URBAN CULTURAL DYNAMICS MODELLING USING SWARM INTELLIGENCE AND GEOGRAPHICAL INFORMATION SYSTEMS

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ABSTRACT

This paper deals with the understanding of collective cultural shape dynamics within urban area. The cultural facilities inside the city are various and follow complex spatial mecanisms. Both geographical aspects and social factors are major in these dynamics, leading to specific equipment. The complexity of these phenomena which are the basis of the cultural development, needs some specific modelling technics. In a first step, we propose some analysis and description of the cultural activity distribution based on a specific geographical information system (GIS). A case study is developped for the french city of Rouen in Normandy. In a second step, and respecting the complexity of the studied systems, we propose to use swarm intelligence models over this GIS to model the urban cultural dynamics. The goal is a better understanding of the relevent interactions within multi-criteria interactions.

HOW MODELLING THE DIFFUSION OF CULTURAL INFRASTRUCTURES WITHIN THE CONTEXT OF URBAN DYNAMICS COMPLEXITY

Urban dynamics are the result of complex systems development where a great number of entities and factors interact. The bottom-up class of modeling consists to define the city as a collection of individual-based description, behavioral rules-based description and interaction systems. From this constructive approach, we want to obtain an emergent description of the whole system or of some sub-systems included in a hierarchical process. Two complementary methodologies can be used for that and we detail them in the following paragraphs.

The first methodology consists to generate a simulation where all the components, behaviors and rules-based, interact over a environment, perceiving and acting on it. The environment evolving is the support of emergent properties. The cellular automata modeling deals with this kind of simulations. The basic definition of cellular automata for urban or regional modeling, for instance, consists in the decomposition of the city, region or any geographical area in a lattice of cells. Each cell is in some state which belongs to a finite set S. At each time step, the cells change its own state according to some transition rules based on its previous state and its neighbor cells. Many works based on cellular automata, have been developped for geographical systems and urban dynamics (2; 9; 15). To deal with some urban dynamics, we need an important extension to cellular automata where we have to represent individual moving, for instance. The mixing of spatial data and cellular automata with autonomous entities, like agents, is here needed (7).

The second methodology to deal with emergent description in micro-modelling, consists to complete the previous approach based on simulation, by introducing some computational processes which are able to detect emergent systems or organizations. The final goal of this method is then to be able to re-introduce these emergent systems or organizations inside the simulation and manage their evolutions and their interactions with the components of the system. The re-integration of the emergent systems, during the simulation, can be explicitely expressed like in the multiscale fluid flow simulation proposed by P. Tranouez (25) or it can be implicitly expressed using an adaptive process as we will describe in the following.

Cultural equipment development within urban dynamics must be understanding through two aspects: the specific mecanisms which control the creation of cultural infrastructures and the use and attraction phenomena of

these cultural equipments to follow their development. Emergent systems and organizations simulation must be implement to analysis the cultural dynamics and we will propose swarm intelligence technologies to model these phenomena.

ANALYSIS OF CULTURAL ACTIVITY DEVELOPMENT BASED ON GIS - A CASE STUDY FOR THE FRENCH URBAN AREA OF ROUEN

Our goal is to study the diffusion of cultural facilities and propagation during time, inside the urban area of Rouen. A contructive approach is proposed in order to understand the spatial dynamics of cultural infrastructures development. We want to better understand what are the relevent interactions within heterogeneous phenomena.

Data Support

We design the cultural mechanism in a social and territorial context. The cultural activities and equipment are particularly all services present in French city (20), where the majority of the population is located in, considering the general urbanization of the French Society. Like others French cities, Rouen proposes a large diversity of cultural activities in the hopes of educating, entertaining and satisfying inhabitants, but also for self-promotion.

The data from the city of Rouen concern urban environment and public or private cultural equipments within wide vision of culture. There are with academic sites (museums, operas, theatres, libraries, ...) and popular ones (musical pubs, concert places, festivals, cinemas, ...). These data have been obtained from the agglomeration population composed of 400,000 inhabitants. We plan to study the various logic of geographical repartition and the motivation to create and build cultural equipment, including strategies for municipalities or commercial exploitations.

