A Multi-Agent Based Simulation to Support the Digital Assistant for Participatory Public Management

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Abstract. *In this paper, we introduce our current research project geared towards a computer-based support for constructing democratic governance in urban scenery, in order to promote citizens' involvement on public management. The goal of this research is to help public managers to choose socio-environmental aspects to invest governmental funds in order to diminish most popular citizens' complaints. In order to achieve this goal, we take in consideration users' feelings about some socio-environmental aspects and the possibility of correlations between some of these aspects, time, and place. There are three main components in our project: a responsive web application coupled with a mini-station to collect socio-environmental data, a miner agent, and a decision support agent. Our approach combines techniques such as: multi-agent systems, knowledge discovering in database, sensor networks, and multi-criteria analysis. Some of these components were tested and our proof of concept demonstrated the feasibility and the potential of our approach.*

1. Introduction

Most of Brazilian cities, as other cities in democratic countries, have been failing to implement democratic management of public policies. One of the main challenges in these cities is the construction and implementation of methodologies to support participatory governance in public policies.

This goal became more strategic since 1988, when the current Brazilian Constitution, established a new model which favors participation by civil society in public management [Brasil 1988]. Currently, one of the Brazilian principles of public management refers to participatory processes of social actors in public policies. For example, the Brazilian Law 9985/2000, that defines the Brazilian National System of Conservation Units (SNUC), was established in order to regulate and organize management strategies for protected areas, considering social participation as a key issue [Irving et al. 2007].

In some cities, the public budget has been predetermined according to civil society interests. The matter of integration of civil society's members in the management of public budget and in public policies is still broadly under discussion in applied and fundamental fields.

Recently, some initiatives to address participatory governance in public policies were proposed based on bottom-up approaches, from which local actors' roles are relevant. Such approaches reverberate the Companion Modeling (ComMod) research movement. Over the last fifteen years, they have developed a participatory method and applied it in different countries. They have applied their method to support negotiation and decision making in collective management of natural resources. ComMod method is based on the joint use of role-playing games and agent-based simulations of the referred environment and its resources [Barreteau 2003]. Among these researches, we can highlight pioneers on participatory simulation, such as Self Cormas [d'Aquino et al. 2003] and SYLVOPAST [Etienne 2003] and later works such as SimCommod [Guyot et al. 2006], JogoMan [Adamatti et al. 2007], and Simparc [Briot et al. 2009].

Most researchers of these works have investigated (i) human behaviors during negotiations about resources use, (ii) computer support and artificial intelligent agents support on human decision making, (iii) human learning in resources management, etc. However, to our knowledge, they do not approach the correlation between time, place, and socio-environmental aspects (e.g. water pollution and exploitation of forests; air pollution and time of the year; and street light, robbery, and time) in order to support (participatory) decision-making processes. Note that the use of simulation in this project is not (or not yet) geared towards prediction and participatory simulation.

In this paper, we will first introduce our motivation, goals, and the ADGEPA[1] (which means Digital Assistant for Participatory Public Management) project. In Section 3, we will discuss the necessity for the multi-agent simulation in this project; the artificial agents modeling human subjects, the environment agent, the manager agent, and the miner agent; the current simulation architecture; and the simulation cycle. Then, we summarize our preliminary work. In Section 5, we will discuss ongoing and future work before concluding the paper.

2. The ADGEPA project

2.1. Motivation

For many public managers the integration of public agencies' (such as Security Department, Traffic Department, and Environmental Agency) information is a huge challenge. Many public agencies set their goals and strategies according to their own databases and admeasurement. Empirically and scientifically, there is a consensus on existence of correlation between socio-environmental aspects (e.g. sanitation and human health). We estimate that the discover of new correlations between socio-environmental, temporal, and spatial factors is very important because we understand that this new

[1] ADGEPA in Portuguese stands for *Assistente Digital para Gestão Pública Participativa*

information can help one to find strategies that may be more efficient than most of current governmental strategies to deal with socio-environmental concerns.

