Evolution in AmI: Multidisciplinary Research Perspectives Enhancing Dependability and Security in AmI

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1 On Evolution of Socio-technical Systems

The Ambient Intelligence (AmI) paradigm in the 6th EU Framework has opened new research and practice challenges[1]. The AmI paradigm further extends the vision of socio-technical systems. Despite the fact that the system approach[2] highlights that any system indeed consists of heterogeneous parts, the development (generally, the entire life cycle) of (socio-)technical systems is mainly technology driven. The system approach therefore emphasises a comprehensive viewpoint highlighting the interaction among heterogeneous parts. On the one hand the design and deployment of these systems continously shape the Information Society (IS). On the other hand these systems are socially shaped[3].

Heterogeneous engineering[4] stresses a holistic viewpoint that allows us to understand the underlying mechanisms of evolution of socio-technical systems. It is possible to analyse socio-technical systems from an evolutionary viewpoint. This highlights a taxonomy of evolution, as a conceptual framework for the analysis of the evolution of socio-technical systems. The evolutionary framework extends over two dimensions, from *Evolution in Design* to *Evolution in Use* and from *Hard Evolution* to *Soft Evolution*, that define an evolutionary space for socio-technical systems (see Figure 1). Evolution in Design and Evolution in Use capture the system life cycle perspective (or temporal dimension). System evolution can occur at different stages of the system life cycle. Evolution in design identifies technological evolution mainly due to designers and engineers and driven by technology innovations and financial constraints. With respect to technical systems, evolution in use identifies the social evolution due to social learning. Social learning involves the process of fitting technological artefacts into existing socio-technical systems (i.e., heterogeneous networks of machines, systems, routines and culture). Whereas, Hard Evolution and Soft Evolution capture different system viewpoints in which evolution takes place (or physical dimension). Each viewpoint identifies different stakeholders. This dimension therefore reflects how stakeholders perceive different aspects of socio-technical systems. Hard[5] evolution identifies

[1] IST Advisory Group. Trust, dependability, security and privacy for IST in the FP6. Report, June, 2002

[2] "Practitioners and proponents embrace a holistic vision. They focus on the interconnections among subsystems and components, taking special note of the interfaces among various parts. What is significant is that system builders include heterogeneous components, such as mechanical, electrical, and organizational parts, in a single system. Organizational parts might be managerial structures, such as a military command, or political entities, such as a government bureau. Organizational components not only interact with technical ones but often reflect their characteristics. For instance, a management organization for presiding over the development of an intercontinental missile system might be divided into divisions that mirror the parts of the missile being designed.", A. C. Hughes and T. P. Hughes (Eds.). Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After. The MIT Press, 2000, INTRODUCTION, p. 3.

[3] The mechanisms underlying the social design and implementation of technology systems are referred to as the *Social Shaping of Technology* (SST) [R. Williams, D. Edge. The Social Shaping of Technology. Research Policy, 25(6):865-899, 1996.; D. A. MacKenzie, J. Wajcman (Eds.). The Social Shaping of Technology. Second edition, Open University Press, 1999.].

[4] "People had to be engineered, too - persuaded to suspend their doubts, induced to provide resources, trained and motivated to play their parts in a production process unprecedented in its demands. Successfully inventing the technology, turned out to be heterogeneous engineering, the engineering of the social as well as the physical world.", D. A. MacKenzie. Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance. The MIT Press, 1990, p. 28.

[5] "Hard systems viewpoints are basically those held by designers and engineers who are trying to create systems to meet an understood

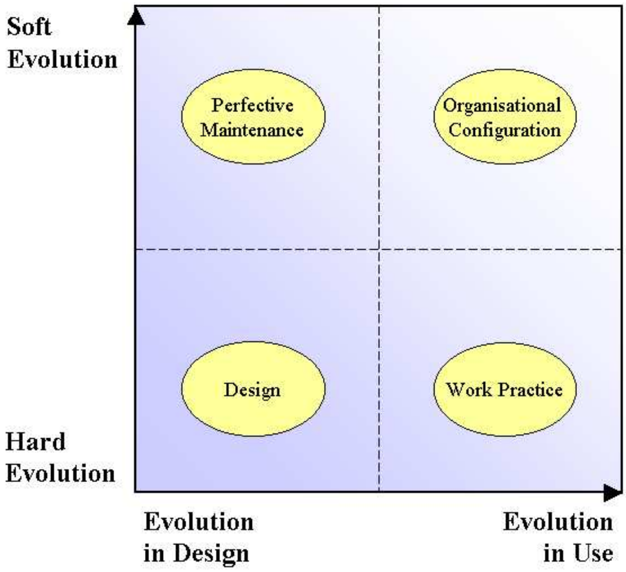

Figure 1: Evolutionary space for socio-technical systems.

the evolution of technological artefacts (e.g., hardware and software). Whereas, soft[6] evolution identifies the social evolution (e.g., organisational evolution) with respect to these technological artefacts. Soft evolution therefore captures the evolution of stakeholder perception of technical systems.

