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Abstract

Designing Socio-Technical (ST) systems requires the designer to account for the intrinsic and interrelated characteristics of the tasks, actors, technologies, and environment. Requirements analysis informs the design of information systems. However, few approaches have emerged to analyze requirements for ST systems, which is considered complex, time consuming, and requires a large body of knowledge. In this paper we present a process model that aims to help identifying ST systems requirements. The process model assumes that ST systems characteristics of tasks, actors, technologies, and environment can help identifying a set of ST imbalances that in turn helps in the identification process of requirements. The applicability of the process model is demonstrated by identifying example requirements of self-care systems and results are presented.

Keywords (Required)

Socio-Technical Systems, Requirements Analysis, Requirement Elicitation, Self-care

Introduction

Baxter and Sommerville (2011) refer to Socio-Technical (ST) systems design methods as "an approach to design that considers human, social and organizational factors, as well as technical factors in the design of organizational systems". The main premise of ST work and system design approaches is to have an equal weight for the technical and human factors in the design process (Mumford, 2006).

Nine ST design principles are identified by (Cherns, 1976, 1987) and revised later on by Clegg (2000). These principles include compatibility, minimal critical specifications, the ST criterion, the multi-functionality principle, boundary location, information flow, support congruence, design and human values, and incompletion. The principles are applied to the design of new systems and they attempt to provide a more integrated perspective than is apparent in existing formulations.

ST systems requirements analysis is considered complex, time consuming, and requires a large body of knowledge. This is because such systems do not consist only of the technical dimension, but also consist of the social dimension which is difficult to deal with because it requires information about people, organization, and processes. As a result, there is a need for a new approach for eliciting requirements of ST systems that allows the analysis of the main component of a ST system, namely task, actor, technology, and structure, as well as the interaction between these components.

In this study, we propose a process model that helps in identifying system requirements based on the ST model (Lyytinen & Newman, 2008). The ST model components, namely task, actor, technology, and structure are used to identify a set of ST imbalances based on a set of properties of each component. Then, the set of imbalances are used to inform the identification of system requirements, both functional and non-functional. The applicability of the process model is demonstrated by identifying example requirements of self-care systems and results are presented.

The rest of the paper is structured as follows. In section 2, we discuss related work in the field of requirements elicitation and ST systems. Next we describe the proposed ST requirements elicitation process model including the ST model components and ST imbalances. In section 4, we demonstrate the applicability of the requirements elicitation process model using a case study example in self-care. Finally, in section 5, we present a summary of the paper, key findings, and future work.

Related Work

In this section we provide a discussion about related work in the field of requirements elicitation as well as the ST system design. In the first subsection, we provide a discussion about ST system design and the main components of any ST system. In the second sub-section, we provide an overview about requirements elicitation for ST systems

ST Systems

In the context of information systems a ST system (Figure 1) can be modeled as a collection of four components, namely tasks, actors, structure, and technology and their inter-relationships (Leavitt, 1964; Lyytinen & Newman, 2008). Tasks describe the goals and purpose of the system and the way work/activities is accomplished. Actors refer to users and stakeholders who perform and influence the work/activities. Structure denotes the surrounding project and institutional arrangements while technology refers to tools and interventions used to perform the work/activities. Each of the components is identified at the work system level, the building system level, and the organizational environment. Gaps or ST imbalances are identified for the combinations of the components, namely task-actor, task-structure, task-technology, actor-structure, actor-technology, and structure–technology.