The Digital Assistant for Participatory Public Management (henceforth ADGEPA) was technologically inspired by the fast increase in the use of mobile devices with internet connection and georeferencing resources, and also by the development of APIs which are developed for users to access maps through web browsers. Considering the thematic point of view, our digital assistant was inspired by (i) web applications which store and present information about events and places, e.g. SpotCrime[2] and Foursquare[3] and (ii) projects whose methodologies support participatory management of natural resources. ADGEPA was designed to consider socio-environmental aspects, a considerable wide scope (cities), participatory public management, and to support decision making in public management.

2.2. Goals

The ADGEPA is an innovative practice to support participatory decision making in public resources management. The ADGEPA has an epistemic goal in order to help public managers to identify strategies to deal with most of the population's socio-environmental concerns. We hope these strategies be more efficient than current strategies adopted by traditional public managers which disregard correlation between socio-environmental aspects and do not consider articulated strategies with other public agencies' managers. We do not (at least yet) intend to estimate how much money should be invested in mitigation of socio-environmental concerns; instead, we intend to rank the most significant actions to mitigate most of relevant socio-environmental worries (according to ADGEPA users' understanding).

Specifically, we intend to implement (i) an responsive web application in which users can select socio-environmental concerns and mark them on a map and (ii) a wireless sensors network to collect environmental data. Once our database is populated, we intend to cluster data according to spatial criterion and then, according to temporal criterion, in order to find association rules between socio-environmental, temporal and spatial data. The last step consists of a multi-criteria analysis of these findings. The analysis varies according to manager profiles. At the end, ADGEPA should output a ranking of strategies to deal with socio-environmental concerns.

2.3. The Digital Assistant for Participatory Public Management

ADGEPA was designed to run on any device, since it has internet connection and a modern web browser. By means of the digital assistant, users can input their complaints about socio-environmental aspects and inform where it happened (by clicking on a map and getting the geographic coordinates). The time stamp which users enter their complaints is considered by ADGEPA as the time the event happened or was perceived by users.

We consider 23 environmental aspects including water, air, soil, illegal use of natural resources, and illegal invasions of protected areas. We consider 36 aspects about social concerns, including security, education, health, urban infrastructure, and illegal invasions of public areas and buildings. The wireless sensors network is responsible

[2]SpotCrime: for more information visit <http://spotcrime.com/>

[3]Foursquare: for more information visit <https://foursquare.com/>

to collect environmental data about humidity, luminosity, temperature, and carbon monoxide.

In a nutshell, the ADGEPA can be considered as 3 main components: (i) a responsive web application and a wireless sensors network to collect socio-environmental data; (ii) a miner agent; and (iii) a decision support agent. Figure 1 depicts the ADGEPA components. Since the collect of date takes a considerable amount of time to the web application and to the sensors network, and we do not have available data for our variables (socio-environmental aspects), the simulation of data is necessary; then, it emerged as a component.

