Socially-Sensitive Systems Design

Kirstie Bellman [1]
Jean Botev [2]
Hanno Hildmann [3]
Peter R. Lewis [4]
Stephen Marsh [5]
Jeremy Pitt [6]
Ingo Scholtes [7]
Sven Tomforde [8]

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[1] Topcy House Consulting, U.S.
[2] University of Luxembourg, Luxembourg
[3] Universidad Carlos III de Madrid, Spain
[4] Aston University, Birmingham, U.K.
[5] UOIT, Oshawa, Ontario, Canada
[6] Imperial College London, U.K.
[7] ETH Zurich, Switzerland
[8] University of Kassel, Germany

Introduction

In human society, individuals have long voluntarily organised themselves in groups, which embody, provide and/or facilitate a range of different social concepts, such as governance, justice, or mutual aid. These social groups vary in form, size and permanence, yet in different ways provide benefits to their members. In turn, members of these groups use their understanding and awareness of group expectations to help determine their own actions, to the benefit of themselves, each other, and the health of the group.

As a result of this observation, interest has grown [13] recently in exploring how such social concepts can be captured in both the design and operation of hybrid systems that consist of both humans and machines. For a system to do this, we argue that it requires i) *social awareness*, i.e., an ability to sense, perceive and build models upon which to reason about social concepts, and ii) *social action*, i.e., the ability to act in accordance with this understanding, to intentionally bring about desirable social states. Accordingly, this position paper discusses the question of how to understand and formalise the role of social concepts in self-organising socio-technical systems. When a system is both socially aware and socially active, we coin the term *socially-sensitive system* to describe it.

In elaborating upon the vision of socially-sensitive systems, we draw on the key role of self-awareness for adaptive behaviour [27] [25], extending this in order to emphasize the role therefore of socially self-aware systems. Social awareness and social action, we argue, further adaptivity of both individuals and of collectives, through the gains of having multiple agents engaged in intentionally coordinated efforts.

Further, we discuss how systems that are sensitive to social concepts might be realised through engineered socio-technical entities (e.g., electronic institutions and online social networks). We will therefore be required to design social concepts into technical systems in a principled way. Core to this is the engineering of systems that *explicitly contain* social concepts, and an awareness of them, at run time.

In order to make the consideration of social awareness and social action more explicit in systems design, and to make progress towards a principled way of designing socially-sensitive systems, we further propose a conceptual framework for their design (such a design activity will also be required to be socially-sensitive), thereby advocating *socially-sensitive systems design*. The framework has three tenets: social organisation, social values and social relations. Social organisation relates to issues of network structure and roles. Social values relate to states of the system *that matter* to individuals, and can, through social mechanisms, come to matter to the group as a whole. For social relations, we build on Sztompka's [37] sociological hierarchy, which differentiates a spectrum from social behaviours through social actions, to social interactions and social relations.

In socio-technical systems, just as in human society, there are however issues that arise, associated with free riding, scale, and time. We argue that by appealing to socially-sensitive systems design, we can support systems to be resilient to these issues, as they can be in human societies, by engendering better social positioning: by moving beyond simply *groups* of interacting agents, to *societies* of them.

Current social media systems, for instance, are based on simplified, unidimensional models of social relation and interaction; the consequent weaknesses of which have been exposed during recent electoral campaigns and the large amount of false information published [15]. However, initial trust- and recommendation-based mechanisms have already been successfully deployed in various areas such as e-commerce and agent-based systems, with the aim of mitigating and containing potential misuse. Yet these systems themselves are not free of issues [24], and even trust systems have reached a level of complexity where intermediation is necessary [28] [39].

Some of the new concepts discussed in socially-sensitive systems design will demonstrate how, by going beyond the notion that collective behaviour is only driven by immediate (non-social) goals, mechanisms can be created that lead to more enduring, value-driven collective behaviour, while incorporating social mechanisms that support human social values.

One of the key benefits of socially-sensitive systems design is therefore that it leads to systems which engage intentionally in better positioning of themselves, through the increase of social potential. This implies awareness and continuous redesign of the social aspects of the system, in order to ensure resilience and generalisation to future, unknown situations. This is a key idea in human societies, where apparently wasteful activity in the short term leads to societies being better positioned to deal with an unforeseen event in the future.

