Web-based Interactive Support for Combining Contextual and Procedural Design Knowledge

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ABSTRACT: Design study can take design as a process in the form of observing what designers do and how they tackle their tasks. The content of designer decisions and the organization of the process can be corresponded to contextual and procedural design knowledge respectively and they are typically inspected in design process. In this paper, we build a web-based interactive computational tool for designers to support their design process by integrating contextual and procedural design knowledge model. We use a scenario-based analysis to model the contextual design knowledge and the concept of Petri-nets to model a graphical workflow of procedural design process. To exemplify and illustrate our concepts, we focus on a sign design process, even though the system can be applied to a wide variety of design domains.

1 INTRODUCTION

We can examine design as a process by observing what designer do and how they tackle their tasks. When implements to designing are intended, the content of the designer decisions and the organization of the process and have to be concurrently considered, and these two types of knowledge, named *contextual* process-oriented decisions and *procedural*, are typically inspected in a design process (Horváth et al. 2000). The process used to design a product strongly influences the manifestation of the designed product (Horváth et al. 2000). Currently there is much research, available in the literature and from industry, on the structure and kinds of tasks used during designing. However, it is not easy to gather appropriate information within a reasonable amount of time, for the following reasons. First, it is innately complex to consider both the contextual and procedural aspects simultaneously. Second, most designers tend to use paper-based media and manual methods, which can result breaking continuity of thinking in the design process. Third, the information on designing is disorganized and sometimes too abstract to be captured. These problems can be partially overcome through computational support. This requires a better understanding and formalization of the context of design processes from an information theoretical background. For this purpose, we use a scenario-based analysis to model the contextual design knowledge, and the concept of Petri-nets to model a graphical workflow of procedural design process. These two knowledge models are integrated in an interactive tool to support design activities and assist designers.

In this paper, we build a web-based interactive computational tool for designers to support the design process by integrating contextual and procedural design knowledge models. We use a sign design process for illustrating our concepts. First, we attempt to do knowledge acquisition for the sign design process from experienced designers as well as from a literature survey. After the information has been gathered, we use scenario-based analysis and Petri-nets to model the phases of the design process in parallel, and match each one-by-one. Using the framework, we try to validate the approach by designing and implementing an interactive computational prototype, and illustrate how the prototype works through concrete examples. Figure 1 shows the concept diagram for combining contextual and procedural design knowledge.

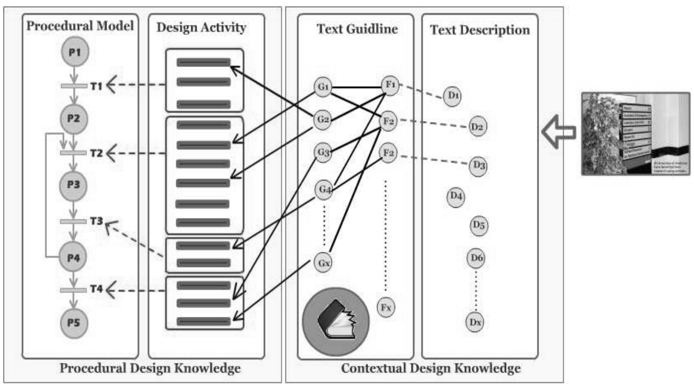

Figure 1. Concept diagram for combing procedural and contextual design knowledge

2 BACKGROUND

2.1 *Overview of Sign Design Process*

As mentioned above, using paper-based media and manual methods would breaks continuous thinking for a process. To solve this problem, contextual process-based analysis is proposed. In order to develop sign design process, interview with the domain expert and reviewing literature were conducted. Figure 2 shows a typical sign design process, which can be divided into five phases: client requirements, design, protest, produce and maintain.

