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Representing social intelligence: An agent-based modeling application

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ABSTRACT

Intelligent systems are composed of autonomous components that interact each others, with and through the environment, in order to give intelligent support for reaching specific objectives. In such kind of systems the environment is an active part of the system itself and provides input for runtime changing and adaptation. Modeling and representing systems like this is a hard task. In this paper we propose a biologically inspired approach that combined with the use of Agent-Based Modeling allows to create a means for analyzing emergent needs of the system at runtime and converting them into useful intelligent services to be provided. The experiment proposed for validating and illustrating the approach refers to the construction of smart university campus.

Introduction

An intelligent system, both biological and artificial, is a system able to autonomously supply the most proper service for specific emergent needs. In the case of smart ambient (smart cities, smart district, …), in order to deal with intelligent and complex "smart" systems, there is the need to have a software system that acts as a butler, hence someone able to catch and understand the needs of the master of the house (the user of the software systems). The butler normally intervenes in the life of his master by providing the most useful "service" for enhancing quality of life or wellness. In doing this, the butler refers to his own knowledge on the master's habits that he acquired during the years and, even and especially, he refers to signals coming from the environment he and his master live. This is a scenario where the master (the system user) and the butler (the system providing services) inhabit the same environment, they both are part of the environment and a change in the behavior of one of them causes a change in the behavior of the other.

Our aim is to create a support system to a smart ambient (therefore a butler). For doing this, given the features of a smart ambient, we have to consider the smart ambient as a whole where some components let needs emerge and other components satisfy those needs.

For modeling and designing such kind of systems, we need a way both for representing the elements and for combining an intelligent phenomena/behavior of a smart ambient to the representation of emerging needs of the smart components (users, citizens in the case of smart cities and so on).

Generally, a way (in the literature), for conducting the analysis on the users' need of whatever system, is to collect interviews or textual documents. They describe the specifications and the behavior required by the system starting from the description of users' behavior and their lifestyle for which intelligent support is required.

In the case of a smart city domain, analysis becomes more difficult due to the peculiarities of the application domain that, as said, expects a system being able to self-adapt to users'/citizens' changes that at the same time depends on the changes occurring in a highly dynamic environment which both users and system are part of.

We propose to combine the representation of intelligent phenomena that a system has to expose to the representation of the emerging needs of users by a brain metaphor and agent-based modeling techniques.

The idea is to use the latest technological advancements that see citizens to own several intelligent devices, mainly used for exchanging information with other citizens through the use of social networks. A great amount of data is, thus, available and may aid in retrieving and inferring information about citizens' needs and system requirements. In order to represent the flow of data and information within a city, to plan the urban policies and identify values and potentiality we get inspired by the "brain traffic" representation (Taylor et al., 2000) and we propose a biologically inspired model for analyzing and managing these data. In Seidita, Chella, et al. (2016) we proposed an experiment: the representation of aggregated data exchanged among students in the University of Palermo campus (UNIPA campus), here considered as a small city district. That work allowed us to identify some measurable variables, representative of the intelligence in the campus, that in this paper we use for identifying citizens' emerging needs to be mapped onto intelligent services. Then services can be provided in order to realize the overall chain, from the perception of a need to its

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satisfaction.

The focus of the present work is, indeed, on the agent-based computational model for representing the emergent behavior and needs in an intelligent society of agents. Finally, we use NetLogo for representing and interfacing with the agent-based model.

The rest of the paper is structured as follows: Section ‘Background and motivations’ introduces the smart city context, its characteristics and it details the motivation of our work; Section ‘A brain metaphor for representing intelligence in the city’ briefly describes the previous work on the brain metaphor we use here; Section ‘Agent-Based Modeling (ABM)’ analyzes agent-based modeling paradigm and why we consider it useful for modeling emergent behavior in the context of smart cities; Section ‘Experimenting intelligence in a university campus’ illustrates the experiment setting we propose; Section ‘Applying ABM to intelligent social phenomena’ illustrates the computational model, for modeling emergent behaviors, that is then used inside an ABM platform (NetLogo) for illustrating the experiment on the chosen smart district (the University of Palermo campus); finally in Section ‘Conclusion’ some discussions and conclusions are drawn.

