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ROUANTS SIMULATION PLATFORM TO MODEL SERVICE-USER DYNAMICS OF CULTURAL SITES WITHIN URBAN AREA

Rawan Ghnemat [*], Françoise Lucchini [†] and Cyrille Bertelle [‡]

Abstract. *Rouants* simulation platform concerns spatial analysis of urban dynamics described here by services development and their practice by users. A study case allow to analyse cultural sites development applied to the French urban area of Rouen.

Keywords. Urban Dynamics, Cultural Sites, Swarm Intelligence, Geographical Information System, Urban Spatial Environment.

1 Introduction

This paper emphasizes the interest of understanding the functioning of dynamics of collective cultural forms in urban area, as social reality for everyone [5]. Geographers have focused on understanding the interrelationships that people forged with their territory. They work on experiments on social systems belonging to specific territories, such as cities [2, 18, 25]. City is generally understood as a complex system that can be described with several organizational levels [3, 17]: micro, meso and macro levels. At the micro level, the system is the set of interrelationships linking intra-urban elements such as individuals, households and institutions. At the meso level, the city is considered as a systemic entity with functional responses generally included in the mechanisms of competition and/or complementarity with other neighboring entities. Finally, at the macro level, urban systems are composed of interdependent cities belonging to national and international territories. We position this research at the intra-urban level.

It is possible to describe cultural behavior of citizen according to cultural sites on a real urban environment. We focus on describing how the spatial configuration of a city may compel individual behavior within social systems [19, 21, 22]. In this paper, we explore, for a specific intra-urban area (Rouen, French urban area), the complex spatial mechanisms linked to an urban activity development [20]. We specifically study the development of cultural sites in time and on a specific city space, as well as the practice of social individuals to these cultural sites. We are also interested in understanding and modeling the adaptive mechanisms of these cultural sites according to their user practices [14].

To reflect the complex reality of the creation and practice of these cultural sites, we have built a theoretical model of relationships between actors who produce and use the cultural sites. For this purpose, the model proposes to experiment a spatio-temporal system consisting of three groups of actors; the social individuals, the cultural sites and the urban spatial environment, as described on Figure 1. The complexity results from the interleaving of different types of interactions:

- The complexity coming from interactions between social individuals and producing self-organization [3];
- The inherent complexity of social individuals characterized by multiple criteria which are themselves in interaction (age, gender, educational level, social level, etc.);
- The game of competition and/or complementarity in the attractiveness of cultural sites varying on several levels of attractivity depending on their nature and their location (for example, the attractive power of a cinema in comparison with the attractive power of an opera, or, as another example, the attractive power of a site at central urban location in comparison with another site at peripheral urban location);
- The effect of the general spatial configuration of a city being more or less constraining and so acting on the formation of self-organized dynamics (as examples, the barrier effect from a river or from an industrial area, the attractor effect coming from a municipal center or from a high density residential area, the accessibility produced by road transport planning and by public transport planning).

Spatial dynamics and temporal dynamics are mixed. It is usual to observe that, after some periods, bifurca-

[*]Rawan Ghnemat is with German-Jordanian University, Amman, Jordan. E-mail: rawan.ghnemat@gju.edu.jo
[†]Françoise Lucchini is with UMR IDEES/MTG, University of Rouen, France. E-mail: francoise.lucchini@univ-rouen.fr
[‡]Cyrille Bertelle is with LITIS, University of Le Havre, France. E-mail: cyrille.bertelle@univ-lehavre.fr

