Interactive Self-Governance and Value-Sensitive Design for Self-Organising Socio-Technical Systems

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***Abstract*—The saturation of the physical environment with sensors, the proliferation of personal mobile computing, and the prominence of Artificial Intelligence in (so-called) 'smart' objects has created new opportunities for the development of socio-technical systems. We are particularly interested in the convergence of people and computational processes (agents) in the creation of digital communities for sustainability and successful collective action. However, prior experience with intelligent and adaptive user interfaces suggests that the symbiosis of people and technology needs to be carefully considered. This paper presents three applications of self-organising socio-technical systems, from which we derive design guidelines for implementing *interactive self-governance*. The guidelines are related to the methodology of *value-sensitive design* and the need to actualise *human values* as a critical supra-functional requirement of future socio-technical systems.**

1. Introduction

The saturation of the physical environment with sensors, the proliferation of personal mobile computing, and the prominence of Artificial Intelligence in (so-called) 'smart' objects (e.g. smart meters, smart cars, smart houses, etc.) has created new opportunities for the development of socio-technical systems to realise visions of a *Digital Society* and the *Digital Economy*. Indeed, this Digital Society is increasingly characterised by an ecosystem of smart, socio-technical applications, especially for infrastructure management and sharing economy. Examples of infrastructure management include electricity generation, distribution and storage [1], water management [2], and urban transportation [3]; while examples of sharing economy applications, involving a transient ownership of goods from a stock of physical assets provided by peers (C2C, i.e. consumer-to-consumer), are manifold [4].

The unification of these applications within a single 'ecosystem' is, perhaps, best exemplified by the concept of a *smart city*. We are particularly interested in the convergence of people and computational processes (agents) in the creation of digital communities for sustainability and successful collective action in smart cities. However, as well as being embedded in environments that are fully instrumented with devices and sensors, inter-connected (e.g. through both social and sensor networks) and intelligent (interleaving both social (human) and computational intelligence [5]), socio-technical systems supporting these communities are necessarily *interactive*.

This interactivity raises three issues. Prior experience with intelligent and adaptive user interfaces [6] suggests that the interaction of people with adaptive technology based on machine learning is not guaranteed to be perfect (since people are, frankly, mercurial at best in the short term; but there are significant factors to consider in long-term, perhaps life-long operation [7]). Secondly, there is evidence to suggest that neglecting what might be called the *human-infrastructure interface* can either miss opportunities for, or have a deleterious affect on, collective action, e.g. for sustainability [8]. Finally, there is an issue of control, and that the symbiosis of people and technology inevitably turns from delegation to deskilling and dependence and eventually to determinism (e.g. prescriptive analytics producing discriminatory outcomes that may even be in contravention of human rights legislation [9]).

This paper is concerned with addressing these three issues. Starting from Ostrom's work on self-governing institutions [10] and polycentric governance [11], we have proposed computational formulations of these ideas based on algorithmic (self-)governance [12] and holonic systems [13]. Here, we extend these ideas to the concept of *interactive self-governance*, in the context of a more general concern for qualitative human values.

Therefore this *position paper* is organised as follows. The rationale for interactive self-governance as an extension of algorithmic and polycentric governance is developed further in Section 2. Section 3 presents three applications of self-organising socio-technical systems, from which we derive design guidelines for implementing *interactive self-governance* in Section 4. In Section 5, these guidelines are related to the methodology of *value-sensitive design* [14] and the need to actualise *human values* as a critical supra-functional requirement of future socio-technical systems. We summarise and conclude in Section 6 with some remarks on a new vision for smart cities based on Ostrom's ideas.

2. Rationale

Previous work, investigating self-organising electronic institutions for common-pool resource management in open systems, focused on the formalisation of two related mechanisms for self-governance. The first mechanism was *algorithmic governance*, defined as the use of computational logic to formalise governance procedures in executable protocols and programs [12]. The second mechanism was *polycentric governance*, defined as the use of concepts from complex systems science, such as holonic designs, to support both multiple centres of decision-making at multiple scales, and facilitate compromises between their potentially conflicting interests [13].

However, the interaction between computational intelligence and social intelligence (and technology in general) is absent from Ostrom's original work. Given the criticality of the interface between users and their infrastructure [8], and if that infrastructure is highly instrumented, as is the case in smart cities, then the human-computer interaction and ergonomics issues must also be considered. In particular, to avoid the literal application of rules which produce purely deterministic outcomes that do not allow for extenuating circumstances, common sense or other 'normal' tolerances, it is essential to keep humans in the loop.