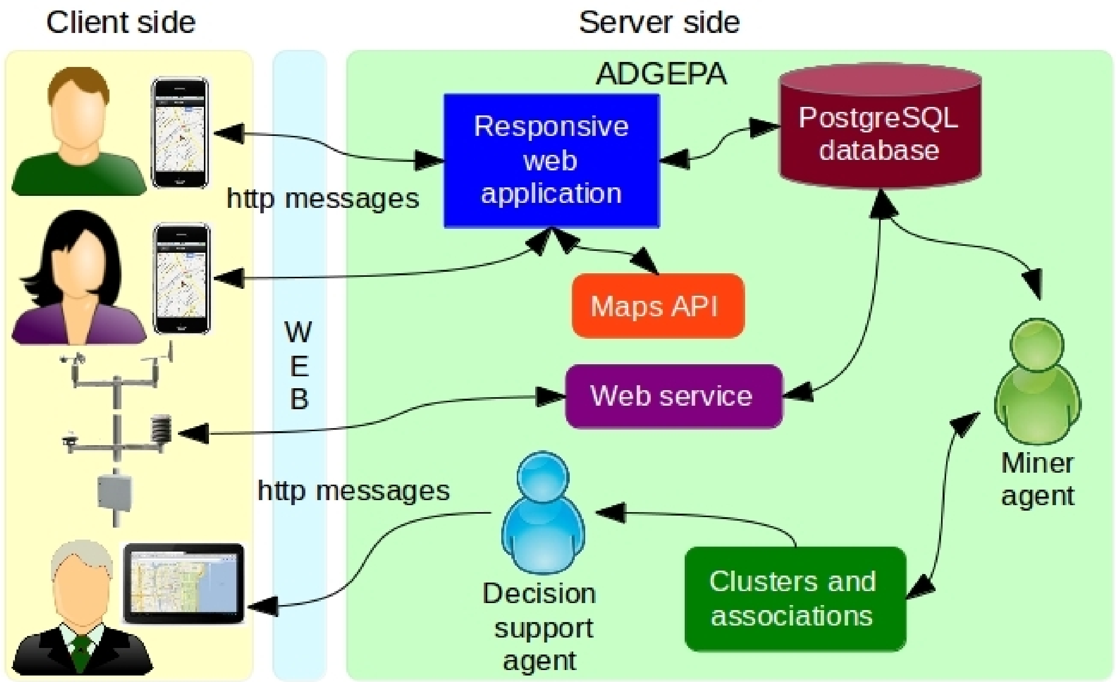

Figure 1. The ADGEPA components

The responsive web application was designed to be used by members of civil society. One needs just a smartphone, tablet or any computer with internet connection and a modern web browser for smartphones or desktops, such as Mozilla Firefox, Chrome, Opera, Safari, and Internet Explorer. Our first prototype was implemented using JSF with PrimeFaces 0.9.3. Since PrimeFaces has not enough maturity for mobile application, this attempt was not successful. We plan to use HTML5, Java, and JQuery Mobile API. Our first mini-station to collect environmental data was successfully implemented using Arduino AT-mega328P, Ethernet communication, breadboard, and USB power supply. However, urban infrastructure for wireless communication and power supply is not adapted for our first prototype.

Our first model of the Miner Agent (henceforth MA) was proposed to cluster data according to coordinates. Then, the MA clusters the obtained data groups according to time. After, the MA looks for association rules in the second cluster level. This agent is not yet implemented and its model was experimented using WEKA[4] software and random

[4]WEKA: for more information visit <http://www.cs.waikato.ac.nz/ml/weka/>

data.

The Decision Support Agent (DSA henceforward) was designed to sort the socio-environmental aspects which are present in most of association rules. After, it calculates the means of the confidence of the top 10 aspects with other socio-environmental aspects according to subsets (they are: water; air; soil; illegal use of natural resources; illegal invasions of protected areas; security; education; health; urban infrastructure; and illegal invasions of public areas and buildings). These 10 means are considered as the criteria for the top 10 aspects. Using the weighted sum method and one of the DSA profile (which determines the weights for each criteria), the top 10 aspects are ranked. The final ranking indicates which aspects should be considered in order to solve most of the relevant concerns suggested by ADGEPA users.

For the purpose of our current research, we consider 3 profiles: more sensitive to environmental aspects (weight of 60% against 40% for social aspects), more sensitive to social aspects (weight of 60% against 40% for environmental aspects), and hybrid (weight of 50% for both). We could easily change this profile in order to determine ranks according to specific interests. For example, if one major are more concerned with water pollution, we could change the weight of water variables - it could change the DSA results (we discuss this subject in Section 5).

We also should highlight that the socio-environmental aspects used in this project were empirically chosen by a domain expert and they are also considered by the Brazilian Governmental Departments. Some of them are not allowed by law, e.g. vandalism; however, users can use the application to delate these kind of concerns.

Our simulation model is described in details in Section 3.

3. Multi-Agent Based Simulation

In Subsection 2.3, we present the three components of the ADGEPA. The one, designed to collect users' complaints (socio-environmental concerns) and environmental data, takes a considerable amount of time to populate our database. Therefore, we decided to simulate the use of the system. However, we should simulate data considering the scenario, i.e. we cannot simulate a complaint about water pollution in the middle of an avenue, for example.

The elementary reasons to use Multi-Agent Based Simulation (MABS, henceforward) are its similarity to OOP paradigm (easy to use), it has many frameworks and documentation, and is a mature approach. The technical reason to use MABS is that agents have some features that suit our project requirements: proactivity, reactivity, cooperation, autonomy, communication capacity, and they are capable to operate in dynamic environments [Ferber 2007], [Wooldridge and Jennings 1995], [Sebba Patto 2010].

