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Franco Bagnoli*, Andrea Guazzini†, Giovanna Pacini*, Ioannis Stavrakakis‡,
Evangelia Kokolaki‡, George Theodorakopoulos§

* Department of Physics and Astronomy and CSDC
University of Florence
via G. Sansone,1 50019 Firenze, Italy
Email: franco.bagnoli@unifi.it
Email: giovanna.pacini@unifi.it

† Department do Education Science and Psychology and CSDC
University of Florence
Email: andrea.guazzini@unifi.it

‡ Department of Informatics and Telecommunications
University of Athens,
Email: ioannis@di.uoa.gr
Email: evako@di.uoa.gr

§ School of Computer Science and Informatics
Cardiff University
Email: G.Theodorakopoulos@cs.cardiff.ac.uk

***Abstract*—Collective awareness platforms (CAPs) are internet and mobile tools for collaboration, sustainability and social innovation that can allows drastic improvement of our lifestyle, beyond the standard economic model. However, their development is often driven (and motivated) by technology, while their adoption and usage characteristics are determined by the social interactions and can be affected by many items, up to failure. We describe here our approach to CAPs modelling that includes elements from cognitive and evolutionary sciences, in the hope of providing instruments for the improvement and the assessment of CAPs.**

I. Introduction

Collective Awareness Platforms (CAPs) are all those applications based on Internet or mobile communication that exploit social networking for creating communities, deliver new services, build innovative knowledge, exploiting and promoting collective intelligence.

There are ”big” CAPs like Google, Wikipedia or Facebook, and small ones like the myriad of free applications for mobile phones. Indeed, many social innovations have originated as CAPs in recent years, and with the pervasiveness of the Internet of Things (sensors and tags embedded in every item we use) many more application will arise.

The Collective Awareness Platforms are currently viewed as a promising vehicle for unlocking the tremendous potential that technology-enabled, highly-connected, distributed and participatory human beings can bring about for the benefit of the society and the environment. However, CAPs largely rely on the collaboration and contributions of human beings with very different personality attributes, cognitive strategies, and varying exposure and sensitiveness to social influence. Their behaviours combine in different proportions (pure) altruism and rational selfishness (*i.e.*, economic man), exhibit psychological and cognitive biases, and are shaped by real and virtual communities they participate in. Moreover, many CAP instances need to overcome the concerns of end users about the privacy of their data and locations; again, the intensity of these concerns varies broadly across the (candidate) contributors. Last, but not least, CAPs usually represent a paradigm of service provision that deviates from familiar rules and prescriptions of market, and may stand competitively against purely commercial alternatives. For all these reasons, their wide adoption, sustainability, and effectiveness presents major challenges.

Most of CAPs are not driven by profit, and this represents in some sense the modern incarnation of the free software movement, to be compared with the traditional market-driven approach. For many applications of this type, the social acceptance (*e.g.*, number of users, their activity) is the crucial factor that discriminates thriving from dying. This is not implying that the market dimension is not important: Google owes its fortune to the mass of users that contribute (informed or not) with a piece of knowledge either by adding a link to a web page (*e.g.*, page rank), or by clicking a search topic, or writing an email in gmail and so on. A similar analysis applies to FaceBook.

The European Union is betting on CAPs as an instrument for sustainability and social innovation [1]. Indeed, the opportunities offered by the present communication system allows to transform everyday life in several ways, from worse to better in environmental terms. Differently from the US scenario, mainly funded by charitable and profitable investments, in EU many researches are driven by public funds.

CAPs embody one of the possible directions that the future Internet evolution may take, strongly promoting collaboration and social values, against more individualist approaches that envision Internet as (yet another) field of commercial competition.

However, CAPs development is often driven by the technical aspects. Given a need (real or perceived), the developers concentrate on the development of the CAP, frequently considering the cognitive and the social aspects (*i.e.*, the socio-cognitive ergonomy) as accessories to be addressed later. This often implies the lack of community support to the CAP and therefore its failure. Rarely the opposite happens: a real community promoting the development of a needed application.

We are missing the instruments for an abstract classification and dynamical modelling of CAPs, instruments that would allow to monitor the "healthy status" of the application, of its reference community, eventually furnishing assessment indicators. The principal ingredient of this modelling is clearly the human factor, in terms of individual, community and society. We shall try to list here some of the main aspects of the social part of a CAP.