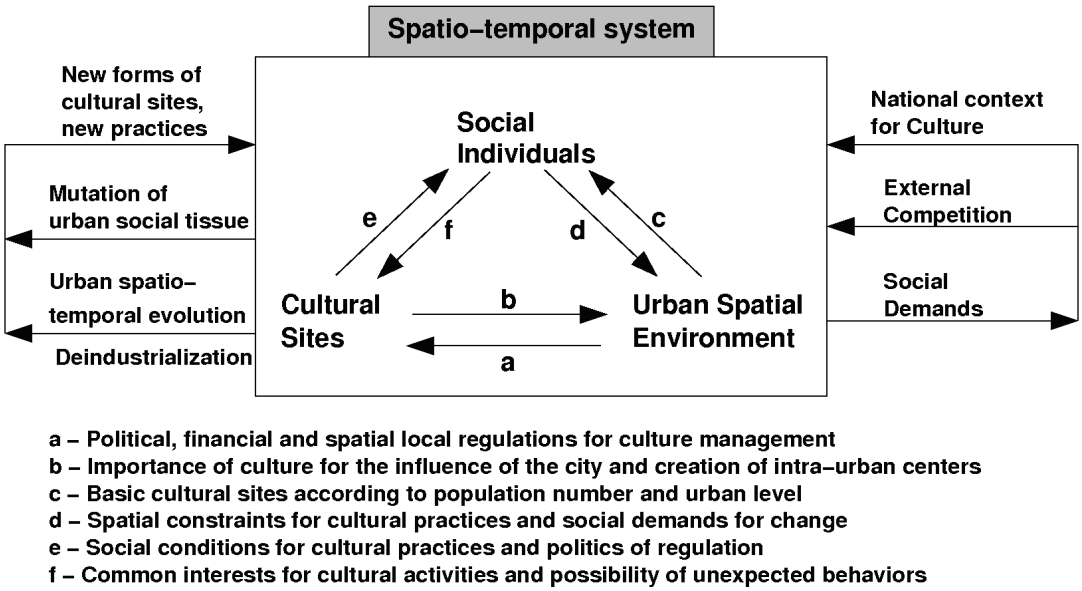


Figure 1: Spatio-temporal system to model the actors involved in urban cultural site development

tions appear in urban planning: for instance, it is the case of the reorganization of brownfields into cultural centers, within spaces previously dedicated to productive activities and so repulsive to cultural sites.

This works results from dialogue between geographers and computer scientists, in order to understand territory functionnalities. Territory is usually grasped by geographers as a system of interrelations linking itself with its inhabitants. "How territory works as system?" is the core of our approach. First, we need to understand what are the relevent components of this system, then to highlight the associated mechanism of actions on them to finally being able to design operational objectives of management. Temporal and spatial dynamics act jointly on all territories. For instance, urban change is a permanently renewed process that geographers have integrated since long time ago within their analysis of urban territories. Dynamics of such changes can be expressed in following terms: how urban territory evolves when a new activity takes place on a specific urban location? For instance, what will be the impact of new cultural structures like a cinema multiplex or a new music scene in requalifying urban zone produced by industrial and harbour brownfields? It is precisely what's happend on the urban area of the French city of Rouen. The process of requalifying old sites into new uses began in Rouen since 2009, particularly in an important part of its central area, previously devoted to intensive industrial and harbour activities on each side of the Seine river. "Seine Ouest" project deals with the reality of urban rehabilitation by the development of cultural centers and by their attractive potentiel they are able to generate in terms of visitor number on this urban zone.

ROUANTS simulation platform has been created to allow the visualization of the attractivity of cultural centers within the urban area of the French city of Rouen. This platform open ways of "explanation" about the most discriminent criteria, about competitive games involving cultural centers, about mobility questions and strategies of adaptation. We let organization emerging from a world of uncertainty.

2 Modeling service-user dynamic of cultural sites

2.1 Urban Modeling

The first models designed for urban modeling are mostly based on dynamical systems. One of the first famous approaches was proposed by I.S. Lowry [18] and J.W. Forrester [11] and consists in describing the city by global dynamics on socio-economic indicators. This kind of models are decomposed with stocks and flows. For instance, based on this approach, Dendrinos and Mulally [9] use a prey-predator model, assuming that the increase of city population makes the economic status decreasing. The predators represent the urban population and the preys, the per capita income. Like in other disciplines, during the last two decades, important efforts have been made to develop, beside these previous top-down models, decentralized methods called bottom-up models. In this new categories of models, we focus on local knowledge, like people behavior, or on spatial local information. The increase of information systems and specifically the accurate geographical databases included in Geographical Information Systems (GIS) allow to combine spatial management and local information, as a major contribution

