THE TRANSLATION OF CPN INTO NETLOGO ENVIRONMENT FOR THE MODELLING OF POLITICAL ISSUES: FUPOL PROJECT

Miguel Mujica[(a)], Miquel Angel Piera[(b)]

[(a,b)]Autonomous University of Barcelona, Faculty of Telecommunications and Systems Engineering, 08193, Bellaterra, Barcelona

[(a)]miguelantonio.mujica@uab.es, [(b)]miquelangel.piera@uab.es

ABSTRACT

The FUPOL project aims in a better way of fostering e-participation through the use of several tools and the social networks. The designed tool will make the citizens participate in the decision-making process in a more active way. The modelling and simulation of social activity is one WP of the project which is in charge of developing multi-agent systems capable of simulating the different actors that participate in the policy process. In order to determine the behaviour of citizens in a unambiguous and formal way the coloured Petri net formalism is used as the modelling framework to govern the agents behaviour. The characteristics of the CPN formalism allow a better understanding of the causal relationships present in systems and in particular in the case of policy process it allows simulating policy domains taking into account the causes of the decisions which contrast with the traditional approach that normally uses data trends or regressions to forecast the future outcomes. In this paper a way to translate the CPN semantic rules into the rules used by the agents called Turtles, links or patches in NetLogo is presented.

Keywords: timed Petri nets, state space, optimization, simulation, manufacturing.

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 focus 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 (Figure 1).
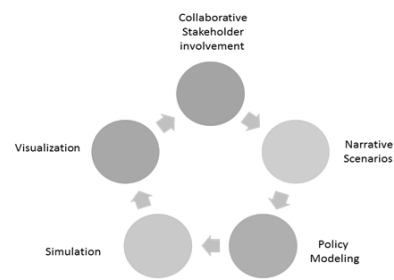

Figure 1: Policy development lifecycle

It will address issues related to the integration of the different components through advanced technical solutions and demonstrate an integrated ICT solution with a collaborative environment for policy modelling to generate different formal scenarios through simulations and scenario-based future development. This will include ICT support based on integrated Web 2.0 / Web 3.0 collaborative tools and policy simulation tools with scenario generation and visualization. It will also assist the long-term strategic planning of governments at all levels and policy operators in any policy area to better address and shape future developments so that the demands of citizens and economy are met.

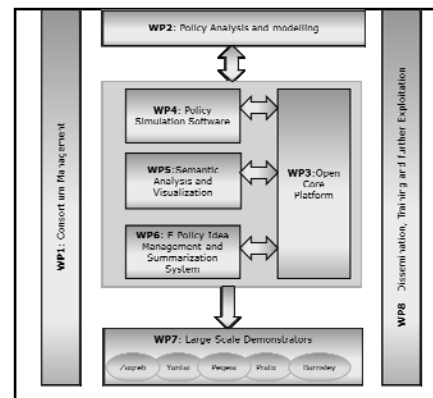The overview structure of the FUPOL project is illustrated in figure 2

Figure 2: Overview of the WP Structure

Proceedings of the European Modeling and Simulation Symposium, 2012
978-88-97999-09-6; Breitenecker, Bruzzone, Jimenez, Longo, Merkuryev, Sokolov Eds.

555

The main task of the WP2 is the modelling and validation of policy models of different domains. The selected tools to model the different domains use techniques such as fuzzy cognitive maps (FCM) and coloured Petri nets (CPN) under a multi agent system (MAS) environment which presents great advantages in order to analyse social systems (North and Macal 2007).

2. COLOURED PETRI NETS

Coloured Petri Nets (CPN) is a simple yet powerful modelling formalism which allows to properly modelling discrete-event dynamic systems which 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 formal definition is as follows.

A Coloured Petri Net can be defined as the tuple (Jensen1997):

$$CPN = (\Sigma, P, T, A, N, C, G, E, I)$$

Where

- $\Sigma = \{C1, C2, \dots, C_{nc}\}$ represent the finite and not-empty set of colours. They allow the attribute specification of each modelled entity.
- $P = \{P1, P2, \dots, P_{np}\}$ represent the finite set of place nodes.
- $T = \{T1, T2, \dots, T_{nt}\}$ represent the set of transition nodes such that $P \cap T = \varnothing$ which normally are associated to activities in the real system.
- $A = \{A1, A2, \dots, A_{na}\}$ represent the directed arc set, which relate transition and place nodes such as $A \subseteq P \times T \cup T \times P$
- $N = $ It is the node function $N(A_i)$, which is associated to the input and output arcs. If one is a place node then the other must be a transition node and vice versa.
- $C = $ is the colour set functions, $C(P_i)$, which specify for the combination of colours for each place node such as $C: P \rightarrow \Sigma$.

$$C(P_i) = C_j \qquad P_i \in P, C_j \in \Sigma$$

- $G = $ Guard function, it is associated to transition nodes, $G(T_i)$, $G: T \rightarrow EXPR$. It is

normally used to inhibit the event associated with the transition upon the attribute values of the processed entities. If the processed entities satisfy the arc expression but not the guard, the transition will not be enabled.

