Social Machines: A Unified Paradigm to Describe Social Web-Oriented Systems

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ABSTRACT
Blending computational and social elements into software has gained significant attention in key conferences and journals. In this context, "Social Machines" appears as a promising model for unifying both computational and social processes. However, it is a fresh topic, with concepts and definitions coming from different research fields, making a unified understanding of the concept a somewhat challenging endeavor. This paper aims to investigate efforts related to this topic and build a preliminary classification scheme to structure the science of Social Machines. We provide a preliminary overview of this research area through the identification of the main visions, concepts, and approaches; we additionally examine the result of the convergence of existing contributions. With the field still in its early stage, we believe that this work can collaborate to the process of providing a more common and coherent conceptual basis for understanding Social Machines as a paradigm. Furthermore, this study helps detect important research issues and gaps in the area.

Categories and Subject Descriptors
H.4.0 [**Information Systems Applications**]: General

D.2.0 [**Software Engineering**]: General-*Standards.*

Keywords
Social Machines, Social Software, Web-Oriented Systems

1. INTRODUCTION
The Web of today is the open programmable platform of information, applications and services that is increasingly transformed industry and society [1]. As a consequence, it has also been especially influential in the way we develop software [2][3]. The emergence of a new generation of web-based technologies relying on social computing is changing the semantics of computation. Nowadays, more than ever, computing means connecting [4]. In fact, the Social Web has fueled the growth of systems that not only make use of concepts from computing, but also are guided by social processes. As a consequence, novel breeds of applications are rapidly emerging and new computational models and paradigms are needed to deal with them.

Several studies that adopt different visions have been conducted with the aim of creating innovative approaches to support the blending of computational and social elements into software. Consequently, these visions deal with the challenges of building this new generation of social systems. The topic of "Social Machines" has been investigated as a way to address this challenge, appearing as a promising model for unifying both computational and social processes. Recently, Social Machines have gained significant attention from academia with the organization of a specific forum for discussion: The International Workshop on The Theory and Practice of Social Machines.

However, in spite of being a promising topic, the concepts behind Social Machines overlap different research fields and, consequently, have created confusion and raised several questions. For instance, we have found some researchers that have had difficulties in understanding the boundaries of this research topic and how it can contribute to their research fields.

Thus, with the intention of minimizing such problems, this work proposes to investigate existing efforts related to Social Machines and characterize such topic, systematically mapping foundational studies into a common and convergent classification scheme. As a result, we provide an initial overview of the research area identifying the different visions of Social Machines as well as unify them into a central idea within the field of computer science. Furthermore, this study provides a basis for the process of defining Social Machines as a paradigm.

The remainder of this paper is organized as follows. Section 2 introduces some related work. Section 3 outlines the adopted research methodology. Section 4 shows the different visions of the "Social Machines" paradigm and, finally, Section 5 presents some concluding remarks and directions for future work.

2. RELATED WORK
Initial ideas of Social Machines are presented in [5][6]. Currently, there is no systematic mapping study characterizing the Social Machine area as a whole. However, there are some studies that analyze and categorize specific aspects of related topics such as human computation [7][8] and knowledge acquiring systems [9]. Yuen et al. [7] give a survey on various human computational systems, defining the categories and their characteristics. They also present a discussion on performance aspects of human computation systems. In order to answer which technique is better in terms of costs and benefits, Thaler et al. [8] evaluate two prominent human-computation techniques: GWAP and microtask. Shadbolt [9] provides a comprehensive review of Knowledge Acquiring (KA) Systems and characterizes new kinds of emergent and collective problem solving. In this context, he presents a vision of Social Machines as KA Systems.

WWW 2013 Companion, May 13–17, 2013, Rio de Janeiro, Brazil.
ACM 978-1-4503-2038-2/13/05.

3. RESEARCH METHODOLOGY

We decided to adopt Systematic Mapping Study [10][11] as a research methodology to better understand how existing research efforts have blended computational and social elements into software with the purpose of providing a more common and coherent conceptual basis to the understanding of Social Machines as a new paradigm for software development.

Hence, based on the process and guidelines defined in [10][11], we specified a protocol for a Systematic Mapping Study of the Social Machine related topic areas. In this paper we present the preliminary results of the first phase of this process whose main goal is to provide an overview of the Social Machines research area, focusing on the different visions we identified during the mapping process.

