Creativity in the Design of Complex Systems

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Abstract: This position paper describes applied research to support more creativity in the specification and design of complex socio-technical systems and in particular air traffic management systems. It summarizes a series of creativity workshops, the air traffic management projects to which they were applied, and results from these workshops for the projects. The paper ends with a short discussion and directions for future research into creativity in the requirements and design phases of complex systems development.

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Keywords: Requirements, Creativity, Innovation.

Introduction

There has been little work on introducing creativity into the development of socio-technical systems, though there are some exceptions, such as the work by Couger et al at the University of Colorado. The closest most projects will typically come to introducing creativity into the development process is through the use of brainstorming or RAD/JAD techniques where some constraints on idea generation are removed for a short period. The situation is worse still in the development of complex, and particularly safety-critical systems, where methods introduced to deal with complexity (such as the RUP (Jacobsen et al. 2000)) and to deliver safe systems (see, for example, Leveson et al. 2001) can sometimes limit innovation and creativity. Many methods adopt a reductionist approach that limits opportunities for combinatorial creativity, whilst the need to capture full rationale means that new ideas resulting from innovative thinking need extensive and time-consuming verification before their inclusion in a design.

Integrating creative techniques into the structured processes that are needed to handle complexity often complicates innovative design processes. In particular we need new techniques to integrate creative thinking with assessments of risk of tight coupling that are used to handle complexity and safety. The use of creativity in requirements processes can bring enormous benefits. Requirements are a key abstraction that can encapsulate the results of creative thinking about the vision of an innovative product. This vision can then inform the rest of the development process. Ours is a view shared by Couger (Couger 1989), who suggests that the use of creativity techniques nesr the conclusion of requirements definition can be particularly beneficial. However, this is a view that requirements engineering researchers and practitioners, with their current focus on elicitation, analysis and management, have yet to take on board.

In RESCUE, our integrated process for requirements engineering, we combine the systematic approach offered by structured methods with opportunities for real creativity. Processes and methods needed to model, analyze, specify and sign-off stakeholder requirements are integrated with creative thinking techniques as described below. We have applied this process in a number of UK and European large projects including CORA-2 (a socio-technical system for resolving conflicts between aircraft), DMAN (a system for managing departures from major airports), MSP (a multi-sector planning system for gate-to-gate) and EASM (a socio-technical system for enhanced airspace management). All of the systems were large and complex. The requirements process for each lasted a minimum of 10 months. The two completed projects – CORA-2 and DMAN – specified 22 and 15 use cases and 400 and 700 requirements respectively. The MSP and EASM systems are of a similar size. In each case, it has been deemed worthwhile to make a significant investment in the requirements process, and in particular, in the use of techniques that encourage creative thinking about future systems.

Managers in the domain of air traffic management are understandably cautious about big new ideas. Change is potentially risky, and very expensive, not least because of the need for extensive retraining of air traffic controllers. However, there is an inescapable need to move on from the technologies of the 1960's, including paper flights strips often still annotated by hand, in order to cope with increasing demand for air travel.

The RESCUE Process

RESCUE was developed by multi-disciplinary researchers at City University, working together with experts in the domain of air traffic management from Eurocontrol (Maiden et al. 2003a, 2003b), to help address this need. It supports a concurrent engineering process in which different modeling and analysis processes take place in parallel. The concurrent processes are structured into 4 streams. Each stream has a unique and specific purpose in the specification of a socio-technical system:

1. Human activity modeling provides an understanding of how people work, in order to baseline possible changes to it;
2. System goal modeling enables the team to model the future system boundaries, actor dependencies and most important system goals;
3. Use case modeling and scenario-driven walkthroughs enable the team to communicate more effectively with stakeholders and acquire complete, precise and testable requirements from them;
4. Requirements management enables the team to handle the outcomes of the other 3 streams effectively as well as impose quality checks on all aspects of the requirements document.

Creativity workshops normally take place after the system boundaries are specified, to discover and surface requirements and design ideas that are essential for system modeling and use case specification Inputs to the workshops include the system context model from the system goal modeling stream and use case diagrams from the use case modeling stream.

