Towards Collective Awareness Systems

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Abstract. Progress on smart interconnected devices and sensors allow access to large amounts of real time information coming from multiple sources, allowing reaching new levels of awareness and creating opportunities for new applications. Motivating engineering PhD students to look into the potential of this new wave of research is a crucial element in their education. With this aim, the doctoral conference DoCEIS'14 focused on technological innovation for collective awareness systems, challenging the contributors to analyze in which ways their technical and scientific work could contribute to or benefit from this paradigm. The results of this initiative are briefly analyzed in this chapter.

Keywords: Collective Awareness, Internet of Things, Cyber Physical Systems

1 Introduction

Fast progress on devices with increased computational capabilities and connected to computer networks, namely to Internet, give users access to unprecedentedly high amounts of real time information coming from a large diversity of distributed sources. This situation greatly extends our capability of being aware of the surrounding environment and expands the reach-ability of our perception horizon.

The multi-dimensional nature of the accessible information sources and their growing pervasiveness opens the opportunity for new levels of awareness, and thus the development of new applications, virtually in all domains of human activity.

In this context, a large variety of research challenges emerge, ranging from devices development, communication mechanisms and protocols, to high-level information interpretation, and novel services development. The very nature of the involved areas, combining the physical and the cyber worlds, requires a multi-disciplinary approach, in which the competencies typically covered by the disciplines of Electrical and Computer Engineering play a relevant role.

Considering that a substantial amount of technological innovation results from the research works of engineering PhD students, it is important to call the attention of students in this area, which typically tend to focus on a specific research topic, for the potential of the "interconnected information sources" and the role they can play in the innovation process. The DoCEIS'14 (5th Doctoral Conference on Computing, Electrical and Industrial Systems) was thus organized with this mission and some of the results are summarized in this paper.

2 Related Concepts and Trends

The term collective awareness represents a concept that has been evolving since the 19th century [1], originally related to the works of the French sociologist Émile Durkheim, and referring to the common norms, values, and beliefs shared by the members of a community. With the developments of the information and communication technologies, the concept has been revisited and rephrased under the perspectives of human-computer interaction, computer-supported collaborative work, virtual communities, and information management systems. One example reflecting this evolution is the definition provided by Daassi and Favier [1]: "*Collective awareness refers to a common and shared vision of the whole team's context which allows members to coordinate implicitly their activities and behaviors through communication*".

Depending on the adopted perspective, different definitions have been proposed, which might be seen as different types of awareness. In this way, some authors have attempted to also classify the different types of awareness. For instance, Daassi et al. [2] consider: Activity awareness, Process awareness, Availability awareness, Informal awareness, Workspace awareness, Social awareness, and Group-structural awareness.

Progress on web-based technologies, social networks, wireless sensor networks, and the proliferation of smart devices connected to Internet, are inspiring other views and extending the concept of awareness to other directions. For instance, the FutureICT project [3] elaborated a research roadmap for what they call *Planetary Nervous System*, which addresses awareness issues at the world-scale. The roadmap addresses the needed scientific and technological developments based on three pillars: social sensing, social mining, and the idea of trust networks and privacy-aware social mining. In the framework of the European Research Programs FP7 and Horizon 2020, a particular focus on using collective awareness to solve big societal problems has emerged under the term "Collective Awareness Platforms for Sustainability and Social Innovation". Such platforms are defined as "*ICT systems leveraging the network effect … for gathering and making use of open data, by combining social media, distributed knowledge creation, and Internet of Things. They are expected to support environmentally aware, grassroots processes and practices to share knowledge; to achieve changes in lifestyle, production and consumption patterns; and set up more participatory democratic processes*" [4].

Also as a result of recent technological developments, a number of other related terms have emerged to represent partially overlapping perspectives or focused application contexts. Some examples:

- ***Context Awareness***: A term frequently associated to mobile smart devices and regarded as the capability to both sense and react based on their environment and circumstances of events. Examples of characteristics of a context include location (where), time (when), identity (who), and activity (what). Other features / information can nevertheless be considered. The notion has been generalized in context-aware computing to the capability of understanding the *context of use* [5]. A survey of context-aware systems can be found in [6].
- ***Ambient Intelligence***: A concept that represents electronic-enhanced environments, which are sensitive and responsive to the presence of people [7].

