UNIVERSITY
OF TRENTO

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38050 Povo – Trento (Italy), Via Sommarive 14
http://www.disi.unitn.it

SOCIO-TECHNICAL SYSTEMS IN ICT: A COMPREHENSIVE SURVEY

Alexis Morris

September 2009

Technical Report # DISI-09-054

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Alexis Morris

University of Trento
morris@disi.unitn.eu

Abstract. Socio-technical systems research aims to optimize two of the most important parts of the organization, the social network, and the technological network. The field is highly multi-disciplinary, and covers a host of issues, ranging from the management of complex systems, teams and work groups, interactions, and cognitive factors. Many approaches in the literature have adopted aspects of the socio-technical ideas, leading to four general perspectives. Depending on the view of the organization, solutions proposed are either those of the abstract organizational scientist, the social scientist, the technologist/engineer, or the complex systems engineer. This work surveys the field with these perspectives in mind, and highlights literature exploring such systems.

1 Introduction

> *"All organizations are socio-technical systems; that is no more than a definition, a tautology."* - Albert Cherns, [1]

In every organization, whether consisting of humans, machines, or natural phenomena (such as a flock of birds, or school of fish), the principles of complex systems are at work. In the natural world, seemingly chaotic processes result in unexpected patterns and behaviors that quite often stabilize to some form of real equilibrium (similar to Adam Smith's invisible hand theory in economics). The components of such system may be rational, semi-rational, or non-rational actors, each effecting its neighbour, and also the entire organization. Thus such organizations may be controlled at the lowest levels, of individual interractions between components, thus controlling facets of the higher "meta" levels. This introduces the field of complex and emergent systems engineering (see books like [2] for more) where the focus is on the appropriate design and study of such systems, and their behaviors. For the purposes of this paper complex organizational systems are those that involve rational, and semi-rational actors(whether human, or artificial). Non-rational components of such systems are regarded as parts of the environment; tools for use by these actors.

One problem is how such systems may be coerced into a form of "controlled chaos" where desirable properties of emergent systems may be derived through appropriate mechanism designs, [3]. In organization sciences, this control is seen in varied forms and structures of management, from traditional hierarchical chains of command, to distributed, democratic, and decentralized teams, [4]. This notion arose in the 1940's/1950's research of factory workers organized into units of production that was initially controlled by the speed of conveyer belt technology (see [4], or [5]), which thereby controlled the speed of outputs of the overall factory system. The problem with this form of control was that it formed rigid work hierarchies that did not use the full capacity of its human rational agents. This form of organization is termed "technological determinism" and was the study of the 1950's researchers, Emery and Trist ([6], [4]) and their focus on work practices. They performed onsite-analyses of such factories, and discovered that the problems of efficiency in such organizations related directly to its lack of balance between its human and physical resources. Their work promoted the idea that organizations are "open systems" [1] according to Bertalanffy's theory (for physics and biological systems) [7]. They also justified the need to address the social aspects of the system.

> *"Every organic form is the expression of a flux of processes. It persists only in a continuous change of its components...this maintenance involves continuous change of the systems of next lower order: of chemical compounds in the cell, of cells in multicellular organisms, of individuals in superindividual life units...[so] every organic system is essentially a hierarchical order of processes standing in dynamic equilibrium..."* - Von Bertalanffy, [7]

This fascinating connection was used by these researchers to justify that the components of organizations, "individuals in superindividual life units", needed to be in equilibrium. What Trist and Emery realized was that the social, human needs of early factories were not in equilibrium with the technological abilities of the same organizations. Their work showed that bridging this inequity resulted in considerable improvements in the quality and structure of the organizations studied [8], [9]. Their pioneering work sparked the beginnings of the discipline of socio-technical systems (STS).

1.1 The Purpose of this Paper

In this work, the broad field of socio-technical systems (STS) is surveyed and presented according to four key perspectives found in the literature. The principle objective is to show the breadth of socio-technical systems work, and to discuss the theory, analysis, design, and engineering of such systems. Section 2 overviews the concept in more detail, describing the definitions, characteristics, principles and the general importance of the paradigm. Section 3 describes the differences in perspective relating to the STS. Section 4 discusses literature approaches

[1] "A system is closed if no material enters or leaves it; it is open if there is import and export and...change of the components." Being open means a system is able to adapt to changes in the environment as well as display other properties, such as it may reach a steady operational state, [7].

according to the perspectives mentioned previously. Section 5 provides a short discussion and concludes the paper.