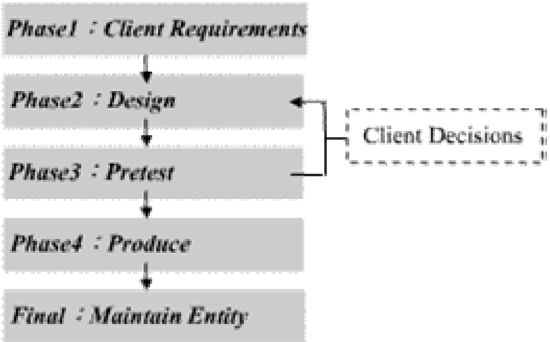

Figure 2. Typical sign design process

There are brief descriptions for each phase:

- *Client Requirements:* In this stage, designer gets environment information and user requirements from client and decides sign types, their positions and sign quality.
- *Design Phase:* Designer considers pictogram design, content text, and letterform. After that, the designer arranges the layout of pictogram and letters, decides color usage, and makes samples to use in the next phase.
- *Pretest Phase:* Designer uses samples to test the visibility in the real environment and check if proprietors accept it or not. If the test is passed, the designer draws working drawings. Otherwise, the designer has to redesign them.
- *Produce Phase:* If all design cases are passing through examinations, the designer sends working drawing to manufacturer to produce entities.
- *Maintain Phase:* Designer has to periodically maintain signage.

For the next two sections, we discuss two knowledge models in design process: contextual design knowledge and procedural design knowledge.

2.2 *Contextual Process-based Design Knowledge*

In general, the design process is evasive and has a number of communication behaviors among different stakeholders. To deal with such an ill-structured and complexity problem, we take a scenario-based design (SBD) approach. "Scenario is stories that about people and their activities, and support reasoning about situation of use, even before those situations are actually created" (Carroll, 2000). SBD manages the complexity of design problem solving by concretization and uses scenarios describing situations at many levels of detail from different perspectives (Rosson and Carroll, 2002). Figure 3 shows an overview of the scenario-based design framework.

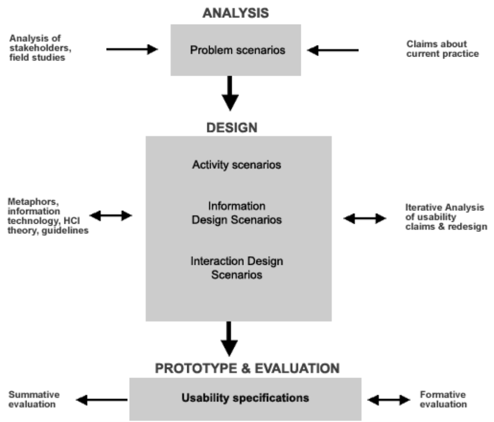

Figure 3. Overview of the scenario-based design framework (Redrawn from Rosson and Carroll, 2002)

This feature of SBD makes ambiguous and dynamic situations easy to evoke reflection in the design process by embodying concrete design actions.

We develop design scenarios, each of which describes a specific phase corresponding to that of the sign design process (Figure 4). The design scenarios can help to extract contextual design knowledge from domain experts and to define functionalities and requirements of a system meant to support the process.

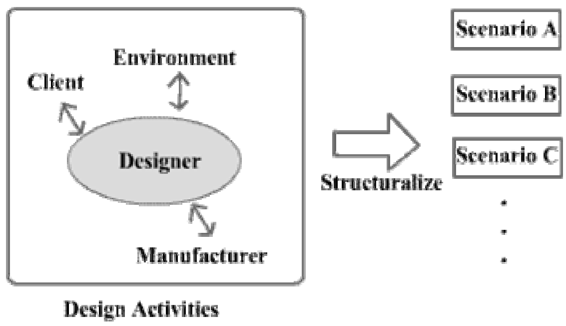

Figure 4. Structuralize designer activities into scenarios

Each design scenario can be decomposed into several sub-scenarios, each of which has a more detailed design task description. Figure 5 shows an example of scenario descriptions for each phase.

Using SBD approach, the unstructured design process can be structuralized and formalized so that we can call *contextual process-based* design knowledge. Figure 6 shows the association between sign design process and scenarios.