Therefore, we require three aspects of governance. Firstly, we need community-defined rules and regulations expressed in computational logic, and so amenable to automation (technical systems). Secondly, when several communities must share common resources, where each community may have several interests, which may be in conflict with those of other communities, the above concerns must be designed for scalability and diversity support. Thirdly, on the basis of presentation and representation of the protocols and structures of algorithmic and polycentric governance, humans must be able to (seamlessly) participate in defining these rules, monitoring their implementation and handling special cases, evaluating their outcomes, adjusting the rules.

This third mechanism is *interactive self-governance*, defined as the use of visualisation and affordances to make the conceptual principle of self-determination (i.e. those affected by a set of rules participate in their selection and modification) perceptually prominent in, and accessible through, the socio-technical interface. In the next section, we consider three exemplars of socio-technical systems exhibiting various aspects of interactive self-governance.

3. Three Exemplar Applications

This section presents three exemplars of interactive self-governance, keeping 'humans in the loop' in the governance of socio-technical systems, i.e. where people are engaged and empowered to leverage algorithmic governance – the embodiment of Ostrom's third institutional principle, that those affected by a set of rules should participate in their selection and modification, and indeed application.

The first two exemplars stem from perceiving collective action situations everywhere, and interpreting a shared space, firstly for working and secondly for living, as a common-pool resource, to which occupants provision to or appropriate from according to prosocial or antisocial behaviour respectively. The third case study addresses a pressing issue in healthcare.

We would argue that these scenarios are representative of a sub-class of socio-technical system, although certainly not all, in that they exhibit specific features of general interest: self-organisation of conventional rules, collective action for the common good, sustainability of qualitative values that cannot (should not) be commodified and metricated, and incentives for community building.

3.1. Shared Workspaces

Open-plan offices and hot-desking are workplace arrangements intended to promote flexible and cooperative working practices, but can also create situations where violation of (implicitly or explicitly stated) conventional rules, or social norms, can cause instances of incivility [15]. Such incivility, characterised by a low-intensity form of deviance from accepted norms, can be difficult to detect and resolve, but is also very harmful for the people who experience it regularly, and have serious consequences for the organisation in which it occurs.

Therefore, it is a pressing problem in both ergonomics and workplace planning to reduce the negative side-effects of incivility. The technological solution we have proposed for addressing the incivility problem, is MACS (M—s Affective Conditioning System): a system that attempts to avoid, reduce and/or resolve incivility before it escalates into a higher-intensity situation, e.g. conflict or aggression [16]. MACS is intended to emphasise stakeholder engagement and empower collective choice: firstly by avoiding micro-management, as incivility episodes are resolved between stakeholders (i.e. the occupants of the shared space themselves), and only as a last resort by appeal to higher authorities; and secondly by providing social support, through a network of communication and mutual obligations, via the collective selection, monitoring and enforcement of the stakeholders' own social norms and pro-social processes such as forgiveness [17].

We envision the shared working space as a *common pool resource* which we seek to manage according to Ostrom's institutional design principles, as previously presented. In this respect, the metaphor we are pursuing is that the (intangible) 'office ambience' is a pooled resource which the office occupants can deplete by anti-social behaviour and re-provision by pro-social behaviour.

Figure 1(a) depicts the first screen displayed for a user, after a successful login to MACS. The navigation bar, on top, and the footer bar, at the b0ttom of the screen, are constant throughout MACS. The navigation bar provides direct access to the home screen, the social norms screen and the historical information about events where the logged-in user has been involved in, as an offender. Below the navigation bar, is the set of avatars representing all the people with whom the user shares the workplace. By hovering

(a) User start screen (b) Social norms interface (c) Administrator interface (d) Open events

Figure 1: Interactive self-governance for shared workspaces.

the mouse over each of the avatars, the text “Flag *person’s name*’s violation of norms” shows up, where *person’s name* is replaced by the chosen person’s name. By clicking on an avatar, the user is taken to the flagging screen, where they can create a new event, by flagging a violation of norms by the person they chose. At the bottom left area of the screen there are two different items regarding the logged user: their current reputation (standing with the community for compliance with norms) and its evolution graph for the previous 10 days, their avatar and their name. Note that reputation can be reinstated directly by forgiveness, or restored over time towards a homeostatic equilibrium.