- $E = $ these are the arc expressions $E(A_i)$ such as $E: A \rightarrow EXPR$. For the input arcs they specify the quantity and type of entities that can be selected among the ones present in the place node in order to enable the transition. When it is dealing with an output place, they specify the values of the output tokens for the state generated when transition fires.
- $I = $ Initialization function $I(P_i)$, it allows the value specification for the initial entities in the place nodes at the beginning of the simulation. It is the initial state of a particular scenario.
- EXPR denotes logic expressions provided by any inscription language (logic, functional, etc.)
- The *state* of every CPN model is also called the *marking* which is composed by the expressions associated to each place *p* and they must be closed expressions i.e. they cannot have any free variables.

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.
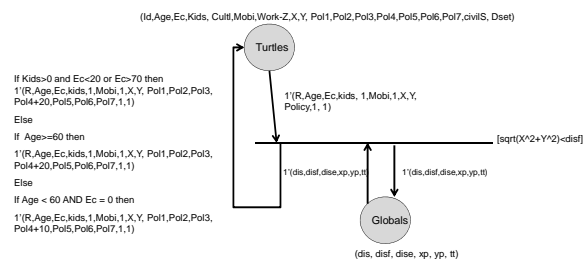

Figure 2: CPN model of land use participation

Figure 2 illustrates a graphical representation of a CPN model with all the described elements.

2.1. Dynamic behaviour of the CPN

The transitions in the CPN models play the role of activities, actions or decisions in the real system. The firing of a transition is caused by the satisfaction of several restrictions imposed by the colours, arc expressions and guards. In the case of social systems the set of conditions or restrictions that cause a particular behaviour or decision are modelled with the

use of colours, arc expressions and guards. In order to enable a transition (i.e. the possibility of an action, activity to occur) It is necessary to satisfy all of the following conditions:

•   The number of tokens in the input place nodes are greater than or equal to the arc weight

•   There must be at least one combination of tokens within the input place nodes whose colours have the particular values stated in the arc inscriptions. If there are free variables, the variables take the value from the correspondent token colour.

•   The Boolean expressions of the guards (generally related to the token variables) must also be satisfied.

Once the restrictions have been satisfied it is said that the transition is enabled and the modelled activity can occur. In such a case the following actions are performed in the input and output place nodes:

•   The tokens that enable the transition are consumed (destroyed) from the original input place nodes

•   New tokens are created in the correspondent output place nodes based on the values of the variables, the arc expressions attached to the output arcs and the weights of the arcs (there must be created as many tokens as the weight of the output arcs).

The configuration that is obtained after the execution of a transition corresponds to a new state of the original system.

3.   NETLOGO

NetLogo is a simulation environment which has been widely used in academia not only for teaching purposes but also for research ones (Romus-Catalin, 2011).

NetLogo is an agent-based model programming environment built on the programming language JAVA and authored by Uri Wilensky. Due to its flexibility it is suited to fully integrate the semantic rules present in CPN using the code available in the procedures window of NetLogo. The implementation of CPN semantic rules 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.

3.1. Agents in NetLogo

The NetLogo environment is made up of agents. Agents are beings that can follow instructions. There are four types of agents:

•   Turtles. Turtles are agents that move around the NetLogo environment.

•   Patches: The world is two dimensional and is divided up into a grid of patches. Each patch is a square piece of "ground" over which turtles can move.

•   Links: Links are agents that connect two turtles. Links can be directed (from one turtle to another turtle) or undirected (one turtle with another turtle).

•   The observer: The observer does not have a location - one can imagine it as looking out over the world of turtles, links and patches. Generally speaking the observer is the developer and can test instructions over the environment developed in order to verify the behaviour of the different agents.

4.   CPN RULES AND THE CODE IN NETLOGO

In order to make a straightforward translation from the CPN formalism into the NetLogo environment, it is necessary to determine a way to code the transitions, the place nodes and the firing rules within the NetLogo environment. The main idea is to combine the capabilities of the CPN formalism with the ability to manage the different agents that interact within the program in such a way that the emergent dynamics are more transparent to the analyst. The implementation of the CPN models will be exemplified with the use of one transition of the Open Space land-use model developed for the FUPOL project.

4.1. Definition of Colours in the NetLogo environment

The CPN of the open space model needs some colours to be defined. These colours are used as part of the different agents with the purpose of tracking down the information flow that takes place when a decision is performed by the agents. The following table illustrates the kind of attributes and colours that are used for the open-space CPN model.