Therefore it builds upon the notions of pervasive computing, embedded systems, context awareness, and human-centric computer interaction. One of the relevant application areas is the so-called ambient assisted living (AAL), which uses technology to assist elderly. In these environments technology becomes invisibly embedded in our natural surroundings, present whenever we need it.

- ***Collective Intelligence***: A notion representing the shared intelligence of groups, which emerges as a result of interactions (e.g. collaboration and competition) among group members. It is a form of distributed intelligence and implies some form of collective awareness (members' awareness of each other, awareness of the environment or task at hands and its progress, etc.). Internet developments, allowing for shared information and rapid information flows, organization and operation of communities, contributes to the emergence of many examples of collective intelligence (web-enabled collective intelligence) [8].
- ***Big data***: A term that refers to massive data sets and stream computing that due to their large size and complexity are beyond the capabilities of traditional databases and software techniques. The expansion of sensing capabilities, sensor networks, smart devices, and other sources, generating huge amounts of data, motivates the importance of the topic. Interest in big data has emerged in science (e.g. medicine, astronomy and spatial exploration), business (e.g. understanding market trends, social media analytics, energy management in smart grid), security (e.g. analyzing surveillance data, identifying hidden networks), and many other [9]. Context awareness or collective awareness may require the adoption of techniques being developed for big data.
- ***Internet of Things*** (IoT): Understood as "*a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*" [10]. In this context, a "thing" can be understood as a real/physical or digital/virtual entity that exists and moves in space and time and is capable of being identified [11]. A large class of objects connectable to Internet constitutes (smart) sensors or (smart) devices able to provide status information, thus an important enabler for collective awareness.
- ***Internet of Events***. Less popular than IoT, it corresponds to a perspective of the IoT that puts the emphasis on time dependency and discrete events handling [12]. As such, events modeling and management, time critical reactivity, and process modeling and supervision are the relevant issues here.
- ***Sensing Enterprise***: A notion introduced by the FInES (Future Internet Enterprise Systems) cluster of projects [13] to refer to an enterprise anticipating future decisions by using multi-dimensional information captured through physical and virtual objects and providing added value information to enhance its global context awareness. In other words, this notion particularly focuses on enriching enterprises' context awareness through intelligent, interconnected and interoperable smart components and devices to power enterprise systems, making them responsive to events in real time and aiming at reaching seamless transformation of (raw) data to (tailored) information and (experienced) knowledge.

Each one of these concepts share a number of facets with the notion of collective awareness, namely sensing / acquisition of multi-source distributed data, interpretation / mining of these data, structured communities or ecosystems, and some forms of collaboration.

When the term “system” is added to the picture, it typically refers to a kind of cyber-physical system which not only considers the interlinking of the physical and cyber worlds, but also supports a community of interacting entities, helps integrating and analysing rich multimodal information sets towards reaching a common and shared vision of the surrounding environment and situations, and facilitates collaboration among these entities. Such system is thus an instrument for achieving collective awareness.

3 Example Contributions

Collective Awareness Systems (CAS) involve a set of topics that are particularly relevant for Electrical and Computer Engineering (ECE) researchers and professionals. In the last decades, the scope of ECE has expanded so widely that it risks some "fragmentation". Most professionals (and students) focus on a specialization sub-field, rarely mastering a comprehensive view of the whole field. However, most contemporary challenges in our society require the capability to address problems from a multi-disciplinary perspective. Since Collective Awareness Systems require a "strong dialogue" among the various sub-fields of electrical and computer engineering (and other areas), it represents a particularly interesting subject to bring them together.

Under this assumption, a challenge was presented to DoCEIS'14 conference participants [14], which are doctoral students from various countries and different sub-fields, as summarized in the following alternative questions:

- *In which aspects your research can contribute to the development of the Collective Awareness Systems?*

or

- *In which aspects your area of work could be affected / influenced in the future by the development in Collective Awareness Systems?*

As a result, all contributors made an effort to analyze the relationship between their specific research work and the *Collective Awareness Systems*. Among the accepted papers there is an almost balanced distribution between those that can benefit from CAS adoption and those that contribute to the development of support technologies and models for CAS [14], as summarized respectively in Fig. 1 and Fig. 2. The figures also include the percentage of contributions in each specific sub-field.