In many complex systems at present, especially in systems of systems and networks, we are already building in early forms of social processes without recognizing them as such, and hence without being able to explicitly bring in better types of social processes. Therefore, in building up the foundations of socially-sensitive systems design, examples may be taken from classically difficult integration problems of large and heterogeneous systems (e.g., the space station), as well as systems of systems and multi-agent systems, where we want intelligent, autonomous behaviour at both individual and collective level.

Socially-sensitive systems design has the potential to lead to socio-technical systems that behave in a way that recognises their social obligations. This can help ensure the endurance and ongoing value of the system, by sustaining its social aspects. Ultimately, we aim to ensure that system's behaviours support human society, leading both to fewer social pathologies and more robust systems.

Why Design Socially-Sensitive Systems?

Socially-sensitive systems design will bring benefits in two intrinsically quite different types of system: those that are purely technical, and those that are socio-technical.

In purely technical systems, a key benefit will be derived from the notion of *better positioning through increasing social potential*. Uncertainty often exists around what individual entities (e.g., components, agents) or a group as a whole may face, or will be required to do, especially as complexity increases. Nevertheless, entities within a system will still need to achieve certain goals, often quickly. In a complex system, this will require interaction with, or even perhaps cooperation of other entities within the broader system or wider world. This in turn extends the boundary of the system.

As one example of this, resolving a resource contention issue with a degree of immediacy may require other entities to give up claims to that resource quickly. Further, these types of challenges are typically not one-offs: entities within a system may know, or learn, that they are going to have to iterate. The other entities involved in the interaction, in our example perhaps the one who is asked to give up the resource, will be encountered again. In future uncertain scenarios, perhaps the pattern will be repeated, or the roles reversed. Given the uncertainties associated with these complex systems, operating in unfolding situations, there will be a need to be able to account for and generalise to future unknown situations such as this.

For example, a system may be uncertain as to what is in the environment (e.g., as in target identification and tracking, or mobile devices searching for nearest neighbours). There may be uncertainty in how quickly the environment is changing, leading to the need to recruit new components or switch out algorithms and computational methods dynamically (e.g., as in cloud applications, service discovery, and many run-time modeling applications). There is always uncertainty in the execution of plans, responses to data-driven processes, and embedded systems in operational environments. Adaptive behaviour is exactly about how quickly one can change one's goals and actions in order to take advantage of or to respond to a change in the environment – or in change in the capabilities of the system itself (e.g., unexpected attacks, loss of power, loss of components, loss of data, and so forth).

Collectives can help reduce the uncertainty of a given system since multiple agents enhance both i) the scope or range of senses and ii) the scope and repertoire of actions available to the system. In addition to enhanced scope, multiple agents can also add a different set of experiences and expertise based on learning or familiarity with the operational setting. Multiple agents also have different perspectives or viewpoints that can be exploited by socially-sensitive systems, which can help either by seeing it from the outside or by integrating diverse viewpoints for a more robust response.

Hence, even when we take classically difficult system engineering challenges like that of integrating a space station, we can begin to consider the advantages of thinking of their numerous interactions in terms of the control of social and collective processes.

The Space Station has two and a half million moving parts, and the coordination of components, establishment of interfaces and communications among components and integration of required behaviour from the behaviour of massively different components is a major part of the decade long development of space systems. The relationships among components can be dynamic, even semi-autonomous, but they are not social. The current uncertainties that must be dealt with by this system include the unforgiving impacts of the space environment, data quality / gaps, and the continual monitoring for, identification of, and mitigation of faults due to loss of function, degradation, inadequate adaptiveness to the current environment – from an enormous variety of causes. Currently the main strategies used to mitigate such losses are a limited adaptivity in the component parameterization and responses and a set number of redundant components. Human engineers from the ground are sometimes able to use the existing instrumentation and other components in astoundingly creative ways in order to regain some losses in functionality – but often at considerable cost in terms of recovery time and loss to the overall mission. Socially-sensitive systems design can help us reevaluate how we are using the current interfaces, instrumentation, and communications that we have in complex systems such as this. For example, how could early social processes such as external perspective and viewpoint be used to improve the fault detection of one subsystem through the feedback that other interacting systems? Could concepts of trust be used to supplement the current approaches to switching to redundant components?

In cases such as this, groups of individuals can use social organisation, values and relations to move themselves *as a group* to a better position to be able to deal with these factors. In doing so, the group builds what we call social potential[9]. Without social concepts explicitly embedded in a system and its decision-making processes, there will be a lack of primitives with which to reason about the system's social state, and increased social potential cannot be explicitly targeted.