Table 1: Colour attributes of the open space example

Colour	Meaning
Age	Age of the citizen: most urban policies are highly dependent of the population age of citizens that will be affected. Age diversity usually is a problem when trying to devise the beneffitsa certain urban policy
Ec	Economical incomes rate: It takes a value between 0% to 100%. 0% means unemployed without subsistence. 100% means a well standing economical position. This information is highly relevant to simulate the economic impact of urban policies.
Kids	Amount of kids bellow 18 years olds: this information is important to evaluate the social impact of urban policies.
CultL	Cultural level: A value between 1 (no studies) until 5 (PhD level). This information is useful not only to evaluate the impact of a policy, but also to describe how his affinities can affect or can be influenced by their neighbourhood ´s opinions.
Mobi	Mobility: Describes the preferences of the urban population to access places (working, leisure, shopping, etc.). It is parameterized using 5 values: 1 – Car, 2 – Public urban transport (bus/subway), 3 – Public regional transport (train/buses), 4.- alternative transport means (cycle / by food)
Work -Z	Work place: A discrete value indicating the amount of zones to travel to reach its working company. In this example it is used binary information indicating if the work place is in the area of the study.
X	Vector information (x coordinate with respect to a reference coordinate) which is used to evaluate the impact of a landing change in citizens living close or fare away of the land cell.
Y	Vector information (y coordinate with respect to a reference coordinate) which is used to evaluate the impact of a landing change in citizens living close or fare away of the land cell.
Policy	A value between 0% to 100% to describe de rate of acceptability of policy identified by colour Idp1.
CivilS	Is the civil status of the agent
Dset	this is only an identifier used for taking decisions.

These colours will be used for modelling the information flow within the model. It is possible to define these attributes with the use of lists to define several attributes referenced to the turtles, links or patches (agents). The next figure illustrates the kind of attributes that have been defined for the model within NetLogo.

```
turtles-own [ Age Ec Kids CultL Mobi Work-Z X Y policy civilS dset]
links-own [turtle-id prox-affin]
patches-own [ usage ] ;; 0 non-usage 1 school 2 health 3 park  4 tran
globals [ dis disf dise xp yp tt]
```

Figure 3: Agents attributes

In the figure it can be appreciated that 4 kinds of agents are being used for the model: Turtles, links, patches and globals. In particular *Globals* is not an agent but a list variable that can be used as a global list which can be accessed by the agents in order to keep track of some global changes of the model. The global attributes can be thought as another place node that participates in all the transitions within the model.

The other attributes are just lists (among brackets) and are attached to any instantiation of an agent class.

4.2. The place nodes

Since the agents in the NetLogo environment can have attributes which can be represented with the use of lists, it is possible to establish a direct relationship (1 to 1) between the coloured tokens and the attributes of the agents. If the modeller make this kind of mapping then the set composed by agents (turtles, patches or links) with common attributes could be representing the entities or tokens that belong to a particular place node. Figure 4 illustrates the association of the attributes of the agents in NetLogo to the colours of the correspondent place nodes.

(Age,Ec,Kids, CultI,Mobi, Work-Z,X,Y, Policy,civilS, Dset)

Turtles

(Turtle-id, prox-afin)

Links

(Turtle-id, prox-afin)

Patches
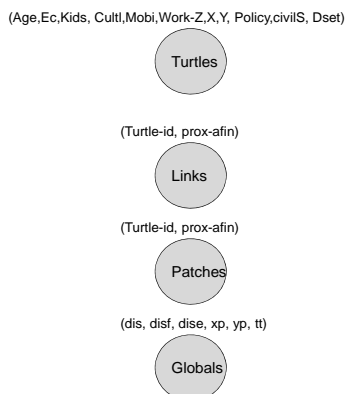
(dis, disf, dise, xp, yp, tt)

Globals

Figure 4: Set Colour association

Despite the fact that different agents have their own predefined attributes, it is possible to perform the particular definition of attributes through the use of lists.

4.3. Transition nodes

As it has been previously mentioned, the transition nodes are modelled through the definition (coding) of the different restrictions that must be satisfied by the set of agents that participate in the evaluation. All the restrictions imposed by the CPN elements (arc expressions, guards, weights) are evaluated in a single procedure that takes into account all of them in order to determine if the selected elements (agents) satisfy the correspondent restrictions.

Figure 5 is an example of a typical transition that has been modelled in NetLogo for the Fupol project.
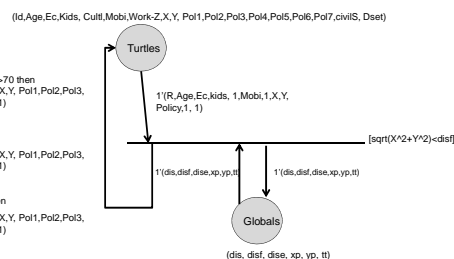

Figure 5: A CPN transition node for land use participation

The transition in

Figure **5** models the decision taken by the agents (turtles) in order to foster the transformation of a particular open space into a green park area within their neighbourhood. This transition uses the sets composed by the turtles and globals and in order to determine if the agents foster or not a particular use of the patch. The key attribute to be satisfied in this example is the proximity of the agents to the land space under study. The latter is evaluated using the global attribute *disf* which evaluate that the distance from their current location to the space under study (assuming that it is located at the 0,0 coordinates) is within reasonable range: $(sqrt(x^2+y^2) < disf)$. Where *disf* is the distance a normal family walks in order to get to the park. The following table explains the values of the colours that must be fulfilled by the agents in order to fire the transition:

