Incorporating Users into System Design Processes: Overview and a Proposed User Model

이용자 중심의 시스템 디자인 방법론에 대한 개략 및 이용자 모델 제시

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ABSTRACT

In order to make interactive computing systems, including information systems, usable it is important to bring users into the design process. This article surveys and introduces several major system design approaches that are widely accepted as approaches from a users' perspective. A user model developed by the author is introduced following these existing approaches. This user model is developed from actual users' understanding of their goals and strategies to solve their information needs by using Dervin's Sense-Making Theory with Sense-Making Timeline Interviews. This user model reveals a different timeline from the default menu presentation orders that originally comes with the software. Steps for developing a user model from the Sense-Making Timeline Interviews are suggested for further application and guidelines in developing user models for system design and evaluation.

초 록

이용자를 시스템 디자인 과정에 적극적으로 참여하는 것이 유용한 정보 시스템의 디자인을 성공시키는 필수요소이다. 본 논문에서는 이용자 중심의 시스템 디자인에 관한 대표적인 방법론을 조사하고, 그 조사결과에 따라 최적의 이용자 모델을 제안하였다. 최적의 정보시스템을 설계하기 위해 실제 이용자들이 자신들의 정보요구를 만족시키기 위해 어떠한 정보를 필요로 하는지와 그들이 수립하는 일련의 정보전략을 분석하였다. 본 연구에서 사용한 분석기법은 더빈의 Sense-Making 이론에서 사용한 Sense-Making Timeline 인터뷰이다. 특히 이 연구에서 제시된 이용자 모델은 이 연구에서 사용된 소프트웨어가 본래 가지고 있던 메뉴 배열순서와는 상이한 절차(timeline)를 보여주고 있다. 궁극적으로 본 연구에서는 장래에 수행되어질 시스템 디자인과 그 평가에 적용시킬 수 있기 위해, 이용자 모델수립에 필요한 개발과정의 단계들을 제시하였다.

키워드: 이용자 모델, 이용자 중심 시스템 디자인 방법론, 정보시스템 디자인
      Sense-Making theory, Sense-Making Timeline

1. Introduction

Usability is one of the most crucial and core concepts in system design and evaluation since its introduction decades ago. Usability concerns the issue of how much users can use systems' functionality, and is defined as assessing both the efficiency of the process(usableness) and the effectiveness of the product(usefulness)(Gluck et al., 1999). Usability has attributes such as learn ability, efficiency, memorability, errors and satisfaction (Nielsen, 1993). The concept of usability is generally considered in terms of system evaluation, but it would be seen as the broader concept that is embedded in design approaches as user-center design or user participated design(Sugar, 1997; Sonnenwald & Lievrouw, 1991). As strong advocates of "know the user" and involvement of users in the usability engineering lifecycle, its iterative design process with the pool of true representative of users is the focal point of user based system design approach.

There has been a call for a paradigm shift from the system oriented to the user-oriented viewpoint. Broadly, in the field of human computer interaction and specifically in information system design and evaluation, necessity and importance of explicit and direct user involvement in design process has been addressed pervasively in the literature of research and practice. The issue now is what to know about users and how to convert and incorporate user information into the design process and design specifications through scientific methods and rigorous and systematic techniques.

This article briefly surveys and describes several different existing system design approaches and methods, and introduces a case of developing a user model for interface design from a constructivist viewpoint as an example of a user-based approach.

2. System Design Approaches in User's Perspectives

Several major design approaches have been proposed under various names such as User-Centered System Design(UCSD), contextual design, cooperative design, and GOMS. Unlike most research in system design and evaluation in human-computer interaction (HCI) which mainly focuses on the Human Information Processing (HIP) model, user centered system design approaches emphasize user centeredness in activities carried out by users. In other words, users play an active role in the system design processes, and their actual work situations or experiences are incorporated into design considerations. User centered system design approaches consider end-users as the experts on what the

system should support in their context. Here are some examples.