A core function of MACS is to support users in suggesting and voting for norms. Figure 1(b) displays the “Social Norms” screen for an open plan office. Here all norms are presented, ordered by severity level, from the most to the least critical. Each norm is printed in the colour code that reflects its severity. Red means the norm is very critical, orange-red means critical, orange means average, and finally yellow means minor. In this case, there aren’t any minor severity norms to be displayed. In front of each norm, in square brackets, is its category. Categories are “noise”, “privacy”, “food”, “environment”, “politeness” and “borrowing items”. Below each norm is its description. And finally by each norm are an approve (thumbs up) and a disapprove (thumbs down) buttons, which can be used to vote positively, or negatively, respectively, for the norm. At the bottom of the list of norms is the suggestion box, where the user may suggest a new norm for their workplace. There is an open question how users should specify the graduated sanctions for violation of new norms: according to Ostrom’s principle of self-determination those affected by rules should participate in their selection and modification, but this does not always seem to apply directly to the principles of monitoring, sanctions and conflict resolution.

To ensure that MACS meets its objective of reducing incidents of incivility in shared spaces, the contribution of formal models of social processes (e.g. conflict and forgiveness) to the mechanism of interactive self-governance (by user selection and modification of norms) is critical. However, MACS also offers an administrative role, as shown in Figure 1(c) and Figure 1(d) so that the administrator can observe votes and declare results, and can track events to avoid collusion or false accusations. However, ideally we would eliminate the administrator role altogether.

3.2. Shared Living Spaces

In fact, we would contend that *any* shared living space, and not just an open-plan office, but also a communal flat, tenement building, or even a public space such as a park, can be approached as a common-pool resource management or collective action situation.

In the context of an ongoing housing crisis in the UK[1], university students or young working professionals are often thrown into situations where they have to live together with new people, maybe for the first time. Sometimes long-lasting friendships are formed, but others can have a miserable time. They may have issues of (in)tolerance, mutual cooperation and other conflicts to address, sometimes driving even the most tolerant people to passive aggressive, or even aggressive stand-offs with their flatmates. Again, leveraging interactive self-governance based on a computational formulation of Ostrom’s institutional design principles, we propose a socio-technological solution to foster more open and mutually agreeable living arrangements.

By treating the flat as a shared resource, we can apply Ostrom’s design principles for common-pool resource management to create a system for self-organised governance at a hyper-localised scale. In particular we can leverage mobile computing with technology for collective action, manifested as an app which provides an interface for self-organised interactive governance. Making the assumption that all members of a flat-sharing group exhibit the same basic pro-social and technological tendencies (it cannot deal with the intentionally disruptive, or those who opt-out) we have developed a prototype platform to manage the state of self-organised governance within the flat. The app provides

1. For example, http://www.theguardian.com/society/2016/may/24/revealed-foreign-buyers-own-two-thirds-of-tower-st-george-wharf-london

a convenient means to partake in such a governance, and as a means of expressing gratitude or discontent with the actions of other members in order to dispel any potential hesitance and (socially awkward) barriers to bringing these matters to light.

An overview of the interface is illustrated in Figure 2. This illustrates the main features of the interface enabling interactive governance supported by the system: reputation, visualisation of user mood and flat moods, activity feeds, social networking, action judgements, apologies, solicitation of prosocial feedback, notifications, voting, and setting rules.

Figure 2: Interactive self-governance for communal spaces.

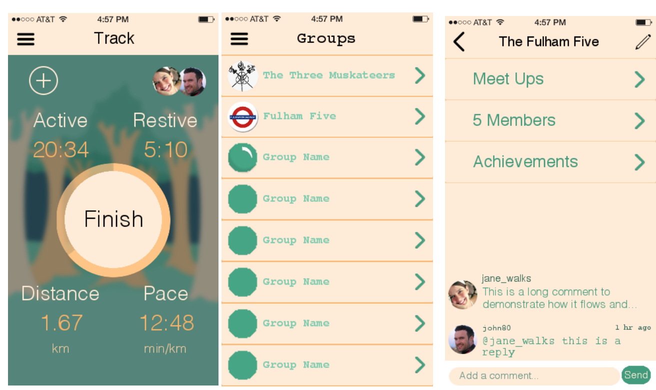
A small-scale field trial of the system has been undertaken, to evaluate its potential for enhancing living conditions in shared flats. It was installed in two flats, but with mixed results. One flat embraced it and was very receptive to the idea of mutually-agreed rules with an electronic representation, and there were some positive improvements in their living standards, and strongly supportive qualitative feedback. The second flat resisted the system or did not observe their own agreed rules, showing that people have to 'buy into' both the collectivity and the technology, but also that the technology has to deployed carefully to magnify its prosocial benefits rather than its potential pathology (for example: false reporting, bullying, collusion, etc.).