At this local level we wish understand two mechanisms. The first one is the conditions that conduct people or private and public institutions to create new cultural structures and how the new locations are chosen. Second one is to better know the circulation of the inhabitants during time in these cultural places which have different levels of attraction. Because, in addition to the problem of geographical distances, other parameters play an equal role in accessing culture: social, educational and economic selection constitute another restraint for the cultural practices of citizens (5).

First Graphical Analysis using GIS

Urban environment is based on land use of Rouen from topographical maps from IGN. Various GIS have been developped from these maps, mixing communication networks and cultural edifices (see on figure 1) or mixing land use and cultural equipments (see the figure 2). The mixing with the municipality administration and service attractivity is also plan to be studied.

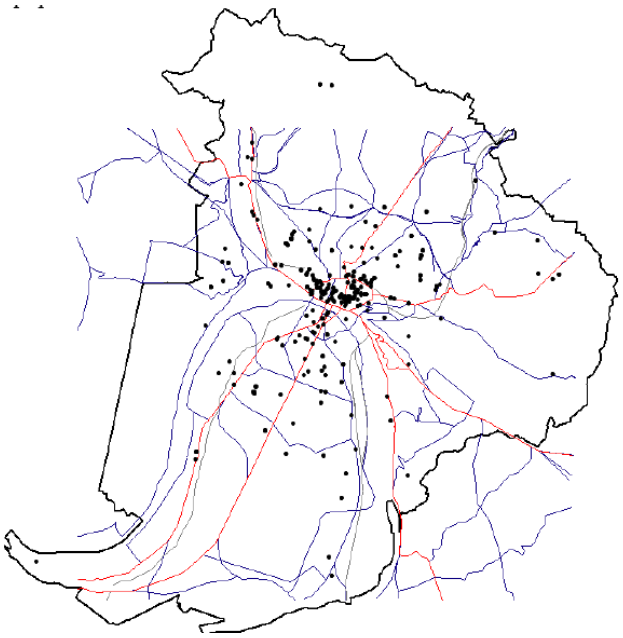


Figure 1: Communication networks and cultural equipment development mixing

Processes Analysis and Formalization

Cultural equipment repartition within city does not follow stochastic distribution (26). This implies that the geography of these activities call on other dynamics than that of chance. This repartition is very different from sports equipment development, for example, as we can see on figure 3. The sports development follow the public school development that the cultural equipment does not follow.

These observations lead us to better understand what are the mechanisms involved in cultural phenomena. We have to study first the specific spatial constraints : river separation for the city of Rouen, industrial and housing proximity and municipalities service location. Spatial constraints are so a major aspect within the development dynamics, including heterogeneous factors. To model such complexity, we propose a swarm intelligence method base on ant systems as detailed in the next section.