to these decentralized models [21]. Moreover, intensive developments concerning diffusion in spatial process [15] had been achieved on cellular automata simulations for various purposes, facilitated by the development of computer power leading to grid computation of large dimension [10]. Since the last decade, geographical and social systems have seen their greatest development on modeling by the use of coupling GIS, cellular automata and multiagent systems, allowing this last concept to describe with accuracy the behavior of the inhabitants of these spaces and especially their social interactions [1]. A classical example of the need of extended cellular-based with agents comes from T. Schelling's model describing the segregation process [24]. More recently, the development of multiagent platform engineering [23], allows to integrate dynamical simulations within GIS [7]. The study presented in this paper is based on such technologies, mixing GIS and simulation within the platform Repast.

2.2 Collective intelligence models

Multiagent systems are a very promising concept for decentralized computations concerning wide range of problems solving modeled by distributed artificial intelligence approaches. Multiagent systems concept consists in describing a phenomenon by a set of autonomous entities, called intelligent agents, interacting in social way and interacting inside an environment [8]. If the interactions are complex, self-organization phenomena can appear or emerge as additional properties of the system interaction, not described from the entity behavior level. Such emergent high-level organizations coming from the low-level entity interaction system are frequently observed in human society but also in society of insects, each of them having a very simple behavior. To represent and to model such property transfer from individuals to systems, a specific classe of agent computing algorithms have been developed and lead to the concept of collective intelligence or swarm intelligence models. The current two major developments of swarm intelligence are (i) a class of methods based on the bio-inspiration of bird flocking or fish banks, the particle swarm optimization [16] and (ii) a class of methods based on the bio-inspiration of insect society, like bees or termites, called ant systems models [4]. The study presented in this paper is based on this second class category and is based on a combination of two algorithms, ant clustering and ant nest building [6].

2.3 Urban cultural dynamics modeling

The goal is to understand and to analyse the cultural practices in city. *Rouants* is a dynamical model for studying attractiveness of cultural sites in city. It is built on the achievements of the sociology on culture in order to identify the behavior of people depending on cultural sites. The model was applied to the design of cultural offer for the city of Rouen. We use swarm intelligence methods and stigmergy concept to model the dynamics of cultural center development. Specifically, we rebuild, by dynamical simulation, a multi-centre and multi-criteria system. The people dynamics, movement and decision, are inspired by self-organized processes existing in collective movements designed by swarm intelligence and stigmergy [4]. These processes correspond to the dialogue between individuals and environment for a collective benefit. The model includes a mixture of deterministic and probabilistic behaviors, corresponding to the part of unpredictability in human behavior.

2.4 Specification of multi-criteria multi-pole services-users dynamics model

Each center has several attractive criteria. Specific colors of pheromone are associated to these criteria and allow to model attractive mechanism according to age, gender educational level and social level of each individual.

Figure 2 is a schematic representation of an easy-to-understand simulation composed of two cultural centers, a cinema and a theater. We represent on this figure, the pheromone/attraction functions as circles around the centers and we label them with the associated characteristics/colors. Materials represent here users which will be carried and moved by ants, following the complex spatial system of attraction functions.

A spatial multi-criteria multi-center simulation is described by a set of centers and by a set of colors, each color corresponding to a specific criteria which can be expressed as a attractive function by a cultural center. Statistic values of national uses of cultural centers translate the capability for a center to attract a percentage of people belonging to specific class of criteria. This attractive phenomena are modeled by a colored template function emitted by each center. The mathematical expression of the attractive function of color c_j expressed by the center P_i, is given by

$$\Phi_{ij}(M) = a_{ij} \exp\left(-b_{ij}\left(d(M, P_i) - r_i\right)^2\right)$$

Where the amplitude a_{ij} is proportional to the capability of the center to attract people carrying the corresponding color/criteria; b_{ij} is the template slope, corresponding to the spatial diffusion of the attraction phenomenon; r_i is the radius defining the area of attraction of the center P_i. In the model, people are described by material including a table of characteristic colors which corresponds to the criteria that the individual is carrying.