3.3. Self-Supervised Exercise

Vascular surgeons have recognized that the condition of many patients presenting with intermittent claudication and peripheral arterial disease is better treated by exercise rather than endovascular or surgical intervention [18], in line with current evidence, and international best practice and (grade A) consensus guidelines (see e.g. [19]). However, this exercise causes pain, before and until the health improvements are realized. Unfortunately, patients experiencing pain tend to stop doing that which causes it; unless they are supervised performing the necessary exercise programmes; but supervised exercise is an extremely costly and time-consuming use of medical resources.

Addressing peripheral arterial disease is a significant and unmet clinical and health economic need, but the treatment of intermittent claudication using supervised exercise remains largely under-utilised due to a lack of appropriate resources. In addition, we note that other medical conditions, such as diabetes and hypertension, can also be managed by a similar convergence of self-supervision and ICT, and interactive self-governance. Therefore, we propose an alternative approach based on a digital community for *self-organised, self-supervised exercise*, using information and communication technologies (ICT), including new healthcare sensors and devices and computing models based on self-organising socio-technical systems to provide communal support and collective action (cf. [20]), and have experimented with the design and implementation of a mobile device-based app to support self-organised, self-supervised exercise.

Example interface mock-ups for tracks, groups and communications are illustrated in Figure 3, illustrating the interface design of a putative app which applies some ideas from gamification with the intention to increase self-efficacy. As a result, the app is an exploration game in which to progress, the user must exercise in real life. The user has an avatar that has crashed on an unknown world and has been injured. In order to heal themselves and to stay alive they must explore the area and find items such as food or medicinal plants. To do so, the user tracks their walks through the app. Items are awarded at the end of the session depending on how far they've walked. The users can also connect through the app to find people to exercise with and, by tracking exercise in a group, they can pick up bonus items that are too 'heavy' to lift alone, providing both self-supervision, monitoring and mutual verification. Finally, an exercise plan can be self-created or prescribed by a qualified professional, and if the users stick to the schedule they are rewarded, and incentivized – in appropriate ways (see below).



(a) (b) (c)

Figure 3: App interface mock-ups for self-organised, self-supervised exercise.

One inspiration for this solution to self-supervised exercise is parkrun (http://www.parkrun.org.uk/), which coordinates a timed, free to enter, volunteer-organised 5k run, which is, arguably, a textbook example of Nowak's bubble theory of social change [21], in the way that it expanded from a single event in 2004 with 12 people in one park, to its current size as of 2016 (over million registered participants, over 400 parks in the UK, 8 other countries). One can also point to the success of Pokémon Go, which for all its faults does appear to have the side-effects of encouraging stereotypically sedentary people to go outside, move about and interact face-to-face with others. However, a significant challenge for interactive self-governance is to build a generative platform for developing community-based systems, e.g. for self-supervised exercise, rather than bespoke systems such as that supporting parkrun and Pokémon.

4. Principles of Interactive Self-Governance

In [22], we described a Serious Game called *Social mPower*, which investigated how smart meters could be used to encourage pro-social behaviour and collective action (as opposed to simply monitoring or managing electricity consumption). Based on this work and the exemplars described in the previous section, we derive the following interface guidelines for implementing interactive self-governance in self-organising socio-technical systems

- Interface cues and affordances for collective action, indicating that participants are engaged in a collective action situation – for example the use of avatars, and especially those which express emotions;
- Visualisation: appropriate presentation and representation of data, making what is conceptually significant perceptually prominent, in particular significant events, the status of rules, the progress of protocols and the structure of multiple organisations – for example, the status of norms in MACS;
- Social networking: fast, convenient and cheap communication channels to support the propagation of messages in a seamless, unobtrusive way – emphasisng contextually meaningful private communication between members of a local community known to each other, rather than global platforms that encourage the pursuit of 'followers', 'friends' or 'likes' from strangers;
- Feedback: inform individuals that their ('small', individual) pro-social action X contributed to some ('large', collective) action Y which achieved beneficial outcome Z – for example the representation of the office ambience or the flat 'mood';
- Incentives: typically in the form of social capital [23], awarded for absolute/collective rather than relative/individual endeavour and achievement.

