Field study techniques for supervisory control systems

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***Abstract*— Namahn, a Belgian User Centered Design consultancy, researches on methodologies for creating user centered designs for critical systems. In this context, we are currently conducting field studies at the signal cabins of the Belgian national railway organization. We devised a specific approach for conducting field studies in supervisory control systems, based on ethnomethodology, situation awareness, and mental models represented as an abstraction hierarchy. The field studies are particularly targeted at uncovering important aspects of human computer interaction for supervisory control: interaction among humans, interactions between the human operator and the computer, situation awareness, and decision making. The field study is aimed at providing a clear overview of the work environment, tasks and cognitive load of the signalers and of possible bottlenecks in the current way of operating.**

***Index Terms*— Patterns, methods and tools for field studies: situation awareness, ethnomethodology patterns; Multi-agent distributed decision making; Cognition-based approaches for awareness and decision support: abstraction hierarchy**

I. Introduction

Namahn, a Belgian user-centered design consultancy, decided to specialize in UCD for critical systems. These systems have stringent requirements in terms of error avoidance, efficiency and risk management. Performance errors are serious because of their enormous impact on human health, the environment or financial results. Typical applications are: aviation control, nuclear power plant management, medical applications, and trading tools. To design for these types of system, Namahn needs to acquire specialist knowledge, techniques and expertise. Additionally, design decisions need to be traceable and rooted in research findings. We are currently in the final quarter of a 2 years' research project funded by the Brussels Regional office for research and innovation (IWOIB/IRSIB).

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II. Research project on methodology for HCI critical systems

Our major goal concerns acquiring knowledge about models, theories and frameworks (further referred to as 'MTFs') that is useful in interaction design for critical systems, and translating that knowledge into practice-oriented and market-worthy methods. To this end, we adopted a three-step process, applied to a number of MTFs selected from [1]

* Ethnomethodology (ETHNO);
* Distributed Cognition (DC);
* Human Decision-making, stress and error (HDM);
* Mental Models (MM);
* Cognitive Work Analysis/Ecological Interface Design (CWA/EID);
* Human Visual Perception (PERC); and
* Motor Behavior Models (MOTOR).

A. *Project approach*

Our approach consists in taking three steps:

1) *Hypothesis*

Every MTF topic owner explores the literature and distills hypotheses about the applicability of ideas. These hypotheses address the question "How could we use this theoretical knowledge when designing for critical systems?"

2) *Validation (case studies)*

We test the value and our understanding of the hypotheses in case studies within client-like organizations. Four case studies have been set up in our target domain of critical systems:

a) Medical diagnosis:

a support tool for evaluating a patient's evolution on the basis of radiological images;

b) Medical decision making:

preoperative planning for maxillofacial surgery, based on the mapping of a model of chirurgical operations on a patient's 3d model

c) Configuration

of ground based satellite equipment

d) Supervisory control

of railway signaling equipment.

3) Consolidation

The lessons learned from the validation step are translated into methodology components, providing for each methodology component a definition, the applicability, a roadmap and resources.

Overarching the investigation of these models, theories and frameworks, we also work on the following methodological issues:

* Ontology: what is the essence of critical systems?
* Design rationale: how to make our decisions accountable?
* Lingua franca: following a recommendation of [2] to bridge the worlds of research and practice, we build a collection of terms and design patterns typical for critical systems.

B. Intermediary outcomes

During the first phase of the project the proposed MTFs were further evaluated on their applicability to critical systems and the case studies. We decided not to further investigate the following MTFs: Human visual perception and Motor behavior models (interesting but not specific enough to critical systems).

On the other hand, new MTFs were added: Risk assessment (RISK), Task analysis (TASK) and situation awareness (as a subtopic of human decision making). Also Cognitive Function Analysis [3] was added as a source of inspiration. More details about the project can be found in [4].

III. Case study: Validation of field study techniques

Our fourth case study focuses on the work of signalers in the signal cabins of Infrabel (the manager of the Belgian railway infrastructure). By conducting field studies, we aim to obtain a clear understanding of the cognitive and socio-technical dimensions of the work. The approach developed for these field studies is based on the MTFs below.

A. Ethnomethodology: patterns of interaction

During the field studies, we try to grasp the tacit knowledge and informal communication in the work environment by focusing on patterns of cooperative interaction. These consist of generalized findings of ethnomethodological studies that can be reused. Ref. [5] have specified ten of such patterns. Most of these patterns are not specific to critical systems, but they are recognized to be very important in field studies of critical systems. We will use them to structure our findings afterwards.

B. Situation awareness: goal structure with SA requirements

Situation awareness (SA) is important for effective decision making. It is closely related to the goals associated with a specific job. Therefore, we validate the goal-directed task analysis (GDTA) as a method for examining how SA can be supported in the signalers' work situation, as stated by [6]. Via observations and interviews, we attempt to uncover what goals signalers are seeking to achieve, which decisions need to be made for attaining these goals, and which information is required for taking these decisions. This information will be organized into a goal hierarchy, which contains the relevant SA requirements for each goal.

C. Mental models: abstraction hierarchy

To cope with problems in control of complex systems, an operator has to transform the problem to the appropriate level of resolution: some problems require a detailed view on the information, while for others, a high-level view is more appropriate so as to not make the problem unnecessary complex. Signalers thus need a good mental model of the railway infrastructure, which helps them in structuring the situation in several levels of complexity. We want to verify whether the abstraction hierarchy, as presented by [7], provides a good framework for representing such a mental model. We try to elicit the signalers' mental model on each level of abstraction in interviews, and later on, we will use this information to construct a mental model.

IV. Conclusion

We have presented our research project on MTF's that seem relevant in user-centered design for critical systems. With it, we have introduced the case study on the work of signalers. Currently, we are conducting the first field studies at the signal cabins, trying to validate our hypotheses on ethnomethodology, situation awareness, and mental models. In the workshop "Supervisory Control in Critical Systems Management", we will present preliminary results from our field studies and we would like to discuss the following issues:

-- *Ethnomethodology:* What is the added value of the patterns of cognitive interaction for interaction design? What can we do with the recognized patterns?

-- *Mental models:* We have met with difficulties in developing a field study approach for eliciting the abstraction hierarchy. We even wonder whether it is possible to create an abstraction hierarchy when not an expert ourselves. Are there any suggestions on a good approach?

-- Are there other MTFs that might be useful for conducting field studies in supervisory control systems?

Finally, we are also interested in the subsequent steps towards the design of critical systems, and in particular how the output of field studies determines interaction design decisions.

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