Background and motivations

Smart city or intelligent city (or urban context) is a new emerging term applied to the vision (future) of an efficient and sustainable city. A model of the urban development where human, collective and technological capital is used for an efficient and sustainable urban development (Angelidou, 2014). A shared definition of smart city is still missing, perhaps because it is still an idea (Hollands, 2008; Komninos, 2011; Wolfram, 2012; Nam & Pardo, 2011); it is however recognized that in order to be smart a city has to include a set of strategies (supported by technologies) for improving citizens’ quality of life. The citizen is the core of the smart city. Some examples of smart support to citizens’ quality of life: availability of efficient eco-friendly public transportation system, including transport with a low ecological impact such as bicycles; software systems and advanced solutions of mobility management and info-mobility with the aim of handling daily transfers citizens; waste lowering, waste separated collection/recycling; virtualizing the cultural heritage and traditions; using advanced techniques for creating interesting, customized and theme cultural paths of the city thus becoming easily available to everybody; customized learning programs.

The latest technological advancements are the central elements of this new vision for smart cities. Smart cities cannot exist without the use of technology, even why the cost reduction of technological devices and their increasing performance allow conceiving and also using solutions for getting everything smart.

Thus, when we face the development and planning of a smart city we cannot do without thinking that all the daily activities of citizens must be supported and handled by intelligent software systems that, for their peculiarities, are then complex systems.

In this context the citizen inclusion is of central importance, the citizen is at the same time the user of a system that has to provide him with intelligent service and also the customer that provides system requirements at runtime, meanwhile he is “living and using” the smart city. The needs of the user citizen and then the requirements of the software system *underpinning* the smart city emerge from the interaction context of citizens with the environment; it is worth to be noted that the software system itself is a fundamental constituent part of the environment. Analysis, design and development of such a kind of system cannot follow design standards that see requirements as statically identified and elicited. Indeed, retrieving and implementing the most useful service mainly depends on citizen, on the kind of environment he lives in and on the kind of smart action to be realized.

In this context there are several challenges to face, the most important one is related to the impossibility of using a systematic design approach, from analysis to coding phase, for identifying requirements, goals and features and convert them into interoperable components providing intelligent services at runtime; this because the evolution of the smart system is not a priori known but it evolves at runtime when all the interactions take place. Another challenge is to handle synergistic interactions between users and software components that have to be proactively and purposefully involved with the users interaction. So, smart objects and devices are more than simply responder, they have to be autonomous and situated; this is a very key factor in designing smart cities.

Several challenges have to be taken into consideration, both on the technological and theoretical perspective: (i) having a systematic approach, from analysis to design and implementation taking care the fact that the system requirements evolve at runtime; (ii) handling the synergistic interactions and collaboration between software and users that let a collective behavior, needs or tasks emerge; (iii) actively and autonomously involving of citizens in the system creation and evolution; (iv) presence of smart objects that are not only simple responder but proactively support the users and act on his behalf.

It is also to be considered that a society of citizens is the result of a dynamic process where citizens are constantly in motion, they talk, listen and do. The need of acquiring appropriate data is very demanding. The standard literature proposes interviews for gathering data but it is not enough for smart complex systems, more precise methods are required given that societies are complex and with emergent features.

We propose to create a methodological approach exploiting data and communication knowledge coming from the great amount of devices that citizens own and the great amount of data they exchange to represent how they aggregate and then how they can be conveyed to emergent needs/behavior thus triggering the right services from the system. In this work we are inspired by the brain traffic representation by Taylor et al. and we employ agent-based modeling technology for modeling citizens emerging needs. In (Seidita, Chella, et al., 2016) the data representation has been illustrated and in the following we give a brief summary in order to have the basis for describing how to employ Agent-Based Modeling (ABM).

A brain metaphor for representing intelligence in the city

The work presented in Seidita, Chella, et al. (2016) was the first step towards the design and implementation of a smart urban district. We decided to bring an experiment inside the campus of the University of Palermo and to apply a biologically inspired representation of the intelligence in the campus in order to manage important information coming from the great amount of data exchanged among students and employees through social networks. In analogy with the brain and employing the work by Taylor et al. (2000) we considered the flow of data exchanged in the social network as equivalent to the flow of data carried by the blood and oxygen in the human body. Human body is made by organs, or anyway components, even atomic one, that need to be smartly managed by the brain, by the site owning the intelligence. In the brain, neural models interact for solving tasks and for activating actions that need to be performed by specific parts of the body. In the same way in an intelligent city, we have to analyze how module interact for first triggering intelligent services at an atomic level and then a complete intelligent behavior at the city level.

Taylor et al. focused on understanding the brain operations using a specific representation of the network of modules performing suitable functions. After the acquisition of brain imaging data from PET or fMRI, they employed the structural equation modeling (SEM) to analyze the acquired brain images (Bollen, 2014; Kline, 2015; Loehlin, 1998). After the representation of the brain, SEM is used for analyzing data so that the so called latent variables may be measured by means of observable and measurable variables. The latent variables depend on the observable variables. In Taylor’s approach, some variables are associated with the areas in the brain activated by tasks and the use of SEM allows