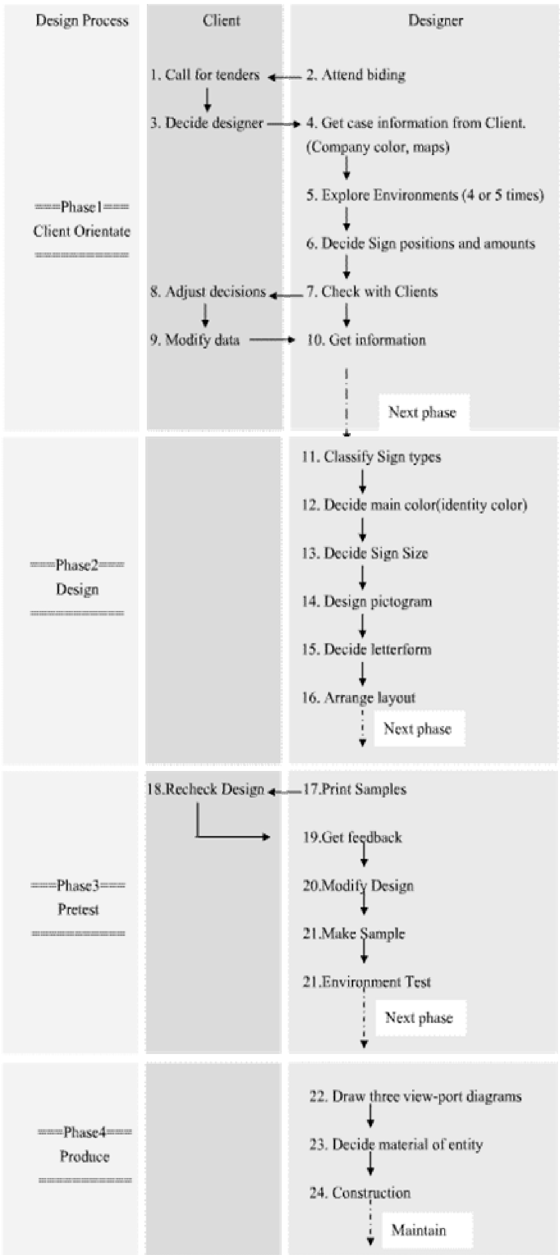

Figure 5. An example of scenario descriptions for each phase

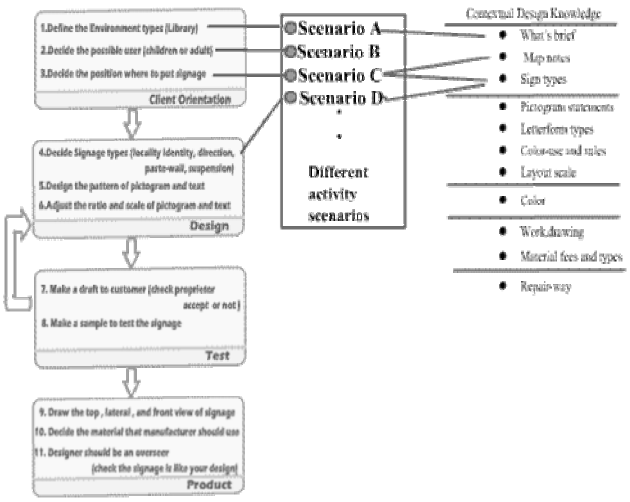

Figure 6. Sign design scenarios mapped to design process

2.3 *Procedural Design Knowledge*

To support the computer mediated selection of design actions and generating a straightforward net of activities, we have to better understand and formalize the context of design processes based on information theoretical principles. It has become accepted that the structural aspects of a design process can be captured by various network representations (Horváth et al. 2000). Up to 1996, more than 250 Workflow Management Systems (WFMSs) are under development. Among a lot of methodologies, there are several good reasons to explain why using Petri-net-based WFMS can benefit (Aalst, 1996). Petri-net is a graphical oriented language for design, specification, simulation and verification of systems. It is in particular well-suited for systems that consist of a number of processes which communicate and synchronies (Jensen, 1997). Figure 7 shows the basic graphical symbols used in design process with Petri-net.

