A MAS APPROACH BASED ON COLOURED PETRI NET FORMALISM FOR URBAN POLICY DESIGN

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ABSTRACT

Simulation transparency is becoming more crucial in the decision making process when quantitative computer tools are used to justify some strategies. E-governance is one of these areas in which the use of Multi Agent System (MAS) simulation systems could be used to foster e-participation in which citizens could be involved in the design of urban policies that affects their habitat environment.

The Colored Petri Net (CPN) formalism is a promising modelling approach to foster simulation transparency by means of state space traceability tools and it has been proven to be useful for modelling system dynamics with concurrent and conflict patterns in more efficient ways.

We propose a modeling methodology to represent and analyze a context-aware multi agent-based system, which tends to be highly complex. We introduce CPNs as a method of capturing the dynamics of this contextual change. We define CPNs and a way to apply them in context-aware agent-based systems. We also describe a prototype system that we have developed which translates CPN specification into Repast Simphony agents' behaviour.

Keywords: Urban policy, state space, petri net, MAS simulation, e-participation

1. INTRODUCTION

The European Commission launched a call under its framework 7 program dealing with ICT solutions for governance and policy modelling (Objective ICT-2011.5.6).

Target Outcomes are ICT solutions for governance and policy modelling. The research is focused in the development of advanced ICT tools for policy modelling, prediction of policy impacts, development of new governance models and collaborative solving of complex societal problems.

The main objective of FUPOL is to demonstrate that, with ICT support the whole policy development lifecycle of policy formulation, collaborative stakeholder involvement, policy modelling, scenario generation, visualization of results and feedback is feasible and a core element of future policy development at local, regional, national as well as global level (Mujica and Piera 2012).

Most urban simulation models do not take into account the demands and skills of the multiple and heterogeneous users of a model in practice. There exist fears, expectations and prejudices among the practitioners against the models: quantitative models are monsters and do not capture the social aspects in an adequate way. A lack of credibility in the models is reported due to non-scientific actors being not aware of the uncertainty inherent in such models. As a result, mistrust or communication problems can be found generally between scientists and actors.

In contrast to traditional urban modelling methodologies, the proposed causal modelling approach in FUPOL takes into consideration that actors have different skills and pre-knowledge of the complex urban system. By incorporating users' heterogeneity in non-scientific knowledge (subjective values), interests and preferences, FUPOL modelling approach contributes to overcome one of the main shortages of present policy models: citizen e-participation.

The term e-Participation is quite new and it is widely used in e-Governance and e-Democracy programs. E-participation in urban decision-making means the use of ICT for enabling and strengthening citizen participation in democratic decision-making processes. The use of ICT in e-Participation process consists on motivation and engagement of a large number of citizens through diverse modes of technical and communicative skills to ensure broader participation in the policy process, real-time qualitative and accessible information, and transparent and accountable governance (Islam 2008).

By means of a Multi Agent System (MAS) simulation platform, FUPOL models allow citizens to test the benefits and shortages of different proposed urban policies and check new policies according to their own beliefs.

Figure 1 illustrates the selected tools to model the different urban policy domains by properly integrating fuzzy cognitive maps (FCM) and coloured Petri nets (Moore and Gupta 1996, Jensen 1997, Christensen et al. 2001, Mujica and Piera 2011) under a MAS environment, which presents great advantages in order to analyse social systems (North and Macal 2007).

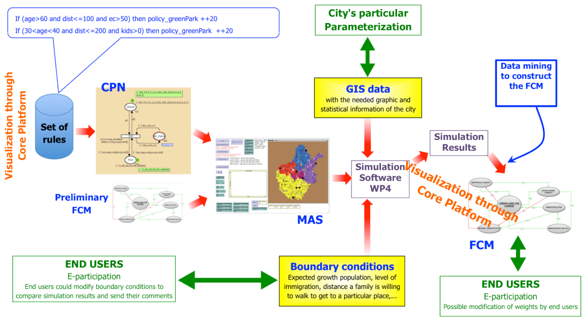

Figure 1: Main FUPOL Simulation Tools

The urban policy models consist of a library with citizens' affinities together with urban areas defined by social activities (constrains and facilities). Citizen affinities can be categorized considering the particular attributes of each person, such as their age, the amount of kids, the incomes and sex among others. Thus, the different citizen behavioural rules are defined by a set of acceptable attribute interval values. All these citizen affinities are described as a set of informal rules that can be easily checked/maintained/modified by different end-users.

The library of rules (citizen affinities together with social activities) is automatically translated to CPN formalism for a causal-based state space analysis. A set of rules is obtained from CPN and used to describe the agents' behaviour, which are modelled using Repast Simphony.