3.1. Simulation goals

The current simulation model was geared towards simulation of users' actions through the web responsive application. Currently, we are not interested in simulating the wireless sensors network. Our simulation model has a very complex environment in which many agents perceive it and act on it. The simulation of the use of the web application has two main agents: the Environment Agent[5] (EA) and the User Agent (UA).

The EA represents an environment like a city and should be perceived by UA. The UA, on the other hand should represent the application users (human beings). The UAs should move through the environment via their routes. Since they perceive the environment, they can record their socio-environmental complaints directly in the database. In a synthesis, the main goal of the simulation is to populate a database with coherent data in order to save time.

3.2. The Environment and User Agents

Currently, we are implementing the EA and the UA using JADE[6] (Java Agent Development) framework because it meets our needs, it has a good documentation, JADE is based on Java programing language, is well accepted in MABS scientific communities, and supports FIPA[7] specifications [Lima Silva et al. 2013].

According to the Wooldridge and Jennings' weak notion of agency, the EA has the first three of the following four properties: autonomy, social ability, reactivity, and proactivity [Wooldridge and Jennings 1995]. The UA has these four properties.

The EA main function is to represent an urban scenario in which the UA can perceive it and its elements. The EA has the coordinates to limit the city (as a quadrangle), has the coordinates of each element in the city (schools, hospitals, churches, bars, restaurants, movie theaters, theaters, schools, universities, supermarkets, shopping malls, agricultural marketing, offices, etc.), and has methods to inform UAs: these elements' coordinates and the element of a specific coordinate. Elements are identified by index (e.g. School0 has the coordinates present in the first position of the array of school coordinates). Big elements such as universities, hospital, lakes, and shopping malls are represented by quadrangles. Small elements such as bars, churches, restaurants, and offices are represented by small circles (with 20 meters radius). Streams and rivers, which look like line segments in a map, are represented by small rectangles (with 10 or 20 meters from one shore to another). Currently, the environment is not set up automatically, in our first model the information was set up in the agent source-code.

The UA main function is to move on the environment and perceive it in order to record its complaints in the database. As most of the web application users, UAs have their homes and go to schools, offices, markets, hospitals, bars, restaurants, movie theater, etc. When the simulation starts, UAs have no information about these elements' coordinates. They are informed by the EA about all elements' coordinates and each UA saves some of them (for example, University3's coordinates and the Supermarket1's coordinate). According to elements saved by UAs, each UA defines its route that can vary according to the week days. In our model, we considered IBGEs[8] census to determine the percentage of the population which works and goes to school. We considered IPEA[9]

[5]The environment is also an agent because in JADE, even the environment is implemented by extending the "Agent" class.

[6]For more information about JADE framework visit <http://jade.tilab.com/>

[7]FIPA - Foundation for Intelligent Physical Agents. More information at <http://www.fipa.org/>

[8]IBGE - Brazilian Institute for Geography and Statistics. Available at <http://www.ibge.gov.br/english/>

[9]IPEA - (Brazilian) Institute for Applied Economics Research: Available at: <http://www.ipea.gov.br/portal/>

survey to determine the percentage of population who goes to theater and movies theater. We estimate that 10% of population goes to bars, restaurants, churches, market, and hospital. User Agents go to school and offices 5 days per week. The other destinations were defined empirically (for example, UA goes once or twice a week to a supermarket). It is important to highlight that we do not intend to represent faithfully any real city. Since UAs cross the environment via their routes, they perceive the environment randomly. Each route was divided into 10 steps which could be perceived or not. According to UA's random profile, it can be concerned in different kind of socio-environmental aspects.

3.3. The simulation support architecture

Figure 2 represents graphically our simulation's architecture. The main two components, the EA and the UA were modeled to simulate the web application users and the environment they perceive daily. Via their interaction, complaints should be recorded in the database. After the simulation ends, the Miner Agent clusters the simulated data, firstly according to spatial constraints; then each spatial set is clustered in temporal groups. After, using the Apriori algorithm, the ME identifies the most associated socio-environmental aspects (considering the confidence). Since the ME generates clusters and association rules csv files, the Support Decision Agent executes a multi-criteria analysis in order to rank the most relevant aspects to mitigate most of population concerns.

