

# Geosimulating the Swarming City

## Managing Complexity

Think about a city as an ant-hill. Despite the evident limits of such analogy, the great advantage of this approach is that it highlights the stupendous complexity we are all embedded in, so deeply that we usually tend to forget it. Just think about all the people you fugitively perceived on your way to work this morning. Try to remember those you interacted with, and try then to imagine those you couldn't see. Imagine all these individual lifelines, in parallel most of the time, sometimes crossing each other at specific nodes in space and time.

By Arnaud Banos

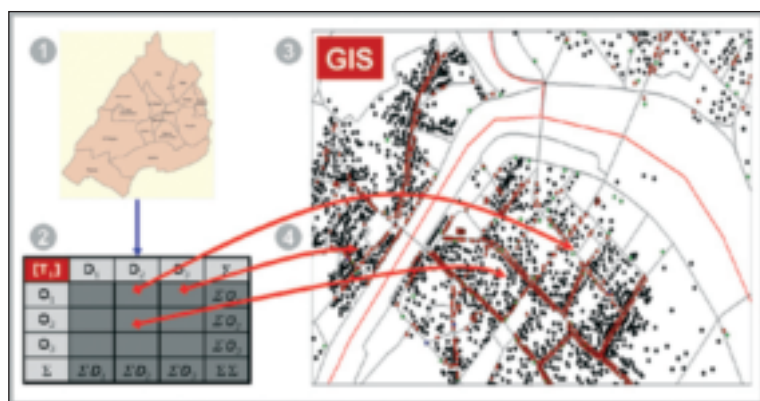


Figure 1: Desegregating spatial mobility data in a GIS.

### Scientific Manner

What seems to be an irreducible mess for our human brain is just the daily routine in our cities. Does this mean we cannot try to study it in a scientific manner? Of course not! Furthermore, it is evident today that we'd better learn to manage complexity, as we cannot always reduce it. In such a perspective, we propose a 'bouquet of alternatives', showing different visions of the city on the move. During this tour, we'll first present a 'place-based' approach to urban mobility, providing a global thus dynamic view of the swarming city, based on Monte-Carlo simulation and map animation. Then, we will shift to a 'people-based' paradigm, trying to recover by simulation and to visualize individual 'space-time paths' from a given mobility survey at hand. Finally, we will present the SAMU prototype. This allows exploring pedestrians/cars interactions in a brand new way, based as it is on agent-based modelling and parallel computing.

### Traffic Zones

The first approach [Banos and Thevenin, 2005] deals with very classical aggregated data, available in most of the cities today, see Figure 1. Basically, the urban space is divided in a limited number of traffic zones (1), allowing building a typical origin/destination matrix (2). Each cell of this matrix is filled with an estimate – based on sampled surveys and traffic counts – of the number of people leaving one traffic zone (origine) and going towards another one (destination), for a given time period (usually a typical week day). In the example we are dealing with, based on the French city of Besançon, 800 000 trips were estimated that way.

The key idea then is: using complementary data on the temporal distribution of these trips and on the location of residential, working and shopping places (3). Can we try to allocate these 800 000 trips within traffic zones, directly to the buildings (4)?

This computer intensive simulation, called Monte Carlo, based as it is on pseudo random numbers, then allows producing different views of the city, for successive time periods, see Figure 2. The depressions reflect areas that are emptying, as people being there at that moment of the day are leaving. The up-swellings indicate local accumulations of population in the given time-slot. The full animation (<http://www.univ-pau.fr/~banos/banos-animation4.html>) then provides new insights on the global dynamic of that agglomeration, at least for the 'typical' day studied. Anyway, despite its good points, this first approach has a number of limitations that push us towards complementary studies. For indeed, we are not dealing with people here, but with trips, which means more segmentation and independence of one another. Furthermore, there is no interaction at all in the process, while urban life is above all based on interactions. Some scientists even argue that a city is a typical form of spatial organization that maximises social interactions between its residents.

