Blending theories towards understanding and designing socio-technical scenarios

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ABSTRACT
To understand the interweaving of ubiquitous computer systems and their dynamic social relations different theoretical sources are necessary. Socially Aware Computing provides a deep understanding on how information systems emerge from and interact with the social context, whereas Actor-Network Theory represents a promising referential to explain how people and artifacts mutually actuate to render social structures. In this paper, we assess the paradigmatic compatibility of these two theories, proposing a blend, which provides a single basis to enrich the understanding of complex scenarios for designers of socially-aware technology, followed by an example of application in a real-world problem.

Author Keywords
Actor-Network Theory; Socially Aware Computing; sociotechnical networks; social software design.

ACM Classification Keywords
H.5.3 Group and Organization Interfaces; K.4.3 Organizational Impacts.

INTRODUCTION

When computers began to be used in business, they were data-processing machines enclosed in datacenters, under the supervision of technicians and operators. However, they soon became a working tool on office desks, supporting individual or collaborative tasks, and providing information for decision-making directly to their users. Nowadays, computers can be found in the houses, cars, and even pockets of people around the world, fulfilling the role of a medium of expression of interests and intentions [11] in contexts where goals and constraints may be not clear or well defined. Nevertheless, much of software development is still carried out with focus on technical aspects, with little attention to the formal and informal social aspects of the organizations and society in which they exist. Consequently, the impact of the introduction of computer systems has unexpected consequences on the social groups involved, either positive or negatively.

Socially Aware Computing – SAC – is a design model proposed by Baranauskas [4] to support the design of interactive systems, articulating ideas from Organizational Semiotics – OS – [19, 20], Participatory Design [27] and Universal Design [21] in order to create a socially responsible vision of the design of computer systems. In this model, design is a social process with focus on both characterization of the design situation and proposition of solutions.

The Actor-Network Theory (ANT) [15] is a theoretical and methodological set of Sociology, which arose in Social Studies of Science and Technology to understand the relationships between scientists, and was expanded to social phenomena in general. This theory aims to offer an alternative approach to the study of social phenomena, providing the interested observer with a "sensitivity" to capture how these phenomena work. It states that the only forces responsible for sustaining social aggregations come from their participants, and acknowledge the participation of both human and non-human entities.

In this paper, we extend the theoretical framework of SAC, by articulating it to the theoretical reference of ANT, in order to complement and refine the characterization of the social context in which the software participates. Since they are theoretical and methodological sets arising from independent scientific paradigms, it is important that any effort towards their merge should not be an ad hoc process, but instead, should be driven by their stances regarding concepts of the philosophy of scientific knowledge [23]:

- Ontology: definition of what is accepted as existing beings;
- Axiology: clarification on the purpose and values of the producer of knowledge;
- Epistemology: relationship between subject and object of research;
- Methodology: establishes valid conducts and procedures for obtaining knowledge.

In the following sessions, we provide a summary of the theoretical framework of Actor-Network Theory, illustrating its main concepts with examples from other works, which applied this theory in the description of socio-technical systems. Next, we present main concepts of SAC and discuss the philosophical stances of both underlying scientific paradigms. Finally, we present and discuss a proposal to merge these two theories and the implications for the design of computer systems, aiming at the understanding of social participation of information systems, followed by an illustrative case study.

ACTOR-NETWORK THEORY: MAIN CONCEPTS IN SOCIO-TECHNICAL SCENARIOS

In order to understand the origin and nature of social phenomena, some branches of sociology propose the general concept of agency, according to which the ability of individuals to act independently and make their own decisions by means of free will is the source of social phenomena. Then, social structures would be a consequence of the usage of cognitive and physical abilities of individuals, driven by their interests and intentions. In this context, ANT relies on its own interpretation of agency, proposing to understand social groups as chains of associations distributed in time and space. These groups depend on the continued actuation of their participants onto each other, producing a dynamic structure. An **actor**, therefore, is defined as any entity that acts on another, or that puts some other to act, changing a certain state of affairs.

Unlike many sociological theories, which consider society composed, produced and maintained only by people, ANT introduces the need to look also at the material reality of objects and artifacts. The social activities of these participants create **associations** among them, aiming to get support, to propagate forces, to forward interests, and to mobilize other partners to achieve mutual goals and benefits. These allies can be found among humans, among non-humans, but in most cases, the set of partners is heterogeneous. ANT is theoretically grounded on the principle that the basic social skills of humans are able to generate only weak ties with short range and duration [15, p. 65]. For the associations to become long lasting, they require non-human actors to take part on it, ensuring stability and action at distance, either by semiotic or material modes [17].