Table 2: Description of the expressions used in the model

Colour Restriction	Description
Dset = 1	The turtles that have the identifier Dset set to 1 will participate in the evaluation. This value indicates that this agent is within one particular radius (in the example is 10)
sqrt(x^2+y^2) < disf	This guard specifies that the agent is within the acceptable walking distance for a common family
If Kids>0 and Ec<20 or Ec>70 then 1'(R,Age,Ec,kids,1,Mobi,1,X,Y, Pol1,Pol2,Pol3, Pol4+20,Pol5,Pol6,Pol7,1,1)	If the agent have kids and has a certain income, it will foster the policy related to the Park with 20 units
If Age>=60 then 1'(R,Age,Ec,kids,1,Mobi,1,X,Y, Pol1,Pol2,Pol3, Pol4+20,Pol5,Pol6,Pol7,1,1)	If the agent is older than 60 it will foster the Park development with 20 units
If Age < 60 AND Ec = 0 then 1'(R,Age,Ec,kids,1,Mobi,1,X,Y, Pol1,Pol2,Pol3, Pol4+10,Pol5,Pol6,Pol7,1,1)	If the agent is younger than 60 yrs but is in bankruptcy, it will foster with a lower quantity the transformation to a green park.

4.4. NetLogo Code

The previous model can be coded in the *Procedures* window of NetLogo. The correspondent code whose outcome is the one obtained from the previous CPN model is shown in Figure 6

```
to cit-policy-2  ;; Industry ---> Park green
    ask turtles [set dset 0]
    ask patches with [pcolor = green] [
      ask turtles in-radius 10 [set dset 1]]
    ask turtles with [dset != 1 and (kids > 0 and ((ec < 20) or (ec > 70)))] [
    set label ec
    dist xp yp xcor ycor
    if (dis < disf) [
        set color green
        set tt (item 2 policy)
        set policy replace-item 2 policy (tt + 20)]]

    ask turtles with [dset != 1 and age >= 60] [
    dist xp yp xcor ycor
    if dis < disf [
        set color green
        set tt (item 2 policy)
        set policy replace-item 2 policy (tt + 20)]
    ]
    ask turtles with [dset != 1 and age < 60 and ec = 0] [
    dist xp yp xcor ycor
    if dis < disf [
        set color green
        set tt (item 2 policy)
        set policy replace-item 2 policy (tt + 10)]
    ]
end
```

Figure 6: The equivalent code to translate the CPN model

The code is a subroutine within a more general program, but it is useful to exemplify the translation of the previous model into the environment.

The name of the procedure is called *cit-policy-2*. The first line *asks turtles [set dset 0]* initializes the value of the *dset* attribute to 0.

The line *ask patches with [pcolor = green] [ask turtles in-radius 10 [set dset 1]]* verifies that the agents (turtles) within a certain distance will participate in the evaluation, if so; the *dset* attribute is set to 1.

The next three lines of the code do not correspond to any expression of the CPN model. The following ones correspond to the restrictions stated in the formalism.

For example the lines

```
ask turtles with [dset != 1 and (kids > 0 and ((ec < 20) or (ec > 70)))] [
  set label ec
  dist xp yp xcor ycor
  if (dis < disf) [
      set color green
      set tt (item 2 policy)
      set policy replace-item 2 policy (tt + 20)]]
```

Verify that the *dset* attribute has the value 1 and based on the value of the *kids*, *Ec*, variables, it assigns the new value for the evaluated policy. The function *dist* :

```
set label ec
dist xp yp xcor ycor
if (dis < disf) [
    set color green
```

Calculates the distance of the evaluated agent to the studied cell: (sqrt(X^2+Y^2))

Then it assigns this distance to the global variable *dis*. In the next statement, the value of the *dis* variable is compared to that of the global variable disf. Finally the new value for the correspondent colour (*item 2 policy)* is updated making use of the auxiliary variable *tt*.

The two remaining *ASK TURTLES* subroutines are the equivalent for the corresponding *IF* expressions of the output arc of the model in Figure 5:

```
If Age>=60 then

1'(R,Age,Ec,kids,1,Mobi,1,X,Y, Pol1,Pol2,Pol3, Pol4+20,Pol5,Pol6,Pol7,1,1)

Else

If Age < 60 AND Ec = 0 then

1'(R,Age,Ec,kids,1,Mobi,1,X,Y, Pol1,Pol2,Pol3, Pol4+10,Pol5,Pol6,Pol7,1,1)
```

It must be clarified that in the case of the variable *Policy,* it is used a list for the attributes *PolX* instead of single variables just for the purpose of code readability.

The previous subsection illustrates how it can be translated a CPN model into a NetLogo environment. The following section presents some parts of an Open Space model which has been implemented in NetLogo in order to be used as part of the module that will simulate the behaviour of societies under particular policies.

5. OPEN SPACE MODEL

The model represents an old industry placed in a town that during last decades has been surrounded by residential habitats, and due to several economic and social factors it has been moved to an industrial area. Different options for the land cell in which this industry was placed are under evaluation under a social and economic perspective.

The main actors that should be modelled to predict the acceptability and the exit of a certain land change are:

Proceedings of the European Modeling and Simulation Symposium, 2012
978-88-97999-09-6; Breitenecker, Bruzzone, Jimenez, Longo, Merkuryev, Sokolov Eds.

559

1. Set of Land use Policies: For each land entity the set of acceptable land changes should be described as a policy. In this particular problem, a set of acceptable land changes are described in the next table.