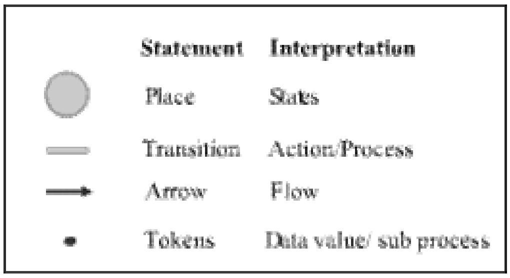

Figure 7. Basic graphical representation of Petri-net

The first reason to using Petri-net is the fact that process logic can be represented by a formal but also graphical language. Figure 8 shows how the six workflow primitive identified by the design process can be mapped onto Petri-nets: AND-join, AND-split, OR-join, OR-split, Iteration and Causality.

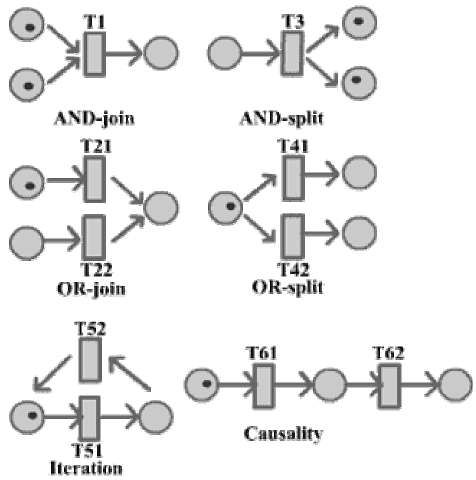

Figure 8. Workflow primitives represented by P-nets (Redraw from Aalst, 1996)

The second reason is that in contrast with many other process modeling techniques, the state of a case can be modeled explicitly in a Petri-net. While other event-based modeling techniques cannot explicitly model the states between subsequent transitions, in Petri-nets, the tasks are modeled by transitions and intermediate states are modeled by places. Using Petri-nets would easy to show each tasks with sub-process.

The third reason is that it contains abundance of analysis techniques. Based on different requirements and situations, users can use different types of Petri-nets to analyze their systems (Aalst, 1996). Figure 9 shows the sign design process drawn by Petri-nets.

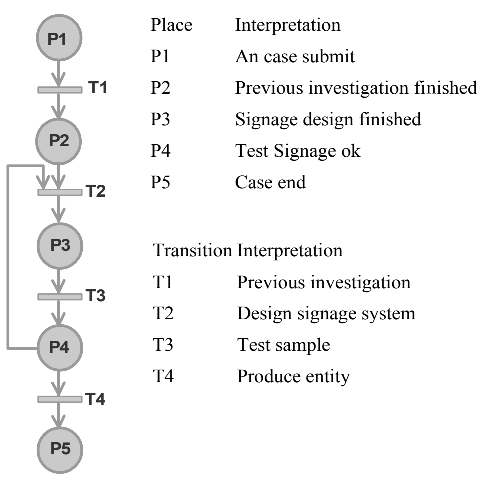

Figure 9: Sign design process with Petri-nets

Each state (P) represents a phase of sign design process and transition (T) represents the actions to be done between states. For example, when designer acquires a design case (P1), he/she has to do environmental investigation to get client's requirements (T1). P2 shows the state that the previous investigation task has been finished. In this process, the designer can start to draw some sign designs (T2). After the designer finishes designing the signage, which changes to a state named signage design finished (P3), the designer prints samples to client to get their opinions (T3). P4 shows the state that the test has been passed. If so, the designer sends the working drawing to manufacturer to make real entities (T4). Otherwise, the designer has to go back and re-design the signage (T2). This is an iterative process until the client satisfied with the design. Finally, when the process has finished, the state is changed to P5, which means the design case is over.

A state comprises several sub-states, each of which has a set of associated main tasks, and so on. Therefore, the whole Petri-net diagram is accumulated grown up and mapping with appropriate Petri-net symbols are required.