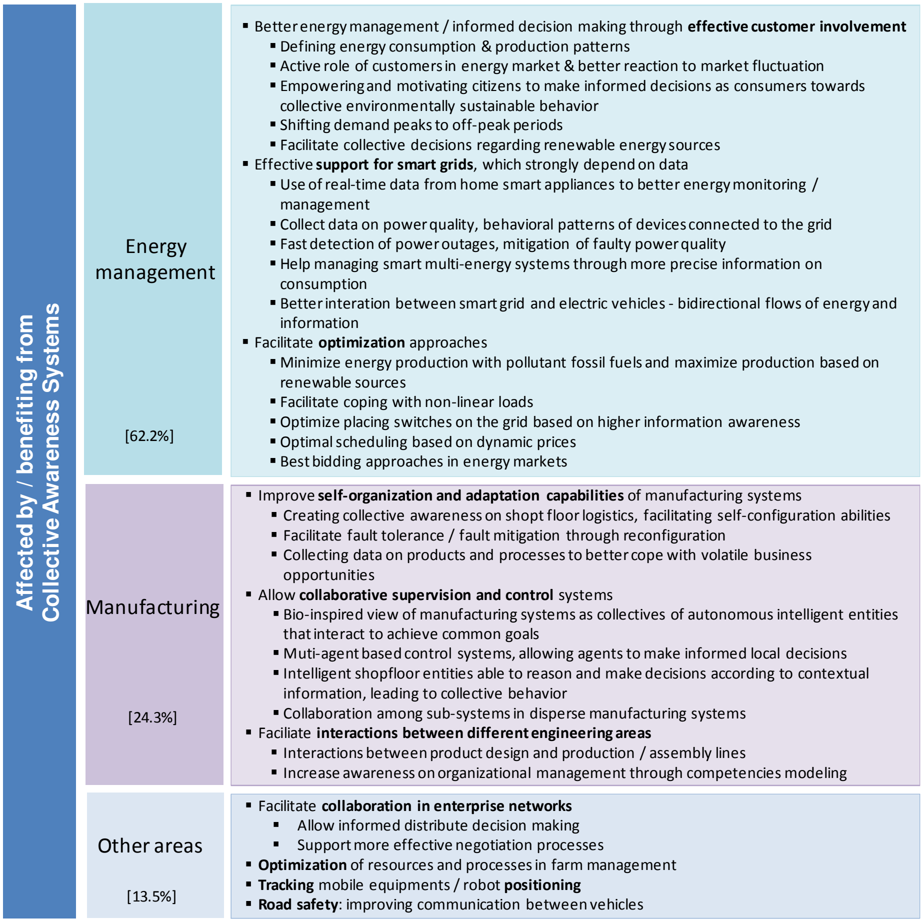

Fig. 1 – DoCEIS'14: Benefiting from Collective Awareness Systems

In terms of areas that can benefit from a collective awareness systems approach, energy management is the most represented in terms of submissions to the conference. This is certainly a result of the current challenges faced by society regarding the development of sustainable energy solutions. The materialization of smart grids strongly relies on ICT and sensing / measuring capabilities in order to shift the emphasis from the traditional "predict and supply" model to a more flexible and responsive "demand-based" model [15]. The full realization of this idea requires highly distributed cyber-physical functionalities, but also the involvement of the customers in close (collaborative) interaction with providers, a process that should go far beyond the traditional client-supplier relationship. The concept of collective awareness can help reaching a shared vision of long-term sustainability and facilitate more effective use of resources.

Another area indicated as major potential beneficiary is manufacturing. Achieving truly agile manufacturing systems, able to dynamically adjust to market dynamics, requires novel approaches that take the shop-floor as a collaborative ecosystem of (progressively more) intelligent and autonomous machines / resources. The implementation of self-organizing / adaptive capabilities, and collaborative supervision systems, requires reaching a high-level of collective awareness and even collective intelligence among the members of this ecosystem. On the other hand, there is a need for stronger synergies among the various engineering areas involved in product design, manufacturing system design, manufacturing system deployment, manufacturing system operation, etc., which can also benefit from the conceptual insights of collective awareness systems.