Traditionally, groups of people who interact with each other are of interest of Sociology, while groups of objects that are assembled in an orderly fashion – i.e., machines – belong to the domain of the Technology. The point of contact between people and technical devices gets attention, from one side, from the various disciplines of "human factors" and, on the other, from the social studies of science and technology [8]. ANT proposes that these phenomena should be handled together. The understanding of social reality requires that boundaries between these areas be overcome, giving more attention to the sequence of interactions rather than the nature of its participants. Figure 1, adapted from Akrich and Latour [1], exemplifies these heterogeneous chains, showing the *loci* for different partial attention.

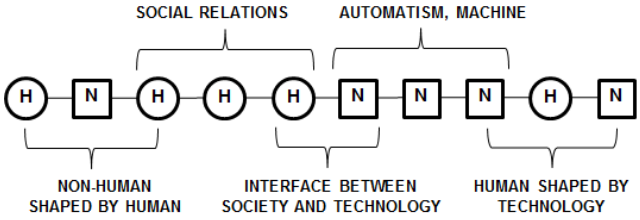

Figure 1: Chains of associations in a heterogeneous social phenomenon. Rounded figures denote human actors, while squares represent the non-humans.

In the real world, these relationships are not always in a single row, neither the boundaries are so well defined. For example, applying ANT to understand the evolution of personal digital assistants – PDAs – in the 1990s, Allen [2] reports that when Palm Pilot was released, its target audience was chosen to be busy executives who needed access to simple applications for management of personal information. On the one hand, the battery would have to be small, requiring a CPU with limited processing capacity. It was also chosen a pen-based input mechanism (*stylus*), thereby eliminating the need of a keyboard. In other words, human actors shaped in many ways the new object under creation. On the other hand, given the CPU limitations and poor algorithms for handwriting recognition available at the time, data entry algorithm did not recognize normal handwriting, only a simplified alphabet called Graffiti, compelling the user to learn to write in a new way. This is an example of a set of non-humans forcing a change of behavior on human actors.

The process of building associations between actors is named **translation**. It happens when an actor, wishing to change certain state of affairs, find other actors whose actions and skills can be beneficial, encourage their interest in associate with one another, and control their behavior so that their actions have some predictability over time. This effort creates order, in the form of devices, institutions and communities.

Akrich and Latour [1] suggest that these interference and negotiations occur not only between each pair of actors, but also in longer chains of associations including several participants. Interests and intentions are forwarded through existing associations until reaching the actor who others wish to influence. When actors keep connected, forming a **network**, the consequences of success or failure spread through the associations; so, there are mutual interests in the success of their partners. Callon [7] states that a successful translation is carried out in four moments: problematization, interessement, enrolment and mobilization of allies.

There are several strategies on the problematization for starting to assemble a network, for instance, following existing chains of associations in search of new allies. Spiess [29] used ANT to analyze the emergence of LibreOffice suite. He describes the effort of two Brazilian programmers to translate a code, which previously belonged to StarOffice and then to Sun Microsystems. At first, these Brazilian developers tried to contact another free software evangelist, who had previously volunteered himself for the translation to Portuguese, but they had no success. They then established contact with members of the OpenOffice.org project, hosted by Sun Microsystems, who assigned them officially the translation task. Next, they summoned up more volunteers using e-mail forums.

In the interessement phase, Latour [14] categorized some general strategies (Figure 2) that an actor can use, applying different persuasion forces on the others, to change their "regular behavior" towards a desired one:

1. an actor gives up part of their interests in order to align with another stronger actor;
2. an actor can convince a stronger one to change their goals;
3. the weaker actor must convince the stronger one that there is an obstacle in their plans, and suggest an alternative route beneficial to both;
4. it may consist in inventing new groups and objectives, making successive unnoticeable deviations from the original path, or successive approximations towards a target, occurring commonly in a scenario with several participants;
5. an actor becomes essential. In this case, no negotiation is required.

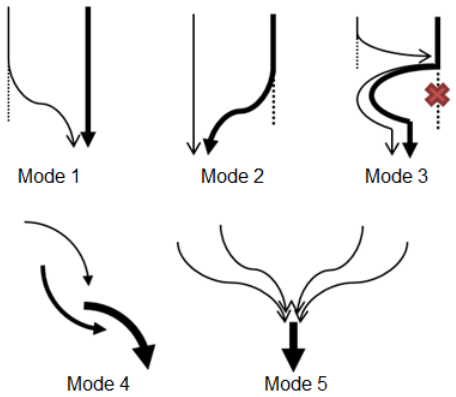

Figure 2: modes of translation. Adapted from [14].