Table 3: Different Policies

Policy 1	Industry ---> Park green
Policy 2	Industry ---> Facility : School
Policy 3	Industry ---> Facility: Health
Policy 4	Industry ---> Facility : Leisure area
Policy 5	Industry ---> Facility: Intermodal transport
Policy 6	Industry ---> Commercial Area
Policy 7	Industry ---> Residence Area
Policy 8	Industry ---> Business Area

Each policy is described accordingly to its acceptability by a certain profile of citizens. Thus, considering Policy 1, its acceptability could be fostered by:

• Elderly people: Residents above 65 years old (retired people) with an acceptable healthy conditions (mobility) could be users of a green area close to their homes.

• Family residents: Parents with young kids could be users of a green area during week-ends or after school hours. The green area should be located close to their homes or close to the school.

• Unemployed people: Parks are frequented by people without job obligations.

• Cafe owners: Cafes, pubs and lounges placed close to a small green area use to increase the amount of customers.

There are other aspects that can affect these rules, such as the weather conditions (i.e. rainy area), security conditions in the neighbourhood area, accessibility, amount of green areas located near the proposed area, etc. Some of these aspects can be modelled as boundary conditions which can be seen as predictions that can change on a year basis time. The model proposed, allows an open source policy description, which a parameterized weight influence that can depend on the boundary conditions, which can also be described by end-users.

2. Set of Citizens: Land changes appear because of humans needs. Usually, citizens' needs can be described as a combination of social, economic and environmental needs. Since urban policies will be described in FUPOL considering the effects in citizens' needs (i.e. Citizens' acceptability), citizens should provide all the information and data to predict how an urban policy would fulfil its preferences.

5.1. Coloured Petri Net Description

The description of the causality of the different agent decision making will be defined using the CPN modelling formalism. With the use of the CPN causal models, the land use change can take into account not only the influences by the surrounding areas (adjacent cells) but also by the interaction with other areas or agents that affect the decision of fostering one or another kind of policy.

• Citizen Agents. The attributes or characteristics of the different citizen agents can be described by the colours of the tokens that flow through the model.

In the next table, the attributes are presented for the following colour set which is used for modelling the industrial land-change:

$Cz = productAge*Ec*Kids*CultL*Mob*Work*X*Y*Z*idp1*p1V*idp2*p2V*idp3*p3V*ta$

Table 4: Citizen Attributes

Colour	Meaning
Age	Age of the citizen: most urban policies are highly dependent of the population age of citizens that will be affected. Age diversity usually is a problem when trying to devise the beneffits of a certain urban policy
Ec	Economical incomes rate: It takes a value between 0% and 100%. 0% means unemployed without subsistence. 100% means a well standing economical position. This information is highly relevant to simulate the economic impact of urban policies.
Kids	Amount of kids bellow 18 years olds: this information is important to evaluate the social impact of urban policies.
CultL	Cultural level: A value between 1 (no studies) until 5 (PhD level). This information is useful not only to evaluate the impact of a policy, but also to describe how his affinities can affect or can be influenced by their neighbourhood ´s opinions.
Mob	Mobility: Describes the preferences of the urban population to access places (working, leisure, shopping, etc.). It is parameterized using 5 values: 1 – Car, 2 – Public urban transport (bus/subway), 3 – Public regional transport (train/buses), 4.- alternative transport means (cycle / by food)
Work	Work place: A discrete value indicating the amount of zones to travel to reach its working company. In this example it is used binary information indicating if the work place is in the area of the study.

Table 4. (cont.)

Colour	Meaning
X	Vector information (x coordinate with respect to a reference coordinate) which is used to evaluate the impact of a landing change in citizens living close or fare away of the land cell.
Y	Vector information (y coordinate with respect to a reference coordinate) which is used to evaluate the impact of a landing change in citizens living close or fare away of the land cell.
Z	Vector information (not used in this example) which can be used to evaluate the impact of a landing change in citizens living close or fare away of the land cell.
Idp1	A citizen should have certain preferences towards certain land changes fostered by some policies. This colour is used to identify a policy for which the citizen could feel a certain degree of acceptability.
P1v	A value between 0% and 100% to describe de rate of acceptability of policy identified by colour Idp1.
Idp2	A citizen should have certain preferences towards certain land changes fostered by some policies. This colour is used to identify a policy for which the citizen could feel a certain degree of acceptability.
P2v	A value between 0% and 100% to describe de rate of acceptability of policy identified by colour Idp2.
Idp3	A citizen should have certain preferences towards certain land changes fostered by some policies. This colour is used to identify a policy for which the citizen could feel a certain degree of acceptability.
P3v	A value between 0% and 100% to describe de rate of acceptability of policy identified by colour Idp3.
ta	The citizen attribute information must be understood as a time stamp data. Thus, some values can change according to a simulation time basis mechanism. This attribute represent the time stamp of the information represented in the attributes.

