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On Managing the Social Components in a Smart City

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***Abstract*—Recent technological and societal developments, reflected in the appearance of Internet of Things, Cloud Computing, Crowdsourcing and the shift towards a sharing economy, put the humans in the position not only to consume the services, provide data or execute simple (computational) tasks, but also to actively engage and shape the hybrid collaborative activities. These changes are opening up the possibilities for novel forms of interaction, collaboration and organization of labor. This becomes especially relevant in the context of the Smart City, where the focus is shifting from optimizing physical infrastructure and resource savings to include empowerment of citizens and support for neighborhood-scale complex/creative human collaborations. The expectation is that such collective activities can bring a disruptive change to the society. In this paper we present our vision for initiating and managing socially-driven collaborations in a Smart City context by considering research challenges related primarily to the human-centric aspects of the said collaborations.**

I. Introduction

With well over 60% of the world population projected to reside in cities by 2050 [1] the development of sustainable urban ecosystems is one of the major challenges that we face. The concept of *Smart City* is used as an umbrella term for solutions from a number of research areas that lead towards sustainable living in urban environments. The sustainability aspect refers to a number of improvements and optimizations in the public and private infrastructure and urban processes.

The primary attractiveness of the Smart City as a research domain lies in the fact that, although lacking a uniquely agreed-upon definition, it acts as a powerful alignment and complementation catalyst for various research fields. In the domain of ICT, the broad vision of the Smart City can probably be best understood as the ultimate *system of systems*, where the notion of ultimate synergy implies smart physical environments where robots and IoT devices sense, interact and act to optimize the environment and urban processes, backed by the practically unlimited analysis, computation and optimization capability powered by the Cloud/Edge Computing. However, the citizens are often neglected in this technology-centric ICT vision of Smart City. They are indeed expected to be the beneficiaries of the technological advances, but not so much their enablers or active stakeholders.

We believe that the full potential of the Smart City vision can only be achieved if all the technological advances are exploited to ultimately enable creation of completely novel business and societal values. As these values are of exclusive meaning to humans only, humans must necessarily be in the focus of the ICT research in the Smart City context.

In order to connect societal values with the low-level (hands-on) goals of concrete research efforts, a gradual approach needs to be taken, where the high-level values are achieved through a number of intermediate objectives. In our recent book [2] we present a vision of such an *architecture of values* for Smart Cities in more detail. We focus on a number of key research areas and present an ICT research roadmap that we believe will shape the research landscape in the coming years.

One of the key objectives in the architecture of values is the *citizen empowerment*. This implies development of a number of technologies to support humans in performing their cognitive, creative, collective and social activities, both in the physical and in the digital domain, while embracing the distinguishing human imperfections as inherent features of the system. As an indicator of the importance of the research on citizen empowerment and human-driven collective initiatives – in the period 2014-2015 the European Commission has awarded research grants worth 43 million euros under the Horizon 2020 program to the CAPS[1] research projects supporting collective activity platforms, with further funds to be awarded in future calls. The funded platforms are collections of financial, organizational and software tools supporting long-running citizen initiatives of societal importance in specific areas (e.g., democracy, environment, health).

In this paper we present our vision of the value-driven, human-centric collaborative systems for the citizen empowerment in a Smart City context. While sharing the same empowerment values and many similar intermediary objectives with the CAPS projects, our vision differs in that it advocates developing generic, executable software mechanisms supporting ad-hoc, fully citizen-driven collaborations.

The paper is organizes as follows. In Section II we describe the current research landscape and the state of the art. In Section III we then present our vision of the future ICT developments relevant for the management and empowerment

[1] https://capssi.eu/caps-projects/

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of the citizens of Smart Cities. This vision is then formulated in terms of concrete research challenges that are presented and discussed in Section IV. Finally, Section V concludes the paper.

II. Related Work & State of the Art

As it is common for a yet evolving research area, there is a number of commonly-related terms used to refer to similar and cognate ideas. In an attempt to clarify the current research landscape and facilitate the positioning of this paper (Fig. 1), we briefly give an overview of the different classes of systems involving human and computational elements.

The term *Collective Adaptive Systems (CAS)* [3, 4] is a term covering various subclasses of systems with the common trait that they all deal with managing collaborative activities performed by teams (collectives, swarms) of actors. These need not necessarily include humans, but can be robots or software agents. The focus is on managing collaboration, self-organization and adaptivity, often at a large-scale. The subset dealing with both human and machine agents is called Hybrid CAS (hCAS) [5].