2 Socio-technical Systems(STS)

Definition: A concise definition of such systems is difficult to pinpoint in the literature, due to its abstract nature. Majchrzak and Borys , [10], note that the concept is based on open systems theory, but at the same time is "a philosophy and a methodology...a paradigm consisting of a conceptual scheme..., a design process, a set of values about work, contextual conditions..., and an historical tradition based on psychology, sociology and workplace research." Griffith and Dougherty, in their discussion of the role of such systems in engineering and technology management, [11], defines the STS perspective as "organizations [that] are made up of people (the social system) using tools, techniques and knowledge (the technical system) to produce goods or services valued by customers (who are part of the organization's external environment)." The definition most in line with the ICT field is that of Baxter and Sommerville, [12], that socio-technical systems are "systems that involve a complex interaction between humans, machines and the environmental aspects of the work system."

Continuing with the definition in [12], the STS is composed of people, machines, and the environmental context where they interact to produce organizational goods/services. These three factors, and the relationships between them provide the foundation for STS studies. Socio-technical analysis represents the longstanding efforts of Emery, Trist, and the Tavistock Institute [5] (in the 1950's to present day), and provided ethnographic studies/"action research" of work environments. Socio-technical design explored the methods of structuring the social system so as to make it self-managing. Socio-technical engineering, a more recent term, [12], aims to bridge failures in complex systems by continuously bringing systems engineers and stakeholders to consider the social environment during the systems design life-cycle. This is especially targetted towards software engineering, to reduce software failures through social context awareness and considerations.

2.1 Characteristics and Principles of STS

Incidentally there are various synonymous terms in the literature that describe similar systems that are more or less socio-technical, as defined above. Some of these are: Techno-social System, Cyber-physical System, Ensemble Engineering, Software Intensive System, Holarchies, Actor-Network Theory, Agent-oriented Mechanism Design, Autonomic Computing, and Societal Computing. Baxter and Sommerville, have provided one of the most comprehensive surveys of the field from the ICT perspective, [12], and have singled out several key characteristics of any such systems and base principles for socio-technical design. They also motivate the need to combine insights and achievements of five key communities into a single unifying discipline of Socio-technical Systems Engineering (STSE).

Key communities in socio-technical research: There are many aspects so the STS research, but several are key to future advances in the field (according to [12]). These are:

- Designers of work, and workplace.
- Information systems.
- Computer-supported cooperative Work (CSCW).
- Cognitive systems engineering.
- Human-computer interaction.
- Ubiquitous computing

Key characteristics of socio-technical systems: This section notes how to distinguish a socio-technical system, according to general characteristics, from [12].

- They have interdependent parts.
- They can adapt to changes in the environment in order to pursue goals.
- They have an internal environment as well as a real world environment.
- They have separate, but interdependent, technical and social subsystems.
- They operate in an environment where there is the existence of choice/decision-making.
- The joint optimisation of the system depends on optimising each subsystem.

Further, Trist describes the following characteristics of STS as a paradigm, showing how the STS research approach is different from technological determinism. The figure 1 shows this in detail.

Old Paradigm	*New Paradigm*
The technological imperative	Joint optimization
Man as an extension of the machine	Man as complementary to the machine
Man as an expendable spare part	Man as a resource to be developed
Maximum task breakdown, simple narrow skills	Optimum task grouping, multiple broad skills
External controls (supervisors, specialist staffs, procedures)	Internal controls (self-regulating subsystems)
Tall organization chart, autocratic style	Flat organization chart, participative style
Competition, gamesmanship	Collaboration, collegiality
Organization's purposes only	Members' and society's purposes also
Alienation	Commitment
Low risk-taking	Innovation

Fig. 1. This figure, from [4], shows the fundamental differences between socio-technical systems as a paradigm versus its predecessor, technological determinism. It also shows alot of the characteristics unique to such systems