The work of Faraj *et al.* [9], which analyses the evolution of web browsers from the perspective of ANT, brings several examples of translations. In 1993, one of the first versions of Mosaic web browser tried to encompass other protocols, such as Gopher and FTP, in addition to its primary functionality of rendering html pages retrieved via http, intending to attract more users. That is, a weaker and less known actor changed its properties in order to benefit from stronger players – translation mode 1. In 1995, Netscape Corporation decided to improve their browser adding interactivity and dynamism. Plugins for Java applets and PDF – Portable Document Format – viewers were incorporated within the browser, requiring a change of route both by Netscape, who had to create APIs – Application Program Interfaces – to support plug-ins, and the application providers, who had to adapt their codes to run within a browser – mode 3. In parallel, Microsoft tried to promote its Internet Explorer relying on a strong integration with its well-established Windows operating system. Therefore, Windows had to be modified, for example, to match the idea that the browser would become the standard user interface to access local files. A stronger actor was diverted from its original path to strengthen the weaker – mode 2. In 1996, Lawson Software Company became the first one to use a web browser as a user interface for their ERP – Enterprise Resource Planning application. Immediately, other vendors such as SAP, Baan and PeopleSoft rushed to provide the same type of web interface. The browser had become an actor able to attract by itself the interest of others, which in turn changed their ways in order to benefit from an existing actor – mode 5.

In cases where the interessement is successful, translation reaches the enrollment phase, in which actors may accept their new roles, outlining responsibilities. At this stage, Callon [7] states that strategies range from the consent without discussion to the imposition by physical force. Returning to the example of Faraj *et al.* [9], the effective enrollment of various actors led to the definition of what currently is understood as a web browser: a piece of software capable of supporting various protocols and software plug-ins, and not only able to provide static content, but also to serve as an interface for dynamic systems and diverse types of media. Browsers' role and behavior are well defined for the other participants: developers, companies, content providers and users share a general concept of what it is.

Any achieved social structure is temporary and unstable. Actors' arrangements are subject to decay, due to internal changes of interests, unexpected behavior, or external influence of new participants. At this step, known as mobilization of allies, Latour [14] points out two major concerns: to find the weakest link in the chain of associations; and to seek for more allies to shield the weakness and help to maintain the network cohesive. It requires assessing whether the actions undertaken by the actors already enrolled are being propagated, and if necessary, promoting new translations to bring more participants to the network, creating alternative paths to ensure the effectiveness and durability of associations. For example, Lee and Oh [18] used ANT to describe the competition between the wireless network security standard called WEP, used by the Wi-Fi Alliance Consortium, and a competitor protocol supported by the Chinese government,

named WAPI. WEP had known security flaws, which featured as a weak element in the chain of associations Wi-Fi Consortium used to reach its customers. Wi-Fi Consortium had to develop the WPA standard, compatible with most of the existing hardware requiring only a firmware upgrade, and at the same time having forward compatibility with the IEEE 802.11i standard under construction. These new actors made possible to keep the other allies under control.

When translation is effective and the various actors are led to act synergistically, with support of mechanisms for mutual control, the complexity of the network can be encapsulated in a **black-box**, which can be seen as a single actor. Recovering the example of the Palm Pilot, while its developers see a complex web of interrelationships, where several components have well defined roles, users interact with the device as a black box, a single actor. This example illustrates another important concept proposed by ANT: the ontological planarity. Local and global, part and whole, are not hierarchically separated or embedded one inside the other, differing only by their connections. "The more attachments [an actor] has, the more it exists" [15, p. 217]. Hardware and software components are not "inside" the actor representing the device, but instead, its parts link to the whole, and distinct paths of interaction for users and developers provide distinct views.

When accidents or unexpected behaviors occur, the network that constitutes the actor is exposed, often showing heterogeneous chains. For example, companies are an aggregate of people, machines, and documents; they make decisions, have market strategies, and so on, behaving like a single actor for the society outside. For all practical purposes, the responsible for a specific behavior is not highlighted until it becomes necessary, for example, in case of liability for damage to third parties, determining if it was a human error or technical failure. When inventors, designers, and engineers create novelties, they have representations of the target users and uses for the products they develop. This intended behavior model is incorporated into the device being produced, in a process Akrich and Latour, [1] name inscription, assigning sequences of actions or influences that its creator hopes that takes place in specific contexts.

Technological artifacts have the ability to modify the way people think and act, and can be used in a different fashion than they were originally designed for, sometimes in unexpected ways, having thus some level of independent action, what can be regarded as a kind of agency [13]. It does not mean, however, to attribute intentionality to non-human actors, but instead, we should not overlook their potential for interaction and mediation of other relationships. Humans should be treated as such, recognizing their rights, obligations and responsibilities [17]. It is clear, however, that *a priori* separation between humans and non-human is not essential to the understanding of a social phenomenon, because both are important to the network and no place in particular is reserved for any of the kinds.

Instead of categorizing actors according to their nature, human or non-human, ANT claims it is more important to identify the role they fulfill in the associations chains when transporting forces and influences as intermediaries or as mediators. An actor is considered an **intermediary** in a chain of associations when it transmits the actions received without changing them. The behavior of an intermediary is predictable and the inputs determine the outputs. A network composed only by intermediates can be easily encapsulated into a black box, regardless of how complex and intricate their relationships are. When analyzing a network, intermediary actors often stay unnoticed. On the other hand, a **mediator** contributes with new behavior for the system. Mediators modify, distort, amplify or translate incoming stimuli. They are creative and show variability and unpredictability to act on the others, resolving asymmetries and conflicts between actors. This classification is circumstantial: the same actor can act both as mediator and as intermediary under different stimuli and contexts [3].