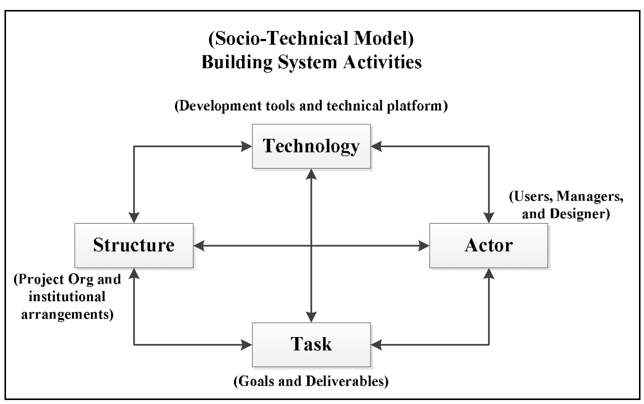

Figure 1. Components of a ST System (Lyytinen & Newman, 2008)

Requirements Elicitation for ST systems

Requirements engineering is considered one of the software engineering phases that has its own distinct research area. Requirements derive the whole software development process, especially during the design phase where much of the system's qualities are identified (Gross and Yu 2001). Software systems requirements engineering "is the process of discovering and identifying stakeholders and their needs, and documenting these needs in a form that is amenable to analysis, communication, and subsequent implementation" (Nuseibeh & Easterbrook, 2000).

Requirements elicitation is the process of seeking, identifying, discovering, acquiring, and elaborating information systems requirements (Zowghi & Coulin, 2005). In literature, few requirements elicitation methods for ST systems have been addressed. Bryl, Giorgini, and Mylopoulos (2009) have proposed a tool that supports the process of requirements analysis for ST systems. The proposed tool adopts several planning techniques that can be used for exploring the space of requirements alternative and the number of social criteria for evaluation. RESCUE is an integrated method proposed by Jones and Maiden (2005) for specifying requirements for complex ST systems. RESCUE integrates several components that were used to elicit requirements for ST systems. These components include, human activity modelling, creative design workshops, system goal modelling using the *i** notation, systematic scenario walkthroughs, and best practice in requirements management.

Sutcliffe and Minocha (1999) proposed a method for analyzing ST systems requirements by analyzing dependencies between computer systems and users/stakeholders in an operational environment. Also, the authors have used the domain scenarios that describe the system and its context to build an environmental model based on *i** notation. The Inquiry cycle is another method that uses scenarios in order to determine barriers or obstacles that arise in the social dimensions of the system, on the other hand, stakeholder analysis methods are used for requirements modeling based on different user categories or viewpoints (Potts, Takahashi, & Antón, 1994). Finally, Yu (1997) stated that using model of dependencies among people and systems using *i** notation of enterprise models enables assessing the impact of different technical solutions, as well as giving techniques for trade-off analyses between conflicting goals and non-functional requirements.

Mavin and Maiden (2003) suggested the use of scenarios for eliciting requirements for ST systems. Generating and walking through scenarios is considered one of the effective techniques for electing requirements. Systematic walkthroughs of simple scenarios with less domain knowledge are more effective for discovering the necessary requirements. Also, ethnographic techniques have been used for eliciting ST systems requirements by gathering the necessary data on social issues and then generating the requirements from such data (Sommerville & Sawyer, 1997).

Overall, most of the proposed models for requirements elicitation only focus on specific methodologies or techniques (Hickey & Davis, 2004). These models include but not limited to models that use scenarios (Holbrook III, 1990), using models that combines scenarios, prototypes, and design rationale (A. G. Sutcliffe & Ryan, 1998), communication-based model of elicitation (Browne & Rogich, 2001), and using viewpoints to elicit requirements (Sommerville, Sawyer, & Viller, 1998). Moreover, using such techniques results in less generalizable models or analytic methods for requirements and that the quality of the elicited requirements depends on the practitioner's experience (Sutcliffe & Minocha, 1999).

None of the proposed methods for eliciting ST systems requirements is based on the idea of the ST imbalances between the ST model components. So, there is a need for a new method for eliciting requirements of ST systems that focus on both the social and technical aspects of the ST system, and inform the generation of a comprehensive list of requirements based on the ST model itself rather than using traditional methods such as scenarios and communication models.