One example of this in the human sphere is a football team who, while they may not be under immediate attack from the opposition, nor know what form such an attack may take, apply organisation (in the form of roles and positions), values (e.g. solidarity, respect, fairness and loyalty [33]) and relations [22] to put themselves in a better position to deal with such an attack, when it does come. On a longer timescale, such social positioning in football teams has been found not only to increase the potential for success within the specific game or even group itself, but this even generalises to future life events, such as professional success [21].

In a technical example, in ad hoc wireless networks, we have built in methods for making the devices aware of their nearest neighbours, with some communication and with some reasoning about how best to combine current capabilities (for power or for load balancing). But to what extent can we use the team analogy here, for example adding in the notion of a team player – to have devices that could act altruistically for the good of the whole network or protectively and proactively for the good of each other?

More broadly, if we want a system of systems to integrate adaptively and intelligently then we may be aided by thinking about not only the social processes that help build trust (which is already being looked at widely), but those that help mediate and resolve differences, that learn from previous failures and grievances and so forth [3].

The rise of socio-technical systems and their weaving into the fabric of human social interaction means that such values will be ever more important. Indeed, we even venture as far as to argue that such an approach is not only desirable, it is essential to preserve the intrinsic richness and value of human social interaction, as technical systems are increasingly interwoven into our everyday lives. To do otherwise, would be to degrade the quality of the human experience in a socio-technical world.

[9] This is not the same as social potential identified in [34], but is more closely related to social capital, in the spirit of how Fukuyama [19] sees it.

State of the Art and Challenges

In order to make progress towards socially-sensitive systems design, it will be useful to be able to more formally describe, analyse and hence understand the impact of different forms of social value, alongside the role of various forms of social relation, in socio-technical systems.

Of course, we are far from the first to attempt to tackle problems of rapid adaptivity in unpredictably dynamic and uncertain environments. There is now an expansive literature in the fields of multi-agent, self-adaptive and self-organising systems, computational intelligence and artificial life, that describes mechanisms to engender or manage collective adaptivity. Indeed, some of this is directly inspired by social systems found in nature, such as colonies of ants and bees, flocks of birds and schools of fish, while some is inspired by human societies, such as those based on norms and institutions.

Despite this, there is very little consideration in this literature, or the approaches it describes, of deeper aspects of social relations or social value. In order to approach a formalisation of such concepts, we can instead turn to sociology and psychology, where pre-formal theories of human social relations can inform the development of formal computational theories of relations and value. On the other hand, social organisation has been studied in some depth by systems researchers, where progress already made can contribute to the formalisation of this aspect of socially-sensitive systems design.

The remainder of this section identifies key challenges arising from our analysis of insufficiencies in existing state-of-the-art approaches.

Challenge 1: Social Awareness and Intentional Social Action

In computing and biological systems alike, additional “devices” can help increase the scope of the system’s sensors (helping us to perceive more) and effectors (helping us to do more). Many of such contributions can be unintentional on the part of the device or agent. Hence a device like a rearview mirror, a telescope, or a microphone can add to the range of our sensors; there is adaptive behaviour on our part in using these devices but there is no intelligence in the basic form of these devices. A bird’s sudden trill, stranger’s glance upwards, or a cat’s ear movements may all convey information to us that we can adaptively use, but again without any intentional communication of such to us. On the effector side, bulldozers and bullhorns, amplifiers, spears, and guns are just a small number of the inventions we have developed to enhance our scope of our actions.

In previous work [4] [5], we have emphasized the importance of reflective processes and self-awareness to the adaptive behaviour of complex systems. And we have noted that the information generated by a self-aware system can be in turn communicated to other agents, greatly facilitating cooperation. What has not been sufficiently explored however is the role that others play in a system’s ability to correctly formulate how its behaviours and capabilities fit into (or not) a given operational situation. Others can literally see things that the system itself cannot; they have a different scope, different viewpoints, and different experiences – all which can be critical to correctly understanding how a given system is contributing or not to some goals within a specific situation.

As discussed in the introduction, uncertainty can be reduced by using a collective of agents to enhance the scope of sensing and actions, adding a diversity of experiences, perspectives and expertise. The challenge here is to design these collectives, and their diversity more specifically, such that the system (in terms of its parts) supports itself in a mutually beneficial way, that adds knowledge, capability or reasoning, in support of the system's goals.