2. 1 User-Centered System Design

(UCSD) was proposed by D. Norman and Draper in 1986. This is not a specific method or technique of computer system design, rather a broader term which embraces various perspectives in understanding human interaction with interactive computing systems. A variety of approaches such as the human information processing model, social context of computing, or feeling of direct engagement based on the human's subjective experiences are associated with this approach.

One of the seminal works that supports UCSD is D. Norman's theoretical tools (1986) to understand the fundamental principles behind human action and performance.

He sees two aspects of human actions. Execution which involves doing something and evaluation which involves a comparison of what happened in the world and what the human expected to happen. To solve the discrepancy between psychological and physical variables driven from human actions, two "gulfs", a gulf of execution and a gulf of evaluation must be bridged(1990). Gulf of execution is the gap from human's goal to the physical system(in broad concepts, the world), which is bridged through four segments known as forming intention, specifying the action sequences, executing the action, and making contact with the input mechanisms of the system interface. Gulf of evaluation is comparing the interpretation of system states with the original goals of the human. This gap is bridged in four segments known as the displays of system's output, perceptual processing of the displays, interpretation, and evaluation. According to D. Norman, the gap between human goals and system should be bridged if the system can be used.

Hutchins, et al.(1986) proposed the notions of "distance" and "direct engagement." The feeling of distance is inversely proportional to the amount of cognitive effort it takes to manipulate and to evaluate a system, which is the result of the extent of both the gulf of execution and the gulf of evaluation. Direct engagement is the qualitative feeling that the human is directly engaged with control of the objects of interest, and it creates the sensation in the human of action upon the objects of the domain. These notions have been conceptualized and materialized as direct manipulation(Norman, 1986) that is a precursor of the current graphical user interface(GUI) development.

Such man's situated actions(1987) and Laurel's human computer interactions as theatre(1986, 1993) among others share the same viewpoints with UCSD.

2. 2 Cooperative Design was introduced

by Kyng(1991) and others(Grudin 1991: Greenberg 1991; Greenbaum & Kyng 1991). Its key concept is to get users into the design process to make computer system and applications fit the work they support. In other words, cooperative design is how to represent the work for the purpose of design, thus emphasis is upon the importance of bringing together the competence of designers and users. This approach is based on the belief that the complex texture of workplace life should be handled primarily through action-based techniques. In Creating Contexts for Design, Kyng(1995) introduced a contextually based design artifacts and creation of concrete work-like contexts such as 1) key insights and summaries of work of end users: 2) work situation description and work situation overviews, 3) user scenarios: and 4) mockups and prototypes with examples. The main concern here is how to set up design processes in such as way users may participate directly in design process. Consequently, representational techniques are aimed at rendering work practice into the form of a design concern. The representations used in cooperative design could be divided into 'representations of the system being designed' and 'representation of work.' The former includes primarily mock-ups and prototypes, covering both interface aspects and the structure and content of the system such as drawings,

work plans, or patient records.

Another similar design approach, Participatory Design(PD), has been pioneered in Scandinavia. This approach is characterized by concern with more human, creative, and effective relationships between those involved with technology design and its use(Suchman, 1993). The basic idea in the Participatory Design is the power shift of democracy from those who control the system to those who are affected by a decision or event, and who should have an opportunity to influence it(Greenbaum 1993). One of the leading projects that applied PD in Scandinavia is UTOPIA(Training, Technology, and Products from a Quality of Work Perspective) which started in 1981. This project was incorporation with the Nordic Graphic Workers' Union and researchers in Sweden and Denmark with experience from the first generation of work-oriented design projects. As a research project on the trade-union-based design of computer technology and work organization, UTOPIA developed a design approach called the tool perspective(Ehn & Kyng 1984). The main idea is that new computer-based tools should be designed as an extension of the traditional practical understanding of tools and materials used within a given craft or profession. Design must therefore be carried out by the common efforts of skilled, experienced users and design professionals. Users

possess the needed practical understanding but lack insight into new technical possibilities. The designer must understand the specific labor process that uses a tool(Ehn 1993). Clearly, the historical UTOPIA project had demonstrated the possibility of providing solutions for demarcation disputes among stake holders of new technologies.