### Individual Movements

For the reasons mentioned above we decided to shift to a 'people-based' approach. We tried to reconstruct and reveal - at least partly - some of the individual movements hidden

# ty: a Bouquet of Alternatives

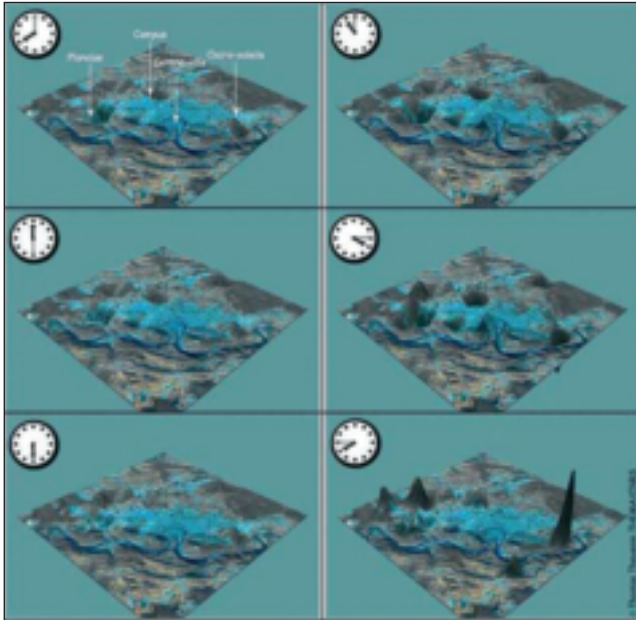
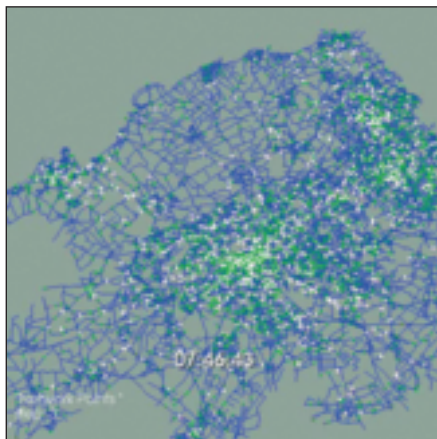


Figure 2: The city of Besançon, France, around the clock.

behind this global 'around the clock' view of the city. After all, some individual data in most of the larger cities in France are based on standardized space-time-activities surveys. They provide very detailed information on the mobility behaviour of a limited but representative number of sampled individuals (typically around 1 per cent of the living population), for a typical day of the week again.

The precise locations and routes of individuals are unknown which makes these data far from perfect. However their accuracy is good enough to allow us reconstructing - in a GIS - the possible routes of these individuals. This problem clearly belongs to a specific family of routing problems under spatio-temporal constraints, where multiple locations are



unknown and must be found on the fly, as well as their corresponding routes. While being still in progress, the proposed algorithm provides preliminary results that directly lead to a new question: how can we visualize a potentially large number of individual routes (13 000 here), in order to provide valuable insights on the kind of internal movements a city hosts?

**Animations**

Obviously, various solutions come to mind when thinking about it. Figures 3 and 4 show different screenshots from animations proposed in collaboration with Bruno Jobard and Julien Lesbegueries from LIUPPA [Lesbegueries, 2005]. The left part of Figure 3 provides a global view of the city of Lille (France), at 7:46 am. Green dots are static individuals while white dots are mobile ones. Individuals, depicted as dots, follow the road network, in blue, retracing possible routes of the 13 000 sampled individuals. The right part of Figure 3 focuses on a single simulated path (in red), highlighting our capacity to follow individuals or groups of individuals of specific interest.

Of course, while focusing on individuals we lose the global trend, which is of capital importance for a planner or a decision-

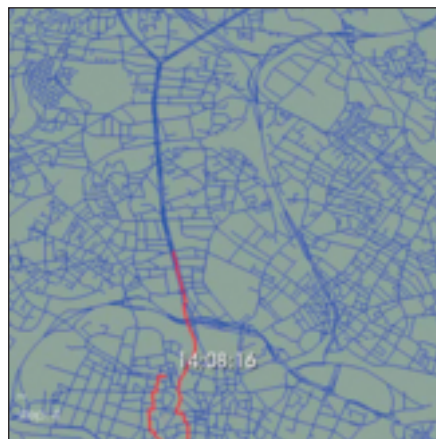


Figure 3: Retracing individual paths (Lesbegueries, 2005).