Next Figure illustrates the CPN model of Policy-1: Industry –> Park green, in which the policy impact acceptability is described according to the boundary conditions, the citizen characteristics and the city resources capacities.
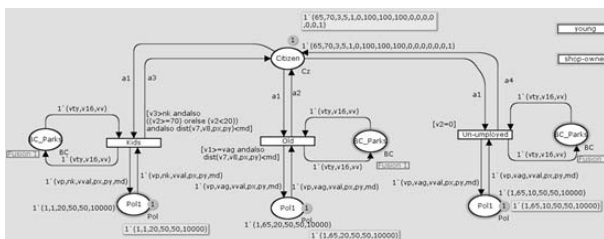

Figure 7: Policy Model1

The arc expressions of the model are presented in the following table.

Table 5: Arc expressions

A1	1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13,v14,v15,v16)
A2	if (v10=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11+vval,v12,v13,v14,v15,v16) else if (v12=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13+vval,v14,v15,v16) else if (v14=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13,v14,v15+vval,v16) else if (v11 <= v13) andalso (v11 <= v15) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,vp,vval,v12,v13,v14,v15,v16) else if (v13 <= v11) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,vp,vval,v14,v15,v16) else 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13,vp,vval,v16)
A3	if (v10=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11+vval,v12,v13,v14,v15,v16) else if (v12=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13+vval,v14,v15,v16) else if (v14=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13,v14,v15+vval,v16) else if (v11 <= v13) andalso (v11 <= v15) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,vp,vval,v12,v13,v14,v15,v16) else if (v13 <= v11) andalso (v13 <= v15) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,vp,vval,v14,v15,v16) else 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13,vp,vval,v16)
A4	if (v10=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11+vval,v12,v13,v14,v15,v16) else if (v12=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13+vval,v14,v15,v16) else if (v14=vp) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13,v14,v15+vval,v16) else if (v11 <= v13) andalso (v11 <= v15) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,vp,vval,v12,v13,v14,v15,v16) else if (v13 <= v11) andalso (v13 <= v15) then 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,vp,vval,v14,v15,v16) else 1`(v1,v2,v3,v4,v5,v6,v7,v8,v9,v10,v11,v12,v13,vp,vval,v16)

In the previous figure there are 3 transitions (driving forces) which evaluate the impact (benefits to the population) of changing the industrial use to a green park.

Elderly People (*old* transition): There are 3 different entities (agents) that take part when evaluating this driving force: Citizen (Place node *Citizen*), Policy impact on elderly people (Place node *Pol1*) and boundary conditions (place node *BC_Parks*). In this transition it is checked the characteristics (arc expression a1 described in precedent tables, of the agent (citizen), using the arc expression:

[v1>=vagandalso dist(v7,v8,px,py)<md]

which tests if the agent is an old citizen (first colour *Age* of the arc expression A1, variable v1, which is compared with the estimated age of pensioners which is represented in the variable *vag* in the arc expression **1`(vp,vag,vval,px,py,md)**) and that lives close to the land cell under study obtained using the variables v7 and v8 which represent the home location of the agent mapped with the colours X and Y in arc A1, and the variables *px* and *py* which represent the industrial land location in the arc expression **1`(vp,vag,vval,px,py,md)**).

As a consequence of this driving force, the agent acceptability for this policy will be updated with a certain increment represented in arc expression A2. The right increment will be defined partially in the policy definition, but also on the agent affinity to other policies (such as for example a leisure or a commercial area). Thus arc expression A2 allows computing the affinity in

Proceedings of the European Modeling and Simulation Symposium, 2012
978-88-97999-09-6; Breitenecker, Bruzzone, Jimenez, Longo, Merkuryev, Sokolov Eds.

561

the colour Pv1, Pv2 or Pv3 in case the agent has shown other preferences using as a reference the value of variable *vval* specified in the policy definition.

Next figure illustrates this transition, in which a citizen represented by a token has the following characteristics:

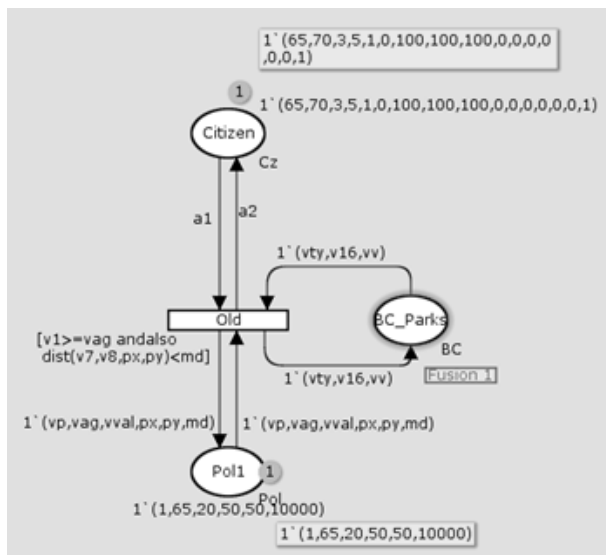| Age	Ec	Kids	CultL	Mob	Work	X	Y	Z	Idp1	P1v	Idp2	P2v	Idp3	P3v	t
65	70	3	5	1	0	100	100	-	0	0	0	0	0	0	

Figure 8: Citizen evaluation

As a result of firing the transition, the new agent state information will be:

