Context Sensitive Interactive Systems Design: A Framework for Representation of contexts

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Abstract

The performance of interactive systems is determined in relation to the context in which the system and users interact for task execution. It is obvious that the significance and complexity of contextual information require systemic approaches for managing it in the design process. As the system complexity and diversity of types and ranges of use context increase, context sensitivity becomes a critical mechanism to enhance system performance and interactive qualities. This research attempts to introduce a representation framework for contextual information critical for developing a methodological foundation for user-centered design practice. First, this paper explains what compose contexts, how contexts are structured, and how they can be described. Then, strategies and methods to incorporate context sensitivity are discussed from the perspective of system development in relation to types of system architecture that can effectively implement context-sensitivity in design are discussed.

1 Introduction

The term "context" has been loosely defined and used in interactive systems design practice to represent various factors and conditions surrounding and influencing the use of the system. The performance of interactive systems is determined in relation to the context in which the system performs its intended roles. The system that performs well in one context may not necessarily perform well in other contexts. While the context dynamically changes, systems are usually designed to remain the same and to be operated within a very limited range of the context. For example, the user interface of an existing mobile information system cannot respond to a change from business use in the office to personal use in the automobile to achieve effectiveness of interaction and qualities of user experience. In order to maximize the system performance, therefore, the system needs to be sensitive to the change and range of the context.

Some contexts are composed of factors that reside in users such as cultural, social, chronological and cognitive factors; some are composed of external factors that reside in operational environments such as organizational, spatial and social factors; some contexts might be composed of combinations of factors that are distributed across users, systems and operational environments. These different types of contexts interact with each other and compose complex, underlying layers of operational conditions for the performance of interactive systems which are often referred as situations. This complex nature of contexts, points out the need for multidisciplinary viewpoints in developing frameworks for understanding contexts and for developing coherent mechanisms to incorporate those frameworks in interactive systems development.

This paper intends to discuss the following three areas of research: 1) The conceptual framework of the context in interactive systems design, 2) Design methodology for systematically incorporating the concept of contexts into interactive systems development, 3) Development strategies for context-sensitive interactive systems. It attempts to reveal the common foundation of Context Sensitive Design across different application domains and critical issues to be addressed in the next stages of research development.

The goal is to introduce a general foundation for context representation in interactive systems design methodology. This research effort particularly responds to the emerging needs for integrating physical and media systems with fast-growing network and embedded technologies that require management of complex contextual issues across many related domains. Only by addressing these issues and needs, users can be provided with living and work environments that most effectively integrate hardware, software, and communication technologies.

2 Contexts in Multiple Perspectives of Design

Much diversity can be found among definitions of contexts from different interests such as context aware computing, usability analysis, urban planning, and its academic origin in linguistics. In context aware computing, some descriptors of the domain such as location, identity, and time, describe conditions and environments of the system operation and are considered to be parameters of context (Dey et. al. 2001, Selker & Burleson 2000). In urban planning, community history is a part of context. In the area of office space planning, contexts of work include social, cultural and organizational aspects. Looking at the office workers' tasks level, information flow, project history, and daily activity patterns become important aspects of the context.

This indicates the characteristics of the concept of context: 1) Multiple aspects of context manifest based on the emergent relevance to the nature of actions and conditions, 2) The granularity of description varies depends on the focus of the viewpoints, 3) Contextual changes are evoked by triggers from different constituents of the domain, 4) Context evolves over time but some aspects change fast and others change slow. In order to understand the concept of context, it is useful to also define related concepts such as conditions, states, environments and situation.

Conditions are defined as individual variables in the domain of concern where the interaction is situated. They include environmental states, system states, and user states that include variables such as location, temperature, sound, users' emotion, and attention level.