Socio-technical/Cyber-Human Systems are broad terms for systems dealing with both humans and software services. While activities are collectively performed through the joint use of human and software functionalities, in most cases we cannot speak of proper collaboration; usually a software platform manages a hybrid workflow and invokes human and machine elements to perform specific tasks resulting in a collective result. Historically, these were most often computationally difficult, but easy for humans to solve (e.g., image/context recognition). Thus the area was originally named *Social Computing* [6], and this term is still widely used to denote the entire socio-technical class, even though the complexity of the systems now encompasses more general (non-computational) activities. Often, socio-technical systems will consider social relationships and other inherently human properties. *Crowsourcing* (in the conventional sense) is a socio-technical system solving complex, but easily parallelizable tasks, by splitting them and sending them out for processing to a large number of anonymous and approximately equally capable human agents (crowd) [7].

The systems dealing with general, complex, activities performed both in the digital and in the physical domains, involving both human and machine elements (services, sensors, devices), characterised by a high degree of self-organization and adaptation are called *Cyber-Physical-Social Systems (CPSS)*. This definition describes an environment where the social and the digital fabric merge with the physical world, and human interactions ever more often take place with, or are mediated by software services, pervasive devices, sensors and actuators. The CPSS naturally complement the recent Smart City developments, most notably IoT and Edge Computing, by allowing the citizens to collectively and distributively make efficient use of the private and the public physical/IoT infrastructure. The focus is on modeling and managing the interactions with Smart Devices and Smart Environments [8, 9].

A *Cyber-Physical-Human System (CPHS)* in its latest iteration, as described in [10], is an extension of the CPSS, where humans are expected to play a more prominent role ("people in the loop"). While bearing striking similarities with the concept of *Social Compute Unit (SCU)* [11] (mostly with respect to the human service capability description model), a major novel distinguishing characteristic of a CPHS is the requirement to accommodate for the human unpredictability and the need for incentivization.

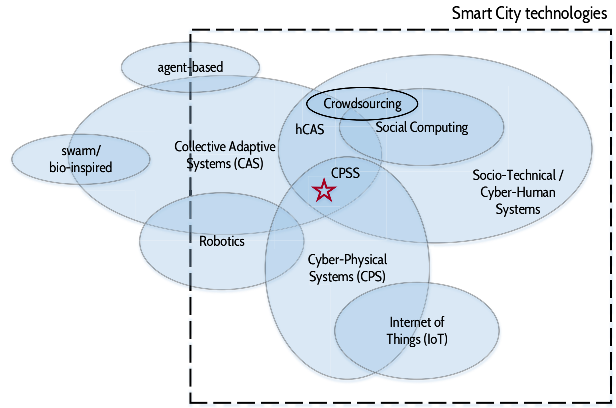

Fig. 1: An overview of the relevant related research fields.

III. Going Beyond State of the Art

Sharing economy has been significantly shaping our society in recent years. Notwithstanding a number of business models focused on centralized platforms that were criticized as exploitative (e.g., Uber), the most drastic change that sharing economy brought along was a wide acceptance of ad-hoc business transactions between unknown people, both in the digital and in the physical domain (e.g., sharing a ride in a private car via BlaBlaCar). We argue that:

Given more innovative collaboration models, the acceptance of the sharing economy principles will cause an even more disruptive societal change by providing a technological foundation for citizens to engage in complex, decentralized and accountable collaborative activities.

This will consequently induce the creation of many innovative, *decentralized* business models to exploit them and ultimately lead to the creation of novel Smart City societal values.

The key assumption in the above assertion is the existence of the innovative collaboration models. Historically, the evolution of related systems (described in Sec. II) was mostly driven by the technological advances. Including people in them meant significantly downplaying human capabilities in order to model the human participants as computing elements. Even when social aspects, such as friendship relationships, were being considered, this data was being used passively, as inputs to recommendation, reputation or team composition algorithms. Such collaboration models are not flexible enough to support the full spectrum of human-centric collaborations. We believe that the scientific community has an ethical obligation to lead the design and development of novel, non-exploitative collaboration models that enable the inclusion of people in their full social and creative capability. We therefore further argue that:

Managing human-centric collaborations will require relaxing a number of expectations and constraints, in exchange for the gained flexibility and active inclusion and empowerment of citizens.

Starting from these assertions, we are able to formulate more specific *distinguishing features* of the envisioned Smart City collaborative models:

F1: Fully human-driven, self-orchestrated, ad-hoc collaborations characterized by imperfection and volatility as inherent properties.
F2: Human motivation as the principal driving factor managed through incentives.
F3: Accountability and transparency by design.

Taken individually and out of the Smart City context, each of these topics was researched before in various areas of Computer Science. However, we believe that the uniqueness of the combination of these properties considered in the specific context makes them collectively an innovative research area, with the perspective of delivering concrete solutions that will be applicable in Smart City environments and produce new societal value. In the following section, we are going to discuss each of the listed features and present upcoming research challenges.

