Embedding IoT in Large-scale Socio-technical Systems: A Community-Oriented Design in Future Smart Grids

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Abstract In traditional engineering, technologies are viewed as the central piece of the engineering design, where the physical world consists of a large number of diverse technological artifacts. The real world, however, also comprises a huge amount of social components – people, communities, institutions, regulations and everything that exists in the human mind – that have shaped and been shaped by the technical components. Smart urban ecosystems are examples of such large-scale socio-technical systems that rely on technologies, particularly IoT, within a complex social context where the technologies are embedded. Despite that the two aspects are deeply intertwined, designing applications that embed IoT in large-scale socio-technical systems is slowly transitioning from a traditional engineering approach towards a socio-technical approach. The latter has not yet entered the mainstream of design practice. In this chapter, we present our experience of adopting a socio-technical approach in designing a community-oriented smart grid user application. The challenges, implications and lessons learned are discussed. The chapter is concluded by offering a set of good design principles derived from this experience, which are also relevant to the design of other smart urban ecosystems.

1 Introduction

The traditional science and engineering philosophy is dominated by technological determinism, the idea that technology determines societal development [7, 10, 12]. Within this reductionist view, technologies are the central piece of the engineering design, where the physical world consists of a large number of diverse technological

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artifacts. The plausibility of this view is challenged by the socio-technical systems view [13] which argues that technological and social development form a "seamless web" where there is no room for technological determinism or the autonomy of technological systems [2]. The latter view is premised on the interdependent and deeply linked relationships among the features of technological artifacts or systems and social systems (i.e. the mutual constitution) [10], since the man-made world also comprises a huge amount of social components – people, communities, institutions, regulations, policies and everything that exists in the human mind – that have shaped and been shaped by the technological components [4, 13]. Engineering design is hence identified as a process through which technologies materialize into products, a process that substantively shapes and reshapes our lives and societies and vice versa [5]. This focus on socio-technical interconnectedness becomes even more visible in designing new emerging technologies [5].

Smart cities, for example, use technologies such as Internet-of-Things (IoT) within a large complex social context where they are embedded. The goal is to facilitate the coordination of fragmented urban sub-systems and to improve urban life experience [3]. The rise of the IoT has important socio-technical implications for people, organizations and society – it is obvious that connecting devices is possible, we yet know little about its implications [11]. A socio-technical perspective can be insightful when looking at dynamic technological development and when considering sustainable development [11]. Although socio-technical systems have been studied for decades, socio-technical approaches are relative new to the design and systems engineering communities [1, 9, 10]. Such approaches are not widely practised despite growing interests [1].

Through this chapter, we review the literature and present our experience of adopting a socio-technical approach in designing a community-oriented smart grid user application. We discuss the challenges, implications and lessons learned from this design experience, and conclude the chapter by offering a set of good design principles which are also relevant to the design of other smart urban ecosystems.

2 Designing in Large-scale Socio-technical Systems

The term "socio-technical" embodies both a research perspective and a subject matter [6]. The socio-technical systems view can be articulated as the recognition of three fundamental concepts [10] as follows. First, the *mutual constitution of people and technologies*. This mutual constitution generates complex and dynamic interactions among technological capacities, social norms, histories, situated context, human choices and actions, etc. Second, the *contextual embeddedness of the mutuality*, where the context is not taken as fixed or delineable. There are dynamic situational and temporal conditions that influence mutual adaptations throughout the course of design, development, deployment and uses of the system of interest. Third, the *importance of collective action*, the joint pursuit of one or more shared (potentially conflicting) goals by two or more interested parties such as problem owners, shareholders, users, communities affected (without implying positive or negative outcomes). The collective action shapes and is shaped by both the context and the technological components.

Researchers who hold a socio-technical systems view investigate more than just the technological system or just the social system or even the two side by side, but also the phenomena that emerge when the two interact [6]. A socio-technical approach tries to abstain from oversimplifications that seek a single or dominant cause of change, but studies the complexity, dynamic and uncertainty in the networks of institution, people and technological artifacts in the process of technologically involved change [10]. Taking a socio-technical approach towards design has a number of implications for (i) the formulation of the design problem, (ii) the products of the design process, and (iii) the design process itself (BootCamp, BC?).