SAC AND THE DESIGN PROCESS: A BRIEF PRESENTATION

The Socially Aware Computing is an approach to the analysis, design and evaluation of digital artefacts with focus on their influences and consequences for the society. It conceives an organization as a group of people who act together towards a purpose, and their action is coordinated by an information system composed by signs and patterns of behavior. In this information system, three layers can be found, regarding the degree of formalization and objectivity: the external informal layer contains beliefs, negotiations and uncertainties; the formal layer reflects the bureaucracy; and the technical layer is where technology and technical procedures are studied. According to SAC, the design process of a piece of software is a movement (Figure 3) starting on the external layers and progressively reaching the inner ones; once the wishes, needs and expectations from the external layers are materialized into the technical layer, the presence and use of a new artefact propagates consequences towards outside.

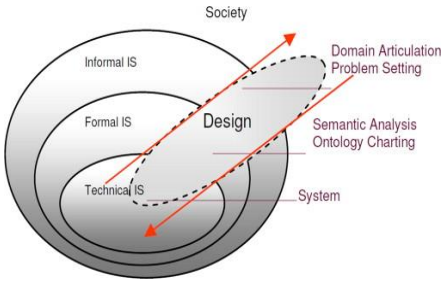

Figure 3: SAC perspective about the design process in a social context. From [22].

Each of these information system layers can be decomposed into semiotic levels (Figure 4). The three lower levels

correspond to how signs are physically supported, what encoding they use, and how they can be organized; they can be projected onto the computational structure of organizations, encompassing hardware, networks, and software. The three upper levels correspond to exclusively human attributions: in the semantic layer, data is comprehended and meaning is assigned; in the pragmatic layer, the system is used with a certain purpose; and if this purpose presupposes or implies other people participating on the system, it reaches the social level. Analyzing an information system from the point of view of each of these levels can provide a broader understanding of how it operates. The usage of SAC in software design is extensively documented in literature; the work of Santos *et al.* [26] provides several examples.

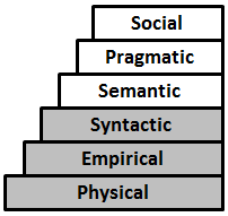

Figure 4: semiotic framework, depicting levels in which signs' presence and activity can be studied. Adapted from [19].

ANALYSING THE SCIENTIFIC PARADIGMS UNDERLYING SAC AND ANT

From the **ontological** point of view, SAC is based on Organizational Semiotics, which adopts a radical subjectivism stance [19], assuming nothing exists without the presence of a knowing subject who perceives and recognizes the existence of other entities by means of actions on the environment around them. OS recognizes the existence of two kinds of entities: agents and affordances. In general, agents correspond to human entities, whether individual persons or collective groups, while the affordances are patterns of behavior of these agents, being provided, allowed or imposed by non-human entities. However, under a deep analysis, this definition is sensitive to context: what differentiates an agent from an affordance is that the former should be able to act responsibly, or to him/her can be imputed responsibilities [19, p. 64]. ANT sees a social phenomenon as played exclusively by actors, and their nature – human or otherwise – is not relevant a priori. On the contrary, separating actors in different domains make it harder to explain society. The network formed by actors should not be seen as a distinct ontological level, a structure above the existence of the actors; actually, actors exist only because they are acting on each other, and the network provides this entanglement of actions.

Axiologically, we focus the analysis on how paradigms expect the results of research to spread beyond the borders of the scientific community in which they were generated. Relationship between science, technology and society historically received many definitions and points of view. One of the most relevant is given by the so-called School of Edinburgh [6], which proposed the Strong Programme of the Sociology of Scientific Knowledge, saying that psychological and cultural conditions in which knowledge is generated are important for understanding it, and the same type of explanations must be employed for either success or failure of scientific endeavors. The name "strong programme" was given in opposition to what was named "weak programme" of the social studies of science and technology, which assumes that society biases the progress of technology away from its "natural" path, generating the common position that "human factors" are responsible for a particular scientific or technological effort not reaching its "perfect" shape.

Following the influences of Participatory Design [5], SAC is clearly directed towards the possibilities of promoting changes in society simultaneously to the construction of information systems. ANT borrows some points of view from the Strong Programme, however criticizing and expanding its bases. Although ANT's studies suggest mutual interference between science and society, there is no clear proposal for social intervention. There are only clues of this intent, as in Latour [15, p. 259]: "it's perfectly true to say that no sociology can be happy with 'just describing' associations". Social contribution of ANT turns out to be to provide a better view of who or what are the participants of a social phenomenon, including non-human actors, to enable more effective action on society.