Age	Ec	Kids	CultL	Mob	Work	X	Y	Z	Idp1	P1v	Idp2	P2v	Idp3	P3v
65	70	3	5	1	0	100	100	-	1	20	0	0	0	0

In the next figure it is represented the same policy (industrial use→ park green) but considering effects on families with kids. The main difference with regards to the previous transition is in the guard expression:

[v3>nkandalso((v2>=70)orelse(v2<20)) andalsodist(v7,v8,px,py)<md]

In which it is checked the amount of kids (represented in variable v3 that corresponds to Kids attribute) and the economical capacity of the agent (represented in variable v2 that corresponds to colour Ec).
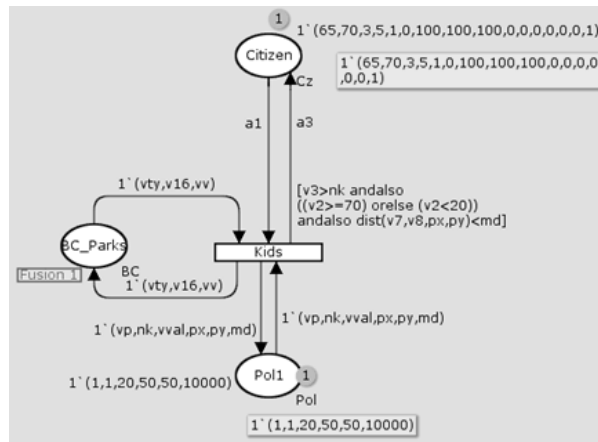

Figure 9: Evaluation of families with kids

Citizen Agent interaction: There are several interactions that can be formalized in a social context, but in this example citizen's interaction has been modelled as a proximity interaction or as an affinity interaction.

Social interaction by proximity has been modelled in such a way, that a policy which is not supported at all by one of the agents and is not highly ranked by the other agent, its acceptability is decreased.

Next figure illustrates the proximity interaction in which 2 citizens explains their opinions to foster or reject a policy. Place node High-op is used to check which one is the policy with highest affinity to each agent.
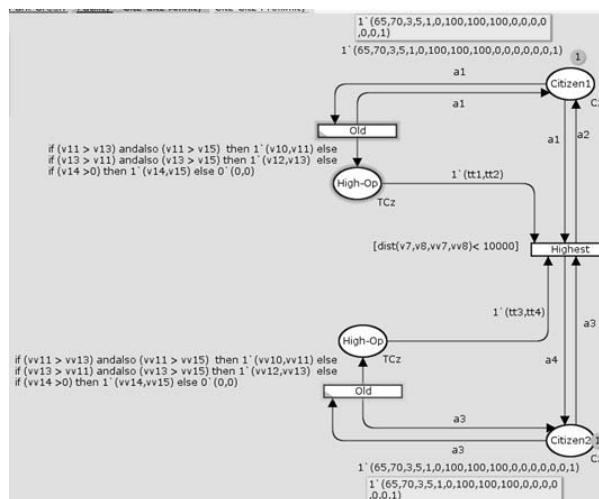

Figure 10: Proximity interaction

As it can be observed in arc expressions a2 and a3, affinity of the citizen to a certain policy is decreased by a certain amount: variables v11,v13 and v15 represent colours P1v, P2v and P3v for one agent, and variables

Proceedings of the European Modeling and Simulation Symposium, 2012
978-88-97999-09-6; Breitenecker, Bruzzone, Jimenez, Longo, Merkuryev, Sokolov Eds.

562

vv11, vv13, vv15 represent also the same attributes but for the other agent.

Guard expression attached to *Highest* transition, checks that both agents are candidates for a proximity interaction (i.e. they live in the same area):

[dist(v7,v8,vv7,vv8)< 10000]

These are just some examples of the different transitions that rule the behaviour of the correspondent agents.

5.2. Implementation of the Open Space Model in NetLogo Environment

After the causal relationships have been defined through the CPN formalism, it is possible to translate those rules into the MAS environment. It is fair to mention that the rules defined with the CPN formalism can be used for implementing the interaction in any kind of agent architecture or MAS simulation program not only in NetLogo environment.

The causal model for land use relies mainly on three different agent behaviours:

- Citizens: This agent allows evaluating the benefits and shortages of the different policies proposed accordingly to the expected needs of each citizen. All citizens are modelled as turtle agents in NetLogo

- Urban Resources: A City or the urban area under study, is represented by a discretized grid of small areas, each one identified by a reference to a certain location (i.e. georeferenced), and by a functionality. Thus, an area can be characterized by the infrastructures and resources deployed, such as for example: a school (1), a health facility (2), a green park area (3), a transport facility (4), a leisure or a commercial centre (5), a residence area (6) or a business area (7). All areas are modelled as patches agents in NetLogo

- Interactions: Citizens could iterate with other citizens based on:

- Proximity relationship: they are neighbours and can casually share their opinion regarding certain policies that could affect the initial score of each policy.

- Affinity relationship: Citizens that live in different areas share some characteristics that allow them by means of physical interaction or through social IT networks to share their opinions regarding policies. All interactions are modelled as link agents in NetLogo.