Although less represented in this conference, several other areas can benefit from CAS, e.g. collaborative enterprise networks, logistics, road safety, etc.

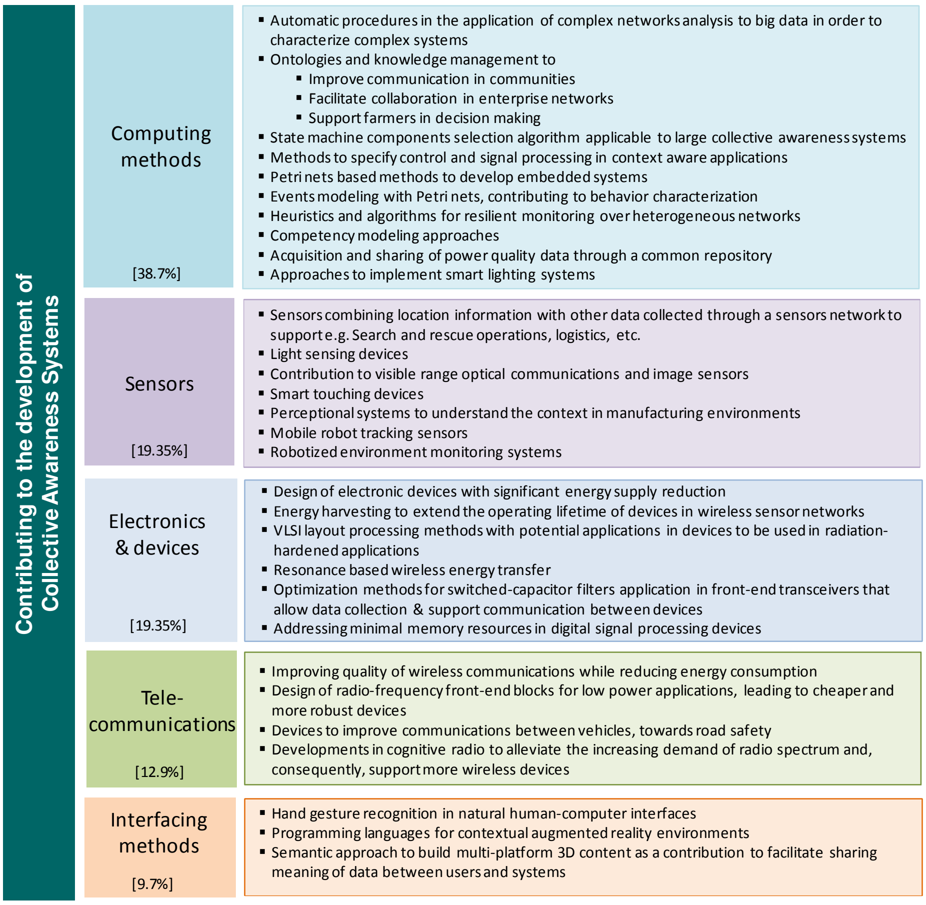

Fig. 2 – DoCEIS'14: Contributing to Collective Awareness Systems

In terms of conceptual and technological contributions to the development of CAS, DoCEIS'14 includes a vast number of elements, ranging from the hardware level (electronic devices, sensors, telecommunication devices and systems), to software (interfacing and computing methods and models), including specific approaches for embedded systems design.

Perhaps the weakest part is the development of intelligent functionalities to reach high levels of awareness and collaboration, as well as proper consideration of safety and privacy issues.

On the other hand, many of these developments are designed in the context of vertical / specialized applications. An urgent need is thus to develop more generic platforms and components (de-verticalization) that can be applied across various domains. On the methodological side, there is also a need to invest more on engineering methods for design, deployment and operation of such systems.

Given the scope of DoCEIS, the mentioned contributions are naturally biased by an engineering perspective. The development of advanced collective awareness systems would, however, require the involvement of other disciplines.

5 Concluding Remarks

The conceptual framework and developments of collective awareness systems are likely to have a strong impact in many sectors of society. Some of these impacts are already visible, but their importance is likely to grow in the coming years.

The needed technological components and approaches to connect the physical and the cyber worlds, as well as required modelling and intelligent functionalities, open important expansion opportunities for the area of Electrical and Computer Engineering. This is clearly reflected in the contributions to the DoCEIS'14 doctoral conference.

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