These guidelines are offered in the same 'spirit' as Nielsen's ten usability heuristics for user interface design [24], i.e. these guidelines are currently closer to 'rules of thumb' than specific methodological steps. This iteration of the guidelines for the purposes of this position paper is at a much earlier stage of development than Nielsen's heuristics, and much more work is required to make them fully operational for the increased benefit of system developers. Moreover, the final guideline on incentives is related to a more general concern about *values*, as discussed next.

5. Values & Value-Sensitive Design

This research is targeting the design, development and deployment of self-organising socio-technical systems to create digital communities for computer-supported collective action. This may be for the specific objective of avoiding a problem, such as depletion or exploitation of a resource such as water, energy, parking spaces or knowledge; or (as described above) hyper-localised solutions to improving ambiance and diminishing incivility in sharing a communal living space, or synchronised behaviour to incentivise individual benefits, e.g. for health reasons.

Underpinning these applications is the implicit and explicit concern for *values*. For example, in resource management, there is an explicit concern for sustainability of the common-pool resource, but also an implicit concern for the 'fairness' in the distribution of the resources. Therefore, applying the methodology of Value Sensitive Design (VSD) [14], which effectively puts values (as well as functionality and usability) as a *primary* design focus, could offer a clear path to the development, deployment and run-time management of self-organising socio-technical systems.

There is an intriguing question concerning the relationship between values, incentives and social capital, especially in the light of the finding that winning encourages cheating [25], which is why we argue that social capital should be awarded for absolute/collective rather than relative/individual achievement. It raises a number of foundational issues in the intersection of technology and axiology (philosophical study of value), for example: understanding how technology changes both values and the *conception* of values; how to mitigate value failures (the processes of metrication and commodification which actually diminish values); and understanding how designers can make cultural, legal and/or moral decisions, embed them within the code, and make these decisions manifest in the interface.

6. Summary and Conclusions

This *position paper* has presented three exemplar socio-technical systems exhibiting the requirement for interactive self-governance, complementary to the need for algorithmic and polycentric self-governance. In a narrow sense, it was an attempt to address issues of instability in adaptive human-technical systems, enhancing opportunities for successful collective action, and ensuring humans remain 'in the loop' with at least some semblance of control. In a broader sense, we have attempted to generalise and unify the separate system developments to derive and propose interface design guidelines for interactive self-governance, and link this to the methodology of value-sensitive design. Clearly, what is currently missing is an empirical study to evaluate the effectiveness of these design guidelines, (at least with regard to specific properties), to determine whether they are necessary and sufficient (the presented applications only cover a relatively small range of the socio-technical system design space), and to reify the guidelines to make them more operational. This is an urgent item for further work.

An indirect aim of this discussion has been to develop varied and cross-cutting mechanisms of self-governance to provide a foundation for an innovative approach to the design and development of socio-technical (eco)systems. The current "big data" approach to making 'sense' out of vast amounts of conflicting and unstructured data flowing in from ICT devices deployed in various areas of social life is leading to some advances in prescriptive analytics, with outcomes that range, arguably, from beneficial and insightful to unwarranted, alarming and intrusive [4], [9].

The foundational and original character of the approach outlined here is to redefine the problem: instead of thinking of "global" as vast, unstructured and/or conflicting we define "global" as complex and holonic. The fundamental objective is to empower the social structure at different levels of 'granularity' so that the self-organizing institutions may collaborate with policy makers to govern the smart infrastructures and the data they are generating through tailored ICT platforms implementing the electronic institution engine. This way, the "global" is deconstructed into local aggregates that themselves analyse, structure, interpret and utilise their data flows. In such a holonic architecture of global systems, policies turn from single-paths set towards globally defined goals into constraints defining the boundaries for micro-governance at each level of the social structure.

Ultimately, we aim to develop socio-technical applications which empower users, and an ecosystem which unites these applications in managing multiple resources for the common good. We propose to start from, but go beyond Ostrom's theories, to provide the foundations for promoting awareness, responsiveness and pro-social incentives for collective action in a socio-technical ecosystem for smart(er) cities. This innovative vision, based on qualitative humans values and grassroots empowerment (rather than, say, tracking personal data to improve traffic flow using 'smart' traffic lights), we might reasonably call *Ostromopolis*.

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