The dynamics of users attraction is computed by (i) ant ability to pick or deposit material and by (ii) ant movement when carrying material.

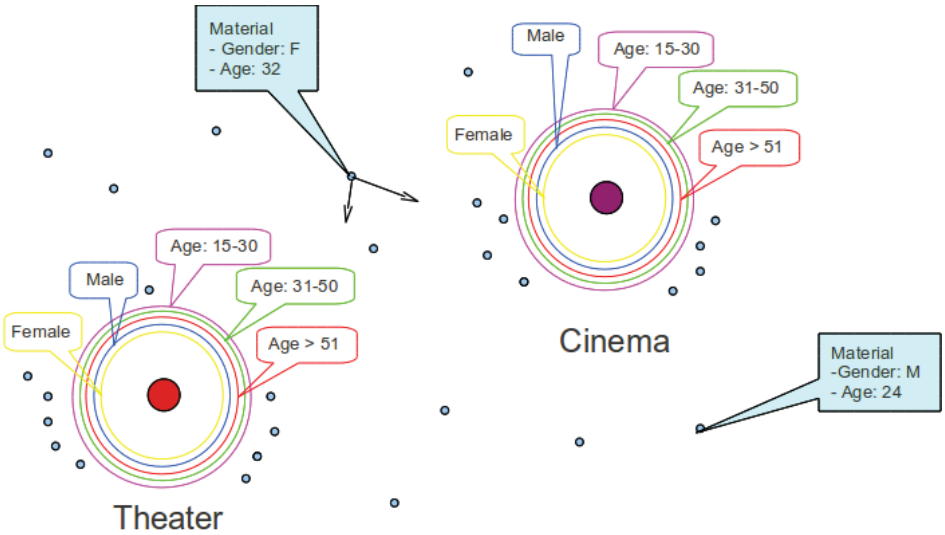


Figure 2: Cultural equipment dynamics modeling

Ant picking and deposit material is a composition of ant clustering computation under the influence of a template function Φ, that is:

- The probability for an ant, at the location M, to pick a material when it is not yet carrying one but are crossing one, is:

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

- The probability for an ant, at the location M, already carrying a material, to deposit it is:

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

Where f is the material density perceived by the ant, k_1, k_2 are two thresholds.

The movement of an ant which is carrying a material is computed by a ranking process. The ranking computing corresponds to the weighted average of some selected pheromones. The selected pheromones are the ones whose color belongs to the table of characteristic color of the carried material [14]. This ranking process movement computation is alternated with random movements, allowing ants to explore the solution space and to not be blocked by other ants, producing in that way, some noise in the linear movement along the pheromone gradient.

Even if ants are used in this bio-inspired model, we don't consider that ant behavior is able to represent human behavior. Ant behavior is used to implement self-organization processes; human behavior is introduced in complex mechanism linking many criteria and specific knowledge expressed by statistical values of social practice described by the pheromone attraction function.

3 Modeling engineering and simulation platform

In this section, we first present a prototyp model built on a very simple spatial situation but easy to analyse. In the second subsection, we describe a more sophisticated simulation platform, integrating a detailed and specific GIS over the French city of Rouen.

3.1 Virtual urban area prototyp and first analysis

Figure 3 is describing Virtual urban area prototyp as an experimental configuration with seven centers and initially random places for the peoples/materials and the ants. Centers positions are described on the left top sub-figure. Each center is emitting heigh attractive pheromone functions associated to a color labeled from 0 to 7. On figure 3, we also represent the amplitude of the colored pheromone functions for the centers labeled from 0 to 2.