IV. Research Challenges

A. Fully Citizen-driven Collaborations

Consider the following illustrative scenario:
A commercial collaborative platform offers organizing personalized city tours to interested clients for a fee. The client submits his/her preferences to the platform. Local citizens, who have previously applied to the platform for participating in organizing such tours (as a commercial activity), can self-organize, and (jointly) propose what they think would be the most fitting city tour for the given client. If the client accepts a proposed tour, the locals who proposed the accepted tour engage (or even become contractually obliged) to organize, split the various duties and carry out the tour (e.g., pick up the client at the airport, buy museum tickets in advance, book a taxi, accompany the client on a city walk). When the task is finished, the platform takes over again, and performs final activities, such as payments or reputation updates.

The key novelty that distinguishes a Smart City collaborative platform from the conventional state-of-the-art platforms is that it does not decisively control the execution of collaborative activities. Instead, the activities are self-orchestrated in a pretty loose fashion by the participating peers. This entails that many execution, consistency and termination criteria need to be relaxed to accommodate humans as first-class citizens in a distributed system. In this scenario the platform plays merely a mediating and a supportive role (Fig. 2), but the actual planning and execution is entirely in the hands of the participating humans. In order to interface these two parts, we need a monitoring functionality (cf. [12]), tracking and composition of provenance [13, 14] and accountability [15, 16], so that the platform (being the mediator, and ultimately enforcing the contractual terms), can make decisions on termination criteria, quality/fulfillment of agreed service, compensations, penalties and reputation. However, tracking human-performed activities that are fully out of platform's control can, in general case, be accomplished only through an active and consensual engagement of the participating humans. The functionalities of the platform figure as key enablers of such complex unconstrained collaborations by providing ad-hoc commonly agreed behavioral rules and a distributively-managed overseeing authority, thus increasing the sense of trust [17] both for the collaborators as well as for the clients and making the successful and fair outcome more likely.

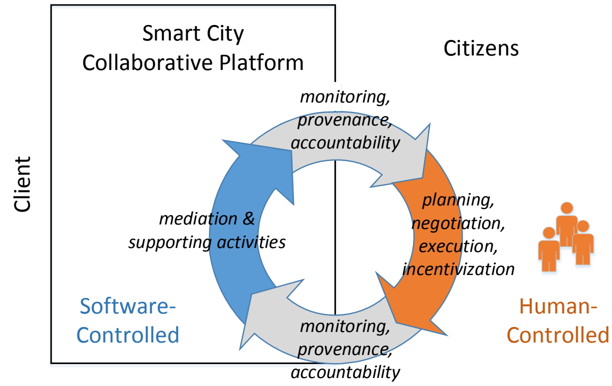

Fig. 2: Efficiently managing human-centric collaborations requires distributing the control loop activities between the participants and a mediating Smart City collaborative platform.

Out of a number of interesting research challenges for supporting the described scenario, we single out the following:

RC1) Semantics interpretation must be primarily performed by the human participants. Inaccurate/incorrect semantical interpretation must be an inherent property of the system. The novel coordination models need to be expressive enough to convey the meaning primarily to the human participants. This will require reducing the comprehensiveness and complexity of the machine-tractable parts of the model (e.g., ontologies, workflows), thus limiting the practical usability of the existing orchestration and monitoring tools and requiring development of new ones.

RC2) Due to the human involvement, the execution is best-effort, open-world, and non-deterministic. The workflows coordinated by the proposed models must be composable at runtime by definition. Termination criteria and quality of service/results may be subject to subjective assessment.

B. Motivation and Controllability through Incentives

Another fundamental aspect that is largely neglected by the state-of-the-art systems is that of the nature of controllability of the Smart City social component. The existing approaches are predominantly passive, simplistic and non-inclusive. The human participants are currently either assumed to execute the given tasks unconditionally (e.g., workflow management systems) or assumed to choose the tasks they want to execute based on an assumed, quantifiable utility function (e.g., conventional B2C crowdsourcing platforms [18], multiagent systems [19]). Both of these approaches are approximations simplifying the computational handling of human elements in the system. While both models proved efficient in the intended application areas, we argue that these simplifications are not appropriate for the described scope of collaborations. The human nature is accounted for by assuming a low availability and a high failure/inaccuracy rate of the human "nodes". The motivation controllability is often reduced to a single factor– the monetary reward, in spite of the evidence [20] showing that this is not an efficient incentivization strategy for anything but the simplest independent tasks. Complex incentivization strategies, when present, are not dynamically adjustable.