As a result of the simulation, numerical data generated is processed under a data mining approach (ANFIS) to automatically generate the main weights for the causal relationships between Fuzzy Cognitive Maps items. End users can interact with the Repast Simphony Model and the final FCM.

First model and results for Community Facilities: Area Design domain, developed for the City of Zagreb, will be presented in this paper. The main target of this model is the design (or configuration) of an area, in this particular case, a green park near the new national centre of autism, in order to overcome conflicts between neighbours and autistics, and also to facilitate the autistics integration in the society.

Section 2, 3 and 4 present the three modelling approaches combined in the methodology: CPN, MAS and FCM. The methodology phases are described in Section 5, and the Zagreb use case in Section 6. Finally, conclusions are presented in Section 7.

2. COLOURED PETRI NETS

Coloured Petri Nets (CPN) is a simple yet powerful modelling formalism, which allows to properly modelling discrete-event dynamic systems that present a concurrent, asynchronous and parallel behaviour (Moore et al. 1996, Jensen 1997, Christensen et al. 2001). CPN can be graphically represented as a bipartite graph, which is composed of two types of nodes: the place nodes and the transition nodes. Place nodes are commonly used to model system resources or logic conditions, and transition nodes are associated to activities of the real system. The entities that flow in the model are known as tokens and they have attributes known as colours. The use of colours allows modelling not only the dynamic behaviour of systems but also the information flow, which is a key attribute in decision making (Mujica and Piera 2011).

The formalism can be graphically represented by a bipartite graph where the place nodes are represented by circles and the transition nodes by rectangles or solid lines. Figure 2 illustrates a graphical representation of a CPN model.

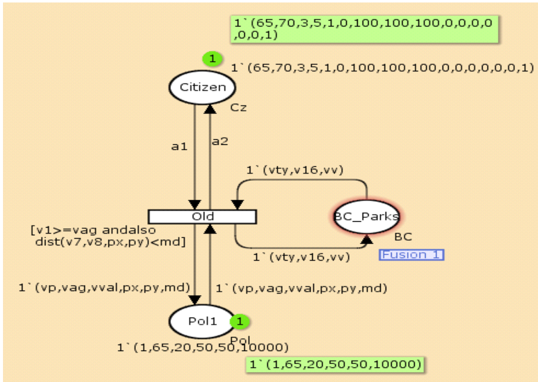

Figure 2: CPN Model Example

3. MULTI AGENT SYSTEMS

Multi-agent systems (MAS) have been applied in various fields related to Human Sciences, such as Political Sciences, Economics, and Social Sciences (Segal-Halevi (2012), Wilensky, 1999), in which an agent can be seen as an actor that has the power of "Agency". The concept of agency is paramount since it extends beyond a single human being to organizations and social systems, where some have "agency" power with the ability to make decisions, while others do not have such power. These agents communicate, collaborate and negotiate among each other in order to meet their design objectives.

During the developing phase of MAS, it is necessary to simulate the system feasibility before the formal implementation. One way to achieve this objective is to develop a model to represent the behaviours of the MAS and then to simulate the model performance. In practice, a lot of time might be spent on modelling MAS behaviours while the resulting process models are typically still not compatible with the original system due to the lack of information about actual behaviours of the MAS. To avoid this difficulty, CPN models can be used to describe agents' behaviour and predict the performance by means of state space analysis tools.

In FUPOL several MAS platforms has been analysed and, among them, Repast Symphony has been chosen as a simulation environment.

Repast Simphony is a widely used, free, and open source environment for agent-based modelling of complex adaptive system. The most recent version, 2.0, was released on March 5, 2012. Repast Simphony is a second-generation environment that builds upon the previous Repast 3 library (North et al. 2013).

Due to its flexibility it is suited to fully integrate the semantic rules present in CPN, and their implementation allow to govern the agents that interact within the environment in a more transparent way which is useful to understand the emergent dynamics caused by the agent interaction.