On figure 4, we show the result of one simulation where ants progressively aggregate the materials around the centers, following pheromone trails and clustering algorithm. On the left top sub-figure, we see the initial distribution of materials and ants. In the other sub-figures, we see successive steps of simulation. We can observe the formation of material affectation to each center in order to respect the attraction process, according to the material characteristics. In [14], the analysis of the attraction phenomena is detailed, allowing to better understand how the computation generates self-organization and distributes the material between the centers.

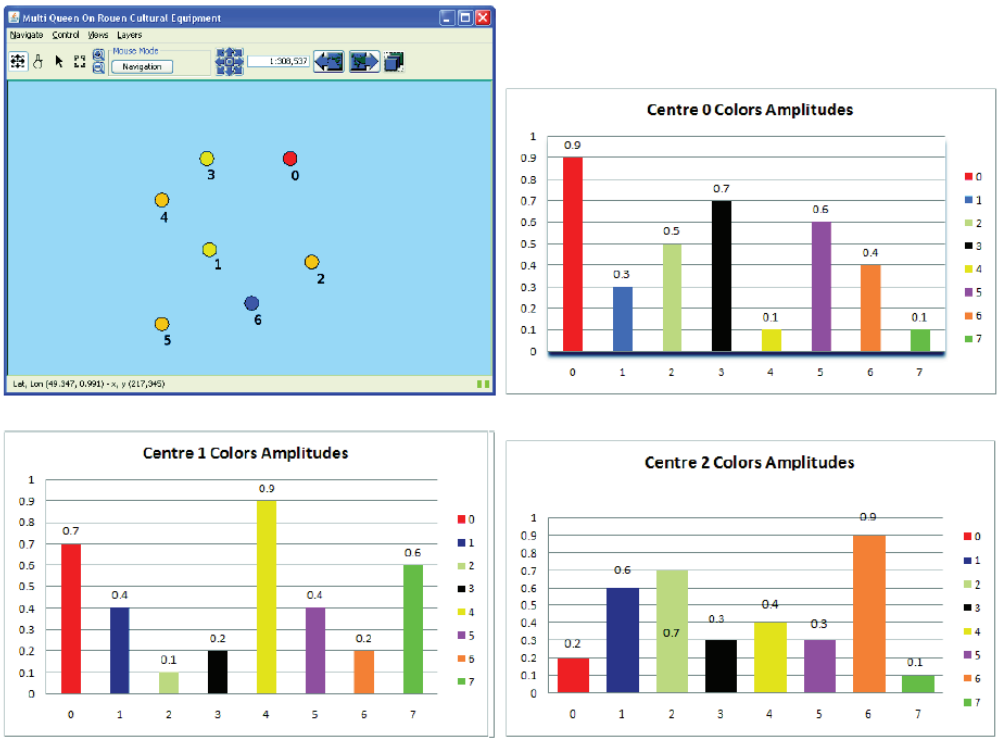


Figure 3: Virtual urban area prototyp on Repast: initial configuration based on seven centers, each of them emitting heigh attractive criteria represented by colored pheromones