4. ONE PARADIGM, DIFFERENT VISIONS

By browsing the literature, an interested reader might experience a difficulty in understanding what Social Machines really mean. In [5], Hendler and Berners-Lee suggest that a Social Machine is a computational entity that blends computational and social processes. However, in a broader sense, we believe that Social Machines actually represent a promising paradigm to deal with the complexity of this new emerging Web around us, and a practical way to explain each and every entity connected to it. Social Machines, from the software point of view, can be a simple, formal and unified manner to describe software on the Web, in order to avoid the pitfalls of *mashware* [12]. Motivated by this position and based on some related work, we characterize the "Social Machines" paradigm as a result of the convergence of three different visions: *i) Social Software*; *ii) People as Computational Units* and *iii) Software as Sociable Entities.* To better visualize this convergence, we use a similar diagram illustrating approach presented in [13]. In this way, it is possible to clearly highlight and classify the main concepts, technologies and standards with reference to the various visions of Social Machines that are best characterized by this mapping. Figure 1 shows the initial result of this process of convergence.

4.1 Vision of Social Software

4.1.1 *Early Social Machines*

Social Machines has its origins on social computing [4]. Thus, some initial generation of Web-based social software (collectively called "Web 2.0" which consists of *blogs, social networking websites*, *video sharing,* etc) can be seen as early versions of Social Machines. These technologies have allowed users to interact and collaborate with each other by storing and sharing various types of content, including messages, photos and videos. In fact, social media such as Twitter and Facebook have substantially changed the way we communicate and be engaged with others.

4.1.2 *Open API Platforms*

Besides transforming the manner we communicate, these systems have also been changing the way we develop software. This is because some of them, mainly social networking sites (e.g., Twitter, Facebook), have started a movement to expose their internal capabilities as Web Services in the form of open online application programming interfaces (*Open API Platforms*). Indeed, such concept of platform of services has completely transformed industry and society [1] and, as a consequence, it has been especially influential in the way we develop software [2]. The Open API Platforms allow third-party developers to interact with social-networking sites, access information and media posted by their users, and create other applications and services, on top of the platform, that aggregate, process, and generate content based on users' interests. That just may be the case in which computing literally means connecting services [14].

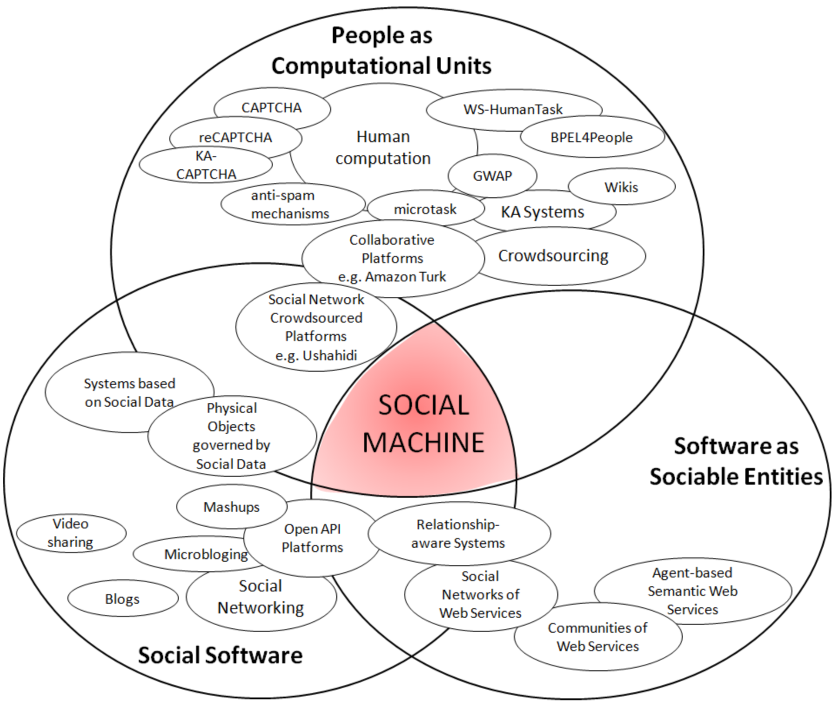

Figure 1. ''Social Machines" paradigm as a result of the convergence of different visions

