Complexity, Requirements and Design

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To an extent we know what causes complexity: multiple interacting entities and uncertainty in their interaction. Similarly we know how to reduce it- modularity, loose coupling, improved reliability and reduced uncertainty. However, we also know the world is never going to become less complex and accommodate our desires for abstraction and simplicity. So do we just throw our hands up in despair over human fallibility in designing complex systems in the face of an uncertain world ? I will argue that we need to take a new look at modelling and the horizon of knowledge, and from there to decide how much complexity can be designed into a system a priori, or left to adaptation as the system evolves to deal with change. Complexity therefore intersects with requirements and architecture theme in the workshop and no doubt others.

Modelling in RE and Systems Engineering is somewhat limited. For instance, we are only just starting to take some of the complexity of humans in the system on board; for instance, we are long way from applying social network analysis to collaborative systems design. The role of the environment is also not modelled with much sophistication, although some better exemplars of environmental modelling can be found in safety critical applications where the influences of weather, organisational culture, legal restrictions, and hardware artefacts have to be considered. RE could learn from modelling schema in safety critical systems engineering. However, representing the world in static models is only part of the answer. To understand complex systems, dynamic interacting models with multiple sub systems are necessary. Such simulations exist in physical domains (e.g. weather forecasting) and exhibit reasonable predictive accuracy. The challenge here is to understand **interactional complexity** which is tractable by mathematical modelling here the behaviour of multiple, interacting entities can be described in a series of simultaneous equations.

In larger scale socio technical systems the predictive accuracy of complex models has a mixed track record (e.g. the UK Treasury model of the economy) or the models are largely untested against reality (e.g. military war-game simulations). Nevertheless, I will argue that simulation is way forward for dealing with complex systems. You might not anticipate the future accurately but the act of modelling and running simulations will teach you something about the world; furthermore, as the models mature, the degree of accuracy will rise, as even the weather forecasts demonstrate. There are interesting trade offs in the cost-benefit ratio of simulations, how much effort you can devote to building them, how accurate is the baseline of knowledge for constructing them and the fidelity of the design insights gained from simulations.

The second approach to dealing with complexity is to partially finesse the problem and design flexible, open ended and evolvable system architectures which can deal with changes in the environment. The key issue here is to identify the horizon of knowledge and hence design for the known unknowns. Fitting a future space of

Dagstuhl Seminar Proceedings 08412
Perspectives Workshop: Science of Design : High-Impact Requirements for Software-Intensive Systems
http://drops.dagstuhl.de/opus/volltexte/2009/1985

requirements to flexible composable architecture can be helped by adopted a scenario brainstorming approach to try to map out the space of future possibilities. However, scenario based approaches always suffer from the completeness of coverage problem and can't deal with the unknown unknowns. Part of the challenge in socio technical systems is to address **semantic complexity** in understanding each other's concepts and theories in a multidisciplinary effort to deal with complex at the social and psychological level. Another part is to understand **intentional complexity** where the agents within our model (people) have minds of their own. Semantic and intentional complexity are not so directly amenable to mathematical modelling, although agent based models with intent and complex beliefs might provide a way forward.

Complexity research and future scenario generation needs further consideration. Many organisations practice future analysis with scenario based techniques, this needs to be combine with model based impact analysis, bringing in my initial theme of simulation modelling. The intersection of complexity, requirements and architecture highlights the need for research on adaptation, composition and evolution of software so new solutions can be produced to complex systems incrementally as needs and understanding emerges with experience. This follows the norm of incremental or normal engineering familiar in other disciplines, e.g. complex avionic systems have developed over 20 years since fly by wire was invented. Complex socio technical systems which are notoriously prone to failure, i.e. government systems may well benefit from incremental engineering as administrative and social norms emerge; unfortunately government is prone to perpetual change and additional complexity as politicians interfere with the social process. Considering the complexity of socio technical systems complexity might involve morphing requirements engineering into economic, socio and political science. There is no escape from complexity in society and global scale physical systems, the best we can do is to research, model and simulate with a time-cost budget, and design for resilience and adaptability.

AGS
October 2008