Key Principles of socio-technical systems: Several principles for STS design are advanced in literature, but the most popular is that of Cherns ([5], [4], [6], [11], [10], etc). Other approaches to STS design in the same paper include cognitive work analysis, contextual design, cognitive systems engineering, among others. The important point is that STS design principles are well studied, but have failed to be adopted into practice for various reasons, which may be corrected through unifying the areas mentioned previously. Cherns, [1], notes that *social systems* have four subsystem functions that must exist in any successful system, and hence must be observed by designers. They must:

- Attain the goals of the organization
- Adapt to the environment
- Integrate the activities of the people, and resolve conflicts
- Fill occupational roles via recruitment and socialization.

Chern's latest guidelines are below, taken from [12], as they help to describe the requirements of socio-technical design and are also useful in describing the important factors of the STS approach.

1. Compatibility: the process of design should be compatible with the design objectives (i.e., processes should be highly participative).
2. Minimal critical specification: whilst objectives should be specified, the means of achieving them should not be.
3. Variance control: variances should be controlled at source (and should not be exported across boundaries).
4. Boundary control: boundaries should not be drawn so as to impede sharing of information, knowledge or learning.
5. Information flow: information should be provided to those who require it when they require it.
6. Power and authority: those who need equipment, materials, or other resources to carry out their responsibilities should have access to them and authority to command them.
7. The multifunctional principle: individuals and teams should take on multiple roles to increase their response repertoires.
8. Support congruence: supporting systems and sub-systems need to be congruent. (e.g., planning, payment systems and career systems)
9. Transitional organization: periods of transition require planning and design, and transitional organizations may be different from the old and the new systems, and are themselves subject to socio-technical design.
10. Incompletion: redesign is continuous and is the function of self-regulating teams.

2.2 Importance of the Paradigm

In short, the socio-technical theory is relevant because of its focus on balance and equilibrium of the entire organization, people, machines, *and* contexts. There are several questions that are the driving forces behind the socio-technical literature. The first asks why systems fail, in general, why even well designed technology may end up producing less than efficient results that do not meet stakeholder's expectations. This centers on how to handle the unpredictable factors of the social environment. The second question is how to improve the organization through giving the social system equal attention and optimization. This is expressed in this foundational quote by Baxter and Sommerville, [12]:

> *"The failure of large complex systems to meet their deadlines, costs, and stakeholder expectations are not, by and large, failures of technology. Rather, these projects fail because they do not recognize the social and organisational complexity of the environment in which the systems are deployed. The consequences of this are unstable requirements, poor systems design and user interfaces that are inefficient and ineffective."*

Hence, the recognition of social context, and the organizational background context should be forefront in software and systems engineering. Additionally, the STS paradigm promotes self-management within organization teams, leading to democratization of work practices, and decentralized decision making. These allow the organization to adapt to changing contexts, and variances, ending up with systems that are more "open," that maintain a steady state (meeting production goals, objectives, etc), without compromising quality of outputs, or quality of working life.

3 Socio-technical Perspectives

The field of socio-technical systems, from the ICT perspective, sits in the class of "software intensive systems" [2], which are those "that involve complex interactions between software components, devices and social components (people or groups of people), not as users of the software but as players engaged in common tasks", [13]. In the literature the definition of such systems centers clearly on the existence of social and technical core subsystems (see [6], [11], [13], [12]). The relationship between the two subsystems is cyclical and based on mutual support between the two. The human/rational social system needs the technical system to perform tasks, and the technical system depends on the social system for common usage, validation, control, and other tasks requiring rational or even knowledgeable actors. Interaction between these different systems, and the context of such interaction has an impact on the organizations abilities to reach its stakeholder goals. See figure 1 for a graphical description of this notion.