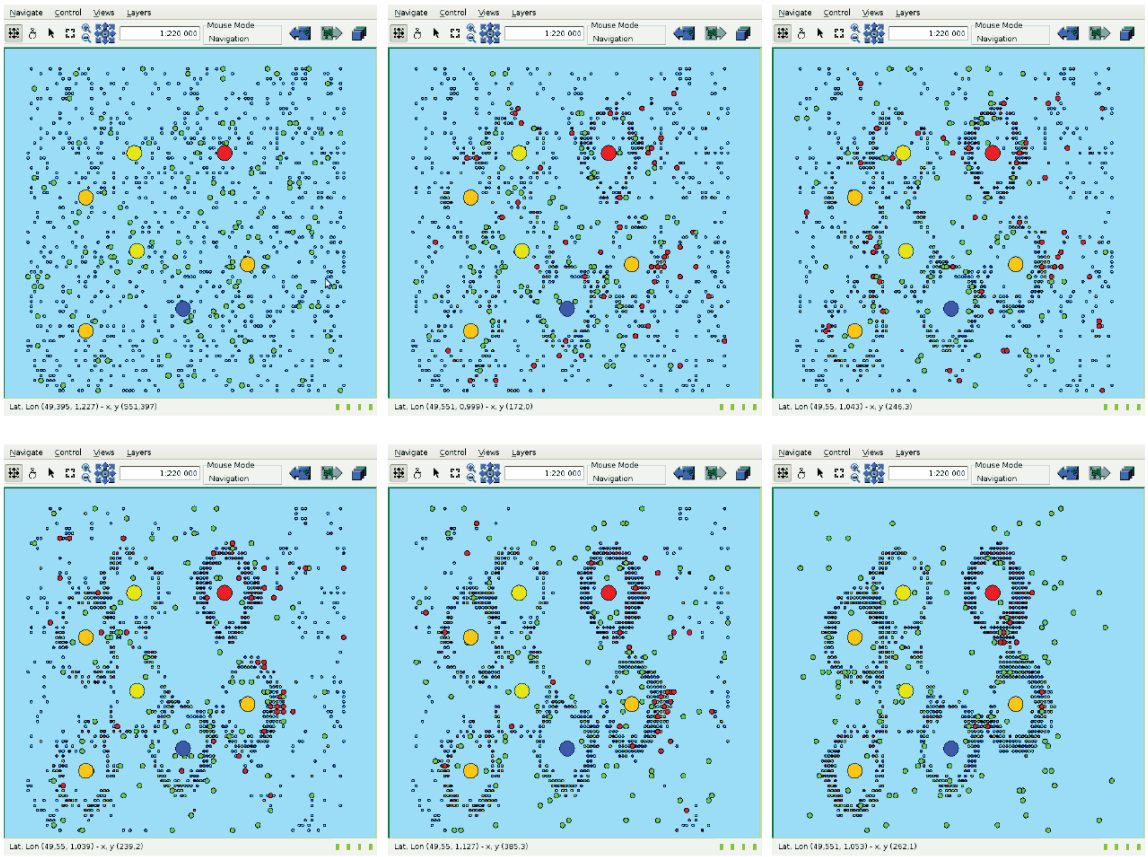
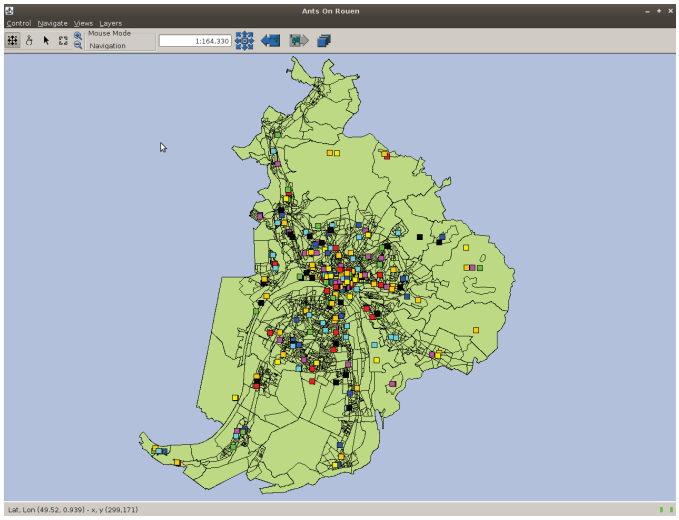


Figure 4: Virtual urban area prototyp simulation computation on Repast, at successive steps from top to bottom and left to right: iteration 0, iteration 152, iteration 250, iteration 370, iteration 601, iteration 1601.

