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Technology for Collective Action

The Digital Society is increasingly characterized by an ecosystem of smart, socio-technical applications, such as smart grids, smart homes, smart cars, and so on. These applications are embedded in a social context with people "in the loop." They are fully networked and saturated with sensors, and they use artificial intelligence for context-awareness and adaptivity. Unlike biological ecosystems, each application, and indeed the ecosystem itself, is critically dependent on human-centred, mutually agreed upon, conventional *rules* or *norms* for its effective and efficient operation.

Therefore, developing socio-technical (eco) systems raises three major engineering challenges, but offers important new opportunities for successful collective action. The first challenge consists in modeling, understanding, and developing the interrelated processes behind the formation, selection, and adaptation of the systemic rules, since these are essential for ensuring desirable macro-level outcomes and avoiding detrimental ones. This may include for instance the definition of efficient and commonly-acceptable rules for maintaining and sustaining the (eco)system over long periods of time.

The second challenge lies in identifying and capitalizing upon the key technology-enabled processes that can motivate or even make possible new forms of collective action. An important opportunity here may come from understanding and exploiting the role that well-managed (big) data and data-flows can have in enhancing societal awareness and responsiveness. Another opportunity may stem from enriching the ecosystem with generative application platforms that can encourage and promote social incentives for orchestrated, synchronized or coordinated collective action.

Finally, the third challenge is to persistently identify and address, via new sets of rules, the novel societal questions that the progressive introduction of technology raises into the ecosystem. For instance, the technology-enabled generation of massive amounts of data may require specific rules for ensuring that data generators are also its beneficiaries. Certainly, the most important difficulty consists in understanding how these interrelated challenges can be addressed concurrently, within a highly dynamic context, so as to provide rich opportunities for collective action and increase the chances for coherent beneficial outcomes.

Collective action generally involves a group of people working together to achieve some shared objective. A frequent problem that can hinder collective action stems from the fact that group members may also have individual interests, which may be in conflict with the group's shared objective. Furthermore, while the benefits of an action performed for the common good might be shared equally among the group members, the costs of the action fall only upon the individual performing it. These asymmetries can lead to many forms of anti-social behavior, such as free riding, and to other undesirable consequences.

In traditional social systems, there is a "standard" mechanism to address such problems of collective action – *institutions*. Indeed, there is a well-established

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understanding of the importance of institutions in the conduct of human affairs, where an *institution* is defined as a conventionally agreed upon, structured rule-set intended to regulate the behavior of people in a collective, whether or not they share a common purpose. This understanding, showing how institutions can provide successful solutions to collective action problems, is perhaps best exemplified by the work of Nobel Laureate Elinor Ostrom [1].

Ostrom especially studied institutions for regulating access to some *shared common-pool resource* that must be sustained (e.g., water, energy, forestries, fisheries, etc.), wherein it was in everyone's long-term collective interest for the resource to endure, but also in their short-term individual interest to maximize their "take" from the resource – but this behavior causes depletion of the resource in the long term. Her pioneering work showed how self-governing institutions could overcome this "tragedy of the commons," deliver successful collective action, and promote sustainability of a common-pool resource. She identified common features differentiating success stories from failures, and proposed these as *design principles* for enduring institutions (see Appendix).

However, these principles are, perhaps, best applied to local small-scale situations that involve physical resources. There is some evidence to suggest that they do not scale well to deal with global collective action situations (for example, the ineffectiveness of the Kyoto Protocol for reducing carbon dioxide emissions). At larger scales, institutions tend to have multiple, deeply entangled priorities driven by possibly competing or even contradictory policy objectives. Furthermore, in the shift of emphasis from analyzing the "evolution" of institutions to the generation or prescription ("supply") of institutions, the principles were essentially static and did not address dynamical qualities that could provide the basis of more adaptive institutions. In addition, the design principles reflect a pre-World Wide Web era of scholarship and content creation, and these developments make it difficult to apply the principles to non-physical shared sources such as data or knowledge commons.