In particular, there are at least four differing viewpoints in the literature about such systems, namely that of the social scientist, the technology engineer, the organizational scientist and designer, and the complex systems engineer. These disciplines represent the interdisciplinary research conducted in the area of social sciences, organizational sciences, engineering, and complex systems. The social sciences literature often regards the STS as a toolset to improve the quality of working life of people within the system ([5], [8]). The opposite perspective of the technologists/engineers focuses primarily on building quality technology systems that have quality assurances (based on common practices). The organizational scientist's viewpoint is more central, aiming to manage real stakeholder goals (efficiency, profits, etc) through the design of an appropriate organizational construct, including perhaps a management structure/hierarchy for the social system, and obtaining the best technological support, and hiring the right persons, [1], [9]. The fourth is that of the complex systems engineer, which explores interactions and contexts in order to orchestrate each component locally, as steps towards meeting the global organizational goals. This viewpoint is also central, and has many open problems, aiming at the creation of adaptive technological systems that support and anticipate human decision-making, work-tasks, and communication criteria as an autonomous computing system. This approach is among the newest to become available, and relies on the advances of technology, and the ubiquitous nature of computing and sensor-networking [2], [14], [15].

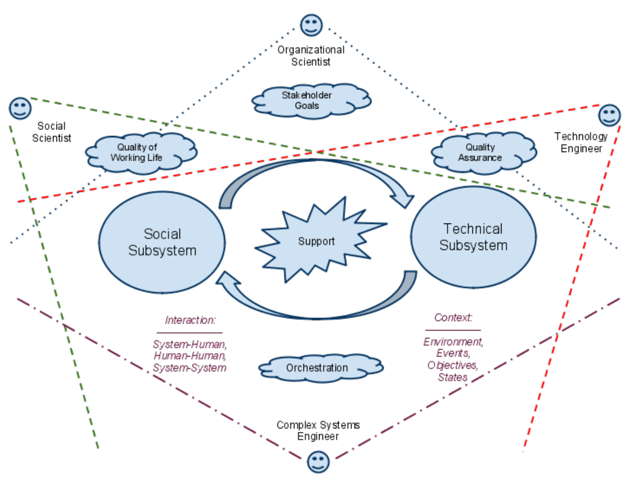

Fig. 2. This figure shows the main components of a socio-technical system from various viewpoints.

4 Literature Summary

Although the literature involved in socio-technical systems is a vast corpus it may be discussed in a topical fashion according to the four perspectives focused on previously. This survey looks briefly at organizational sciences, social sciences, technology from the ICT perspective, and complex systems literatures.

4.1 STS in Organizational Informatics

The Organizational scientist must consider both social and technical perspectives in order to meet important objectives; to achieve stakeholder goals; to optimize the organizational unit according to the needs of the environment. There is some overlap with social and technological viewpoints, for quality of working life and quality assurance of the product. Both organizational and social aspects of STS literature have accepted the reality that technology in the form of information systems have changed the landscape of the traditional organization in a host of ways. In the literature there is agreement that the new way of doing business is knowledge based, as well as product based, and organizations have had to install support mechanisms for both approaches [9], [16].

Kling and Lamb, [17] have explored the socio-technical approach to organizational informatics in digital economies, and have noted the difficulties organizations have in implementing and adopting information systems successfully. They explore four subsectors of digital economic organizations, namely highly digital goods and services, mixed digital goods and services, IT-intensive services or goods production, and segments of IT industry supporting the former three. Figure 3 shows the organizational informatics comparison between standard tools and socio-technical ones. It is important to highlight the impact of politics on systems, and inter-organizational relationships.

Standard (Tool) Models	SocioTechnical Models
IT is a tool	IT is a sociotechnical system
Business model is sufficient	Ecological view is needed
One shot implementation	Implementation is an ongoing social process
Technological effects are direct and immediate	Technological effects are indirect and involve different time scales
Incentives to change are unproblematic	Incentives may require restructuring (and may be in conflict with other organizational actions) (Section 3.1)
Politics are bad or irrelevant	Politics are central and even enabling (Section 3.2)
IT Infrastructure is fully supportive. Systems have become user-friendly, people have become 'computer-literate," and these changes are accelerating with the "net-generation"	Articulation work is often needed to make IT work. Socio-technical support is critical for effective IT use. (Section 3.3)
Social relationships are easily reformed to take advantage of new conveniences, efficiences and business value.	Relationships are complex, negotiated, and multi-valent. (Section 3.4)
Social effects of IT are big but isolated and benign	Potentially enormous social repercussions from IT (Section 3.5)
Contexts are simple (described by a few key terms or demographics)	Contexts are complex (matrices of businesses, services, people, technology history, location, etc.)
Knowledge and expertise are easily made explicit	Knowledge and expertise are inherently tacit/implicit
IT infrastructure are fully supportive	Articulation needed to make IT work