4.1.3 Systems based on Social Data

In practice, the direct consequence was the rapid growth of the *mashup* ecosystem [3] in which Web-based mashups are created by integrating data from one or more sources to build new applications. ProgrammableWeb[1], the largest online repository of information about mashups and APIs, is concrete proof. Clearly, the combination of social information from multiple sources has enabled the creation of a novel breed of applications and service based on social data. In [15], Anderson et al. present systems that take advantage of social data to infer preferences, trust between individuals, and incentives for resource sharing. Based on the results of their social inference functions, such systems can provide social knowledge to support other applications in their decision making processes [16]. Other examples of systems based on social data (in this case, using physical objects) have been created by a digital agency called iStrategyLabs[2], which transforms real-world objects into machines controlled by social data. They call this combination of *physical objects and social data* Social Machines[3], machines that turn a Facebook like, a Tweet or a FourSquare check-in into events to trigger actions on physical objects.

4.2 Vision of People as Computational Units

This vision refers to research efforts that integrate people, in the form of human-based computing, and software into one composite system.

4.2.1 Human Computation

The centerpiece of this vision is the idea of *Human Computation* which relies on systems that makes use of human abilities for computation to solve problems that are trivial for humans, but complex for machines [7].

Adopting this vision, CAPTCHA [17] and its extensions (i.e. reCAPTCHA[4] [18], KA-CAPTCHA [19]) can be considered kinds of Social Machines that use human computation to solve a challenge response test in order to make a distinction between humans and computers.

Standards (e.g., WS-HumanTask [20], BPEL4People [21]) have introduced specifications that consider human interaction in the compositions of services in Service-oriented Architecture (SOA) environments [22]. In the same context, other studies [23][24][25] also propose models, such as the *Social Compute Unit* (SCU) [23] and *Human-Provided Services* (HPSs) [25], in conjunction with frameworks to deal with the seamless integration of human capabilities into a cross-organizational collaboration. In general, we can see these kinds of *collaborative computing systems* as Social Machines, since they incorporate the vision of people as computational units that make *collaborations*, which typically involve both humans and software as computational units.

4.2.2 Crowdsourcing and Collaborative Platforms

Other examples of systems that consider people as computational units can be seen in practice, such as the games with a purpose (GWAP) [26]. GWAP are systems in which a computational process transforms some of its tasks into an enjoyable game and delegates them to human game players. In [8], Thaler et al. evaluate such human-computation techniques and argue that:

> "Human computation lets organizations outsource tasks traditionally performed by specific individuals or experts teams to an undefined group of remote workers over the internet." [8]

This is the case of *microtask* (another prominent human-computation technique) which is the basis of some *crowdsourcing* and *collaborative Web-based platforms* such as *Amazon Mechanical Turk*[5]. According to Shadbolt [9], crowdsourcing and collaborative Web-based platforms can be seen, in a general way, as knowledge acquisition systems in the age of Social Machines.

4.2.3 Knowledge Acquisition Systems

In Shadbolt's review of Knowledge Acquiring Systems [9], he concludes that:

> "These social machines are knowledge acquisition systems at scale and machines that are socially contextualized."

Therefore wikis, which also are knowledge acquisition systems, can be considered Social Machines that make use of human computation, through the distributed co-creation of content. According to [7], other examples of *distributed human computation* can be found in some anti-spam mechanisms (e.g. Vipul's Razor[6]) and systems with the aim of eliminating optical character recognition errors, such as Proofreader[7] used in the Project Gutenberg[8].

Furthermore, in terms of complexity, Shadbolt suggests that the result of combining different social computation approaches (e.g., crowd sourcing, co-creation and social network) might create real Social Machines with relatively unsophisticated software (i.e., comparatively lower compute complexity), but with a stronger social engagement (i.e., higher social complexity). Relying on this idea, he highlights Ushahidi[9], an open crowdsourcing platform for mapping crisis situations, as an example of a more sophisticated Social Machine, in terms of social complexity. In fact, Ushahidi is a Social Machine that combines social networking, crowdsourcing and co-creation to create a unique open source platform on the web for changing the way information flows in the world.

4.3 Vision of Software as Sociable Entities

This vision is focused on works that try to weave social elements into software in order to enable their "socialization", mainly in terms of having "social" relationships with other software and interacting with each other. As a preliminary result, it is important to highlight that we are only considering the Web context. Other topics such as affective intelligent Social Machines [27], which refer to machines that speak our language and perceive our emotions, were not considered here.