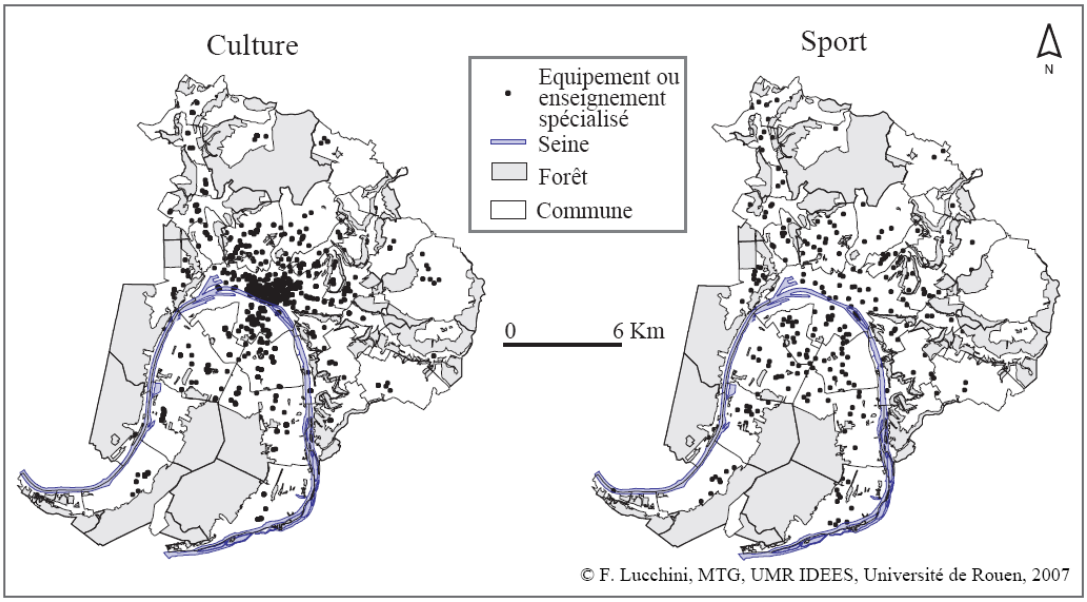


Figure 3: Sports equipement and cultural equipment development within Rouen city agglomeration

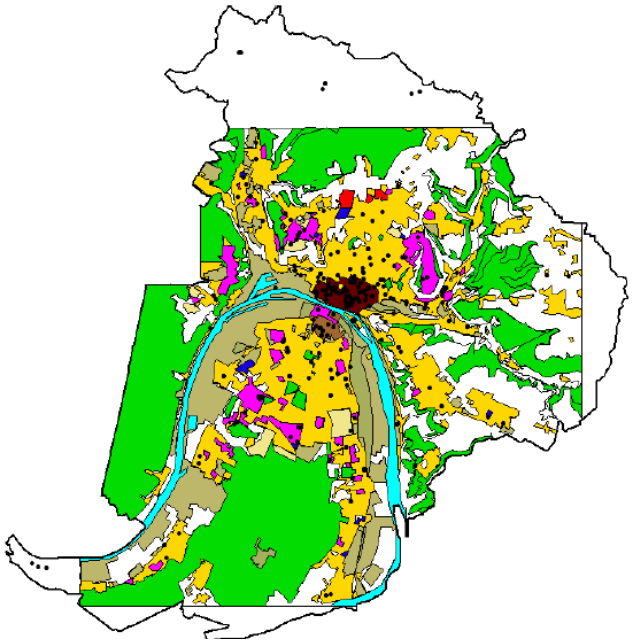


Figure 2: Land usage and cultural equipment development mixing

MIXING GIS AND SWARM INTELLIGENCE FOR THE DYNAMICS SIMULATION

We will describe in this section, the general algorithm which is proposed to model emergent spatial organizations within cultural dynamics. This algorithm is based on the ant clustering. We introduce pheromon template to spatially control the clustering from local attraction. This method is a decentralized approach which allows to combinate multi-center and multi-criteria problems.

Ant clustering

Ant clustering algorithms are inspired by the corposes or larvea classification and aggregation that the ants colony are able to do in the real life. The ants are moving inside a closed area and are able to move some material which are randomly put on this area. After a while, and without any kind of centralized coordonation, the ants success to create some material clusters.

The algorithm is based on the following and very simple behavioral rules that each ant implements :

- When an ant is moving without carrying yet material and find some material, the ant will take the material respecting the probability number :

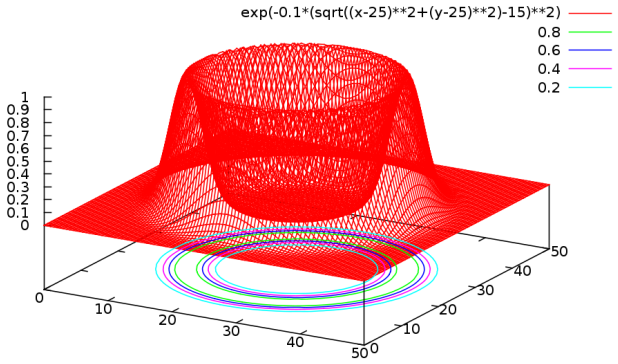
$$P_p = \left(\frac{k_1}{k_1 + f}\right)^2 \quad (1)$$

  where f is the material density that the ant perceives locally around itself and k_1 is the treshold. It is easy to check that if $f << k_1$ then P_p is near the value 1 and if $f >> k_1$ then P_p is near the value 0.