Fig. 3. A comparison of Standard tool models to socio-technical tool models in organizational informatics research, from [17]

The impact of trust on organizations and interorganizational relationships is also important. The social aspect of trust has been studied for a long time, and the notion has been formalized for use in various domains. One pioneering work is by Mayer, et al [18], which provided "an integrative model of organizational trust." Trust facilitates decentralized decision making, which in turn improves flexibility, and response time (reactivity) in the overall system. Second, it facilitates undistorted communication amongst social actors, which improves the accuracy of information flowing through the social system. Third, trust allows different organizations and teams to make smooth partnerships and negotiations (See [19] for more on the centrality of trust in organizations facing crises). In the technical system trust involves the design of technologies that promote security, reliability, dependability, and privacy. These aspects target the functioning of the information system itself, in its overall goal of supporting system actors. The trustworthiness aspect will be dependent on the trustworthiness of the information systems of each separate organization involved, and the trustworthiness of the channels of distribution or communication between them. Other works in this area involve Jarvenpaa and Leidner, [20], on trust in global virtual teams; Panteli and Sockalingam, on inter-organizational alliances, [21], and Handy's work on trust and the virtual organization, [22].

4.2 STS in Social Informatics

The social scientist, or socio-technical designer, takes the social system into consideration first, and the technical system afterwards, usually with a focus on quality of working life. They aim to balance the prevalent technological determinism, that since humans are unpredictable they must be monitored heavily, and constant controls must be in place to manage them. Mumford, [5], notes this well, that "a primary objective of socio-technical projects was to ensure that both technical and human factors should, whenever possible, be given equal weight in the design process...[and] employees who used the new systems should be involved in determining the required quality of working-life improvements." Essentially, this "value system" is the driving force for the socio-technical designer. In [23] the author mentions successful system design criteria, namely knowledge, resource, psychological, organizational, and ethical capability. These core competences are promoted for designers, and several methods with this philosophy are seen in [23] and [12]. Some successful design approaches are Mumford's ETHICS (Effective Technical and Human Design of Computer-based Systems) approach, and Checkland's Soft System Methodology. Participative design and ethnographic approaches are used along with design methodologies to gather requirements and construct a system (see [5]).

A series of relevant papers are published in the 2002 special issue of Journal of Engineering and Technology Management (JET-M), aimed at looking "Beyond socio-technical systems." [11]. These works include research aimed at clarifying the what, how, and why of STS theories, in systematic detail. They aim to define technology, improve the understanding of work, and social processes under the three-point theme: advancing beyond technological determinism, industrial efficiency, and rational/functional thinking. These papers urge that systems thinking is important, and call upon technology researchers to expound its definitions. Social construction, interaction management, laws, and the fit between social and technical systems are discussed along with organizational learning, actor-network theory, and self-organizing systems. Majchrzak and Borys, [10], provided a testable, and repeatable STS enhanced approach, which is important since the lack of such approaches have contributed to the disuse of the STS paradigm in software engineering (according to [12]). These works, according to Griffith, [11], follow "a critical insight...that STS has not only continued to grow beyond its original boundaries, but may even be beyond some of the most cutting-edge theories in development today...[thus] continues to move beyond technological determinism, beyond industrial efficinecy, and beyond rational/functional thinking."

Finally, Kling, [24], describes the contribution of social informatics in information technology when considering changes in context and cultural demographics. He presents early research, key ideas of information technology as socio-technical networks, and generally why a social context matters.

4.3 STS in Information Communication Technologies

The technology engineer has a perspective that puts the technological system to be developed as the primary output; usually the social system is limited to concepts of "user" and "stakeholder". The objectives therefore are motivated by productive quality assurance and meeting stakeholder goals where possible, usually taking into consideration some aspects of the context of the system. While there are many works in socio-technical design that could fit this category, those mentioned below have the aim of a more practical STS, through information systems design. Usually this involves a single, intra-organizational system. There are a number of domain examples where these approaches are seen as well, including health informatics [25], crisis management [26], [27], [28], accident modelling [29], and decision support [30].

