In: *Proceedings of HCI International 2007*

UFuRT: A Work-Centered Framework and Process for Design and Evaluation of Information Systems

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1. Introduction

A current and significant challenge in the design and implementation of information systems (IS) is to deal with the high failure rate of IS projects. A large number of IS projects fail. Most of these failures are not due to flawed technology, but rather due to the lack of systematic considerations of human and other non-technology issues in the design and implementation processes. In other words, designing and implementing IS is not so much an IT project as a human project about human-centered computing such as human-computer interaction, workflow, organizational change, and process reengineering. To address the high failure rate, we need a process that would increase efficiency and productivity, increase ease of use and ease of learning, increase user adoption, retention, and satisfaction, and decrease human errors, decrease development time and cost, and decrease support and training cost. In this paper we present a work-centered process called UFuRT for the design and evaluation of information systems.

2. UFuRT – A Conceptual Framework

UFuRT (User, Function, Representation, and Task analyses) is a conceptual framework and a process for the design and evaluation of work-centered products. It is based on the theory of distributed cognition and work-centered research [1-3]. UFuRT is composed of four major components: User, Function, Representation, and Task analyses (Figure 1).

User analysis is the first stage of the UFuRT process. It provides user information to functional, representational, and task analyses. . User analysis is the process of identifying the types of users and the characteristics of each type of users. User characteristics include expertise and skills, knowledge bases, education background, cognitive capacities and limitations, perceptual variations, age related skills, cultural background, personality, etc. User analysis can help us design systems that have the right knowledge and information structure that match those of the users.

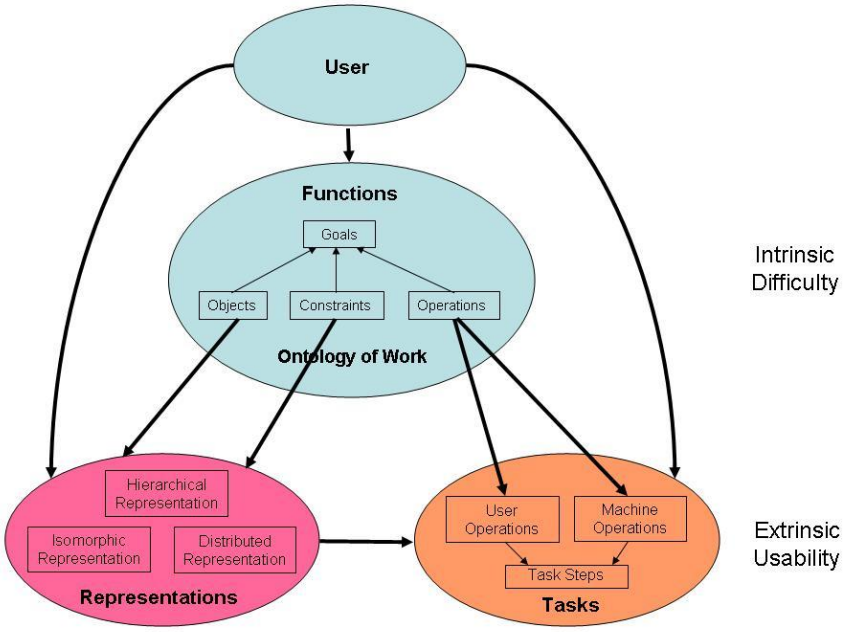

Fig. 1. The conceptual framework of UFuRT. For each type of users, there is an ontology of work. This ontology can be implemented as different representations. Each representation, in conjunction with the distribution of user and machine procedures, is associated with a different set of task steps. The goal of UFuRT is to generate a representation (e.g., display) that matches the ontology of work for a specific type of users such that the task performance is optimized.

Functional analysis is the process of identifying a work domain's abstract structure: the ontology of the work domain [3]. It is a declarative model, unlike task analysis which is procedural. The ontology of the work domain is the basic structure of the work that the system together with its human users will perform. It is an explicit, abstract, implementation-independent description of that work. It describes the essential requirements of that work independently of any technology systems, strategies, or work procedures; it tells us the inherent complexity of the work, it separates work context (geographical, organizational, computational, etc.) from the inherent nature of the work; and it supports identification of overhead activities that are non-essential for the work but introduced solely due to the way the system is implemented. In other words, work domain ontology is invariant with respect to work context, application technology, or cognitive architecture. If the system does not support the ontology of the work, the system will fail, regardless of its large collection of functionalities, fancy and cutting-age features, and purely technical merits.