Similarly, there are some limitations of the design principles when applied to the design of *electronic* institutions. For example, Ostrom's definition and analysis of "action situations" overlooked a fundamental organisational concept called institutionalized power [2]. Institutionalized power is commonly understood in legal and organizational theory as denoting when a designated agent, acting in a specific role in an institutional context, is empowered to create facts of conventional significance by the performance of certain actions (often, but not necessarily, speech acts). The concept of institutionalized power is important in electronic institutions for converting the design principles into executable rules. As another example, in Ostrom's second and third design principles (congruence of provision and appropriation rules to the prevailing environment; those affected by the rules participate in their selection and formulation), there is an implicit assumption of fairness in the resource allocation. In electronic systems, an intuitive, subjective, or emotive understanding of fairness cannot be taken for granted: fairness needs to be computed by some metric – and for this, there are many different metrics and multiple factors to consider (utility, equity, equality, efficiency, and so on).

We mention these limitations because, currently, there is a pressing social need for so-called *Smart Cities*. These are, undoubtedly, large-scale socio-technical systems with many interdependent and interconnected institutions, subject to a myriad of dynamic (and possibly conflicting) policy objectives. It is, undoubtedly, an ecosystem of intelligent, socio-technical applications, with computational intelligence(s) participating in decision making with respect to, and with deep impact on, qualitative human concerns. But rather than discard Ostrom's theories as inapplicable due to these perceived limitations, we propose to *start* from Ostrom's theories, to overcome the limitations, and to provide the foundations for promoting awareness, responsiveness, and pro-social incentives.

Therefore, the challenge addressed by the papers in this special section is: What are the requirements and opportunities for transforming Ostrom's foundational work into institutional design principles for an ecosystem of socio-technical systems? In particular, how can we leverage technology for successful collective action as advances in sensor networks, widespread connectivity and social networking, rapid emergence of cryptocurrencies, and the symbiosis of human and computational intelligence, produce a social environment that is well beyond anything anticipated in 1990, when *Governing the Commmons* was first published?

The articles in this issue attempt to deal with these very questions. In "Scalable Proactive Event-Driven Decision-Making," Artikis *et al.* address the technology that can enhance Ostrom's fourth design principle (monitoring is by appropriators themselves or by agencies appointed by them). This paper presents a new logic-based approach for highly efficient event and situation recognition, taking the notion of "monitoring" of resource management to a different realm of possibilities. Furthermore, it presents an approach for proactive event-driven computing that eliminates or mitigates anticipated problems, and capitalizes on forecast opportunities.

The article by Nowak *et al.*, "Social, Psychological and Technological Determinants of Energy Use," considers the dynamic socio-psychological processes involved in the (bottom-up) emergence, (top-down) supply, and (middle-out) self-adaptation of institutions as they are manifested through energy commons and green energy choices. These processes were largely overlooked in Ostrom's original work, but are essential to self-determination.

In the article by Hardjono *et al.,* "Social Use Cases for the ID3 Open Mustard Seed Platform," a new privacy-preserving platform is presented for user-centric knowledge commons and participatory-sensing applications, where data and information are the shared common-pool resource. Knowledge commons were studied by Ostrom and colleagues [3], but this new platform could provide a route to mass-participation systems in which the data generators are in control of, and also the primary beneficiaries of, their own data.

Finally, the paper by Miorandi and Maggi, "'Programming' Social Collective Intelligence," uses a novel game theoretic perspective to examine the potential for collective action derived from combining social and computational intelligence. This paper offers, perhaps, an intriguing approach for reconciling Ostrom's primarily evidence-based fieldwork with the predictive analytics of game theory, which in the past might be considered to have generated some conflict.

In seeking to understand how technology can be used for collective action in socio-technical systems, we believe that it is necessary to build on, but go beyond, Ostrom's principles and theories. While she might possibly have been surprised at some of the circumstances in which her thinking can be applied, she would hopefully have been excited by the new theoretical insights and innovative technological frameworks inspired by her work – and enthused by the potential outcomes for successful collective action.

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Appendix: Ostrom's Institutional Design Principles

The eight design principles are:

Boundaries: who is and is not a member of the institutions should be clearly defined, as are the resources that are the subject of allocation

Congruence: the rules should be congruent with the prevailing local environments (including the profile of the members themselves)

Participation: those individuals who are affected by the collective choice arrangements should participate in their selection

Monitoring: compliance with the rules should be monitored by the members themselves, or by agencies appointed by them

Proportionality: graduated sanctions should ensure that punishment for non-compliance is proportional to the seriousness of the transgression

Conflicts: the institution should provide fast, efficient and effective recourse to conflict resolution and conflict prevention mechanisms

Autonomy: whatever rules the members agree to govern their affairs, no external authority can overrule them

System of systems: small local communities "at the edge" should be aggregated into larger systems at larger scales of interaction