Design Methodology

We use the design science research methodology to develop a method for eliciting requirements of a socio-technical system. According to Hevner, March, Park, and Ram (2004) "design science research must produce a viable artifact in the form of constructs, models, method or instantiation". In this research, we develop a new method for eliciting requirements for socio-technical systems. The proposed method is of significant relevance to practitioners and software developers as it provides a methodical approach for uncovering the social dimensions of a problem domain and for incorporating them in the requirements specification, thus enhancing the utility of the information system and improving chances of successful adoption.

In order to design and develop the artifact, we rely on a knowledge base of requirements elicitation frameworks, socio-technical models, and behavioral research on the use and adoption of technology. Specifically we leverage the knowledge-base to identify social and technical dimensions of a problem domain and map them to past literature and case studies describing success and failures of information system implementations attributed to the understanding or the incompleteness of the problem requirements. We then use an iterative process to further refine the mapping to ensure comprehensiveness of our proposed method. The resulting method or process model is described in detail in the next section, followed by a demonstration of the feasibility of the method by applying it to the problem domain of self-care systems.

ST Requirement Elicitation Process Model

A new method for eliciting requirements for ST system is proposed in this section. The new method consists of a process model that is made up of three main components, namely ST model components, ST model imbalances, and ST design requirements.

ST requirement elicitation process

Figure 2 shows the overall ST system design requirements identification process. The process model starts by defining the four main ST components, namely tasks, actors, structure, and technology and their inter-relationships. ST model imbalances describe the gaps between the components of the ST model, these imbalances are identified at the properties level of the components with examples from the literature. Once a set of imbalances are identified, an example set of design requirements that address these imbalances and inform the design of the ST system is provided.

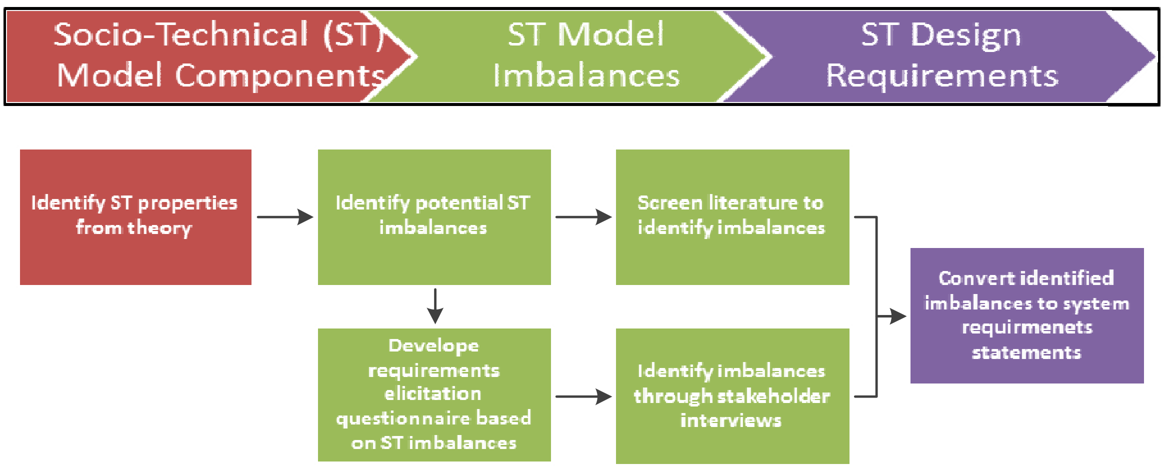

Figure 2. Socio-Technical System Design Requirements Identification Process

ST Model Components

As discussed before, the ST model consists of four main components, namely tasks, actors, structure, and technology. In order to provide a comprehensive list of ST imbalances that can help identifying ST system requirements, it is necessary to provide a list of properties that define each of these components. The task component is defined using four properties namely importance to health maintenance, resources, difficulty, and interdependence. Importance to the goal encompasses whether tasks are performed in a job, if performed, how important they are (Hogan, Hogan, & Busch, 1984). Resources are defined in terms of task frequency, the cost of the task, or time required performing the tasks. Task difficulty encompasses the degree of "(non)-routineness" (Gorry & Morton, 1971), structuredness (Simon, 1960), and analyzability (Perrow, 1967). Finally, task interdependence is the degree to which a task is related to other tasks and the extent to which coordination with other organizational units is required (Thompson, 2011).