2. 3 Contextual Design method was

developed and introduced by Beyer and Holtzblatt (1998) for software design and development. Its core issues are understanding users, seeing their work, and reflecting this understanding in system development. One of the most fundamental and first steps in contextual design is contextual inquiry(Holtzblatt & Beyer 1993; Holtzblatt & Jones 1993) which takes customers' work context, and collaboration among customers into account to understand work structure and its focus.

Based on what the design team observed through a contextual inquiry, works modes such as the flow model, the sequence model, the artifact model, the cultural model, and the physical model are created. The next step is to consolidate these models through affinity diagrams into a system design. Prototyping is used as a major design tool for communicating across design teams and customers, and for the structure, interpretation, and restructuring of the design specifications.

Contextual Design is grounded in principles of data, team, and divergent design thinking. In other words, gathering data about customers and how they work will help the design team to make decisions and redesigns work for users.

2. 4 GOMS(Goals, Operators, Methods,

and Selection Rules) approach was originally proposed in the seminal study done by Card, Moran, and Newell(1983). GOMS refers to Goals, Operators, Methods, and Selection Rules, and has been applied to task analysis and modeling users' behaviors at four different components. The goals are the users' goals to accomplish by using the software/service, and could be subdivided into sub goals. Operators are the actions or features of the software/services the users will take. Methods are the sequence of steps users will go through to accomplish their goals/sub goals. Selection Rules are the decisions made by users if there is more than one method to accomplish their goals. This approach was developed in cognitive psychology to describe and do cognitive modeling on the behavior of a computer user on given tasks, and have been applied to system design and evaluation in various fields. A framework for building an analytical model of human performance with computers through GOMS models describes the knowledge necessary and the four cognitive components of skilled perform-

ance in tasks. Variations of GOMS have been evolved with different emphases. There are four types of GOMS, CMN-GOMS(Card, Moran, and Newell GOMS), KLM(Keystroke-Level Model), NGOMSL (Natural GOMS Language), and CPM-GOMS(Cognitive, Perceptual, and Motor Operators in a Critical Path Method schedule chart)(John & Kieras 1996).

As a system design approach, the GOMS modeling has been applied to a help system and documentation design (Elkerton & Palmiter 1991; Gong & Elkerton 1990), and to the prediction of time to use and learn interface(Kieras, 1998). The results of these studies suggest that the GOMS can aid in the devel- opment of a procedural help system that is easy to learn and use for retrieving help information.

3. Case: Modeling users from constructivist viewpoint

The model drawn from users' process in this article was developed by the author for the *Augmented Seriation* software by using Dervin's Sense-Making Theory. Sense-Making Timeline interview was used for a data collection method, and an inductive content analysis was applied for data analysis. This model is not based on any of specific approaches introduced in the section above, but takes a construc-tivist viewpoint which emphasizes the

importance of exploring the way in which each individual construct his/her own value. In this context, human need and use of information systems are the extension of construction of individual exploration toward the world. Understand and study information system users in context and from "the perspective of the actor not the observer"(Dervin, 1986).

3. 1 Theoretical background

The primary method for data collection of the model was Sense-Making Theory which underlies Sense-Making TimeLine interview. Two of the major theorists among others who proposed sense making are Dervin(1983) in the field of communi-cation and Weick(1995) in organizational science. The basic assumption of Dervin' Sense-Making is "discontinuity" in reality of the human which is essential to our life: between entities, between time and space, and between all entities surrounding them. Human find or face gaps and try to bridge these gaps through time and space. Sense-making and information using occurs when individuals find them-selves unable to progress through a parti-cular situation without forming some kind of new "sense" about something(Dervin & Dewney, 1986). Dervin explains this process as the sense-making triangle of situation-gap-use/help(1992). A "situation" is a state that a human faces where a gap