3 INTERGRATING PROCEDURAL AND CONTEXTUAL PROCESS-BASED DESIGN KNOWLEDGE

In Figure 10, we show a conceptual framework in parallel and matching the contextual design knowledge with the procedural design knowledge. That is, the design process scenarios are mapped with the Petri-nets that can be assisted by the main phases of design process.

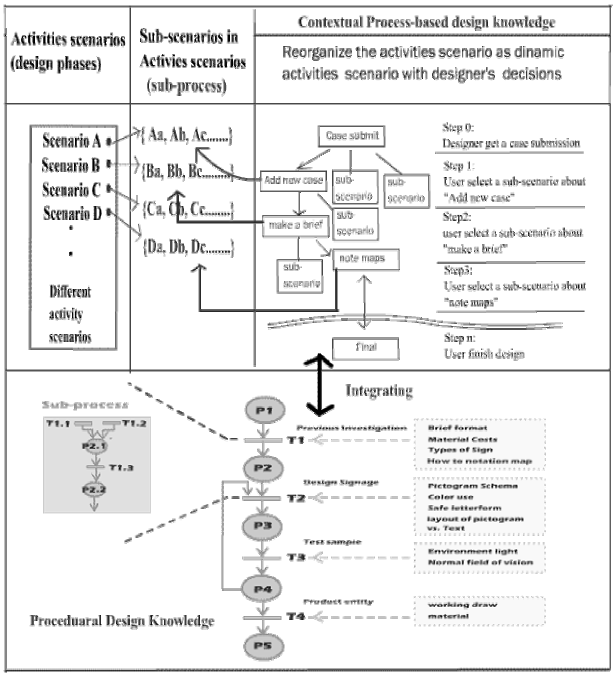

Figure 10. Integrating procedural and contextual design knowledge assisted by the sign design process

The top of Figure 10 illustrates the decomposition of the sign design scenarios. The whole sign design process can be captured by a sufficient number of design *scenarios*. A design scenario, in turn, can be expanded into more detailed *sub-scenarios*, each of which has a set of associated *design moves* that the respective process should accomplish. According to the designer decisions to be made, the shown hierarchical tree generates different alternatives, which is so called *dynamic design decision scenario*. Each hierarchical step represents a corresponding sub-scenario, which is selected from a set of sub-scenario shown in the top of Figure 10. Therefore, the whole procedure from an initial state (step 0) to a final result (step n) generates a unique customized scenario for the designer dynamically.

The bottom of Figure 10 shows the procedural design process represented by Petri-nets. The dynamic design decision scenario tree is mapped onto the design process with Petri-nets. The designer's states and actions are captured and represented with places and transitions of Petri-nets diagram. Each pace and action, respectively, can also expanded into several sub-procedures to describe more details.

4 PROTOTYPE IMPLEMENTATION

Our system is divided into three parts, which include tasks controller module, data management module, and a graphical user interface (GUI) application. Figure 11 shows the architecture of our system.

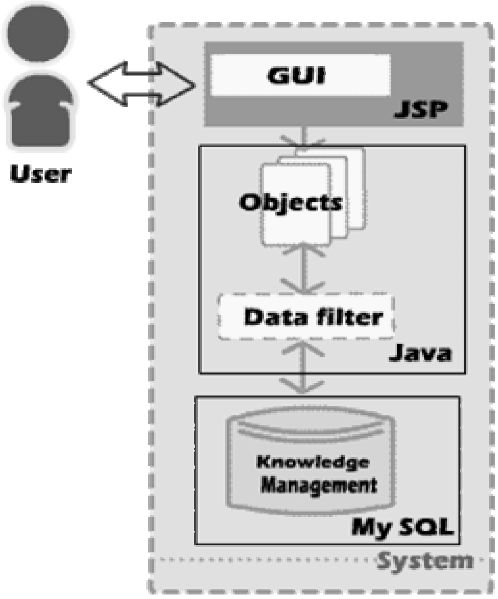

Figure 11. System architecture

Since we want to make a web-based interactive tool for collecting and sharing design knowledge efficiently, the prototype has been implemented by Java, an object-oriented language, to fully take advantage of accessibility through multiple platforms and capability to connect the system in any place. We use Java Server Page (JSP) to make GUI and link to MySQL to manage our design knowledge.