II. Human dimensions

In general, people are willing and capable to adapt their behaviour to sustainable lifestyles if the necessary feedback, support, and incentives are provided. For instance the social influence of the community is recognized as an important factor in energy saving initiatives. Timely electrical consumption feedback (through smart metering), is believed to reduce domestic electrical consumption by a fraction of 5-15% [2]. Social norms can motivate people to question their behaviour, if they discover it is not "normal" [3]. People tend to learn from their social networks and receive encouragement and support. Nowadays, people who are forced to cooperate to achieve a common goal tend to form a trust between them, influenced by their action [4]. Receiving daily feedback and taking sustainable actions in a social context can increase peoples effectiveness [5].

A good understanding of the mechanism that drives human decision making in a collective awareness and participatory environments, is a key factor for CAPs classification and categorization.

A. *Evolutionary constraints*

The main point to be considered is the fact that our cognitive capacities have been selected within a given environment. Beyond the biological constraints, the main selective force that shaped our capacities is sexual selection, in the form of access to reproductive partners [6]. Indeed, the simple selection for survival has little effect on a sufficiently structured society, that is able to provide basic assistance to all members (*i.e.*, at least those that survive after the embryonic development), and moreover possess such a complex structure so that different capacities find their place.

The sexual selection surely shaped our body, as did with almost all sexually-reproductive animals (*e.g.*, just think to the sexual ornaments of birds). It also shaped our brain, favouring (selecting) all the "useless" characters (*i.e.*, the taste for music, dancing, art, probably our sophisticated speech abilities, and effective social problem solving capacities). Indirectly, since one of the main factors for reproduction is social power, it also shaped our social (and Machiavellian) brain. In the human society, the key for success is not the body strength, but rather the capabilities of forming alliances and cheating others.

However, stable alliances imply trusting, and we have several mechanisms for enforcing this aspect: the natural tendency of revealing liars by uncontrolled gestures or displays (*e.g.*, blushing), the sense of loyalty and justice, the reputation and privacy mechanisms [7]. These are the mechanisms still in force for "modern" cooperation even in the cybernetic word.

It might be argued that sexual selection furnished the "gross" texture, *i.e.*, dexterity, language, sense of beauty, metaphors, art; in a few words, our "big brain". However, the technological "run-out" (in analogy with the sexual run-out that promotes the development of more and more conspicuous ornaments) is surely due to trading [8]. The specialization and the necessity of trusting and detecting liars, that come with commerce and bargain, is probably the main promoter of our "collective intelligence" [9]. In analogy with an ant nest with its specialized casts, we are continuously developing specialization and solving collectively optimization problems, adding innovation through cognitive (rather than simply genetic) evolution [10]. What is emerging in the present internet world is the capability of addressing collective efforts in developing big "operas", that are neither driven by profit nor sponsored by a private or public entity: just think to the Linux kernel or to Wikipedia, or the mass of internet pages and free apps [11]. The reputation component is surely an important driving force in this phenomenon.

On the other hand, we (as primates) also developed a fierce tendency to forming gangs, developing identity signs (for instance, dialects), that allow an easy determination of "stranger", and hating "foreign" groups. Global love was never a viable option.

In particular, it seems that we use different cognitive structures for different tasks. Concepts like the bounded rationality [12], the pre-attentive mechanisms producing effects such as the cognitive blindness [13], and the perceptive magnification, seems to be properly intertwined and continuously tuned so to concentrate our attention, making our cognitive system effective for social problem solving and collective decision making. Such mechanisms are presumably the reason why special "social numbers" can be observed in humans and primates [14], suggesting how different social structure could have been evolved in order to solve particular tasks, by means of particular cognitive processes.

B. *Mental schemes and tri-partite model of cognition*

In order to get into account the previous scenario and its quite complex set of coupled processes and mechanisms, we developed a dedicated model of cognitive activity (the Tri-Partite Model [15]), explicitly devoted to the representation of the three main aspects of the cognitive activity, the unconscious perception mechanisms, the conscious elaboration and the learning dynamics, so obtaining a general model with three different sections (see Fig. 1).