4. FUZZY COGNITIVE MAPS

Cognitive maps (CMs) are qualitative models of a system, consisting of variables and the causal relationships between those variables. Causal relationships among the variables in the models are specified and tested with parameter estimation procedures, usually maximum likelihood. These variables can be physical quantities that can be measured. The decision-makers' maps can be examined, compared as to their similarities and differences, and discussed (Özesmi,2003). Stakeholders can be compared to see which groups have more relationships among variables. If some groups perceive more relationships, they will have more options available to change things. The person who develops the cognitive map decides what the important concepts that affect a system are, and then draws causal relationships among these variables indicating the relative strength of the relationships with a positive/negative/none sign between concepts. The directions of the causal relationships are indicated with arrowheads. Also, he decides on the strengths that can be changed easily. More simulations can be done in order to see how the model changes with changing strengths of relationships

Strictly speaking, a FCM is a figure composed of nodes and edges, the former introducing the qualitative concepts of the analysis while the latter are indicating the various causal relationships. Each concept node possesses a numeric state, which denotes the qualitative measure of its presence in the conceptual domain. Thus, a positive numeric value indicates that the concept is strongly present in the analysis, while a negative or zero value indicates that the concept is not currently active or relevant to the conceptual domain. A FCM works in discrete steps. When a strong positive correlation exists between the current state of a concept and that of another concept in a preceding period, we say that the former positively influences the latter indicating this by a positively weighted arrow directed from the cause to the effect concept. By contrast, when a strong negative correlation exists, it reveals the existence of a negative causal relationship indicated by an arrow charged with a negative weight. Two conceptual nodes without a direct link are, obviously, independent.

5. MODELLING METHODOLOGY PHASES

There are several steps to be followed in order to ensure a good performance of the final simulation models. These steps are:

1. Rules generation using the information obtained from the field work make in pilot cities to collect data regarding the corresponding domain. In the case of Zagreb, to collect data regarding the use of the parks in the city
2. These rules are internally verified and validated using CPN models and then, they are used to formalise agent's behaviour in Repast Symphony (MAS)
3. Numerical data obtained by running several MAS simulations is processed under a data mining approach to automatically generate the main weights of the FCM.

After these steps, the MAS model and the FCM are ready to be used by end users, which will be able to modify the boundary conditions in order to test what happen if the initially considered ones are not really satisfied.

6. CASE STUDY: GREEN PARK AREA DESIGN

6.1. Description of the System

The simulation objective for a green park design in Zagreb is to provide the best solution for the facilities that would be included in the green park situated near the Autism Centre. The surface of the park is around 30.000m^2, and the design must satisfy most of the potential users demands and must encourage interactions between autistic people and non-autistic users, while avoiding possible conflicts between them. At the same time, possible conflicts between all kinds of users must be avoided. For example, nobody likes to have dogs around kids while these are playing in a playground. Or nobody is going to sit on the grass near 20 young guys playing football.

6.2. Model Specifications

The officers of the city of Zagreb together with experts on autism disorder have generated the data used in this paper in order to test the simulation model while they perform the field work to collect the real data that they will finally use. They have considered their own experience in green parks around the city. Table 1 presents the considered activities.

Table 1: Green Park Activities

ID	Activity	ID	Activity
A1	Walking through the park pathway	A21	Walking with a dog
A2	Sitting on a bench	A22	Touching objects and surfaces
A3	Sitting around a table	A23	Playing frisbee
A4	Feeding children	A24	Playing with a dog
A5	Playing in the Sandbox	A25	Playing bocce ball
A6	Sitting on the grass	A26	Resting
A7	Sitting and playing on the	A27	Playing in the labyrinth

	grass		
A8	Swinging	A28	Standing
A9	Sliding down the toboggan (slide)	A29	Standing with a parm
A10	Spinning on roundabouts	A30	Watching water movement and/or listening the sound of the water
A11	Climbing on monkey bars	A31	Following the paths with motoric tasks
A12	Roller skating	A32	Walking through the labyrinth
A13	Playing ball on the grass	A33	Sitting in the aromatic herbs garden
A14	Playing rackets on the grass	A34	Walking through the aromatic herbs garden
A15	Riding a bicycle	A35	Listening bells sounds
A16	Playing football	A36	Playing passing obstacles (climbing, crawling, going in and out, etc.)
A17	Playing basketball	A37	Having a party in the amphitheatre
A18	Skateboarding	A38	Playing theatre games
A19	Playing social games sitting around a table	A39	Playing in the Sensory Park
A20	-		

These activities can be performed in specific zones, and these zones are summarized in Table 2.

Table 2: Green Park Zones

ID	Description
Z1	Playground with games 1, for little children
Z2	Playground with games 2, for younger school age
Z3	Playground with games 3, for adolescents
Z4	Sandbox
Z5	Grass zone (with some trees to have some shade)
Z6	Picnic zone (with tables and benches)
Z7	Bike training ground (with basic traffic signs and rules)
Z8	Sensory Park: Labyrinth
Z9	Sensory Park: Music bells corner
Z10	Sensory Park: aromatic herbs garden
Z11	Sensory Park: building in the nature zone
Z12	Sensory Park: amphitheatre
Z13	Sensory Park: paths with different colours, textures and training ground for motoric tasks (jump, skip over, scrape through, reach and pull, etc.)
Z14	Sensory Park: Fountain
Z15	Pathways
Z16	Bocce ball fields

For each activity, the main characteristics of the citizens that could be candidates at different affinity levels together with the most expected time-frame are formalized in CPN. Some agent attributes are summarized in Table 3.