When we consider the design of systems in this way, there are several main questions: Where does it help to have multiple eyes and hands and now how does one coordinate them? Where does it help to have multiple agents watching out for the success of both themselves and others? Where does it help to approach complex problems with multiple viewpoints and experiences – and how does one communicate and integrate those viewpoints?

Challenge 2: Capturing Social Value

Here, we identify a major issue with existing, purely utility-based approaches for capturing the notion of social (human) value in socio-technical systems. Fundamentally, such systems should be capable of incorporating and managing the notions of value we, as humans, associate with social aspects of the world. In many existing approaches to designing socio- technical systems, for example in much of the multi-agent systems literature, an approach is taken whereby direct (often numerical, or at least ordinal) comparability of alternatives may be assumed, based on a universal commodification of such values. We argue that this approach is, in general, insufficient to capture both diverse range of, and nuance associated with, human social values such as obligation, empathy, peace and justice. Nevertheless these are the things that often truly matter the most to humans and the human societies that form part of socio-technical systems.

One of the key issues to address is how to represent and reason with social values, mathematically and computationally, *without* reducing them to base quantities. For example, it has been seen how, when assigning a financial value to a moral, one dilutes the moral value of its force: the nursery which introduced fines for late pick-ups found that collection time just got later; and when they rescinded the fines, pick-ups got later still. They had put replaced moral incentives (i.e. good parenting and consideration to proxies) with a coarse financial one, and when the removed the financial incentive was removed as well, the moral one did not immediately re-assert itself [26]. Much the same commodification of human values has been seen in e-commerce and social media, with concepts like *loyalty*, *trust* and *friend* all being diluted of their social quotient and social potential by representation as numeric terms. There are, however, logical frameworks in which it is possible to represent and reason with values formally without falling into this trap [35].

In capturing human social value, i.e., notions of *how and why things matter* to humans, what is needed is a rich set of theories for how to actualise and operationalise diverse forms of value in computational systems. Such theories will be essential to realise the vision of socially-sensitive systems and their design. Our aim is to produce computational formalizations of a variety of forms of social value, enabling them to be explicitly represented within the technical side of socio-technical systems, and communicated by them. In doing so, we will also provide some of the tools required to ensure that such systems also uphold these social values.

Challenge 3: Formalising Richer Social Relations

As we have noted, a tremendous leap up in the impacts of the advantages of multiple agents occur when we add scope and perspective as well as purposeful and intelligent support by others. These social processes in living systems come in a wide variety of types and levels of interaction and coordination, including ones that make several agents aware of each other, perceptive and anticipatory of each other’s needs, able to model and reason about each others states and goals, able to share goals, to communicate broadly about the environment and the systems own states, collaborative and supportive of each other.

Of course there can be many levels of socially-sensitive processes. A guard dog can alert us and guide us; a mentor can tutor the apprentice – both physically shaping the learner’s behaviour, pointing out how what they do impacts their goals, pointing out what to look at in the environment or intellectually and emotionally, helping one reason through a proof or helping one to not overreact to a social situation, etc. There are many examples of learning, training, mimicry, and teaching – formally and informally.

As discussed above, we have the beginnings of social concepts, including relations, already in use or in research (e.g., trusted for a specific shared goal within a specific context). However, these are typically not noted as such, explicitly. To develop much more powerful social relationship concepts, we will need to take on some challenging topics, such as how to build computational systems that exhibit “intentionality” over relationships, to help or engage socially, and that have the relative freedom or choice to engage. How do we develop the means for communication and interaction among diverse styles of components and processes? How do we generalize the benefits from early forms of social processes to more advanced ones? For example, how do we go beyond agents sharing a goal or trusting one another for a given task to the presence of trust for a culture, a social relationship, or a trust of tribe, institution or group of individuals?

In answering these questions, the potential exists to draw on theories of social relations and repeated interaction in sociology, where the impact of different qualities of relationship underlying interactions has been studied extensively. The challenge is therefore to formalise and operationalise different forms of social relation. In doing so, it will be important to characterise different types of social relation in terms of the (potential) benefits they bring, as well as the costs in maintaining them, which may otherwise be seen as “inefficiencies” from a purely engineering perspective.