The first module is related to perception and unconscious elaboration of data from the external world. The activated schemes filter the outside information and populate the internal context, which may trigger the activation of further schemes. The chains of activated schemes essentially constitute the awareness of the node, while the sum of its entire set of schemes represents the knowledge of the node. There are meta-schemes that control the working of processing, avoiding conflicts among schemes, and promoting a response when

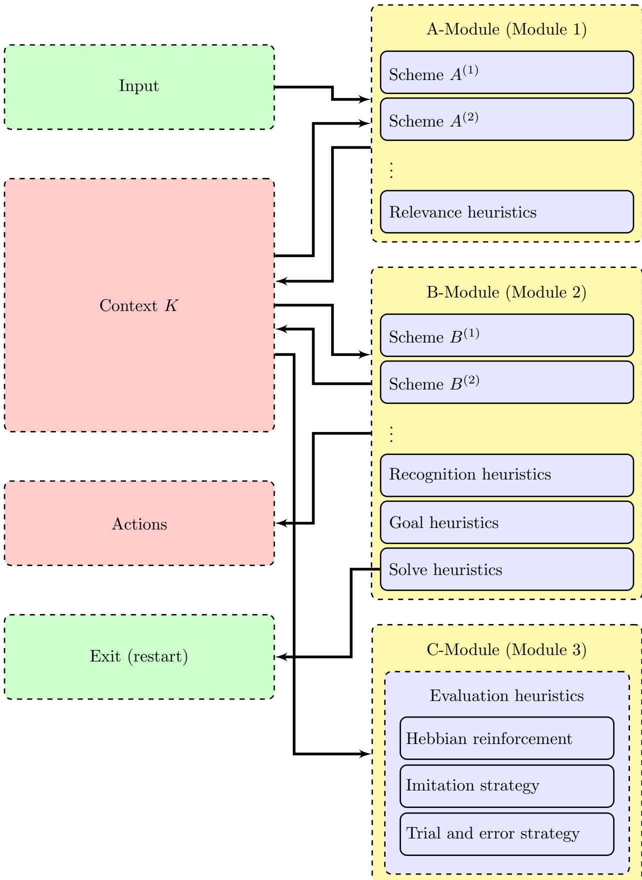

Fig. 1. A schematic representation of the Tri-Partite model

timing is short. This first module is the fastest one and essentially out of conscious control in humans.

The second module has to do with actions, i.e., with outputs and reasoning, but also with emotions. It works in a way similar to the first one, but its actions are well characterized by larger response times (i.e., frequently easily measurable/assessable). Conflicts among schemes and regulative actions (e.g., the resolutions of cognitive dissonance) can be detected by reaction times.

The third module, the slowest one in terms of reaction time, concerns the learning, simulation and planning phases. They act by evaluating the performances of the chains of schemes and the fulfilment of goals by optimizing the activation patterns and scores of schemes.

This model was developed in the context of FET project RECOGNITION [16], aiming at understanding the heuristics-based mechanism of decision making in the presence of incomplete information and/or a limitation of processing resources. Based on this exploration, we are confident that the proposed modular architecture has good potential in capturing, at a sufficiently simple level, the complexities associated with human-driven decision-making in a collective awareness and participatory engagement environment.

In particular, we are applying this framework to the human online communication systems. We humans developed several modalities of exchanging information, of whom the "verbal" content is just a part. Let simply consider how the transcript of an interception looks uninformative and innatural, without the nonverbal components.

When using an online communication channel (e.g., chat, forums, email), humans are exploring new communication media, face new challenges when taking decisions, while at the same time they are exposed to stimuli, information and opportunities for social interaction, altering their cognitive and behavioural characteristics.

On the other hand, the electronic media offer an almost-ideal experimental framework, in which it is possible to capture almost all the communicated information, with accurate timing and already in digital form. Our preliminary investigations are presently devoted to establish the reference framework (communication network structure in the presence of different tasks) [17]. We are now designing interactive cooperative games to explore the basic ingredients of collective intelligence.

III. Collective Intelligence and collective awareness platforms

A first effort to systematically categorize and characterize collective awareness platforms can be found in Ref. [1], and described in Ref. [18], even if the term the authors use is web-enabled Collective Intelligence (CI). It draws on a study of 250 examples of web-enabled CI, carried out in the context of a broader initiative on collective intelligence at MIT. They propose four fundamental attributes for abstracting all such applications, as well as values for them: their goal (create something or inform decision-making), their incentives (money or love/glory), their staffing (crowd or some hierarchical structure), and their procedural operation, which depends on their goal.

Hence, when creation is involved, the goal may involve simple collection or tighter collaboration and synchronization of individual contributions; whereas, when CI applications enable decision-making, the decisions may be taken by individuals or only at group-level, and involve monetary or non-monetary incentives. The authors acknowledge that this categorization "provides a useful start for the much-to-be-done work".

Online collective systems are also considered by Antin [19]. The focus is on the operational aspects of online collaborative systems, and the desired mode of end user contributions to each one of them. Hence, there are systems where the diversity rather than size of contribution matters more. It may be important that individuals indicate their membership to a contribution group, even if they do not actively contribute to the system.