The GUI of our system includes five parts: (A) Displaying the design process by Petri-nets diagram, (B) Selection menu of design tasks in the graphical design phase, (C) Main window for a design task, and (D) List of what-to-do of the design task (Figure 12).

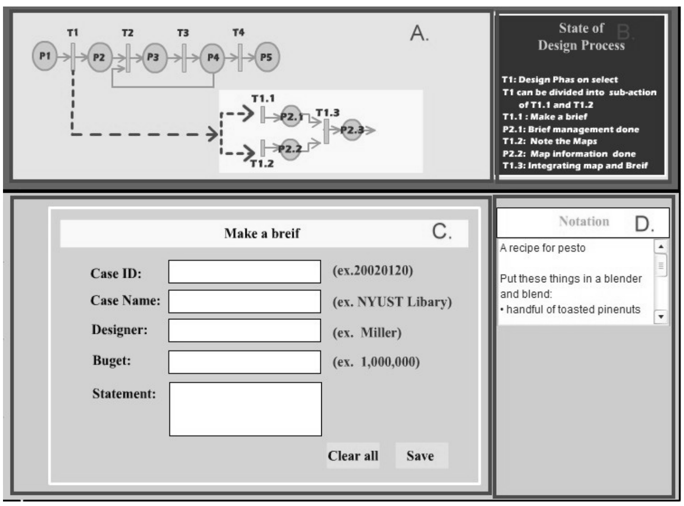

Figure 12. Four parts of the system GUI

Designer can start with selecting a transition of the graphical design process from A. After that, the area B shows the detailed design tasks of the selected transition. When the designer selects a task from B, the main window displays to ask the user for several decisions (C). Area D is the part for providing all what-to-do list of the specific design task. When the designer has finished the task, he/she can push 'Save' button to store the information. In a similar fashion, the user can iteratively assign his/her each decision until all works are done. Using this new tool the designer does not lose the continuity of his/her design process as well as knowledge and tasks for each phase without interruption.

Figure 13 shows the overall workflows between the user and the system.

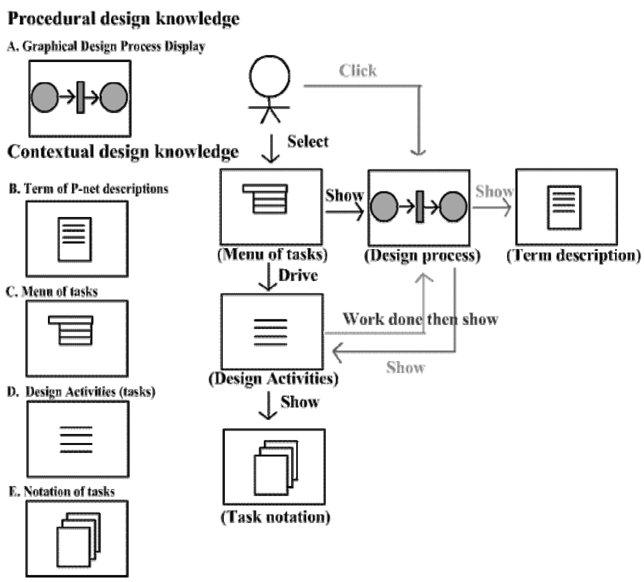

Figure 13. The user workflow interacting with GUI

5 CONCLUSION

This paper describes a web-based interactive system to support the sign design process by integrating procedural and contextual design knowledge models. This new tool can offer a promising application for the design process because it can overcome the limitations of the current problems mentioned in Chapter 1. The advantage of a computational support tool is that users (most likely, designers) can keep continuity of their design knowledge without interruption through the interactive features of the tool. The interactive computational aspect can also be helpful in dealing with the complexity of considering various types of knowledge. Another advantage using the computational tool is that it can be helpful for novices who are not familiar with the specific design process. Design knowledge extracted and converted from expert designers would directly be useful to share with others.

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