From the **epistemic** point of view, OS states that "there is no knowledge without a knower" and "there is no knowing without action". The design of an information system focus on the responsible involvement of stakeholders, instead of their accurate classification [5, p. 37]. Encouraging the participation of agents in the design process is a way to bring their knowledge to the system under development. An ontology chart [20] is employed to represent this knowledge about the existence of affordances and agents, as well as to determine ontological dependencies between them. Well-defined norm syntax is also used to represent patterns of behaviour. Each new pattern is anchored to what is already known by the social group under study.

Latour [14, pp. 88 and 89] illustrates how ANT understands the process of building scientific knowledge, providing a fictitious dialogue involving Pierre and Marie Curie, defending the discovery of a new chemical element – polonium. The dialogue goes on, the Curies providing a list of substances and actions the ore should be subjected to, in order to cast off the possibility of being an already known chemical element. In the end, no other substance behaves the same way to the list of trials. The various substances, equipment and procedures already accepted by the scientific community are employed as intermediates, carrying actions that lead the new actor to show behavior previously unknown, until accepted as the element polonium. In another work, Latour *et al*. [16, p. 14] picture

a hypothetical situation in which someone tries to get information about an unknown person, using his curriculum available on the web. Providing the information contained on the website, the unknown person is able to act upon the person searching for his name, allowing her to build an "image" of who s/he is. In both examples, ANT describes the construction of knowledge recognizing the existence of an actor who wants to know other, whether human or not, and then need to build chains of actions among them, resorting to other actors already known. As someone establishes more links and paths, they reduce the range of possibilities of what or who the unknown actor may be.

The **methodological** conduction of SAC offers a wide range of tools and methods, such as interviews, workshops and so on, including the Problem Articulation Method – PAM –, Semantic Analysis Method – SAM – and Norm Analysis Method – NAM [12]. These methods consider an organization as a group of people sharing a purpose, who need to articulate their actions to solve a problem. PAM identifies human actors – stakeholders – who can affect or be affected by the solution under scrutiny. SAM captures the ontology of the problem domain, recognizing the existence of invariant patterns of action – affordances. NAM records formally the standards of behavior and performance of the identified stakeholders, defining their responsibility. Some artifacts support these methods, for instance, the stakeholders diagram [12]. The identified interested parties are arranged in "layers" that reflect the degree of impact each actor suffers or is able to offer on the system being analyzed: users and persons responsible for the operation, clients for whom the system can provide some contribution, suppliers from whom you expect some kind of input or support, and the surrounding market and community. Such artifacts are constructed collectively during semio-participatory workshops [5].

From the methodological viewpoint, ANT mostly uses face-to-face observations and detailed textual descriptions, applying ethnographic methods. It proposes to "follow the actors in their weaving through things they have added to social skills so as to render more durable the constantly shifting interactions" [15, p. 68]. Actors have their own frame of reference and the transition from one frame to another always adds some uncertainty. Human and non-human actors should be equally allowed to express themselves. ANT recommends following the actors closely, searching for entities that actually make people act, and understanding how actors recruit others to serve their purposes. When it is not possible to observe objects in situ, it is allowed to recover the history of the objects and the state of uncertainty or crisis in which they were generated.

ARTICULATING ANT AND SAC

In this work, we blend ANT and SAC, keeping the theoretical core of OS and resorting to interesting features of ANT. In this effort, we propose to incorporate the ontological view of ANT, making no *a priori* distinction between humans and non-humans, regarding both types as actors, considering only their actions and influences. Their associations into networks keep no privileged or exclusive position to one type or another. However, we chose to consider a relevant feature pointed out by OS: agents are responsible entities, able to make decisions and suffer its effects and consequences. Moreover, only human actors are provided with intentionality.

In Figure 5 we represent graphically examples of situations in which an actor, human or non-human, are placed between two other actors forwarding an influence it receives. According to ANT, the nature of the middle actor is not relevant in this case. However, according to SAC, the source of the influence is a human provided of intentionality; hence, the actor on the left is always human. Figure 6 brings a similar representation, but in this case the actor in the middle is a mediator: distinct arrow lines represent the concept of forwarding different influences.

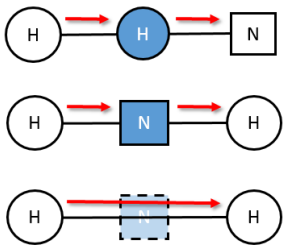

Figure 5: actors as intermediaries in chains of associations. Up: human as intermediary; Middle: non-human as intermediary; Bottom: intermediaries' social role is seldom noticed.