Contrary to the previous work, Antin is not interested in the complete taxonomy of such systems, but rather seeks to identify which social-psychological incentives may apply to each contribution mode, drawing hints for the design of related user interface.

Finally, a less explicit classification is presented in the technical note of Ref. [1], presenting the concept of the collective awareness platforms. The emphasis is here on their goals. The possible missions of the platforms are supposed to go beyond the abstraction of the create-decide tuple. Increasing self-conscience, nudging towards environmental-friendly lifestyles, enhancing democracy, and taming of complex scientific tasks are identified as broad classifiers of CAPs at the mission level.

IV. Privacy, reputation and gamification

Collective awareness platforms are fundamentally dependent on grassroots participation and information sharing by people. However, the information that a CAP requires for its working may be sensitive by itself, or it could be used to infer important pieces of information about users. People have a right to privacy, and if their privacy is compromised, their trust to the CAP can lower, so they cease contributing. Moreover, news about privacy breaches will reach other users, possibly causing a domino effect.

It follows that preserving the privacy of information that users share is a necessary condition for the success, and sustainability operation of CAPs. The tradeoff between privacy and application utility has mostly been studied in the context of publishing data in a database [20]. In this context, privacy is equated with re-identifiability, rather than with *e.g.* the quantity of data disclosed: The data is anonymized and the attacker tries to link it to the user who produced it (*i.e.*, re-identify the user).

Moreover, for the most part, privacy in data publishing has not been studied with a specific application in mind, and hence utility metrics could only be generic: for instance, an anonymized database is useful if it preserves the average of all entries, or, more strictly, if it preserves the distribution of entries [21]. Only recently have specific privacy-utility frameworks been proposed for concrete applications (smart meters [22]). There, (negative) utility is measured as the distortion between the true and the perturbed value of data.

It is common in ICT research to see clever applications, which can in principle meet common needs, be developed but never actually adopted. This problem is particularly evident for those applications whose utility depends on the number of users in a non-linear way. The problem can be better understood from a game-theoretic perspective.

A game is defined in terms of possible actions, payoffs and expected number of encounters. The players can adopt strategies, which dictate how users respond to an opponent's actions given the history of their interactions, and there are techniques to select the "best" strategies, depending on the payoff, the possibility of committing errors, the number of expected re-encounters with the same opponent, or the possibility of being observed by others. Considering for instance the classical prisoner's dilemma, the "best" strategy can switch from "always defecting" to "reciprocal collaborating" (tit-for-tat) depending on the number of expected re-encounters; notably, this approach suggests further ways to motivate collaborative behaviour depending on mechanisms such as direct reciprocity, indirect reciprocity, reputation, group selection [23].

The "best" strategy can be deterministic or stochastic, and there are also situations where the optimum is only transient: in a competitive environment (such as in a market), where each individual can encounter any other one, the overall optimum depends on the type of the other strategies that are present, and the success of one strategy may alter the scenario/situation, and disrupt the very reasons for its success (similar to the "Red Queen effect" in evolution [24]).

This scenario becomes even more complex when the payoff itself depends on the number of strategies present in the population. This is the case with applications or behaviours, whose beneficial return depends on the number of adopters. For instance, garbage separation or blood donation provide little benefit (if any) to the adopter, but can boost a public return if adopted massively. But this is not the whole story. The above analysis is based on the hypothesis that the actor (decision-agent) is "perfectly rational"; this is rather rarely the case with real humans. They often act following "human heuristics", which have been selected for being useful in a social context, have limited computational capabilities (bounded rationality), and limited time; or they may be sometimes "irrational" from the mathematical point of view [25], [26].

Humans communicate at several levels and their decisions may depend on many "psychological" aspects that are difficult to capture in a model. In particular, it is well known that the social group has a strong effect on the resulting behaviour of participants, so it is important to perform observations of group dynamics and community structures, and relate them with user profiles and communication strategies. Fortunately, since most of communication happens today on digital channels, it is possible to collect data and administer surveys in an automatic way, and it is also possible to gather many data about virtual group dynamics using a suitable computer interface.

The data gathering can be facilitated by making real people participate to a simulation, for instance by presenting it as a game (gamification of the problem). Interestingly, the very problem of motivating the broad adoption of new practices had been faced at the beginning of last century by Kurt Lewin and the emerging school of Social Cognition [27], [28], [29]. The question was then how to promote the usage of entrails in face of a shortage of "standard meal" due to the 1929 crisis, since this was clashing against the nutritional habits of Americans.