creates the need to raise questions to be answered. A "gap" is any uncertainty or confusion a human encounters. Human tends to try to bridge this gap using information. "Help" means the questions raised are answered, enabling the human to move forward. In other words, by bridging a gap, the human may get answers to their questions or to reduce uncertainty. "Hurt" occurs when the raised questions are not answered or bridging a gap may cause the human more frustration or embarrassment. Getting help/hurt depends on how human constructs the connections between his/her information needs, systems, and individuals. Human moves through their own time and space via these three steps(interactions) with information that are created by human users in specific time and space. Dervin's Sense-Making is about time, space, movement, gap, but is not linear, purposive, or problem solving. Human information needs, seeking, and use are viewed in this context. Situationality assumes that structure, culture, community, and organization are created, maintained, reified, challenged, changed, retested, and destroyed in communication and can only be understood by focusing on the individual-in-context including social context. Her viewpoint on information needs and uses reflects social constructivism which is represented by Vygotsky and the situated cognition

movement heralded by Gibson(1979), Greeno, Simth, & Moore(1993), and Suchman(1987).

Since Dervin's Sense-Making theory had been introduced, the concept of sense-making has been applied to studies of database use(Jacobson, 1991), information seeking and use, and information system design approaches(Gluck et al., 1996; Hert & Nilan, 1991; Nilan & Pennen, 1989; Nilan et al., 1989).

3. 2 Development of a user model

The model introduced in this article was originally developed from a user's process of using *Augmented Seriation* software in order to redesign its menu based interface. The presentation scheme of menu items of menu based interfaces of computing systems has been traditionally designed based schemes such as alphabetic, random, chronological, frequency of use, semantic similarity, or categorical grouping (K. Norman 1991). The logic behind these schemes seems natural and universally agreeable. However, these kinds of pre-determined order of menu items were constructed without any direct user input into the initial design. Consequently, there is no systematic examination of menu items incorporating direct user process input into menu based interface design. The author attempted to develop a user model for a particular piece of software

(*Augmented Seriation*), which reflects Dervin's ontology on users, for design and redesign of its' user interface.

The *Augmented Seriation* is small-scale data analysis software with menu based interface, which has data matrices and maps. This software enables geographic information users to manipulate data through matrices and maps, and to find visually meaningful patterns in the data. In this software, geographic data in rows and columns can be permuted or re-grouped through the iconized matrix, which represents data in icons in propor-tion to the original size of values. The un-derlying concept of this software is 'seriation', which is literally defined as "formation or arrangement in an orderly sequence". More specifically, as a data manipulation tool in Geographic Informa-tion System(GIS), the data matrix table can be reconstructed by manipulating the objects of a column and a row. This matrix shows a correlation of the whole data set. *Augmented Seriation* incorporates a menu driven interface, color, sound, and map functions in addition to the data matrix in which the concept of seriation is embedded.

The *Augmented Seriation* software is a tool for exploration and a data mining tool for both casual and experienced Geospatial users, and was originally devised by Gluck and McRae(1997). This software is used for this study as a convenient tool that has many traditional standard menu interface

features. It also has uncommon function-ality which permits an environment less con-founded by excessive past user experience.

For development of a model, six GIS experienced subjects were recruited from the Department of Geography and the School of Information Studies(now Col-lege of Information) at the Florida State University. The experienced user was defined in this case was one who had experience in using GIS for one or more years, or who had taken one of more GIS related courses. Three subjects, all male, were doctoral students majoring in geog-raphy. Their experience level was from two to six years using a GIS such as ArcView for their classes, projects or teaching the introductory GIS course in the Geography Department. They had used GIS to conduct spatial analysis of demographic data and voting behaviors from the presidential election. One female and two male faculty members of the School of Information Studies participated in the interviews. The specialty of one subject was information visualization on Web applications. This subject had used Web visualization tools for research purposes over the past several years. Such visualization tools enable the users to view the spatial information space in graphical form using distortion, zoom, and expand-ing outline techniques. The other two subjects had used SAS and SPSS for the analysis of data for their projects related

to the performance evaluation of users of networked information. All subjects participated in the interviews voluntarily with confidentiality of their identities assured.

Data was collected from six sessions of Dervin's Sense-Making interview with these six subjects. Each session had two stages of learning/exploration and interview. In a learning/exploration stage, basic features and an example of software were introduced to subjects because this software is not publicly available and includes several novel functions such as seriation. The subjects were asked to formulate their own information needs for this software, and to use the software for their own purposes with a given data set. Each subject was given a specific data file(filename: SeriDis.gis) for the exploration/learning session that contained a data set of environmental risk assessments by risk managements agency for 57 counties of New York State.