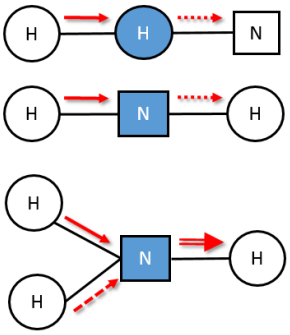

Figure 6: actors as mediators in chains of associations, changing the stimulus they receive. Up: human as mediator; Middle: non-human as mediator; Bottom: mediators solve conflicts and merge stimuli, providing a hybrid outcome.

Axiologically, our proposal aligns to SAC, as it considers that the production of knowledge about a social phenomenon must return towards the participants of the phenomenon so they can benefit from the results of the study. At the same time, its impact remains limited to what is expected from a study based on ANT, i.e., the contribution is the better understanding of who or what are the participants of the phenomenon, simultaneously

highlighting the participation of technology in society and vice-versa.

From an epistemological point of view, there are socio-constructivist influences in both theories, such as concerns about the ontological dependence on SAC, and the dependency ANT points out on the process of recognizing an unknown actor using known actors to discover its affordances. For an inquiring actor, who tries to get knowledge about invariant patterns of behavior of the unknown entity, interactions between them may be mediated by other actors, these ones already known and recognized by the society the inquiring actor belongs. The possibilities of interaction with unknown actors are gradually clarified by means of performances onto it, as well as actions in the opposite direction – from the point of view of the inquiring actor, observations. This interaction may occur direct or indirectly, involving other intermediaries, human or non-human, which contain pre-existing concepts of the society and carry the stimuli and their effects, by physical or cognitive means, allowing the new actor to be understood. In both theories, there is a relationship of ontological dependency describing new concepts based on those who are already socially accepted (Figure 7).

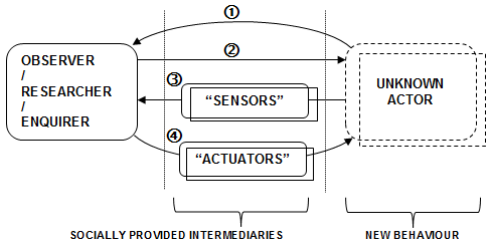

Figure 7: convergent epistemological conception between ANT and OS: 1) direct observation; 2) direct action; 3) observation by other actor(s); 4) stimuli caused by other actor(s). The overlapping rectangles, with straight and rounded corners, mean either human or non-human can occupy the position.

Although ANT and SAC adopt different methodologies, the former attempts to describe the observation of social phenomena, while the latter seeks to explain, capture and converge the concepts and standards governing an organized group of people, usually aimed at computerization. The methodology ANT proposes follows carefully the actors and their relationships, and this can be used to refine the identification and description of the participating entities and their influence on a social group.

In our approach, we interpret stakeholders as actors that act on each other via the networks they belong to, following association chains involving both human and non-human, as described by Akrich and Latour [1] and shown in Figure 1. A stakeholder is defined by its ability to influence and be influenced by the technological artefact under study, and these influences should occur either directly, or through other actors, intermediaries or mediators. ANT helps to understand that for these influences to be effective there must be one or more paths to make the action of the stakeholders reach the others.

Given the "wicked problem[1]" scenarios expected for the joint application of ANT and SAC, in which intentions may not be clear, there may be conflict of interests, and users do not behave as expected by other stakeholders, we focus mediation at the pragmatic level, that is, the component of information system related to action, meaning and intention. OS suggests the study of illocutionary acts to understand intentions as expressed through signs. Without the use of signs, agents are confined to their here-and-now environment [19, p. 67]. ANT extends this understanding to propose that influences occur both by semiotic and material means [17], not only by the communication of interests, but also by any other influence that can shape the behavior of another actor.

The ANT point of view leads us to consider that the system under study may also be part of one or more chains of associations linking stakeholders, propagating influences between them. The technical system under study must be scrutinized for being used for negotiation and modification of behavior, namely the translation of interest. Not only its planned use, but also the very existence of the system can make it an intermediary or a mediator between stakeholders. Figure 8 exemplifies possible paths of influence of stakeholders onto the system and the effect of system on stakeholders, while Figure 9 depicts how the system can be part of a path a stakeholder employs to affect another one.

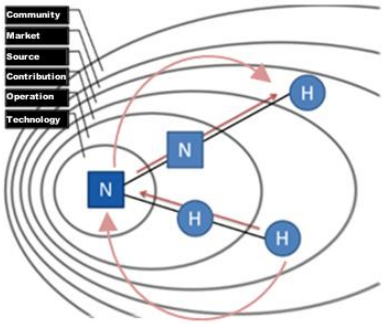

Figure 8: stakeholders affecting and being affected by the system, direct or indirectly

In order to understand how a piece of software placed on the stakeholders diagram is able to influence the behavior of other actors, we must consider not only the communication that happens among its users, but more broadly, all influences and actuations the elements of its user interface may cause on users. Semiotic Engineering proposed by Souza [28] adequately addresses the concept, asserting that there is a meta-communication between the designer of software and its users. This meta-

[1] An unclearly stated problem, with incomplete, contradictory, or changing requirements.

communication would be one of several modes of influence unfolding throughout the software – in this case between two specific stakeholders: the designer and the user. Participation of software as actor also implies it possesses some capability of promoting translation; the proposal of Persuasive Design [10] is aligned to this point of view, showing how technology can be designed to influence people's patterns of behavior.