Creativity Workshops in RESCUE

Creative workshop activities were designed based on 3 reported models of creativity from cognitive and social psychology. Firstly, we design each workshop to support the divergence and convergence of ideas described in the CPS model (Daupert, 2002). As such each workshop period, which typically lasts half a day, starts from an agreed current system model, diverges, then converges towards a revised agreed model that incorporates new ideas at the end of the session. Secondly, we design each workshop period to encourage one of 3 basic types of creativity identified by Boden (Boden, 1990) – exploratory, combinatorial and transformational creativity. Thirdly, we design each period to encourage 4 essential creative processes reported in (Poincare 1982): preparation, incubation, illumination and verification. The incubation and illumination activities are determined by the type of creativity that we seek to encourage. Figure 1 depicts the creativity workshop structure and demonstrates examples of outputs from the DMAN workshop, which are typical of what might be expected from a creativity workshop of this kind. Within this workshop framework, we implement a range of creativity techniques – from brainstorming and analogical reasoning to encourage exploratory to storyboarding for combinatorial creativity and constraint removal for transformational creativity.

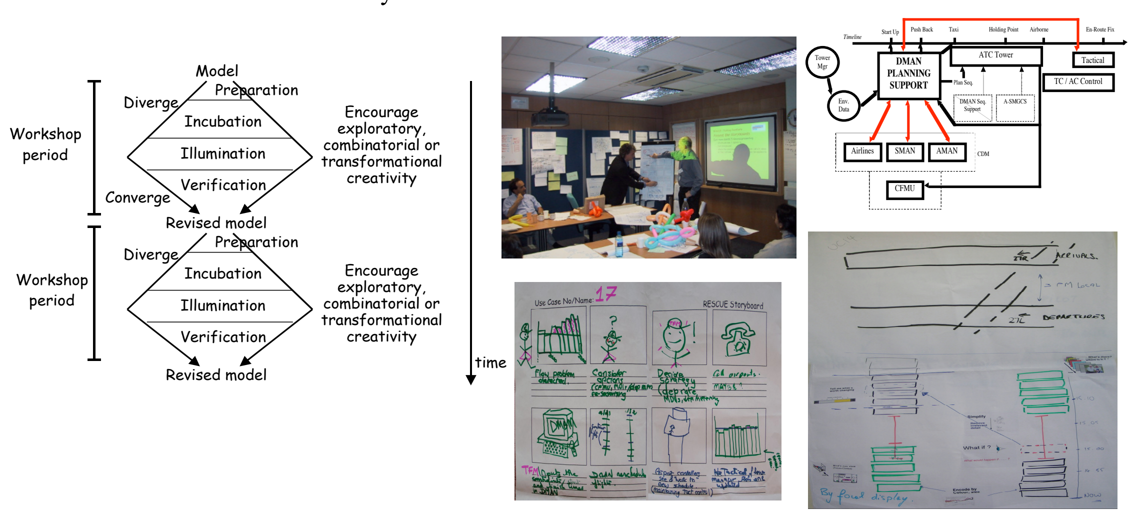

Figure 1. Clockwise from the top-left – the structure of a RESCUE creativity workshop, a typical workshop environment, an emerging system architecture resulting from combinatorial creativity, a visualization of controller information displays resulting from transformational creativity, and a storyboard depicting behaviour specified in one use case specification.

Discussion and Future Work

The DMAN operational requirements document was delivered to the client in 2004 and provided us with the chance to analyze the outcomes from the creativity workshop on the final requirement document to determine their impact, as reported in Maiden & Robertson (2005). This analysis revealed important associations between results of the creativity workshop and elements of the use case specification, which in turn led to more detailed scenarios that were walked through to discover and document more requirements for the DMAN system. Although we do not claim that these requirements would not have been discovered and documented without the creativity workshops, we do report an association between the workshop outcomes and their documented discovery later in the requirements process.

We are also using workshop data to validate and extend a descriptive model of creative requirements engineering based on models that underpin the workshop design (Boden 1009, Daupert, 2002, and Poincare 1982). We are using protocol data to investigate life histories of creative ideas from conception to verification, and linking these histories to patterns of stakeholder communication and artifact use. We believe that these models have general applicability to the design of interactive systems of which air traffic management systems are an example.

Finally, we are also investigating how to integrate creative thinking techniques into other RESCUE sub-processes. One limitation is that the creativity workshops are expensive and time-consuming, so fostering and guiding creative thinking within other sub-processes involving fewer stakeholders is desirable. Therefore, we are currently exploring how to extend the ART-SCENE scenario walkthrough tool (Mavin and Maiden, 2003), designed to ensure requirements correctness and completeness, to support creative thinking.

Acknowledgements

The authors wish to thank all of the workshop participants, and acknowledge the support of Eurocontrol, NATS and Sofreavia in the development of the paper.

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