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[1] www.programmableweb.com/

[2] http://istrategylabs.com/

[3] www.facebook.com/socialmachines

[4] http://recaptcha.net/

[5] https://www.mturk.com/

[6] http://sourceforge.net/projects/razor

[7] http://www.pgdp.net/c/

[8] http://www.gutenberg.net/

[9] http://www.ushahidi.com/

4.3.1 Agent-based Web Services

Agent-based semantic Web Services [28] is a research effort in this vision, since it represents an approach in which semantic web technologies are used to improve the meaning of Web Services' descriptions and, consequently, to facilitate the interactions of loosely-coupled Web Services (at least in terms of discovery, reuse and composition [29]). Some ideas regarding the use of a social unit to facilitate and improve the discovery of Web Services in an open environment like the Internet can be found in the research efforts of Benatallah et al. [30]. In that work it is suggested to gather similar Web Services (WS) into groups known as *communities*.

4.3.2 Communities of Web Services

In [31], motivated by the idea of communities, Zakaria Maamar et al. present the concepts and operations to specify and manage communities of Web Services. Hence, the involved Web Services interact with each other, in communities, to decide who will be responsible for treating a specific request. Under this Social Machines' perspective, these WSs represent services as sociable entities that are related in communities and interact with each other. Agent-based Web Services and the concept of communities formed the basis for the definition of reputation and trust models (e.g., [23] and [24]) that drive the discovery and composition processes of Web Services. However, recently, the metaphor of "social networks" has been considered as an alternative to the use of communities of Web Services. [34]

4.3.3 Social Network (SN) of Web Services

In order to support the process of discovery and composition, some works (e.g., [35], [36], [34], [37]) suggest the use of historical records of Web Services interactions, in a SOA composition environment, as basis for extracting Social Networks of Web Services. Different types of SNs (having Web Services as nodes) are captured, and the basic idea is to make a service recognize the relationships it participates in, and make recommendations about relevant peers. A service's peers include those that it can collaborate with, those that could substitute for it in case of failure, and those that it competes against (in the case of a selective environment). These approaches represent an important aspect for this vision of Social Machines. Once, such approaches turn Web Services into nodes of different social networks (e.g., similarity-based SN, collaboration-based SN) and make them aware of their relationships with others, in this case, to support the process of discovery, composition and other collaborative processes.

4.3.4 Relationship-aware Systems

Systems that are aware about their relationship with others is another aspect that is considered in this vision. In [38] and [39], the idea of Social Machine as a unifying mental model for understanding, describing and designing each and every entity connected to the Web points relationship as a fundamental element of such model. In fact, turning software into services on the Web means allowing it to interact with a huge number of other independently owned (and sometimes unknown) applications and services, and possibly establishing a plethora of "social" *relationships* with them. In this sense, a system can be viewed as a sociable entity whose interactions with each other are determined by their "social" relationships, just like people. In a more general sense, it inspires the idea of what we call *Relationship-aware Systems*, which are an option for describing possibly related and interacting Social Machines that make use of notions from *computing*, *communication* (in the form of relationships and interactions) and *control.*

5. CONCLUSION

In this paper, we characterized the Social Machine area through a mapping study on a set of existing work. We outlined our adopted research methodology, showed the obtained results and made an initial discussion about the outcomes.

From our preliminary mapping, it clearly appears that the Social Machine paradigm relies on social computing and shall be the result of the convergence of the three main visions: *i) Social Software* (as its foundations), *ii) People as Computational Units* and *iii) Software as Sociable Entities.*

The science, technology and implementations of Social Machines are in a very early stage; the purpose of this work is to contribute to the process of providing a more common and coherent conceptual basis to the understanding of Social Web-based Systems from a very broad point of view. Furthermore, we have set the scenario to discuss Social Machine as a proper research area, including avenues of scientific inquiry and possible, different views of research topics. Future work includes extending this study to tackle an even more comprehensive set of references and the generalization of the results to include other aspects of the research area.

6. ACKNOWLEDGMENTS

The authors would like to thank Geoffrey D. Sanders for reviewing the manuscript and offering valuable suggestions. We also thank the anonymous referees for their helpful comments, and all colleagues from SERPRO (serpro.gov.br) and ASSERT Lab (assertlab.com) for helping to improve this work, in particular Prof. Dr. Vinícius Garcia (CIn-UFPE).

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