Unlike similar work in organizational theory that have crossed over into computer science (business processes is one popular example), it has been difficult for STS systems techniques to become adopted in the software engineering community. This is primarily because of very wide interpretations of the subject. Baxter, [12], summarizes these problems as: inconsistent terminology in defining the technical and social systems, difficulties in finding proper levels of abstraction, conflicting value systems, lack of agreement on success criteria, lack of synthesis of ideas, multidisciplinarity of the field, failure to keep up with current advances, and problems of defining details needed in fieldwork. All these have made STS design less attractive to the software engineering community, but while these present considerable obstacles, the field is regaining attention (eg. [26], [31], [32], [29], [33], [34], [15]). "There is still a role for humanistic, socio-technical ideas" that give "equal focus to the employee as to the non-human system," [12]. In answer to this problem, recent work has proposed to develop the discipline by using STS design throughout the systems engineering life cycle ([12], [32]).

Socio-technical Systems Engineering (STSE) was introduced in 2008, [12], and represents the notion of providing usable STSD methodologies and tools for software engineers in order to improve complex systems engineering. While significant research is being done in this area (such as the Indeed project, [35],

[31], and some aspects of the Tropos project, [36]), there are many open problems that remain.

> *"There is a need for current socio-technical methods to evolve into a discipline...where a socio-technical approach pervades the entire systems engineering life-cycle"* [12].

In order to accomplish this evolution Baxter and Sommerville focus on development and analysis of a methodology to bridge the systems engineering process to the change process in an organization. The way this is achieved is through "sensitisation" discussions (bringing STS concerns to stakeholders at design time) and through "construction engagement" (STS concerns are raised during implementation). This methodology is new, and presents many open problems. One point is that it is largely a manual procedure. Figure 4 shows this in more detail. As a means of supporting the design of such systems, Sommerville relies on the technique of responsibility modelling and ethnography [35]

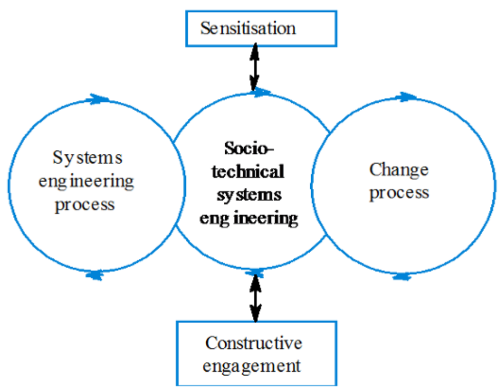

Fig. 4. The sociotechnical systems engineering process is shown here, as seen in [12]. Note that the gap between the systems engineering and change processes are handled by manual sensitisation and constructive engagement activities.

In a paper on socio-technical systems in health informatics, Coiera, [25], addresses the fact that the contextual assumptions of technological systems limit their adaptability, and cause unintended "failures". In the medical domain such variances lead to serious, and costly consequences for patients and patient care organizations. He proposes a lofty goal of creating an STS autonomic system that can sustainably design and reconfigure itself. This, he notes will require "process automation, knowledge management, and enhanced communication and interaction between health care workers." He advocates that socio-technical thinking must connect events, behaviours, and artefact designs, in a formal design language. For this he highlights the need for a layered approach that transitions from algorithms to computer programs to human-computer interaction to socio-technical systems. Research at the first three levels has already attained a reasonably mature status, with the fourth requiring further maturity.

Work done on STS in Requirements Engineering domains is seen in Mat and Silva's recent book, [37], covering basic notions, challenges, and approaches, including Viewpoints, Goal based and Domain approaches, combinatorial approaches, conceptual modelling, and agent-oriented techniques. Problem-frames for socio-technical analysis are also discussed. System of systems and distributed control are highlighted in Chapter 9 of the book. The following section gives more details on such systems in the literature on complex systems. The work of the Tropos group, [38], also addresses requirements engineering in many STS contexts such as security, context modelling, runtime reconfiguration, and AI planning. Requirements engineering techniques is also shown in Sommerville's responsibility modelling approaches [35].