Then the section proceeds with discussing the three implications (1) making relation to the three fundamental concepts (2) using the literature mentioned (can be expanded) in the next grey box

Understanding and formulation of the design problem or situation The understanding and formulation of the design problem

It is not straightforward what needs to be taken into consideration in relation to the design. What systems boundaries to choose. the question of systems boundaries is an issue for technical systems and even becomes more difficult for social technical systems what are the issues to be addressed.[BC]

Ill-structured problem

Products of the design process these not only consists of technological artifacts but also may include rules for behaviour, policies, etc. through which the designer wish to intervene in social-technical systems. what is it that we are designing?

Design process The design process can be seen as a decision-making process where the problem owners, shareholders, users, etc. participate to represent their interests. It is often conceived and implemented in participatory decision-making processes actively involving stakeholders

Large-scale socio-technical systems are often not designed as a whole but incrementally "piece by piece" evolving from legacy systems (BC). Designers are therefore working *in* the context of some socio-technical system with the intention of changing or improving some part of that system [BC]. This means that what matters more in the design is the design process itself, more than the "final status" of the system [11, **?**] because the socio-technical system keeps evolving and exhibits emergent behaviour [8]. An important goal of the design process is to make the design (a product or system) relevant to the evolving context [11, **?**] as social and technical artifacts exist within their socio-technical context [BC].

can be put in the discussion: acontextual and detemporalized perspective approaches , general solution ., is self-limiting focus on situating work and seek to examine all contextual factors , this types of inquiry attempt to construct a holistic view of context: one that does not diminish or remove contextual elements, even those with limited influence. paying little attention to the environment of the organization and temporal dimension of technological innovation [10]

Use and combine content in: (the literature can be connected, e.g. problems mentioned in Norman and Baxter can be mapped to the four layers in Whitworth)

1. [9] (design problems in large-scale socio-technical systems) and
2. [1] (socio-technical approach to systems engineering)
3. [14] (four system levels of Socio-tehnical systems);
4. [11] (a very good article about IoT, socio-technical perspective)
5. see also https://medium.com/rettigs-notes/notes-on-sociotechnical-systems-design-178f161bc9e8

3 CIVIS: A Community-Oriented Design in Future Smart Grids

Discuss the CIVIS project making relation to the previous theory section.

The discussion shall not be limited to the app YouPower, but also the other efforts made around it (if they are related to the discussions in the previous section), e.g. the user stories, focus groups workshops, interviews, participatory budgeting, etc.

Use the YouPower paper as much as possible.

3.1 Understanding and Formulation of the Design Situation

3.2 Products of the Design Process

3.3 Design Process

or call it participatory design process?

4 Discussions

Lessons Learned? / Design Guidelines?

5 Conclusions

Run-in Heading Italic Version Use the LaTeX automatism for all your cross-references and citations as has already been described in Sect. **??**.

Type 1 That addresses central themes pertainng to migration, health, and disease. Blablabla

Type 2 That addresses central themes pertainng to migration, health, and disease. Blablabla

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Fig. 1 If the width of the figure is less than 7.8 cm use the `sidecapion` command to flush the caption on the left side of the page. If the figure is positioned at the top of the page, align the sidecaption with the top of the figure – to achieve this you simply need to use the optional argument `[t]` with the `sidecaption` command

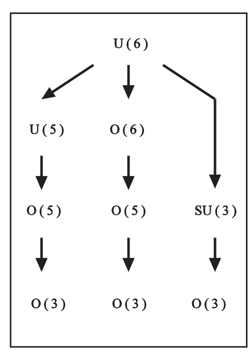

Table 1 Please write your table caption here

Classes	Subclass	Length	Action Mechanism
Translation	mRNA[a]	22 (19–25)	Translation repression, mRNA cleavage
Translation	mRNA cleavage	21	mRNA cleavage
Translation	mRNA	21–22	mRNA cleavage
Translation	mRNA	24–26	Histone and DNA Modification

[a] Table foot note (with superscript)

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