The actor component consists of four main properties namely cognitive/personal factors, behavioral factors, attitude, and subjective norms. Cognitive/personal factors are defined in terms of actors' knowledge and expectation (Bandura, 1977), where expectations is defined as "the satisfaction derived from the favorable consequences of the behavior becomes linked to the behavior itself, causing an increased affect for the behavior" (Bandura, 1986), and knowledge is defined as "condition-specific factual information, and beliefs related to personal perceptions about the specific health condition or health behavior" (Ryan, 2009). Behavioral factors are defined in terms of actors' skills and self-efficacy (Bandura, 1977), where skills is defined as "those personal, social, cognitive and physical skills that enable people to control and direct their lives and develop the capacity to live with and produce change in their environment" (Kickbusch & Nutbeam, 1998), and self-efficacy is people's perception of their ability to plan and take action to reach a particular goal (Bandura, 1977). Attitude is a "mental or neural state of readiness, organized through experience, excreting a directive or dynamic influence on the individual's response to all objects and situations to which it is related" (Allport, 1935). Finally, Subjective Norm is defined as "the person's perception that most people who are important to him think that he should or should not perform the behavior in questions" (Fishbein & Ajzen, 1975).

The structure component is defined using four properties, namely communication processes, authority, workflow, and economics. Communication processes is defined as "the means by which messages are spread, including mass media, interpersonal channels, and electronic communications" (Oldenburg & Glanz, 2008). Authority is defined as "the patient's grant of legitimacy to the physician's exercise of power, on the assumption that it will be benevolent" (Haug & Lavin, 1981). Workflow is defined as "systems that help organizations to specify, execute, monitor, and coordinate the flow of work items within a distributed office environment (Ellis, Keddara, & Rozenberg, 1995). Finally, health economics is defined in terms of methods and theories from traditional economics and epidemiology and can serve as an important supplement to the routine clinical information used by medical and health care programs (Gillian & Braden, 2002).

The technology components are defined in terms of three properties, namely functionality, usefulness, and ease of use. Technology functionality is defined in terms notification, communication, information access, and data processing, where notification has to with alerts and emails that can be accesses and reach immediately, communication include different means of interaction such as phone conversations and email writing, information access is all about reaching the necessary information using search functionality, finally, data processing involves workflow based system, such as electronic procurement and expense reporting (Gebauer, Shaw, & Gribbins, 2005). Ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989). Finally, ease of use is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance (Davis, 1989).

ST Imbalances

The major imbalances between socio-technical elements in the model are shown as gaps; these gaps are identified for the combinations of the four main socio-technical components' properties. The Task-Actor gaps are related to actors' capabilities and other actors' related attributes that influence their ability to perform a task, the task-structure gaps arise when the structure's components are not aligned with the task, the task-technology gaps arise when technology is not adequate to support the tasks, and actor-technology gaps occur when any of the identified actors do not understand, cannot operate, or do not accept the technology, and finally, the actor-structure gaps occur when actors do not know the operating procedures and do not accept the structure.

ST imbalances reflect the gaps that need to be addressed in the design of the new ST systems. As described before, ST imbalances are defined for the combination of properties of the ST model components. For example, in order to identify imbalances related to the task and actor components, we identify the combination of properties of the task and actor components. This will results in a total of sixteen imbalances categories as shown in Table 1. Similar tables have been developed for the remaining combinations of the ST model components but are not included due to space limitations.