Table 3: Some Agent's Attributes

Data (attribute)	**Meaning and Ranges**
Age	Age of the citizen. Range: 0 - 120
Gender	Gender of the citizen. Range: M (male) or F (female)
Dog	Having or not having a dog. Range: 0 (no dog) or 1 (dog)
CultLevel	Cultural level. Range: from 1 (no studies) to 5 (Master or PhD level). This information is useful to describe how the affinities can affect or can be influenced by their neighbourhood´s opinions.
HouseType	Type of house. It is different to live in an apartment than in a house. Range: 1 (Apartment), 2 (Town house without too much garden) or 3 (House with garden)
CitizenOrigin	Type of citizens depending on where they live. Range: 1 (Autism centre), 2 (Surrounding neighbourhood), 3 (Closest districts), 4 (Other town parts) or 5 (Outside the town)
Personality	Level of personality of the agent. High personality indicates that it can influence the other agents. Low personality indicates that other agents with higher personality can influence it. Range: 0 to 100.

Specific citizen behavioural rules that has been formalized in CPN and later on codified in Repast Simphony are:

S1: Kids between 3 and 5 years of age are mostly interested on playing (ie. swings, sand area); however, sometimes they could prefer to sit on a bench or around a table to have some snack or even to have lunch.

S2: Kids between 6 and 12 years of age are also mostly interested on playing (i.e. playing ball); however, their plays are quite different than kids between 3 and 5.

S3: Young people between 13 and 19 years should have other concerns and responsibilities. Some of them can be really interested in sports (individual and collective), and they can be responsible of a dog. And preferences can vary between males and females. However, if they don't like sports, males and females share preferences (it will implies to include them in the same rule), and these are sitting (could be on the grass, around a table, on a bench,...) or some pair situations like walking or sitting together. Due to the fact they can move around by themself, walking pass through the park can be also one of their activities. Regarding sports, they have different preferences that can be summarized using statistics.

6.3. Model Representation

Figure 3 presents the preliminary MAS model representation used by modellers; final interface is still under development. Circles in purple are non-autistics, they are located anywhere, and each point can represent more than one agent because the members of the same family unit are located at the same place, their residence (home); triangles in purple are autistics, and in the current stage they are all located in the cell representing the centre of autism. Red circles are monitors in charge of escorting the autistics, and they are located in the centre of autism also (there are two cells representing the centre). Big circles on the left side represent the different zones considered in the park. Their colour change depending on its occupancy: Green means there is a lot of space (low occupancy rate); orange means that the zone is almost full of people (elevate occupancy rate); and red means that the occupancy rate is at 100% or more, indicating that more space for that zone is needed to fit all the people interested in it.

Figure 4 present the map of the area where the autism centre and the park will be placed. The red area marked with "D" is the area for the autism centre, and the green area with "Z1" is the area for the green park.

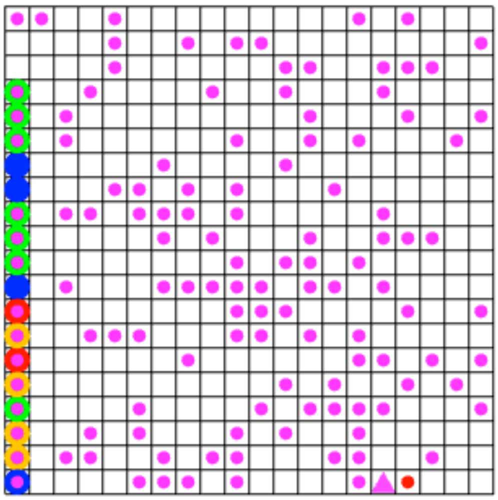

Figure 3: Preliminary MAS Model Representation

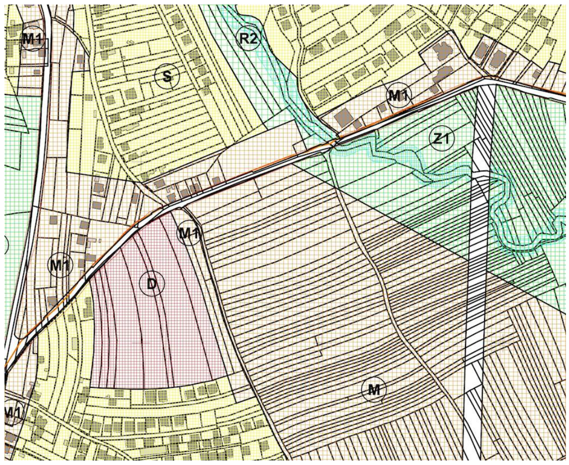

Figure 4: Autism Center and Green Park Area

By means of a multirun approach, the agent observer computes the best surface distribution between different zones that should allocated the different described activities, while minimizing the potential conflicts between activities in the same zone.