- Global Information: There are some data which cannot be represented in the agents, instead they specify global boundary conditions, context scenario information, or experiment hypothesis. In this open space model, it has been setup 4 constants to evaluate different policies for an open space area.

- Disf: The maximum average distance that usually can walk a family with kids from its residence to a green park area.

- Dise: The maximum average distance that usually can walk elderly people to a green park area.
- Xp, Yp: Especify the open space area location under study.
- Global information is formalized by global variables in NetLogo.

In the next figure it is illustrated the NetLogo model implemented using the previous CPN models. There are some *buttons* which allow the user to test different configurations for the same model. The magenta cell represents the open space grid under study.
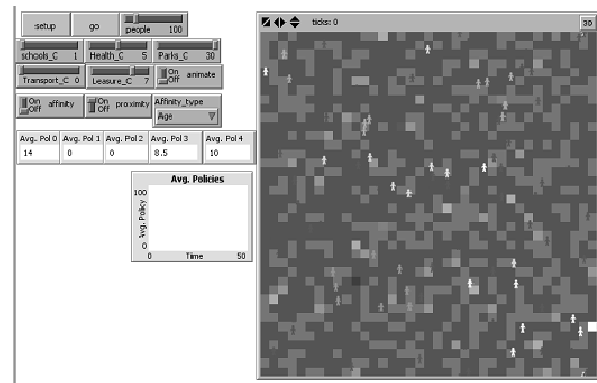

Figure 11: The NetLogo Simulator

The simulator allows also determining which kind of relationship is possible to permit among the agents that participate in the system (e.g. proximity or affinity). The main outcomes that can be obtained from the simulator are the weights of the policies that result more attractive to the general actors within the model (i.e. population). The following table presents some results obtained with the initialization of different parameters which can correspond to particular configurations of an example system.

Table 6: Outcomes for different configurations

Configuration						Outcomes				
People	Schools	Hospitals	Parks	Transport	Leisure	Policy 0 (school)	Policy 1 (health)	Policy 2 (park)	Policy 3 (Transport)	Policy 4 (Leisure)
400	10	5	5	5	5	98	0	45.5	1.3	41.4
400	5	5	5	5	5	100	0	32.4	0	46
400	20	1	10	5	5	52	15	11.7	7	48.5
400	20	1	10	5	10	48	19	20	1	40.4

6. CONCLUSIONS AND FUTURE WORK

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 NetLogo 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. The approach presented will be used during the development of a simulation module within the FUPOL framework which will allow the participation of real citizens through social networks to determine the parameters of some characteristics of the simulation model (boundary conditions). With the previous approach it is expected that more transparency and e-participation will be gained for the common population within a city, region or community.

The next steps of the simulation approach are the following ones:

• Verification of the parameters that govern the behaviour of the particular agents through field studies, polls, questionaries' etc.

• Field testing of the approach with a particular region, city, or community. This step will be performed in the pilot cities of the project.

• The simulation module must be integrated with the IT tool developed by the FUPOL project in order to test or verify that the proposed approach certainly is useful to foster e-participation within a community.

REFERENCES

Christensen, S., Jensen, K., Mailund, T., Kristensen, L.M., 2001. State Space Methods for Timed Coloured Petri Nets. *Proc. of 2nd International Colloquium on Petri Net Technologies for Modelling Communication Based Systems*, 33-42, Berlin.

Jensen, K., 1997. *Coloured Petri Nets: Basic Concepts, Analysis Methods and Practical Use*. 1 Springer-Verlag, Berlin.

Moore, K.E., Gupta, S.M., 1996. Petri Net Models of Flexible and Automated Manufacturing Systems: A Survey. *International Journal of Production Research*, 34(11), 3001-3035.

Mujica, M.A.; Piera M.A.; 2011. A Compact Timed State Approach for the Analysis of Manufacturing Systems: Key Algorithmic Improvements, *International Journal of Computer Integrated Manufacturing*, Vol.24 (2), February 2011.

North M. J., Macal C. M., 2007, *Managing Business Complexity Discovering Strategic Solutions with Agent-Based Modelling and Simulation*, Oxford University Press.

Romulus-Catalin Damaceanu, 2011, *Agent-based Computational Social Sciences using NetLogo: Theory and Applications*, Lambert Academic Publishing.

AUTHORS BIOGRAPHY

Miguel A. Mújica Mota was born in Mexico City. He studied chemical engineering at Autonomous Metropolitan University of Mexico, an MSc in Operations Research in the National Autonomous University of México. He also received a Master's in Industrial Informatics from the Autonomous University of Barcelona and the PhD from the same university. He has professional experience in manufacture and production planning in the cosmetic industry. His research interest focuses on simulation and optimization techniques using the Coloured Petri Nets formalism aiming to solve industrial problems.

Miquel Àngel Piera received his MSc (Control Engineering) from the University of Manchester Institute of Technology in 1990 and his PhD degree from the Autonomous University of Barcelona (Spain) in 1994. He participates in industrial research projects in the logistics and manufacturing field and at present he is Co-director of LogiSim, a Modelling and Simulation Institution sponsored and founded by the local government of Catalonia. Recently, he has published a modelling and simulation book that is being used for teaching in many Spanish universities.