Context is a pattern of behaviour or relations among variables that are outside of the subjects of design manipulation and potentially affect user behaviour and system performance. Example aspects of context for driving are chronological development of the user's activities for the day, a destination and purposes of driving, and a plan for intermediate activities before arriving at the destination. These are aspect models of contexts that all influence driving behavior. Simple terms such as "driving freeway" and "teenager" are also considered ~~as~~ contexts. These are examples of *ostensive* or *indexical use* of words implying particular contexts represented by typical patterns of conditions or characteristics associated with them instead of pointing to their immediate meanings. Some aspects of context take significant roles in forming situations for the current action; some aspects become irrelevant to the current action. We call the former *manifesting aspects of context* and the later *latent aspects of context.* Figure 1 shows how manifesting aspects of context and

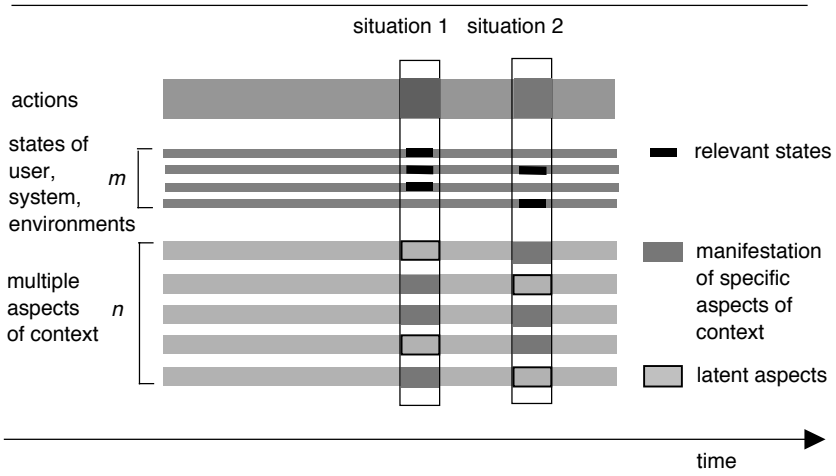

Figure 1: Formation of situations with actions, states, and contexts

conditions form the situation of the action. As a result of the action, some of the aspects of context change and evolve over time.

Situation is a collective condition at the scene of the interaction that is composed of relations among variables of conditions such as environmental states, contexts, systems and users states. Therefore the representation of situations needs to include description of relations as well as the set of descriptors as listed above. In some cases, actions in the situation consequentially become a part of the situation. In Figure 1, *m* state variables and *n* aspects of context are indicated, and a small number of states and aspects of context manifest relevance by having direct or collective effects to the action.

3 Representation of Contexts in Design

The key to the development of an effective methodology is to construct representation methods that enable reliable description, analysis, manipulation, and evaluation of contexts. Different representation methods will be introduced ranging from soft forms of description such as scenarios and story boards to more rigorous and formal description such as aspect-models for computational support of research and design. Different types of contexts also require different representation methods. The temporal dimension is also an important factor in the representation of the context, since some of contexts are constructed over time and interactions between contexts and contextual change take place over time. In order to capture contexts systematic approaches to record, document, and filter, field data is required at the scene of the field study.

Some of principles introduced in formal representation for contextual reasoning in AI are also useful for developing a framework of context representation for design. Examples include principle of locality (reasoning always happens in a context), principle of compatibility (there can be relationships between reasoning processes in different contexts), resolution of representing contexts, partiality of contextual information (stating no complete information, and no complete representation) (Bouquet, P. & Srafini, L. 2001).

The Design Information Framework (DIF) developed to provide structured guidelines and mechanisms to set formats for data inquiry and for the documentation, organization and

interpretation of the collected data. DIF is a unified design information representation platform for bridging different viewpoints, activities and description methods involved in the system development process (Sato, K. 1991, Lim & Sato, 2001). It can be applied to represent contextual information by satisfying the requirements describes earlier. As shown in Figure 2, various concepts and variables used in the system development are structured with two levels of information elements. The basic representation units such as entities, acts, and attributes are called Design Information Primitives (DIP). Design Information Elements (DIL) represents higher levels of concepts such as functions, goals, and plans that can be represented by combination of DIP's. Once data is encoded by DIF, aspect models with different combinations of variables can be generated representing particular viewpoints for analysis, problem solving, evaluation communication (Lim & Sato, 2003). Aspects of context therefore can be represented as aspect models in appropriate forms built on the DIF mechanism.