Table 1. Task-Actor Imbalances

Task-Actor	Importance to the goal	Resources	Difficulty	Interdependence
Personal Factors - Cognitive Factors	Imbalances related to actors' knowledge and expectations, and importance of a task to achieve desired goal.	Imbalances related to actors' knowledge and expectations, and frequency, cost, or time required performing the tasks.	Imbalances related to actors' knowledge and expectations, and the degree of task's (non)-routineness, structuredness, and analyzability.	Imbalances related to actors' knowledge and expectations, and the degree to which a task is related to other tasks and the extent to which coordination with other organizational units is

				required.
Behavioral Factors	Imbalances related to actors' skills and self-efficacy, and perception about the importance of a task to achieve desired goal.	Imbalances related to actors' skills and self-efficacy, and frequency, cost, or time required to perform the tasks.	Imbalances related to actors' skills and self-efficacy, and the degree of task's (non)-routineness, structuredness, and analyzability.	Imbalances related to actors' skills and self-efficacy, and the degree to which a task is related to other tasks and the extent to which coordination with other organizational units is required.
Attitude	Imbalances related to actors mental or neural state of readiness, and the importance of a task to achieve desired goal.	Imbalances related to actors mental or neural state of readiness, and task frequency, cost of the task, or time required performing the tasks.	Imbalances related to actors mental or neural state of readiness, and the degree of task's (non)-routineness, structuredness, and analyzability.	Imbalances related to actors mental or neural state of readiness, and the degree to which a task is related to other tasks and the extent to which coordination with other organizational units is required.
Subjective Norms	Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the importance of a task to achieve desired goal.	Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and task frequency, cost of the task, or time required performing the tasks.	Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the degree of task's (non)-routineness, structuredness, and analyzability.	Imbalances related to actors perception that most people who are important to him think that he should or should not perform the task, and the degree to which a task is related to other tasks and the extent to which coordination with other organizational units is required.

ST Design Requirements

Imbalance between the social and technical aspects of a system are considered gaps that can produce problems in current systems and need to be addressed for better design of ST systems. ST problems can be solved by eliciting a set of requirements that can inform the design of a ST system that account for both technical as well as social dimensions of the system. Requirements elicitation is based on the set of ST imbalances from the previous section.

Case study demonstration in self-care

Background

Self-care and self-management are defined as activities that individuals engage in to promote health or manage chronic health conditions (Akinson, 2001). Current advances in mobile, sensor and other information technologies is making possible the development of advanced information technology (IT) applications, to support self-care and promote patient empowerment. However, the ongoing adoption and effectiveness of many applications is limited as they do not take into consideration the complex Socio-Technical (ST) aspects of the self-care process resulting into many imbalances.

Leveraging IT for self-care, self-management, and patient empowerment require adopting a holistic ST perspective. In a review of literature on self-care systems, El-Gayar, Sarnikar, and Wahbeh (2013) argued that ST considerations are also applicable to information systems for self-care, self-management, and patient empowerment. However, there is limited guidance on how the ST model can be incorporated into an information systems design process.

Self-care System Imbalances

Imbalances represent gaps among different ST model compoenents' properties. Based on the defined imbalances for the task and actor components, an extensive literature review is carried out in order to identify relevant examples that fit for each of the imbalances. The review is done using the ST components properties as the search keywords. Due to space limitations, we only included one of the six tables to demonstrate the examples of ST model imbalances for self-care systems. Based on the literature review, a total of 46 example ST imbalances have been identified for the self-care systems. Table 2 demonstrates ST examples for the task-actor components of the ST model.