Representational analysis is the process of identifying an appropriate representation for a given task performed by a specific type of users such that the interaction between users and systems is in a direct interaction mode. Representational analysis is based upon a robust phenomenon called *representational effect* [1]: different representations of a common abstract structure can generate

dramatically different representational efficiencies, task difficulties, and behavioral outcomes. There is a representational determinism for the representational effect [4]. The form of a representation can influence and sometimes determine what information can be easily perceived, what processes are activated, what can be derived from the representation. One major step of representational analysis is to generate alternative representations of the objects, operations, and constraints in the ontology through the functional analysis [5].

Task analysis is the process of identifying what steps need to be carried out, how these steps relate to each other, what the information is processed to achieve task goals, and how the information is distributed across the human minds (internal representation) and the external artifacts (external representation).

UFuRT is both a framework and a process for work-centered design. As a framework, it captures an important distinction between intrinsic difficulty and extrinsic usability in work-centered design. UFuRT includes an analysis of ontology that corresponds to intrinsic difficulty of work and an analysis of representations and task procedures that correspond to extrinsic usability. Intrinsic difficulty reflects the amount and complexity of work, independent of any procedures, activities, systems, or implementations. Different ontologies are associated with different levels of intrinsic difficulties. Extrinsic usability reflects the difficulty due to implementation and procedure details. Representation effects and workflows are two major factors affecting extrinsic usability.

3. UFuRT – A Process

As a process, UFuRT provides procedures for design and evaluation of work-centered systems. Figure 2 shows how the process is carried out for a simple example: different displays of the same relation between two variables/dimensions. The specific stages might be different for different work domains, but they all fall into the four types of analyses.

- *User Analysis*
  - *Stage 1*. Stage 1 is user analysis, which is to identify categories of users (physicians, nurses, etc.) and characteristics of each type of users.
- *Function Analysis*
  - *Stage 2*. Stage 2 is the first step in function analysis, which is to identify the goals, objects, constraints, and operations. In the example, Stage 2 is to identify all the dimensions in the domain: patient name and patient age.
  - *Stage 3*. Stage 3 is to identify the design space of the dimensions identified in Stage 2. The design space is the Cartesian product of the dimensions.
  - *Stage 4*. Stage 4 is to identify the constraints that will generate relations among the dimensions. In the example, the constraints are observed and collected data. For example, the name West is associated with age 65.
  - *Stage 5*. Stage 5 is to identify the meaningful, implementation-independent operations on the dimensions and relations for a specific group of users. For example, for the two dimensions Name and Age, one operation is to find the age of a specific patient, or to find all the patients who have a specific age.

