A Petri Nets Method for Specification and Automatic Generation of User Interface

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1 Introduction

In process control, many automated applications with high degree of safety require the human operator’s permanent presence. The operators have to control the system’s evolution and to react to unexpected events. Graphical user interfaces inform the operators about the process evolution and assist them in their complex task of problem solving. Several researchers are interested in the improvement of the quality of such interfaces (e.g., Rasmussen 1986; Gilmore et al. 1989; Kolski 1997). Nowadays, the tendency is to provide formal techniques for interface specification. So that, it becomes easier to verify the consistency of the specifications before the interface generation. This is particularly crucial when the interfaces are used in critical domains such as process control or transportation systems. Many works have been carried out within this framework and different approaches have been proposed (Moussa 1992; Bodart et al. 1995; Mahfoudhi 1997; Palanque and Bastide 1997). But, most of them presents slackness concerning for example system analysis, interface specification or automatic generation of the interface. Thus, we try to palliate them by proposing a global approach which covers the different aspects of the user interface design. This approach benefits from Petri Nets formalism and contributes to the “Tools for working with guidelines” domain.

In this paper, we present, firstly, the proposed approach for the design of user interfaces dedicated to process control. Then, we focus on using guidelines and Petri Nets model for the User Interface (UI) specification.

2 Proposed Approach for User Interface Design

We are especially interested in the identification of the user requirements from
the Human-Machine System (HMS) analysis. The objective is to take into account these user requirements in a UI design methodology integrating automatic generation based on ergonomic guidelines (Riahi et al. 1998). This approach is made up of six steps. In the first step, a preliminary and necessary analysis of the process and its command system is carried out in the first step. This analysis provides a document containing the data of the process and its different technical and functional constraints.

The second step consists in analyzing the whole MMS in order to identify the operator’s tasks, the command system and the process features. A combination of different methods and techniques are proposed for that. Indeed, to identify the appropriate graphical displays for the process control, we consider that a first hierarchical decomposition of the HMS is needed. The well-known SADT method is here proposed. This decomposition allows us to identify the appropriate elementary sub-systems to be studied. Then, we propose a malfunctioning analysis in order to identify for each sub-system, the possible failures, invoking their reasons and their effects on the system. For that goal, two complementary methods can be used: FMEA method (Failure Modes and Effect Analysis) and FTA method (Fault Tree Analysis) (Fadier, 1990). Afterwards, we identify for each sub-system and for each functional context (normal and abnormal), the associated operator’s tasks. The analysis of these tasks provides later, the deduction of the user requirements. Thus, we have to model the HMS dynamics describing the system’s evolution inherent to the different events. Petri Nets, which can express aspects of concurrency and parallelism are used. The places of Petri Nets represent the different sub-system states. The transitions express the different possible evolutions of the system’s state. The Petri Nets proposed here are the Interpreted Petri Nets (Moalla, 1985). They introduce the notion of events and conditions as well as the notion of actions. So, we associate to each transition, a passing condition, a triggering event and an action expressing the execution of an operator’s task. One can notice that any modification of the system’s state will imply a changing in the graphical displays. This change can affect either the object’s parameters (e.g., colors, shapes) or the display contents (e.g., appearance or disappearance of some graphical objects), thus allowing the deduction of the user requirements.

The third step concerns the deduction of the user requirements. Controlling the process, the operators need to understand the changes of the process state. This information will be transmitted to them through different displays of the interface (e.g., messages, numeric values, graphic symbols, alarms). Thus, we identify for each state, the appropriate informational variables and associate them to the corresponding place in the Petri Net modelling the HMS dynamics. Likewise, for performing their tasks, the operators need to command some variables of the system in order to correct abnormal situations. For that, the interface will propose a set of control objects to command the process. So, we associate the
necessary command variables to the appropriate transitions expressing the human tasks. The set of these command and informational variables constitute the user requirements.

Once, the user requirements identified, the **fourth step** consists in specifying the UI. It is necessary to identify the adequate graphical displays, to decide on their presentation modes and to describe the human-machine dialogue. The principle adopted for these aims is developed below.

In the **fifth step**, according with Palanque and Bastide (1997), it is possible to benefit from the formal technique used (Petri Nets), to verify the UI specifications. Many researches are yet required for that. The **last step** is dedicated to the automatic UI generation based on the validated UI specifications. First promising results have been obtained thanks to the experience of the Ergo-Conceptor system (Moussa 1992; Moussa et al. 1999). Of course, a more advanced research is required.

### 3 User Interface Specification

The transition from process analysis, task analysis, or HMS analysis to the UI specification is considered as difficult, and is often highly empirical. Few formal approaches are described in the literature. To identify the necessary graphical displays for process control, specific knowledge in Human-Computer Interaction and Software Ergonomics is especially required. In this stage, we propose to benefit from the researches carried out since the eighties, by some researchers concerning knowledge-based approaches for automatic evaluation and design of UI used in process control. In fact, there are many ergonomic rules available in the literature. For instance, Gilmore and al. (1989), inspired by their works with the U.S. Nuclear Regulatory Commission (USNRC), have written a handbook of guidelines for user-computer interface design in process control; these guidelines were organized into four categories, namely, (1) video displays, (2) control and input devices, (3) control/display integration, (4) workplace layout and environmental factors. Each guideline was presented in a structured format. Hundreds of guidelines adapted to this particular field (process control) were listed in the handbook. Other important contributions in this field exist (see for instance O’Hara and Furtado’s papers in this special session).

Several model-based tools for the interface development are described in the literature (Vanderdonckt 1996). The Ergo-Conceptor system, one of these tools, is oriented towards process control interactive applications. So, following the principle of Ergo-Conceptor, our objective is to decide automatically on the appropriate displays to associate to each sub-system. For that, it will takes into consideration, on the first hand, the characteristics of each sub-system (e.g., the list of its functioning states, the user requirements associated to each state) and on
the other hand, specific formalized guidelines stored in its knowledge bases.

Once the different graphical displays are identified, we have to specify the presentation and the dialogue associated to each of them. Interface objects are identified according to the user requirements deduced in step 2 of our approach (figure 1). Their presentations will, also, be chosen according to a knowledge based system, dealing with guidelines, in order to ensure the better ergonomic quality. At this level of abstraction, guidelines are more frequent and it is easier to formalize them (Moussa et al., 1999). Then, we have to model the dialogue component of the interface. For that, we consider that each graphical object presents a control structure. This control structure describes the evolution of the object’s state according to the system evolution and to the operator's actions. The Interpreted Petri Nets are, again, proposed for modeling the behavior of each graphical object. The HMS dialogue is, therefore, completely described by the different Petri Nets used for modeling the HMS dynamics and the control structures of the different UI objects (figure 1).

\[\text{Figure 1: Principle of specifications' generation using Petri Nets and guidelines.}\]

4 Conclusion

In order to study the efficiency of our approach, we are implementing the Petri net model in a C++ environment. Simultaneously, we are implementing a rule based system using a first inference engine and the object oriented paradigm. This system deals with guidelines concerning UI specifications. The validation concerns a simplified example of nuclear power plant. First results are planed to be published in near future.
5 References