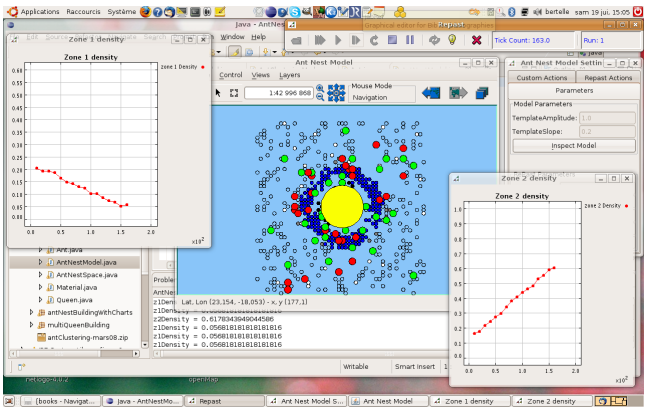
- When an ant is moving when carrying some material, the probability to deposite it is computed by :

$$P_d = \left(\frac{f}{k_2 + f}\right)^2 \quad (2)$$

where f is still the material density that the ant perceives locally around itself and k_2 is another treshold. It is easy to check that if $f << k_2$ then P_d is near the value 0 and if $f >> k_2$ then P_d is near the value 1.



(a) Template function

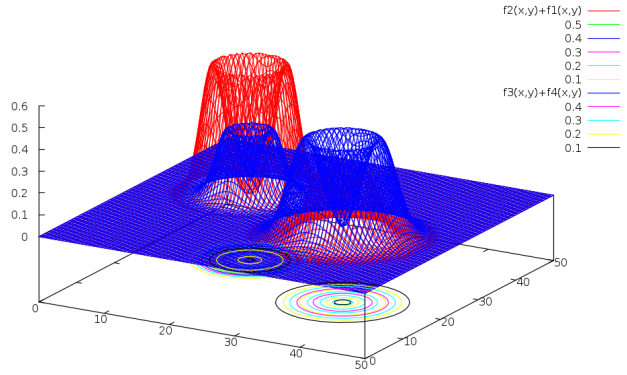


(b) Simulation on RePast

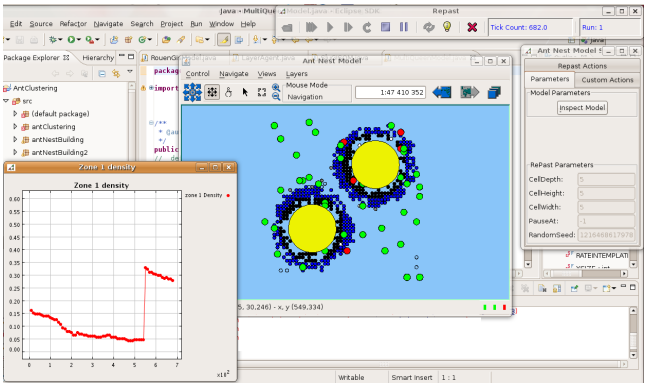
Figure 4: Ant nest building with one center using RePast MAS paltform over OpenMap GIS

Spatial constraints using template

The ant clustering shows some spatial self-organizations but has the specificity to generate clusters at random places. According to the first random moves that the ants start to do in the beginning of the algorithm, some material will initiate aggregation and the clustering processus will complete this aggregation from these initial random first aggregations. To simulate some urban dynamics, we need to introduce specific location with respect to city center for example or cultural equipments. The clustering here will represent the people use of these centers or equipments and we need to introduce an attractive effect by using a pheromon template. This method follow the algorithm known as Ant Nest Building (4). In ant colonies, the center



(a) Template functions



(b) Simulation on RePast

Figure 5: Multi-center ant nest buiding using RePast over OpenMap

corresponds to the position of the queen which needs to build the nest and the ant colony moves around it to protect the nest by various material taken on the ground. The queen emits a pheromon which allows to attract the ants during their building. The ant has to deposite the material carried only if the pheromon quantity perceived belongs to a specific range. We use an attractive fonction called P_t, corresponding to a pheromon template and represented by the part (a) of the figure 4.

Using this template function, we remplace in the clustering algorithm, the two provious probabilities defined in equation (1) and equation (2) by

$$P'_p = P_p(1 - P_t) \tag{3}$$

$$P'_d = P_d P_t \tag{4}$$

In figure 4, we show an implementation of this algorithm using the multi-agent platform called Repast (21). The java version of this platform includes some packages allowing to interface with geographical database and geographical information systems (GIS). The graphical out-

put windows is made under OpenMap which is a GIS developped in Java. In figure, the materials moved by the ants are the small grey circles, the ant moving without material are the green circles, the ant carrying material are the red circles and the queen location is the yellow circle.