The methodology developed by Lewin was named *action research*, and draws on two main overlapping phases: the first about investigation and data collection (research), followed by an active one in which researchers and subjects are involved together on a peer ground (action), discussing and negotiating on the social perception of the problem. This approach can be translated in virtual terms (over social networks and chats), which is an approach that is practically well consolidated and is the basis of "viral marketing", but has not yet been studied systematically.

But even letting aside the complex mechanisms of human decision-making, and sticking to the rational prescriptions of economic theory, it is difficult to understand which market models apply to such public goods. Should one try to evaluate a price and a breakdown number of users, or should one rely on additional services, or the "mass effect" of having many participants? Should one rely on public support (and how to evaluate which application is profitable)? How can one measure the adoption and the penetration of a "free" application?

It becomes, thus, compelling for platforms that engage autonomous users and deliver a utility that depends on the participant numbers and behaviours, to best address all those dimensions that motivate human behaviour. One key aspect is identifying those types of incentives, with reasonable levels of segregation or even personalization, which engage humans into mechanisms of active contribution and sharing of knowledge. In parallel, the question of incentives has to be pursued for all participating players, and entities that are directly (or indirectly) involved in the platform, either as providers/operators, or as open data providers, or as competition when a market viewpoint is taken.

V. CAPs' relevant dimensions

The main problems that we are addressing are: is it possible to classify CAPs using a small number of relevant axes (and which these axes are), how these axes are related to the cognitive characteristics addressed above, and how can we model the interactions among caps and users in order to develop a predictive tool to be used for assessing the status of an application?

Within the activity of the Scicafe2.0 project [30], some of us preliminary analysed 70 instances of CAPs, including those funded by UE and others [31] and, based on that, developed a survey that is currently administered to CAPs coordinators [32]. We are designing a similar survey for CAPs users in order to detect the perceived importance of the relevant dimensions. The final goal is that of identifying the relevant dimensions of CAPS like topic, cost, payoff, privacy, reputation, community structure. Clearly, in this way we are only looking for a static snapshot of the current situation.

The dynamical modelling problem is a more complex task. It requires a simple model of an individual (using the tri-partite system described above), the way in which users interact and develop a community, how the payoff of the CAP (including reputation, gaming etc.) is influenced by the user number and community structure, and how CAPs compete (or collaborate) among them. The previous classification can be fundamental in order to limit the dimensionality of CAPs and user characteristics. This activity is supported by task FOCAL [33] of the UE project EINS [34].

Just to present some preliminary results, we found that the main factor for the competition is how payoff (however defined) depends on the number of users. An always-increasing payoff would bring to the establishment of just one CAP (the FaceBook effect), while CAPs that share a limited resource (like parking assistance) determine the typical dimension of the user community. Moreover, there is often a critical user size below which the payoff (*e.g.*, time required to actively contribute to CAP), is negative. The main difficulty of "young" CAPs is that of overcoming this breakthrough threshold. Clearly, this analysis only applies to a given dimension, and CAPs sometimes span over multiple dimensions (e.g., Google, FaceBook, etc.). This multi-dimensional character may help overcoming the initial threshold effect (for instance, by means of the gamification of a sub-task, or by levering on strong motivations [35]).

VI. Conclusions

Based on the previous elements, we are developing a CAPs classification and modelling approach. We are presently developing models of individuals interacting by means of virtual instruments (based on real experiments), and classifying CAPs on a small number of relevant axes. We think that the actual interplay of users and CAPs in a competitive/collaborative scenario is a dynamical problem, that can better understood by means of simulations. We therefore are developing an agent-based model that takes into consideration the CAP characteristics (as emerging from the survey) and users profiles. The user participation to a given CAP is determined by the match between the CAP characteristics (that may include "irrational" elements), the expected gain vs. cost, and the influence of privacy, reputation, and gaming components, according to the cognitive model of users. Users also react to peer pressure, modulated through the personal community structure. On the other hand, CAPs compete for users' resources (mainly time and participation) and interact among them, also contributing to the formation of users' community structure. The way the gain (payoff) and reputation components depend on user participation couples the users dynamics to that of CAPs.

It is a complex scenario but we hope being able to identify useful parameters to validate the model with static data (those from the survey), possibly offering a way of assessing the "health status" of a CAP using "passive" measurements, *i.e.*, data gathered during the normal activity of the CAP, without the need of directly contacting users and coordinators.

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