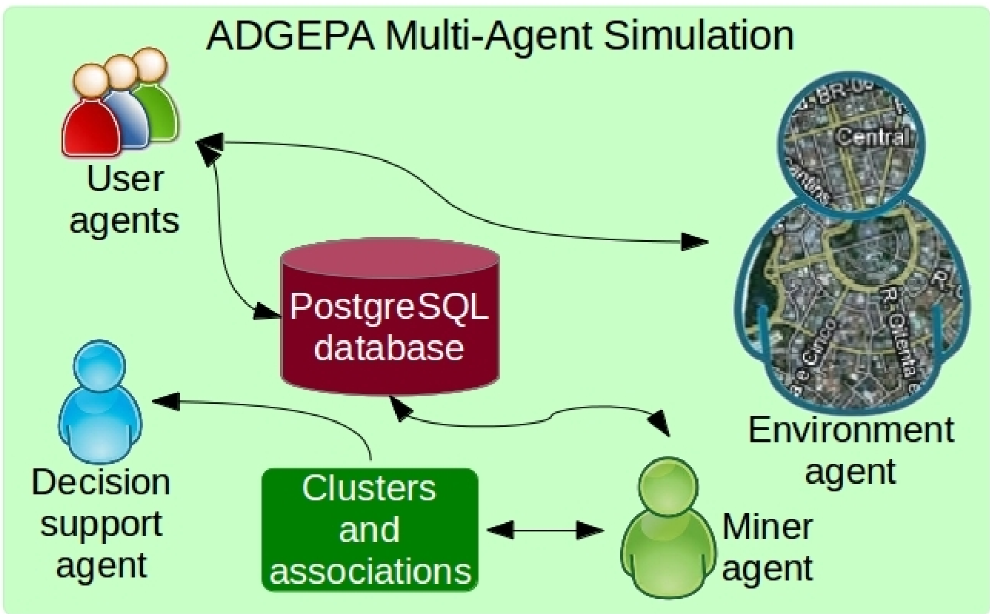

Figure 2. The simulation architecture

3.4. Simulation cycle

The cycle of our simulation represents one day and the simulation can last for hundreds or thousands of days. At the beginning of simulation, one must inform the population of the scenario and how many days are simulated. Since each UA has its own home and may go to school, to the office, to the market, etc., it should roam during the day. Each UA should leave its home at the beginning of the day and should be back at the end of the day.

In our first model, agents' routes were divided into 10 line segments (10 steps); UA may perceive these segments; and they can record their complaints in a database. The last route of each day always ends in UA's home. The next day, the cycle is repeated, but routes may change (e.g. for one UA, Friday night is the right moment to go to the supermarket).

After finishing the last simulated day, ME should read the database in order to cluster data according to spatial criteria; for example, we can consider a rectangular area (of the map) of 10Km for 5Km and we can generate 10,000 clusters according to coordinates data. After, ME clusters each of these 10,000 sets into temporal unities (let's suppose one week or 7 days). From each spatial cluster, 52 new temporal clusters are generated (for each simulated year). The last step is look for association rules in temporal clusters.

The DSA ranks the most frequent socio-environmental aspects in association rules. Then, it calculates the mean for the top 10 most associated with each of the 10 groups of aspects (water, air, security, etc.). After, the weighted sum method is applied in order to designate the aspects considered most important. Since these aspects were found in association rules with other aspects, we believe they can favor or cause other concerns. Further, they were also considered by the population as important concerns.

4. Preliminary evaluation

The first component of ADGEPA is the responsive web application and the wireless sensors network. The web application was not successfully implemented and should be implemented with other responsive web application APIs. The wireless sensors network was well implemented: environmental data were successfully read and sent to a web server. However, power supply and wireless communication infrastructure in our city remains challenged.

The second ADGEPA component is the Miner Agent. We tested its model using random complaints. The records were composed by socio-environmental aspects, coordinates, and time stamps. Using WEKA software, and csv files, we obtained satisfying results using SimpleKMeans and Apriori algorithms. The generated spatial clusters were not perfect 5 Km^2 squares (as such as a grid); however, the generated sets had similar dimensions one to another (we used random data). The implementation of the MA was not finished yet.