Multi-template modelling

The previous subsection describes one local attractive process characterized by the queen and its pheromon template emission. The advantage of this method is to be able to combine the solutions of multi-center and multi-criteria problems, using interactive processes, each one is represented by a queen and its pheromon template.

On the figure (5), we can see a simulation with two queens and two pheromon templates. It is possible also for each queen to emit many different kinds of pheromons : we called them colored pheromons. Each colored pheromon will attract only the ants associated to its color.

Application to cultural equipment dynamics

The multi-template modelling can be used to model cultural equipment dynamics as described in the figure (6). On this figure, we associate to each cultural center (cinema, theatre, ...) a queen. Each queen will emit many pheromon templates, each template is associated to a specific criterium (according to age, sex, ...). Initially, we put the material in the residential place. Each material has some characteristics, corresponding to the people living in this residential area. The simulation shows the self-organization processus as the result of the set of the attractive effect of all the center and all the templates.

CONCLUSION AND PERSPECTIVES

We study in this paper the cultural equipment dynamics within urban area with a specific case study concerning the french city of Rouen. Geographical Information Systems have been developped from large database concerning Rouen Agglomeration and allow to highlight the complexity of this problem: the link between communication networks or land use with cultural development. To model the complexity of cultural center attractivity and use, we propose a swarm intelligence method using a bio-inpired model called ant nest building. This model allows to deal with spatial self-organization dynamics using multi-center and multi-criteria aspects. Implementation on Repast platform with GIS mixing is proposed as the basis or the development framework. Specific results on Rouen Agglomeration are still in progress and are expected to give relevent analysis to better understand these specific cultural dynamics.

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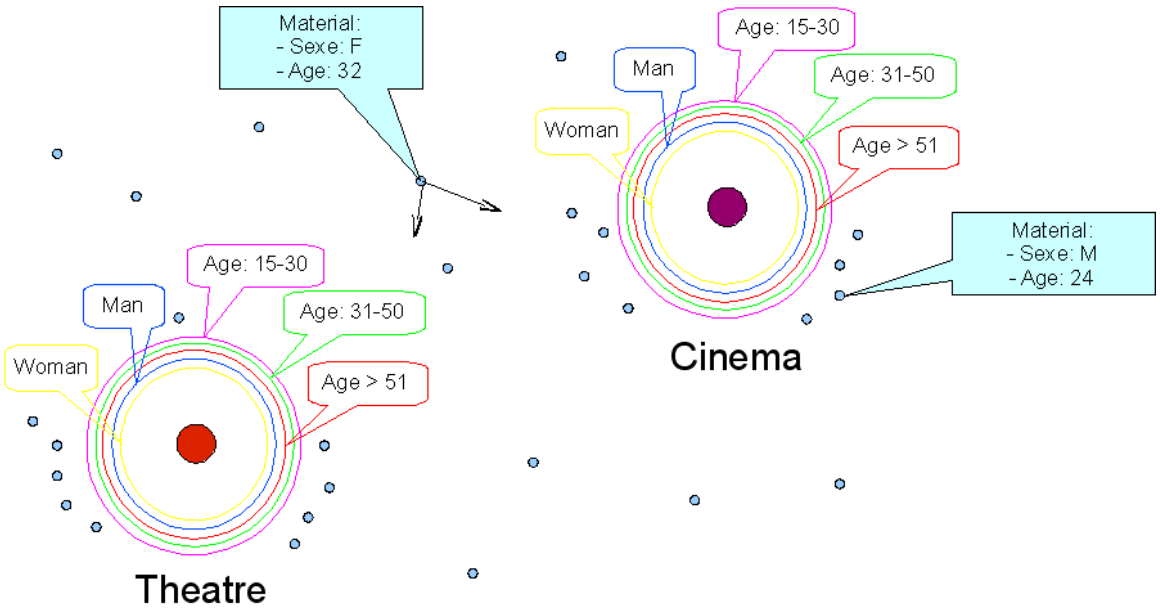

Figure 6: Cultural Equipment Dynamics Modelling

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