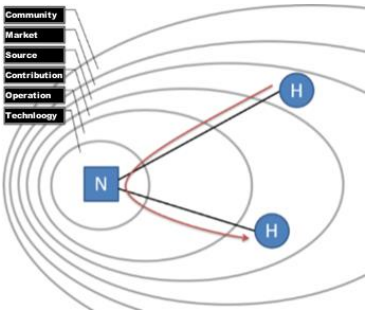

Figure 9: actors taking advantage of the system to influence others.

Knowing that the actions of a digital artifact may cause effects on the social setting surrounding it – and vice-versa – may help in simultaneously shaping the hardware and software and, at the same time, enriching the discussion involving other stakeholders about their interests, expectations about the artifact being designed, and opportunities of catalyze other stakeholders' needs towards a mutually benefic behavior.

A CASE STUDY OF APPLYING ANT + SAC CONCEPTS IN SOFTWARE DEVELOPMENT

A common requirement in scientific projects is to carry out literature reviews regarding the subject to be studied. Prado *at al.* [24] developed software – named *Quid* – intended to help scientists in this task, providing suggestions to improve a literature review, based on bibliographic data publically available on the Internet, and data fed directly on the system as well. In order to provide better and faster outcomes, this software depends on its local database to be kept up to date. To overcome this potential weakness, a functionality was developed to import data from the Brazilian scientific curricula database – named Lattes Platform – developed and maintained by the Brazilian National Council for Research – CNPq. However, this data is not always updated, and Quid requires the import procedure to be triggered manually only after data is reliable.

In this case study, we apply the aforementioned concepts to understand the sociotechnical network that this software participates, aiming to solve the particular problem of how to encourage people to keep their Lattes curriculum up to date and to use Quid to trigger the data fetch process afterwards. What we present here is an excerpt, for illustrative purpose.

Beginning from the stakeholder analysis and diagramming, as performed in SAC-based projects, some participants were mentioned: scientists (potential Quid users), Quid developers, the CNPq, authors of scientific literature (Lattes users), and so on. Enriching this step with the ANT point of view, some other actors were found: non-human that are direct or indirect targets of interests of the previously identified stakeholders; for instance, Quid and Lattes systems. Performing a problematization phase of translation, we seek for potential paths to expand the network. One of them is the interest scientists have in maintaining a personal webpage listing their publications, not in a third-part application such as Researchgate[2], but instead in a website encompassing other research and teaching activities, byproducts, professional schedule and so on. A provisional stakeholder diagram was generated, as shown in Figure 10, containing some paths for interests; for instance: the interest of developers to make users use Quid, the interests of Quid users to show their work to other scientists, and the interest of CNPq to make all scientists to use Lattes.

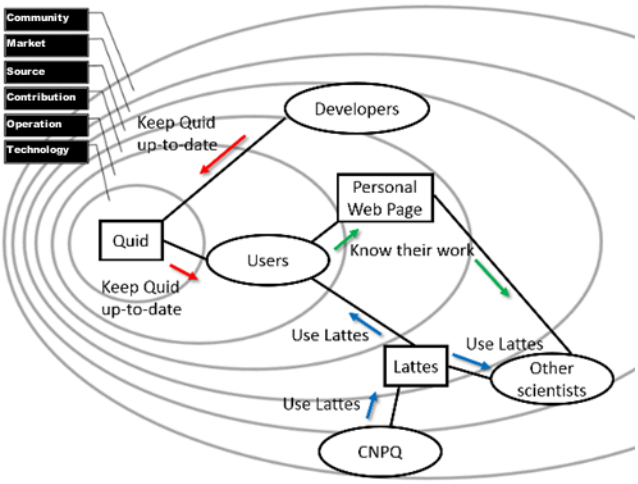

Figure 10: proposed stakeholder diagram, encompassing human and non-human actors.

Heading the translation towards the interessement phase, it was suggested that Quid could assume the role of provider of content, as a web service, to be fetched by Ajax and embedded in any web page, following the layout style of such page. Thus, the effort to insert data into Lattes and triggering the Quid load procedure would be rewarded. However, it would require some effort of Quid developers to create a functionality not originally intended for the software – translation mode 1. The suggestion was accepted by developers and welcomed by the members of a scientific project interested in publishing their bibliographic work in the project web page; therefore reaching the enrollment stage of translation. Finally, as a way to ensure alternative paths to attract interests to use this feature, Quid developers

[2] www.researchgate.net

added a word cloud generator, based on publication titles, which could also be embedded in any web page. The association between Quid and personal web pages create a new path to influence other actors, as depicted in Figure 11: a new interest of users in load data into Quid may emerge, as long as it forwards to their personal web page, and therefore make this data available to other scientists know their work. Quid acts as a mediator, receiving this interest of scientists to upload data and translate it to have a personal webpage with their recent publications. As a plus, it may increase the interest of users in feeding their Lattes resume, and aligns to the interests of its developers in keeping the Quid database up-to-date.