4.4 STS in Complex Adaptive Systems

The viewpoint of the complex system engineer, when considering an organization, is naturally socio-technical as it considers both the social requirements and technological capabilities of the system (or system-to-be). The key difference is the focus on interactions and environmental contexts in addition to stakeholder goals. The highest objective is the orchestration of interactions that optimize and support both social and technical resources.

> *"The theory behind network structures is very appealing. The belief is that complexity can be managed through freedom, that cooperation is economically efficient, and that knowledge comes from attitude and opportunity."* - Mumford, [5]

The field of complex systems research is vast, encompassing natural and artificial distributed systems, network interaction, negotiation, and mechanism design in addition to self-organization of components and software adaptation. Human systems, physical systems, and software are all included in the field, grouped under the title of "Software intensive systems" or "ensembles" according to [2]. Much of the complex systems research (especially negotiation, coalition formation, and mechanism designs) may be found in the literature showing the fundamentals of multi-agent systems, which is well studied in books such as [39].

In a STS context, the primary work system, whole organization system, and the macrosocial (system of systems) are layers which interrelate, and complex systems work may fit in either, [4]. Indeed, socio-technical research is a subset of complex system research. Bygstad, et al, [40], mention that information systems development has developed into a craft where the business environment is turbulent, and the technical environment is complex, posing a challenge for developers. As such they note four "units of investigation" under the topic of integration (or coordination) in a socio-technical context. These are: Socio-technical work systems, Actor-networks, Web of computing, Information systems, and Information infrastructures. The last four are found in the literature for a number of applications, while the first is very abstract (see [40] for more).

Actor-networks: An actor network is “any collection of human, non-human, and hybridhuman/non-human actors who jointly participate in some organized(and identifiable) collective activity in some fashion for some period of time,” [14]. In the literature there are various forms of such networks. Bryl, et al, [34], use social goal-oriented networks and AI planning techniques for predicting requirement alternatives. This approach is based on the Tropos/i* methodology, [36], and has possible uses in dynamic runtime reconfiguration and automated design.

Carley, et al, [28], [41], describes an integrated crises management unit; a social network graph based on an informational meta-matrix. This defines the communication structure of an organization or emergent organization. She discusses the notion of emergent lead organizations arising from decentralized rescue teams, tasks, and control units in a disaster management scenario. The work models the organizational state in pre-crisis, in-crisis, and post-crisis situations. Multi-agent simulation methods are described by the same author in [42].

Dynamic networks are described by Comfort, et al, in [26], where the authors describe efforts to use socio-technical thinking in the development of a risk management and modelling system. The work identifies metrics that characterize regional transportation systems, constructs models for simulating threats and resposne patterns, and describes the use of these in decision support applications.

A similar approach is found in Ulieru’s Self Organizing Security Network, [15], and research on the adaptive risk management platform, [43]. The author proposes an integrated security framework that uses socio-technical actors, modelling various factors in a meta organizational model or holarchy. The approach aims to provide both top-down policy modelling, and bottom-up emergent design mechanisms based on individual actors. Multi-agent based simulation approaches are a key factor. The work investigates problem scope, and inter-agency collaboration as critical challenges.

Finally, Scacchi, [32], and Kling [44] investigates design and interaction through socio-technical interaction networks. This is a general graph based network structure for showing communication hierarchies visually.

5 Discussion and Conclusion

Socio-technical theory is based on the idea that, ”if a technical system is created at the expense of a social system, the results obtained will be sub-optimal.” (Enid Mumford [http://www.enid.u-net.com/Sociotech.htm]). What makes the socio-technical system particularly important is that it bridges the gap between social organisations, and the technologies that such organisations use in order to achieve goals. In sociology and organisation theory, using socio-technical design principles have been shown to result in system structures that are flexible, and decentralized; handling environmental changes through teams and participative decision making (see work in STSD from the Tavistock Institute). Today these ideas are still used, but have not been fully explored for software systems.

Much work needs to be done in order to bridge the current literature with an understanding of human actors, and multi-agent systems.

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