The subjects were not given any guidance in how to formulate and solve their information needs while they explored the software. In an interview session, the interviewer asked each subject to recall and describe her/his own information needs(situation) and all the behavioral and mental processes(events, gaps, and help/hurt).

Examples of users' situations were:
- Finding the counties in New York State that have the highest level of toxic and

nuclear leak problem and the geographic distribution of those leaks.
- Identifying the counties in New York State were vulnerable to natural and man-made disasters.
- Finding out what NY State residents feel were the most significant hazards, and identifying which hazards were least likely to occur.

Subjects were asked to recall and describe their specific information need and all the processes at particular points within the phases of the situation(events). Detail were jotted down and recorded by the interviewer, and all aspects of the steps of task were reviewed by subjects. Each subject's own information needs were captured and categorized as situation, specific steps as events, her/his concerns or questions at the specific moment as gaps, system's response as help or hurt based on Dervin's Sense-Making concepts. It is assumed that the collected data through subjects' interaction with the software reflected subjects' goals and strategies to solve their geospatial information needs.

From the data gathered from the interviews, a detailed mater timeline table was constructed, which includes thirteen events(See E1 to E13 in Note of Table 1). The names for events as described by the subjects provide category names using a standard content analysis method. Based

on this detailed master timeline table, a model Mater Timeline matrix of all subjects situation was constructed(Table 1).

All categories across subjects were collapsed. In this way, all events for all subjects were chronologically ordered from E1 to E13. Subject numbers(S1 to S6) were not considered for the chronology. All the events(E1-E13) were ordered across time and subjects in the timeline matrix by combining all six subjects' complete timeline. The columns indicate subjects, and the rows from E1-E13 indicate master events across all subjects and time. All six sub-jects did not go through every events, or in the same order, but all subject's events were collapsed to generate a master time-line describing all events in all timelines for the use of *Augmented Seriation*. Only events that were manifested as micro-level interactions were content analyzed for the menu interface organization since the interactions from the actual interface menu items. Event 1, 12, 13 were dropped for interface organization because those events were considered as a thought process not interface interaction. Category frequency counts were considered, since

Table 1: User Model based on Master Timeline Matrix of Subjects' Situations

Events	Subjects					
Event No.	Subject1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6
Event 1	xx	x	xx	x		
Event 2	x	x		xx	xx	x
Event 3	xx	xx		xx		x
Event 4	x					x
Event 5						x
Event 6	xx	xx				x
Event 7			x		xxx	
Event 8	x			xxxx	xx	
Event 9	x			xx	x	
Event 10	x				xxx	x
Event 11	x					
Event 12	xx	x	xx	xx	x	xx
Event 13	x	x	x	x	x	x

Note: x: occurrence of event(number of x's indicates frequency of occurrence)
   E1: Selection of variables(columns)
   E2: Clustering columns
   E3: Sort columns
   E4: Clustering rows
   E5: Sort rows
   E6: Data conversion
   E7: Seriate
   E8: Make thematic maps
   E9: Make bivariate maps
   E10: Browsing
   E11: Brushing/Identification
   E12: Analysis
   E13: Decision making

the orders of actions were more important than the frequency of actions within a category.

As seen in this user model, some of the events were repeated by the same subject, and consequently this repeats within a subject represents a monotonic timeline of events. As Dervin pointed out(1997), this non-monotonic timeline seems more natural in real life where the process of all human's information seeking and making sense of the world that is ambiguous and chaotic in nature.

3. 3 Application of this model to design/redesign interface

The purpose of developing this model was to reorganize the menu items of *Augmented Seriation* based on the strategies that the actual user employed to solve their information needs and interact with the software. As indicated in the default(original) menu scheme in Table 2, there is no explicit or underlying logic to the main menu, so random categories such as File, Edit, Matrix, and Symbol are used. The order of File, Edit, and Help seems to follow a *de facto* standard that is used in most software currently. The order of the remaining items does not show any logic. The categorization(or grouping) of sub menu items such as New, Open, Close and so on under the each main item might be based on their functionality.