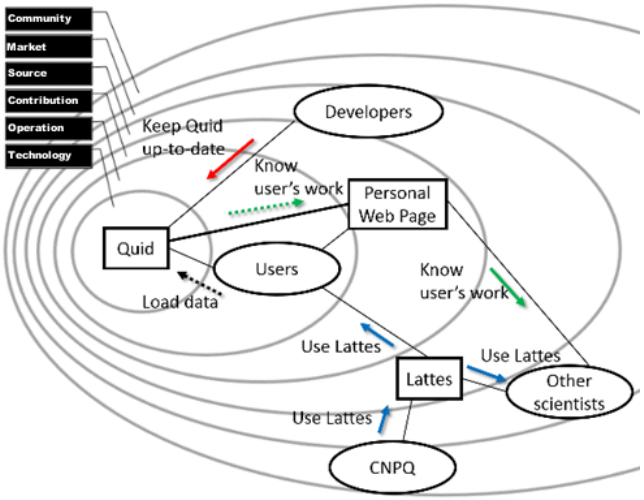

Figure 11: the association between Quid and the personal web page of its users reconfigures the network of actors, allowing other paths for interests. Quid is acting as a mediator.

This analysis and design, however, covers only the social level of the semiotic ladder (Figure 4). SAC states that all levels must be addressed. From the pragmatic perspective, the idea of a trigger from persuasive design [10] was employed, by adding a well-positioned, distinctive feature on the user interface inviting them to improve the data being visualized. At the semantic level, the designers' message was chosen to be explicit ("Do you want to improve this data", providing also an explanation about the benefits of such action). The syntactic and lower levels borrow features from the Bootstrap[3] framework used for implementation, allowing desktop and mobile browsers to share the same user interface, arranged in panels containing: scientist' identification, their list of publications, a word cloud from the titles of their publications, coauthors and so on. The final user interface is show in Figure 12.

FINAL REMARKS

In the scenario of ubiquity of technology we are currently experiencing, there is a lack of theoretical frameworks and methodological instruments capable of modeling the socio-technical networks of artifacts and people. This paper offers a concise overview of ANT and a bridge between it and other theoretical sources well established in computer science. Our purpose was to shed light on complex organizational scenarios mediated by technology and its design.

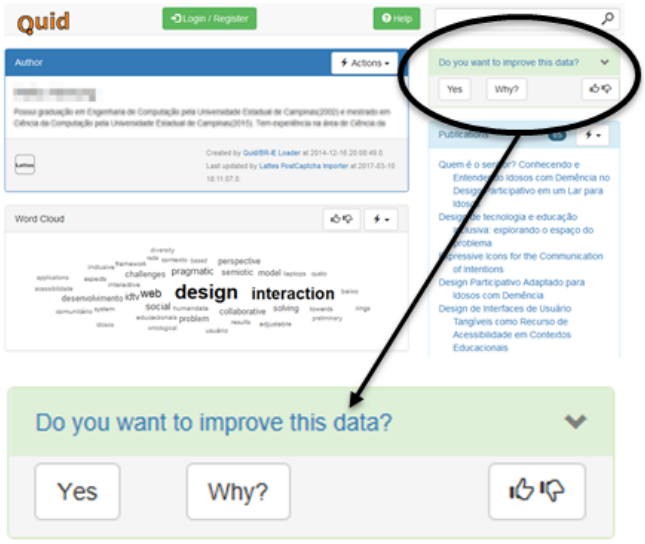

Figure 12: Quid snapshot (above) and the detail of a user interface feature inviting users to update their data (below). Both "word cloud" and "publication list" can be embedded in any other web page.

This work contributes with a theoretically informed discussion on ANT and SAC seeking to build from both, based on the philosophy of science, towards a better understanding of the participation of technology in society and vice-versa. With this work, we provide an interpretation of ANT as a tool for computing researchers and practitioners to find and trace interests in complex organizational scenarios, offering a choice for theoretical and methodological support to understand and design heterogeneous aggregations of people and devices including digital artifacts.

The theoretical construction proposed in this paper already resulted in the analysis of the scenario of scientific data sharing supported by software [25]. Further work involves an exploratory redesign of such software, for instance, finding user interface elements capable of better express and attract stakeholders' interests. Besides, the social and technological blending as described by this work allows investigations on other scenarios in which human and technology are assembled in composite actors, such as wearable devices and Internet of Things.

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[3] http://getbootstrap.com/

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