Figure 1 shows the evolutionary space for socio-technical systems. The space captures different evolutionary aspects of socio-technical systems. For instance, the combination of hard evolution and evolution in design identifies evolutions (e.g., software and hardware) that take place during system design. Other parts of the space identify other evolutionary aspects of socio-technical systems. Another example is the combination of hard evolution and evolution in use. This identifies those evolutions due to technology innovations. Any technology innovation will result in changes in the work practice . Although people adapt their work practice to new technology, most of the time new technology tends to affect (catastrophically in the worst case) work practice. Dually, the combination of soft evolution and evolution in design easily characterises perfective maintenance driven by system usage and evolving requirements. Finally, the combination of soft evolution and evolution in use captures socio-technical systems as organisations. Thus, evolution in socio-technical systems often require careful configuration management at organisational level. Previous research has limitedly investigated these evolutionary phenomena as a whole. Therefore, it is challenging to investigate how the different evolutionary phenomena interact each other. Moreover, the investigation of the different evolutionary phenomena will allow us further to understand how evolutionary failures propagate across the space. In other words, the comprehensive investigation of the evolutionary space will reveal the mechanisms that allow the emerging or the mitigation of evolutionary failures. The identification of a broad spectrum of evolutions in socio-technical systems points out strong contingencies between system evolution and dependability. Socio-technical failures are often failures to evolve. On the other hand evolution can generate failures. We argue that the better our understanding of socio-technical evolution, the better system dependability. Moreover, this stresses the ubiquitousness and pervasiveness of

need in an effective and economic manner. Those in the soft camp caricature the approach as *head-down*, concerned with optimization, obsessed with quantitative metrics and highly pragmatic. So much so, in fact, that the term *system thinking* has been purloined by the soft camp as though they alone thought! The soft camp use the term *engineer's philosophy*, not too endearingly, to describe the hard approach, in which the requirement is stated by a customer and the engineer satisfies the requirement without question.", D. K. Hitchins. Putting Systems to Work. John Wiley & Sons, 1992, p. 6.

[6] "Soft systems viewpoints are those held by behavioural, management, social anthropology, social psychology and other science students concerned with observing the living world, and in particular the human world. Human activity systems (HASs) are *messy*, in that they do not exhibit a clear need or purpose - if they can be said to exhibit purpose at all. Indeed, so complex is the real world of people that the idea of driving towards optimal solutions may be a non-starter - perhaps we should see if we can simply understand and concern ourselves with improving the situation.", D. K. Hitchins. Putting Systems to Work. John Wiley & Sons, 1992, p. 7.

socio-technical systems. Hence, IS is highly dependent on the "correct" functioning of these systems. Moreover, the topology of the IS stresses how socio-technical systems represent a critical infrastructure for the modern society.

2 From Socio-technical Systems to AmI

In order to understand socio-technical systems, it is important to understand the role of the environment(s) in which these systems are developed and deployed. Socio-technical systems are open, as opposed to closed, with respect to their surroundings. The interactions between socio-technical systems and their environments (which often involve other socio-technical systems) highlight the social shaping of technology. Although this comprehensive understanding allows us to characterise socio-technical systems (with respect to their environments), it provides limited support to understand the mechanisms supporting *sustainable* socio-technical systems. This is due to the lack of methodologies addressing the evolution of socio-technical systems. On the one hand many technology driven methodologies rely on the strict management of socio-technical configurations. On the other hand this inhibits the evolution of socio-technical systems. The AmI paradigm captures the shift from characterising to sustaining evolving socio-technical systems. Although the AmI paradigm points out new scenarios for socio-technical systems, it partially addresses the fully integration of socio-technical systems in the IS. Technological aspects are still strong drivers for the dependability in AmI.

Evolution emerges as a new way of looking at socio-technical systems, hence AmI. Although the evolution of socio-technical systems is a desirable feature. On the one hand evolution allows the capturing of emerging social needs. On the other hand evolution allows the mitigation of socio-technical failures. Unfortunately, current methodologies still have severe limitations with respect to the evolution of socio-technical systems. Therefore, as the understanding of the role of the environment represents a shift from technical to socio-technical systems, evolution represents a shift from socio-technical systems to Ami.

3 Evolutionary Dependability in AmI

We think that future R&D should address the following points.

1. Formal investigation of observational models will allow us to capture evolution of socio-technical systems. Evolution stresses new insights in the life cycle of socio-technical systems as well as of AmI. Moreover, this will further address the understanding of evolution in enhancing the dependability and security of Ami. On the other hand evolutionary models will enhance our ability to observe and analyse socio-technical failures.

2. Evolution presents a challenge for future R&D. Evolutionary problems often arise at the system level. This requires a comprehensive viewpoint that is not covered by any single discipline, hence the need for multidisciplinarity. Unfortunately, multidisciplinary R&D is still patchy. In order to address the AmI challenges, future R&D should further address multidisciplinarity. Furthermore, multidisciplinarity should also inform the deployment of (technology) innovations (e.g., by enhancing transfer of multidisciplinary knowledge). Moreover, future R&D should further stress multidisciplinarity in Ami. This highlights that R&D should be socially engaged in order to address the AmI challenges.

3. Evolution therefore has a pivotal role in addressing dependability and security in Ami. This highlights that the most common system development cycles provide limited support for the evolution of socio-technical systems. AmI further stresses the limitations of development life cycles with respect to evolution. Moreover, development cycles rely too often on strict verification paradigms that inhibit evolution itself. Therefore, we believe that future R&D should identify new "development paradigms" that fulfil the AmI perspectives. This will require tight collaborations between Industry and Research Centres. Moreover, future R&D should be socially driven, as apposed to technology driven. In order words, AmI requires socially engaged R&D.