The DSA was tested manually to rank most important aspects. Until this moment, we used the weighted sum method and we believe it meets very well our expectations. In our tests, we used random data; consequently, the association rules make no sense in the real world. Nevertheless, the ranking makes sense according to the 10 analyzed criteria.

The MABS is a very important component because it will save a lot of time. No test was performed because EA and the UA are not implemented yet. They should be implemented and run together.

Even that our approach was proposed to deal with socio-environmental aspects, we believe that it also could be used to deal only with environmental aspects or a group of other specifics indicators.

5. Ongoing and future work

Currently, we are migrating our responsive web application for HTML5, Java, and JQuery Mobile API. We are also studying other APIs such as Twitter Bootstrap. For future work, we could include in the application a functionality to add new indicators or aspects (e.g. visual pollution). So far in this project, we did not think about integrate ADGEPA with social networks or web applications such as SpotCrime (it also could be considered as an additional future work). Our mini-station to collect environmental data was successfully implemented; however, we consider other techniques to send data, as Bluetooth, and to supply electric energy, such as photovoltaic panel. We know in advance that this solution tends to be expensive and some components are delicate. Consequently, we are still looking for low cost and durable solutions.

Currently, our Miner Agent model is satisfactory. In our tests we use small area (around 5 for 3 Km) and one year period. The first spatial clustering generated 1000 sets. We considered 3 days for temporal clustering, thus it gives approximately 120,000 new clusters. Then, the MA looks for association rules. Using SimpleKMeans and Apriori algorithms the results were considerably fast (it takes 111.23 seconds). We intend to implement MA in such way that we can easily use other algorithms. We still need to test bigger areas and long periods of time. Further, we also consider the possibility to model a new ME in order to identify temporal series. And lastly, we intend to remove redundant complaints in the data cleaning step (a preliminary activity of data mining).

The DSA represent an ongoing research. The two main needs are: to study new multi-criteria methods and to identify how we can use temporal series in our decision support component. Currently, the DSA has three profiles: more sensitive to environmental aspects, more sensitive to social aspects, and hybrid. These profiles are used to determine the weight of each criteria used in our analysis. For future works, we intend to create a graphical interface to set DSA weights. Then one could use the 3 predefined profiles, but one could also use a customized profile. Even that it is rare, situations in which aspects have the same value at the end can exist. Then, we also need to identify tiebreaker for this situation.

The MABS component is the most complex part of the model. Currently, our model needs some improvements. The EA was firstly designed statically. We understand that it should change according to the time, e.g. traffic jam occurs when people go to work or school and when they go back home. For UA there are too many improvements that may or may not be considered. Since we simulate human beings, we could use hybrid architecture (reactive and cognitive), we can also include features such as emotions. This is also an ongoing research on a very wide field. Nevertheless, we do not intend to simulate faithfully cities and human beings.

6. Conclusion

In this paper, we presented the ADGEPA project, an innovative participatory public management approach. On order to accomplish our main goal we proposed a tool to favor participatory public management: a responsive web application and a mini-stations to collect environmental data; a Miner Agent to look for standards and association rules in our data; and a Decision Support Agent to rank the most associated socio-environmental aspects with the main concerns of population. In addition to the three main components of ADGEPA we present our MABS solution to surpass the temporal constraint (it takes too long to populate our database).

Some of the Digital Assistant for Participatory Public Management components were tested by computer experts and domain experts. The MABS was analyzed and we identified some necessaries improvements before finishing agents' implementation.

We estimate that our ongoing research is very promising and may be helpful to support democratic governance, since participatory approaches improve stakeholders understanding about the environment which they live in. This way, citizens can become more conscious about their responsibility and the roles they play. We also believe that standards exist and correlations between socio-environmental aspects that are not so obvious (such as correlation between sanitation and health) can be found.

Our ongoing research project still needs integration and many tests, evaluations, and adjustments. Even that we use simulated data, we believe that it will not compromise the quality of the ADGEPA because if we use our application in different cities, we could find different standards and correlations between data of different scenarios. We understand that our first tests and analysis were encouraging; we are welcoming inputs from similar studies and any feedback.

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