6.4. Test Results

Reduced size scenario has been considered to test the model (All zones of 20m2, but zone 15, which are the pathways, with a fixed surface of 80m2), and end users model acceptability has ben reached by introducing extreme scenario conditions, one of which is "Mostly elders and 20% with dog" and it is presented in this paper.

Tests consist on simulations of one week, from Monday to Sunday, and different time frames during the day (9:00 to 12:00, 12:00 to 15:00. 15:00 to 17:00, 17:00 to 20:00, and 20:00 to 00:00). Outputs graphically presented in this paper are:

1) Zones Occupancy presented in Figure 5: it can be observed that zones 6 (picnic zones where elders play table games) and 16 (bocce ball fields) are more occupied than other zones.
2) Zones Surface in Figure 6: due to zones 6 and 16 are more occupied; they need more square meters (surface).
3) Number of conflicts in Figure 7: initial conflicts are in zones 6 and 16 before more square meters are assigned to them. Latter on, due to there are not just elders and zone 1 surface has been reduced, more conflicts appear in zone 1.

Notice that the convergence of the needed surface will be stabilised as many days are simulated.

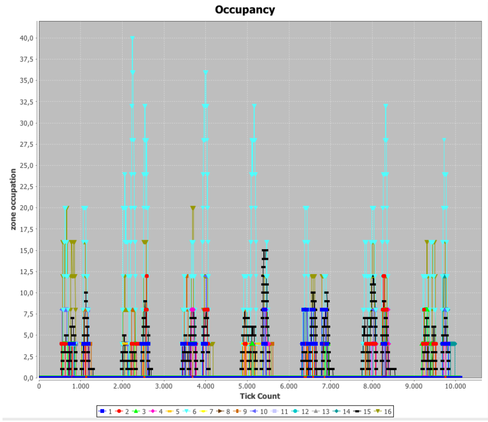

Figure 5: Occupancy of Zones

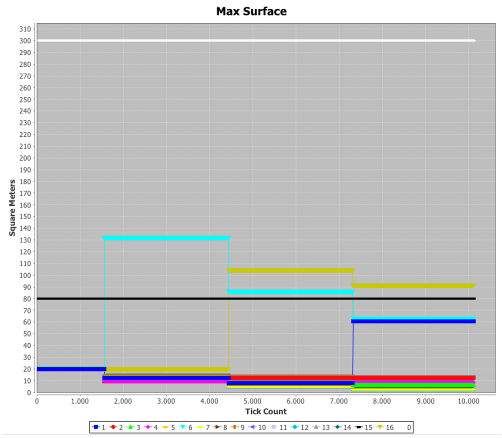

Figure 6: Zones Surface

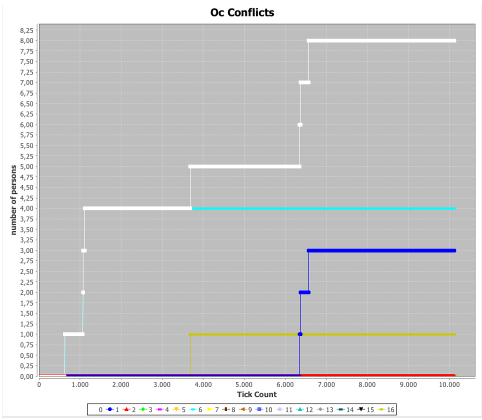

Figure 7: Occupancy conflicts

7. CONCLUSIONS

Under the framework of the FUPOL project one challenging task is the policy modelling and analysis. The proposed methodology has been performed through a novel approach which models the different actors in a policy process as agents whose behaviour is governed by a causal modelling developed in coloured Petri nets. The translation of the CPN models into the Repast Simphony environment allows a novel way of understanding the causal relationships that are behind decision making in society. With the use of CPN it is possible to implement the causal relationships that govern the agent behaviour in such a way that more transparency is achieved during the evaluation of a particular policy.

Results of the green park area design preliminary model show that the developed model can be used to estimate the number of persons performing certain activities in certain zones of the park, which can be used to calculate the surface needed for each zone in order to do not have occupancy conflicts in the park. Final simulation software allowing much more agents will be used to initially design the park and also to predict park maintenance activities.

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