	0.71	1.23	3	1.86
List Of Refferal Doctor By Specialty	2.23	2.08	0	0.23	1.23	1.92	1.85
Write Progress Note	4.43	5	0.14	0.93	1.23	3.79	2
Date The Xary taken Date	2.29	2.29	0	0.38	1.23	2	1.69
Chatting	2.23	2.69	0	0.31	1.23	1.92	1.69

APPENDIX 7 AVERAGE VALUE OF ALL FUNCTIONS FOR EACH QUESTION

subject	usefulness	criticalness	exist old	exist new	satisfaction old	satisfaction new	Preference	preference %
1	5	5	0	1	0	5	2	1
5	4.69	4.69	0	0.47	1	3.18	2	1
7	4.24	3.81	0.21	0.95	1.01	4.89	2	1
11	1.99	2	0.19	0.41	1.11	1.48	1.69	0.69
12	2.12	2.12	0.01	0.99	4.97	5	2	1
13	2.23	2.14	0.11	0.68	1.26	2.39	2	1
15	2.77	2.55	0.26	0.36	1.29	1.72	1.93	0.93
17	4.66	4.61	0.61	0.81	2.91	3.62	1.92	0.92
19	2.31	2.14	0.11	0.68	1.26	2.39	2	1
20	2.31	2.14	0.11	0.68	1.26	2.39	2	1
21	4.14	3.91	0.35	0.79	2.26	4.18	2	1
22	2.77	2.55	0.31	0.36	1.29	1.72	1.81	0.81
23	2.35	2.14	0.11	0.68	1.26	2.39	2	1
25	1.48	2.33	0.02	1	1.08	1.48	2	1
26	1.48	2.33	0.02	0.98	1.08	1.65	2	1