Table 2. Examples of ST model imbalances in systems of self-care

Task-Actor	Importance to the goal	Resources	Difficulty	Interdependence
Cognitive	Individuals do not possess the requisite knowledge to perform self-care tasks (Thrasher, 2002)	Unrealistic patient expectations and demands can make evidence based cost less effective and efficient (Wagner, Austin, & Von Korff, 1996)	Expectations for self-care autonomy exceeding the patients' cognitive and behavioral capabilities may compromise adherence and diabetic control (Wysocki et al., 1996)	NA
Behavioral	Individuals do not learn skills to perform self-care tasks as they believe it will not help in improving their condition (Riegel et al., 2009)	Patients are not able to keep on top of needing different medication at different time – scheduling and coordination of medication (Bayliss, Steiner, Fernald, Crane, & Main, 2003)	Due to differences in technical skills, abilities and learning styles, patients find it difficult to perform specific tasks because they did not gain a comprehensive knowledge of how to perform these tasks (Siobhan et al., 2012)	NA
Attitude	Users lack of motivation for performing self-care task (Thrasher, 2002)	The lack of financial support for IT applications is a major barrier to adoption (Anderson, 2007)	Negative attitude toward insulin therapy is associated with a general lack of understanding of the progressive nature of diabetes (Marrero, 2007).	Negative patient attitude toward insulin may be due to a reluctance to add yet another medication to their daily regimen (Marrero, 2007)
Norm	Family members are not supportive or believe in the importance of self-care tasks (Dunbar, Clark, Quinn, Gary, & Kaslow, 2008) .	Lower frequency of self-monitoring blood glucose (SMBG)is associated with the lack of family support that negatively affect adherence for SMBG (Fisher, 2007).	Diabetes patients show that low support from their family was associated with making their diabetes more serious (Skinner, John, & Hampson, 2000)	NA

Results: ST derived system requirements

Requirements elicitation is based on the set of ST imbalances examples derived from the previous section. A list of self-care system requirements have been derived based on the 46 example imbalances. A sample example requirements as well as example implementations for some of the self-care ST system imbalances are demonstrated in Table 3.

Table 3. Examples Requirements for Self-Care ST Systems

Imbalance	**Example requirement**	**Example implementation**
Patients do not possess the knowledge of self-care and are unaware of its importance.	The system should provide knowledge of health condition and self-care practices.	"Did you know?" HealthTips module for providing knowledge.
Patients do not learn skills to perform self-care tasks as they	The system should provide evidence based knowledge and testimonials	Evidence Knowledge-base and e-learning videos on self-care and

believe it will not help in improving their condition	showing importance of self-care practices to health maintenance	health maintenance.
Knowing importance of self-care is not enough to motivate users to perform self-care.	The system should provide motivational mechanisms to perform self-care.	Gaming analogy and point system for performing self-care.
Family members are not supportive or believe in the importance of self-care tasks	The system should provide the means for family to track patients' performance on self-care tasks and health maintenance.	Use of instant messaging functionality that can help share patients' self-care related information between families and care providers.

Conclusion and Future Work

Requirements analysis and elicitation of ST systems requires the designers to take into consideration different properties that are related to the ST model components. In this paper we present a process model for ST requirements elicitation that is based on the ST model for information systems. The process model starts by defining the ST model components and components properties for ST systems. Using these components' properties, a set of ST imbalances are defined for ST systems. Based on the ST imbalances, a set of design requirements can be generated that address these imbalances. The applicability of the process model is demonstrated using a case for ST system design that support self-care in the context of heath-care. Using the process model, we generate a list of ST imbalances definition and for these definitions, we provide a list of ST imbalances examples that apply for self-care system, finally, we generate an example list of ST requirements for self-care systems based on the example imbalances..

Based on the literature, the proposed process model for ST requirements elicitation is considered unique. None of the previous method for ST requirements analysis and elicitation considered the use of the ST model components to inform the process of eliciting requirements for ST systems. The proposed process model provides a systematic, comprehensive, and generalizable approach to capture imbalances commonly found in ST systems. In demonstrating the applicability of the proposed requirements elicitation process model for self-care systems, we show that social aspects of the ST system play a major role in designing ST system in addition to the technical dimensions, and that self-care systems are considered complex systems that requires effort and time in the analysis phase of system design. Designing information technology solutions for supporting self-care requires a holistic and socio-technical understanding of self-care processes.

Future work will focus on modeling requirements for ST systems, especially non-functional requirements. Properly dealing with requirements, especially non-functional requirements (NFRs), is also considered complex and time consuming. We are planning at modeling functional and non-functional requirements using the Goal, Problem, Causal, and Solution framework and validating the framework by showing its applicability in the consumer health domain.

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