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Towards human-centred design: Two case studies

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Abstract

Currently much system development is done using a technology-centred approach: automating the functions the technology is able to perform. Human-centred design including a cognitive work analysis seems a promising alternative for systems combining skilled humans and automated support. Carefully selected information technology can support this innovative system development approach.

Two correlated case studies assess the merits and limitations of a human-centred approach. To improve human capacity while maintaining or preferably increasing current safety levels automated support is needed. Despite the long-term trend of increasing automated support, the human remains the major contributing factor in accidents and incidents. Combining these two observations substantiates the need for innovative system design. The described results are relevant for other domains relying on human experts supported by complex automated systems.

Keywords: Human-centred design; Complex systems; Human machine interface; Evolutionary management; Software safety

1. Introduction

Complex systems are characterised in Vicente (1999) as many people with different perspectives working together in a dynamic environment with uncertain data, unanticipated disturbances and with computer mediated actions. Humans are retained as not all circumstances can be foreseen, preventing full automation. Historically a technology-centred approach (provide what is technically possible without paying proper attention to the remaining human's task) is used. It is well known that humans are the most important contributing factor to aircraft accidents. Estimates for human involvement range from 60% to 80% of the total number of accidents (NASA, 2004; Kebabjian, 2004). In the last two European Air Traffic Management (ATM) induced accidents, human intervention caused the accident (Swiss mid-air collision of July 2002) or human limitations caused the accident (loss of situational awareness in the Lineate accident of October 2001). Interestingly an analysis of significant incidents in the, similarly safety conscious, nuclear industry shows human performance issues as the largest contributor, causing 52% of the incidents. Design deficiencies, the delayed consequences of human contribution, cause another 33% (INPO, 1985). Even in complex domains without safety concerns, like the fixed telephone network, human error accounts for 52% of the outages (Brown and Patterson, 2001). Surprisingly also in young industries, like Internet services with their continuous availability requirement, human error accounts for 44% of the service failures (Oppenheimer et al., 2003). From non-safety-conscious domains there are numerous examples that automation can actually reduce productivity if insufficient attention is paid to its design and the way it supports the human. For example (Vicente, 1999) states the US internal revenue service

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experienced a 40% productivity reduction after investing in personal computers. Two other studies (Landauer, 1995; Gibbs, 1997) show that investment in information technology in the US has even reduced the long-term economic growth rate. It is clear that there is a need for advanced tools to support well-trained professionals in complex and demanding environments. Attempts to reduce the reliance on human skills by increasing automation have led to the ''irony of automation''. Because in these complex environments not all failures can be foreseen, designers can reduce but not eliminate the need for human intervention. Consequently the human remains for the hard, i.e. unexpected, interventions. However as the routine operations are automated, the human has less experience and is less able to operate correctly in the rare instances that he is required (Reason, 1990).

Human-centred design is an alternative design method for complex systems that addresses such problems by focusing mainly on the user. Norman (1998) defines it thus: ''It's a process of product development that starts with users and their needs rather than with technology. The goal is a technology that serves the user, where the technology fits the task and the complexity is that of the task, not of the tool.'' The foundation of a human-centred design is a structured analysis of the users' tasks. Based on a thorough task analysis, the design process includes activities to ensure its focus on the human, like usability engineering, iterative design and prototyping.

Two case studies have been performed to test the applicability of the innovative human-centred approach. Air Traffic Management (ATM) is chosen as it is demanding, safety conscious and the current technology-centred approach is reaching its limits. Current air transport is affordable and safe, confirming the success of the traditional approach. For busy parts of airspace, communication between controller and pilot is already highly optimised, but the controllers still spend the majority of their time communicating. Historically airspace is divided into sectors to reduce workload, but for busy parts the added inter-sector communication of smaller sectors offsets the reduced controller-pilot communication.

The European vision 2020 (Argüeles et al., 2001) foresees a tripling of air traffic. Its goals include improving safety through a fivefold reduction of the accident rate despite the increased traffic density, while at the same time improving punctuality to 99% (i.e. flights arriving and departing within 15 minutes of schedule). Currently in busy parts of the airspace, e.g. above Frankfurt or Milan, punctuality is eight times worse at 92% (PRC, 2004). For various reasons, including safety, liability and social acceptability, the common opinion is that neither fully automated air traffic management nor fully automated aircraft are feasible options, so a complex system involving humans and computers remains. Simultaneously increasing the traffic density and the number of aircraft under his control will increase the demands on the human controller. New support tools are needed to enable the controller to cope with these requirements.

Section 2 briefly elicits the characteristics of a human-centred design process. Section 3 provides the context description, the findings and the analysis of the first human-centred design case, concentrating on Human–Machine Interface (HMI) issues as the most critical component. The first case combines human-centred design with the waterfall model, common in the domain due to its well understood way to provide software complying with the domain's safety and certification requirements.

Based on the findings of the first case, a follow-on case study has been performed, described in Section 4. In this case, human-centred design is combined with an evolutionary approach and object-oriented design.

The last section summarises the major findings into the conclusions.

2. Human-centred design

The often used ISO standard 13407 (ISO-13407, 1999) describes human-centred design as a multidisciplinary activity, which incorporates human factors and ergonomics knowledge and techniques to enhance effectiveness and productivity, while improving human working conditions. It states that there are four design activities that need to start at the earliest stages of a project: understand and specify the context of use, specify the user and organisational requirements, produce design solutions and evaluate designs against requirements.

Most of these activities are present in any design method, limiting the guidance offered by this standard. Fortunately, an improved version has been published as ISO TR 18529 (ISO-18529, 2000), which contains a more detailed list of the activities and 44 base practices. An in depth presentation of all practices is outside the scope of this paper. Some of the key activities are:

- identify and document the user's tasks;
- identify and document significant user attributes;
- allocate functions;
- produce a composite task model;
- use existing knowledge to design solutions;
- develop and evaluate (early) prototypes.

Including these activities in a design process ensures a continuous focus on the users of the system.

Task analysis is the process of analysing the way humans perform their jobs: the things they do, the things they act on and the things they need to know. This process will identify and document the user's tasks and sig-