4 Strategies for Incorporating Contexts in Design

In order to accommodate context sensitivity in interactive systems design, many different approaches at different aspects of the system must be considered. In the area of context aware computing, three models have been introduced and implemented for information processing level architecture; widget model, infrastructure-centered distributed or networked service model, and blackboard model (Winograd, 2002).

Implementation of comprehensive context sensitivity requires strategies for the three parts of overall systems as follows.

Sensing contextual changes: When relevant contexts are known and patterns of contextual changes are predicted, a sensing mechanism can be designed and embedded in the system to detect and capture indexes of changes, so that the system effectively changes its operational modes and characteristics to optimize its interfaces to users. This requires interpretive filters to detect signs of

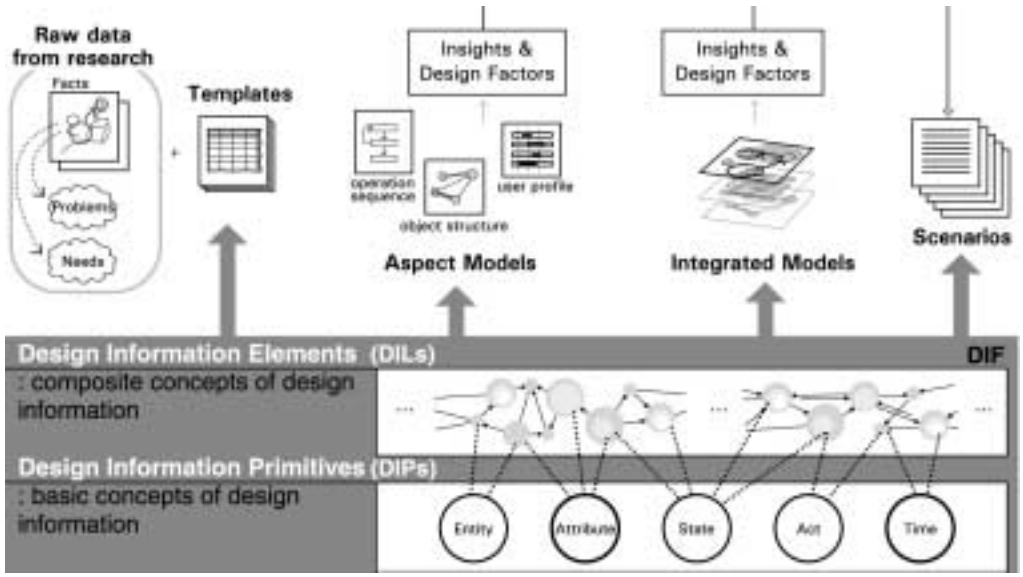

Figure 2: Structure of the Design Information Framework

contextual changes that need to be used as triggers for appropriate transformations of the system or interface configuration.

Re-configurable architecture: Use process of interactive systems is a learning process for developing more skills and knowledge about them. There are two approaches to this issue. One is to make a system re-configurable by its self adaptation mechanisms. The other is to assist users to re-configure the system by themselves.

Creating and managing contexts: In order to support particular user activities, the appropriate setting of contexts is necessary for the enhancement of user interactions with artifacts. Setting courses of cognitive activities leading to the particular actions, and setting a pattern of information distribution over the spatial environment for better user performance are examples of such effects.

5 Conclusion and perspectives

This paper demonstrated that the concept of context, which has been considered as soft and peripheral information in design, can and must become a critical resource for user-centered design practice. Although a general approach to the development of representational mechanisms for contextual information was explained, further formal and empirical research needs to be developed. Particularly use of context sensitivity in many different application domains opens a huge new space for research and system development including topics in architectural issues of physical and media spaces, interaction, and re-configurable interfaces as pointed out earlier.

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