Challenge 4: Harnessing Self-Organisation and Decentralisation

With any system of sufficient complexity, it is important to consider the internal organisation of the system, including how the comprising parts are arranged. In a system of interrelating parts, this includes things such as topological structure that defines the “social network” of the system.

It has long been understood that social and economic activity occur on networks, and the network structure can play a crucial role in determining the outcome of such social or economic activities [41]. On top of this, in open socio-technical systems, such networks are often dynamic in nature, as individuals arrive and leave, and the system's topology forms and reforms on an ongoing basis. While theoretical and empirical research have led to a substantial increase in our understanding of the effect of networks on large scale systems, extending our understanding to temporal networks remains a hot topic with numerous open challenges [23].

Socially-sensitive systems will need to be aware of, and act in accordance with the impact of changing system organisation. This will impact upon economic outcomes, efficiency (in terms of information propagation, for example), distribution of control, and the presence (or not) of emergent behaviour.

Where such a system adapts its own organisation, this is referred to as self-organisation. Self-organisation is often found in large-scale, complex and dynamic systems, such as different communities or human society which have the ability to adapt to unexpected changes and continuously changing environments [38]. Socially-sensitive systems require an even higher degree of reflective capabilities in that they might not only alter their behaviour, but modify their own structural design and organisation, or even their own way of carrying out such self-organisation, on an ongoing basis. This self-design process itself must therefore also be be socially-sensitive. Social organisation is one of the tenets of our framework for socially-sensitive systems design, and how to model and achieve effective, reflective self-organisation, will require the fusing of insights gained from the study of temporal network science, distributed self-awareness, and existing knowledge of self-organisation mechanisms.

Summary of Challenges

As highlighted by the above challenges, to use their embedding in human society as a way to support human social concepts, socio-technical systems will need to demonstrate a sensitivity to social organisation, relations, and values. Of course, this implies the practice of approaches such as value-sensitive design [17] [18]. But socially-sensitive systems go beyond this, as it is not only the design which is carried out in accordance with social values: the systems themselves will also be sensitive to such values. Thus, socially-sensitive systems design could be seen as expanding a form of meta-value-sensitive design. Further, due to additional complexities present in socio-technical self-organising systems, such as decentralisation, unpredictable dynamics and continuous reorganisation, we may even require ongoing socially-sensitive self-design, as the system plays an active role in its own design, on a continuous basis, in accordance with social values that it itself promotes.

A Conceptual Framework for Socially-Sensitive Systems Design

When we talk of systems or a design process being *socially sensitive*, we mean specifically that a system is both *socially aware* and that it is *socially active*. Social awareness implies that the system can observe social aspects of its environment and interactions within it, and conceptualise these, in order to reason about social aspects. This requires mechanisms for social (self-)knowledge to be collected, represented and disseminated about the individuals in a group, on an ongoing basis. Further, *socially active* implies that a system does not simply observe and think, but based on its conceptualisations, acts in a way that is congruent with them, and its own social principles.

We propose a framework for reasoning about socially-sensitive systems and their design. This is built upon three tenets:

1. The group's social values, specifically preferences associated with states of the group and its individuals.
2. The group's social relations, both in terms of type and structure of relations.
3. The group's social organisation, including the network structure, individuals' roles and perhaps rank within it.

Social Values

Unpacking the notion of social values, we can relate the behaviour of individuals within a collective to social obligations. Agents no longer care only for the goals of the group, but also for the members of the group themselves, in terms of their values for how they care for each other. In general, we can consider social values to be descriptions of *states that matter* to individuals, and can through social mechanisms come to matter to the group as a whole. More concretely, we might consider:

- States of a group that matter,
- States of an individual that matter,
- States of a relationship that matter.

States that matter to individuals can matter to groups, too. This may be realised through a variety of mechanisms, such as collective decision-making and aggregation.

As discussed above, some types of value properties will be economic, insofar that they relate to things that can be readily quantified, or at least compared, without losing their primary essence. But other value properties, those that we call *welfare values*, describe qualities of the system that are less readily quantifiable or comparable. These express preferences concerning the ways in which thing are done, in accordance with what matters to individuals and groups. One potential way for formalising this notion is through the use of meta-goals, or constraints over meta-goals.