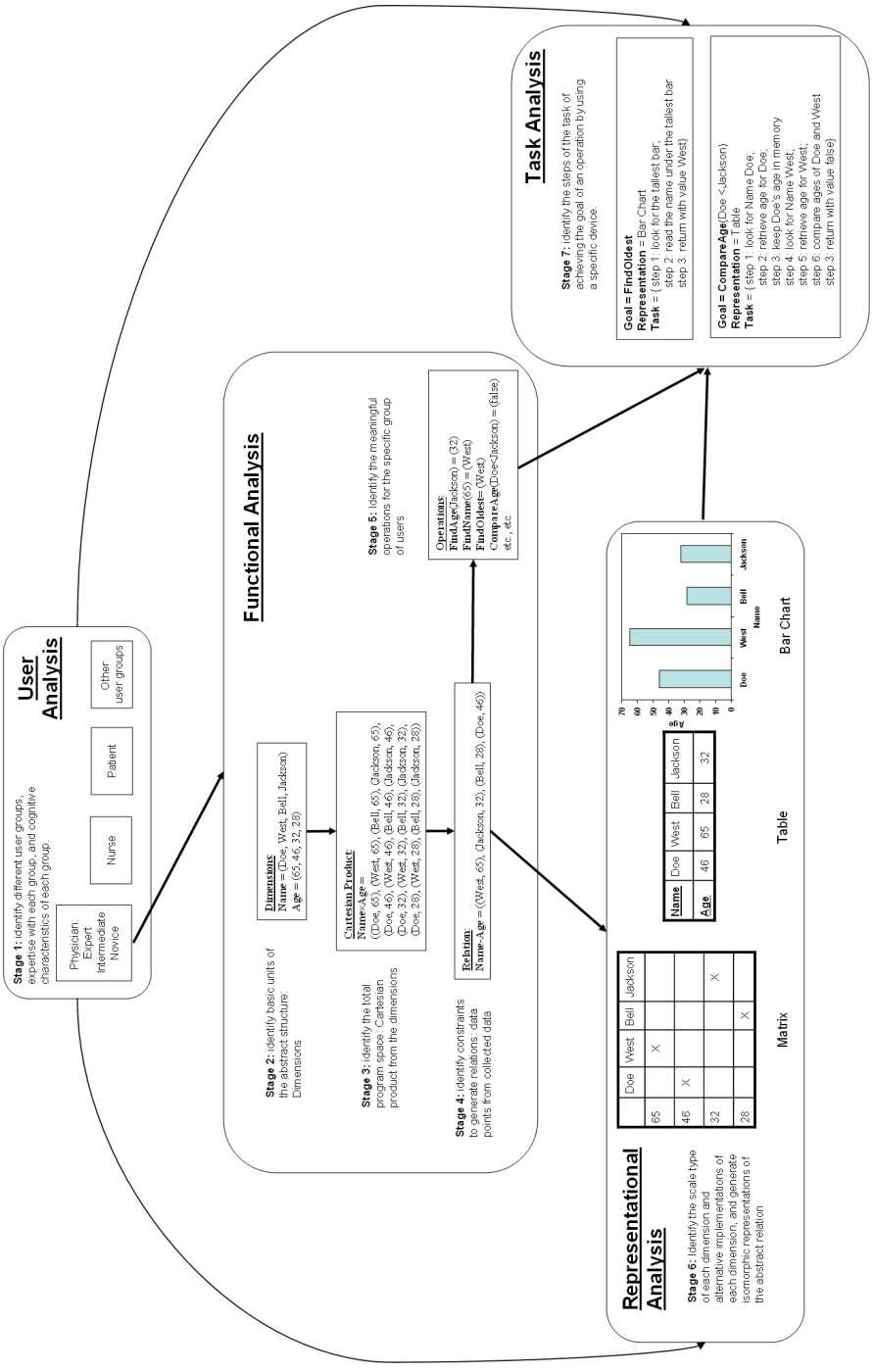

Figure 2. An example showing the UFuRT process.

- Representation Analysis
  - *Stage 6*. Stage 6 is to identify the scale type and alternative implementations of each dimension and to generate isomorphic representations of the abstract relation among the identified dimensions. In Figure 2, the relation between Name and Age can be represented in many different formats, such as matrix, table, bar chart, and many others. There is no universally best display for every operation. So the critical issue here is to find a systematic way to match an operation and a display to optimize user performance.
- Task Analysis
  - *Stage 7*. Stage 7 is to identify the steps of carrying out an operation by using a specific representation. In Figure 2, the steps include not only physical steps but also mental steps. This is the most important feature of cognitive task analysis, which, by considering mental steps, can identify the cognitive factors that make a task easy or difficult. Note that the steps of achieving the same operation are different with different representations (e.g., using Bar Chart vs. using Table). One objective of task analysis is to find out which representation is better for which task, why it is better, and how to generate a better representation.

4. Discussion and Conclusion

The simple example in Figure 2 is for demonstration purpose only. UFuRT has been applied to several real-work complex work domains and generated successful design and evaluation products. For example, UFuRT played an important role in the design and development of a scheduling software system for aircrafts that increased efficiency from a three-day task by three people to an eight-minute task by a single person [3]. We are currently working on semi-automating some of the components of the UFuRT process to make it more efficient in applications.

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