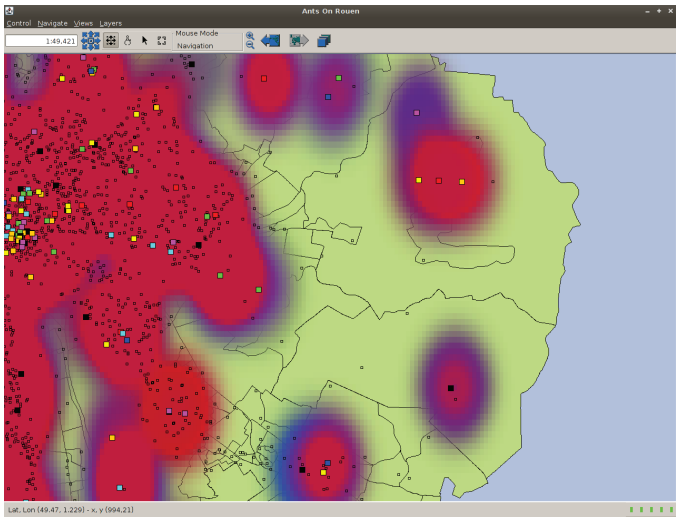
3.2 *ROUANTS* simulation platform

Rouants simulation platform allows to dynamically experiment the complex interrelationships mixing the three types of actors previously described: social individuals, cultural sites, urban spatial environment. This framework implements decentralized approaches and so is devoted to built self-organized mechanisms of collective cultural behavior. The results of the simulation allow to reveal the emergence of spatio-temporal forms from the interleaving of multiple types of interactions and from the spatial constraints coming from urban system[13, 14, 23].

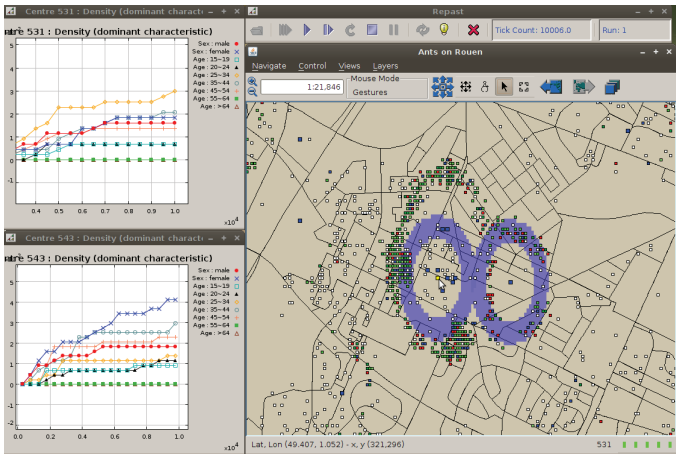
Rouants implements the previously described algorithms of collective intelligence and integrates them inside a specific GIS, representing the cultural sites and the block housing over the urban area of Rouen in High-Normandy. Figure 5 shows different visualizations produced by this platform. On the sub-figure (a), we see the whole distribution of cultural sites and centers over the urban area; the sub-figure (b) is a sumple vue allowing to observe how the pheromones are spreading over the space; the sub-figure (c) described an analysis of some specific places in this agglomeration, tracing on the graphes on the left side of this sub-figure, the temporal series of number of materials being attracted in two zones, according to the dominant color/criteria of the materials.



(a) Rouen Cultural equipments GIS



(b) pheromone density visualization



(c) result output on GIS and graphics

Figure 5: Visualization of *ROUANTS* simulation platform

4 Conclusion and Perspectives

We illustrate in this paper the possibility of experimenting dynamics of multiple services-users in city. Rouants simulation platform is an effective tool for approaching cultural practices in urban situations. Decentralized mechanisms reinforce the suitability of the type of data and methods used to the study of socio-spatial complex systems like cities. We observe emergence of multiple cultural aggregation phenomena in relation to the sociology of culture and to the specific urban and social environment of the city of Rouen. The simulation highlights territorial situations of rivalry and complementarity in cultural practices. The modeling concept of the platform allows also to experiment adaptive capacity and feedback process like politics of regulation of cultural centers, according to the user practices. The social and territorial impacts of these mechanisms are one of our further perspectives and analysis. There is also a general evidence: the use of cultural heritage is a vector for both cultural policy and cultural development.

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