In the redesigned(proposed) menu, several changes have been made in terms of the order of main and sub menu items, duplicated placement of items(Help, Data Representation) under several main items, renaming of main items, and regrouping items to comply with users'processes that were captured in the Sense-Making Timeline interview.

Based on the model elicited from sense making interviews, several changes had been made to the original menu of the software. Some of them are: 1) the original order of File, Edit, Matrix, Symbol, Sort, Sound, Maps, Seriate, and Help to the order of Begin, Manipulate Matrix, Customize Icon/Cell, Make Map, Explore Map, and End; Sort and Seriate are placed under Manipulate Matrix; and 2) Help was placed under all categories repeatedly because users might need help at any point of their interaction with the software.

Augmented Seriation version 23 was used for developing a model introduced. The software was written in Visual Basic for Windows platform. ESRI's MapObjects™ LT was linked to the Visual Basic program module to support cartographic functions of the software. Based on data analysis, all changes for menu item organization had been made to the source code of the original menu interface of the software, and resulted in the proposed menu interface. The two versions of the

interface, original and proposed, were implemented into the system to assess system usability(see Ju & Gluck, 2005).

4. Conclusions

As identified in previous research, there has been and still is abundant sympathy with the view that one of the ongoing issues in designing user interface of systems is how to identify and interpret appropriate user information, and how to apply it toward system implementation. In the efforts to making improvement of current systems, various viewpoints of design approaches have been presented and applied to system design. There are

numerous design approaches other than the one introduced in this article, but those mentioned are widely perceived and accepted by researchers and practitioners. In addition, one case of direct user input for design by the author was added as an example of an approach with a particular perspective.

Though the modeling process is descriptive and straightforward, the specific steps devised by the author for developing a user model employing Sense-Making Timeline Interviews can be applied and extended toward other cases in the future. The steps are: 1) Categorize data obtained from Sense-Making Interviews into event, gap, and help/hurt; 2) Create a detailed timeline table by gathering and

Table 2: Layout of Original Menu vs. Revised Menu

Original Menu								
File	Edit	Matrix	Symbol	Sort	Sound	Maps	Seriate	Help
New	Move	Header	Red	Ascending	Play	Base Map		Content
Open	Undo	Labels	Green	Descending	Speed	Thematic Map		Demo
Close		Cell Size	Blue		Instrument	Bivariate Map		
Import			Properties			Zoom In		
Save As						Zoom Out		
Exit						Pan		
						Identify		
						ShowTag		
						Brush		

Revised Menu				
	Manipulate	Customize	Make	Explore
Begin	Matrix	Icon/Cell	Map	Map	End
New	Move	IconColor	Base Map	Identify	Save As
Open	Sort	CellFormat	Thematic Map	ShowTag	Close
Import	Data Representation	Help	Data Represent	Brush Exit	
	Seriate		Bivariate Map	Zoom In	
	Help		Help	Zoom Out	
				Help	

combining sense-making stages such as event, gap, and help/hurt; 3) Choose only events that were manifested as micro-level interaction and do content analysis; 4) Determine the unit of analysis; 5) Create event categories by the analyst by using traditional content analysis; 6) Collapse all these categories across subjects. By doing this, all events for all subjects are chronologically ordered as in Table 1; 7) Make a master timeline table by marking each subject's process(interaction). All events experienced by each subject are marked down to the corresponding event. Some events occur more than twice by single subject; 8) Consider only event that are considered as interface interactions. Subjects' thought processes are not considered as interface interaction; 9) The timeline of interaction, in other words, the order of interaction shown in a master timeline table is applied to organize or reorganize the order of menu items; 10) The labels of menu items reflect event categories in some cases. In other cases, those tend to be plain and descriptive that reflect users; language. These labels are usually nouns or verbs or adjective-noun or adverb-verb pairs.

The author hopes this modeling procedure can be used in a variety of applications for system design by providing guidelines or suggestions for reconsidering current interface menu organization and enhancing information system to more usable one.

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