There are several examples which can be seen as ways of encapsulating social values in computational form. A leading exponent is *privacy by design* [10], which shows that the choice between privacy and security is a false dichotomy, and it is possible to have both, by considering privacy as a principal design requirement, and not as a feature to be grafted on as an afterthought. This can be seen as instance of the more general methodology of *value-sensitive design* [16] [17], a methodology for engineering socio-technical systems which promotes human values as "supra-functional requirements". Further examples of this can be seen in what could be considered as, effectively, *sustainability by design*, in systems which try to encapsulate Ostrom's design principles for self-governing institutions which support sustainable common-pool resource management [32] through an axiomatisation in (executable) computational logic.

Social Relations

Weber [40] claimed that an action is 'social' if the acting individual takes account of the behaviour of others and is thereby oriented in its course. Further, Sztompka [37] proposed a hierarchy of social interactions and relations, shown in [T.1]. The hierarchy makes clear how several social concepts already familiar to computer scientists relate to each other. For example, *social behaviour* is commonly analysed in ant-based systems (e.g. [14] [16]), where actions (e.g. leaving pheromone) are done for the benefit of other ants, and in doing so for the benefit of the colony as a whole. Similarly, *regular interactions* describe the kinds of interactions occurring in repeated games such as the iterated prisoners' dilemma [1]. Here, knowledge of future interactions with the same opponent is crucial to determining future behaviour.

However, Sztompka's hierarchy demonstrates that there are many forms of social interaction, which require varying forms of knowledge (concerning both oneself, other individuals, and the environment) as well as cognitive capabilities. In developing this tenet of our framework, our intention is to map Sztompka's framework to computational systems, and extend as necessary. In particular, the various forms and distinct characteristics of interaction and relation in the socio-technical complex [9] need to be considered for the design of socially-sensitive systems.

Social Organisation

Organisation is perhaps the most familiar feature of the social nature of technical systems. It is concerned with network structure, roles of individuals and sub-groups within the system, as well as the *processes* by which such organisation arises.

Self-organisation is a concept that originated in physics and chemistry, where it was used to describe how processes and interactions on microscopic level can lead to the emergence of organisation, such as patterns and structures, at a macroscopic level [6]. In biology it can refer to the phenomena that global order can be created through local interactions between molecules or cells [20] and it has been used in the higher level investigations of emergent behaviours of groups of animals such as fish, birds or social insects, e.g. [9]. Self-organisation is

now investigated in a variety of fields, not only the natural sciences, but also life sciences (where it has been studied at various levels ranging from viral particle assembly [36] to flocks and schools of animals [9], in social sciences [29] [31] [30] to more technological fields such as computing sciences and artificial intelligence [7].
Computer scientists [14] [21] have drawn on work from theoretical biology [12] [11] [2] to exploit the benefits of decentralized approaches that rely on the interaction between many agents instead of one central control mechanism. The foundations provided from work on social insects behaviour have been used by researchers to design distributed control and optimization algorithms [7].
There is now a substantial literature on the organisation and self-organisation of (socio-)technical systems, and these aspects will underlie many of the other social concepts that a system may explicitly possess. Indeed, the organisation might be thought of as the platform, or set of constraints, upon which social relations play out, and social values are observed and propagated.

Conclusions

In summary, we propose that for socio-technical systems to possess, be aware of, and act in accordance with social concepts, these social concepts will need to be formalised and made explicit. Further, we argue that they will need to be designed in. We describe such systems and their design process as socially-sensitive systems design. A key benefit of socially-sensitive systems will be better positioning, through increased social potential.

In this position paper, we proposed a framework for the socially-sensitive systems design, based on the three core tenets of social organisation, social values and social relations.
Ultimately, we anticipate the benefit to technical systems to include increased robustness, increased empathy with humans, a reduction of pathologies of digital communities. Further, there is also the potential for insights gained in building and using socially-sensitive systems to impact on our understanding of human society itself. As a result of this understanding feeding back into social science, we expect that we can better support human beings in society at large.

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Tables and Figures

[T.1] Sztompka’s Sociological Hierarchy of Interactions

Type	**Requires**
Behaviour	Physical Movement
Action	Meaning
Social Behaviour	Directed towards others
Social Action	Await response
Social Contact	Unique / rare interaction
Social Interaction	Interactions
Repeated Interaction	Accidental, not planned, but repeated interaction
Regular Interaction	Regularity
Regulated Interaction	Interactions described by law, custom or tradition
Social Relation	A scheme of social interactions