We therefore propose the following research challenges:

RC3) Design novel incentive models, incentive composition mechanisms and supporting tools for the dynamic Smart City collaborative setting. At the moment, the incentivization is always administered exclusively by the controlling platform, acting on behalf of the task owners. While this is a viable approach for B2C business models, it cannot be universally applied in the case of self-organizing Smart City collaborations, where the participants actively shape the execution workflow and have diverging interests. A novel decentralized C2C approach for the application of incentive mechanisms is thus needed.

RC4) Develop incentive "individualization wrappers" to enable translation of general incentive strategies to concrete, individually-tailored rewarding mechanisms. Considering the both the multifaceted and individual nature of human motivation as well as the dynamic, human-driven (C2C) incentive application scenarios, we need mechanisms to individualize both the incentive providers and incentive receivers, honoring the individual and social traits.

C. Citizen-provided Accountability

In a technical sense, accountability of a system implies the existence of mechanisms for clear attribution of responsibilities for the performed activities. If properly recorded, the attribution of responsibilities can serve as the basis for a subsequent rectification, as well as a powerful indirect incentive to discourage malicious and incorrect behavior, which is crucial for the human-centric collaborations.

Although being a property of primary importance to any system dealing with human users and participants, accountability has (surprisingly) long been neglected. We are currently witnessing a significant raise in awareness of its importance [16, 21], as well as first concrete significant regulation steps (e.g., GDPR[2]). However, the existing efforts mostly stipulate requirements of static, company/organization-internal, technological and legal procedures for mitigating associated risks, predominantly in the domain of data management. As such, these solutions cannot be straightforwardly applied to the human-centric collaborations, where neither the algorithm nor the actors are known in advance.

In case of the human-centric collaborations, the accountability can be described as a technical capability to explain or justify how participant decisions where made, on what data they were based, under which terms they were taken, and under which accepted consequences. Assuming that, in absence of continuous automated monitoring, the best possible correctness judgment on a human collaborative activity (performed in the physical Smart City environment) can be made based upon the coherent and consensual responsibility acceptance by the participants, we will need to develop high-level distributed social consensus and accountability models and algorithms for human-centric collaborative environments. The models will primarily need to be capable of evidencing the misbehavior, even in cases of coordinated deceitful behavior of the citizens. The question of how to achieve this remains open.

We can now define the challenges:

RC5) Design models for accountability of participants of human-centric citizen collaborations, resistant to coordinated misbehavior. The challenge lies in distributively managing the tracking of accountability and achieving a relatively high degree of integrity in cases when neither the actors nor the (sequence of) activities is known before runtime. Distributed ledger technologies currently seem like good candidates for solving some aspects of this challenge, but their introduction is still non-trivial, due to the fact that small/neighborhood-scale citizen collaborations are vulnerable to the intentional emitting of false transactions and citizens being de-stimulated to submit, verify or pay for verifying transactions. In such environments, a straightforward application of a conventional distributed ledgers (such as Blockchain) is not possible. We therefore need to investigate a number of adaptations, supporting (e.g., incentive) mechanisms and alternative distributed ledger models.

RC6) Develop state-of-the-art privacy and ethical principles for the human-centric collaboration models. One of the key preconditions for a city-scale citizen engagement and acceptance of Smart City collaborative platforms is building a relationship of trust and confidence between the citizens (participants) and the mediating platform. While trust is a multifaceted property, there is a general consensus that implementation of the mechanisms that rely on accountability (e.g., data portability, pseudonymization, grievance/rectification, right to be forgotten) are important factors of trust. However, the implementation of the aforementioned principles for distributed, dynamic human-centric collaborations involving volatile human nodes is more challenging than for centralized socio-technical platforms.

V. Conclusion

Recent technological and societal developments combined with the shift towards the sharing economy put the citizens of a Smart City in the position to be more than consumers of smart services or providers of data. The future Smart Cities will see the citizens actively engage in neighborhood- or city-wide hybrid collaborative activities with the prospect of actively shaping the city. Furthermore, the active citizen collaborations mediated by Smart City platforms create the base for new business models and flexible organization of labor. We argue that this will cause a shifting of the Smart City development focus from optimizing urban processes, physical infrastructure and resource savings to the empowerment of citizens, bringing along a disruptive change to the society.

In this paper we presented our vision for initiating and managing human-driven collaborations in a Smart City context by considering primarily the human-centric aspects of the

[2]https://ec.europa.eu/info/law/law-topic/data-protection_en

said collaborations. Such an environment requires efficient collaboration and coordination models and algorithms that put the humans in the driving seat – giving them an active role in orchestrating the collaboration in which they take part. This orchestration is performed through "soft" controllability mechanisms – incentives and accountability, intended to stimulate constructive and productive behavior and increase the sense of mutual trust, but also to provide the means for a possible rectification or retribution. This vision is formulated in terms of research challenges that are presented and discussed, to serve as a road map for future research in this area.

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