*Exploring and understanding the swarming city is a major challenge today, especially if our aim is to provide tools useful and relevant enough to assist decision-making processes.*

maker. Therefore, it makes sense to provide a complimentary view of the swarming city, allowing handling different scales of the phenomenon under study at the same time. White and green dots are still identifiable, but enhanced with a third dimension. Extruding picks give an estimate of the number of individuals present in the close vicinity during the given timeslot (here 7:47 am). The idea, therefore, is clearly to provide a place-based and an individual-based view of the urban anthill in the same document, showing local as well as global trends. These two complementary approaches have one thing in common: they rely on our ability to draw specific images of the city on the move from datasets at hand, with the idea of revealing the hidden complexity of these social organisms. But invoking complexity has a strong implication: it is indeed difficult, if not impossible, to study the properties of a complex system by decomposing it into functionally stable parts. This strong limitation of the analytical perspective encouraged us to move towards a more appealing paradigm, broadly embedded in the science of complex systems, and methodologically anchored in geosimulation.

## Localized Interacting Entities

The science of complex systems regroups a huge variety of works, being most of the time transversal to several disciplines and relying, despite their diversity, on a few basic principles. Generally speaking, in its broader acceptance, a complex system consists of a large number of localized interacting entities, operating within an environment. These entities, being human or not, act and are influenced by the environment they are

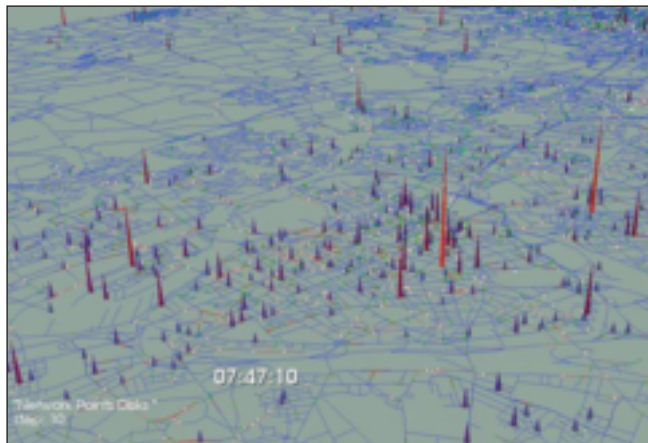


Figure 4. A multi-scale view of the swarming city (Lesbegueries, 2005)

situated in. While the behaviour of these entities may be inspired, guided or limited by various global trends, it is usually admitted that they are not directly controlled by upper-level instances. They operate on their own, having some 'self-control' over their actions and internal states. From that perspective, the study of complex systems requires the development of new scientific tools, non-linear models, out-of equilibrium descriptions and computer simulations, agent-based modelling being one of these tools. The key point we are defending here is that mobility needs not only to be considered as a specific phenomenon. It also needs to be included in a much more global and complex perspective, the urban system as a whole. Individual movements indeed occur in an ever-changing environment. They are defined by constraints and opportunities, but also nuisances and dangers.



Figure 5: SAMU, a virtual lab designed to grow artificial cities.

### 'Virtual Laboratories'

In order to demonstrate the relevance of such a perspective, the SAMU prototype has been specifically designed to explore the behaviour of pedestrians in interaction with the motorized traffic, in a virtual city where most of the phenomenon can be mastered

and studied [Banos et al., 2005]. This idea of designing 'virtual laboratories' within which 'artificial societies' can be grown [Epstein and Axtell, 1995] has become very popular in the recent years. It is largely related to two other fields: science of complex systems and agent based modelling. Moreover, it is firmly embedded in a microscopic approach of urban mobility, where the world

is represented as much as possible in a one-to-one way, which means that "people should be represented as people, cars should be represented as cars and traffic lights should be represented as traffic lights and not as, say, departure rates, traffic streams and capacities respectively" [Nagel et al., 2000].

### Hybrid Models

The prototype SAMU directly relies to these various principles, its originality being defined by its focus on interactions between pedestrian and traffic flows. Developed in NETLOGO, SAMU belongs to the family of hybrid models, combining characteristics of both cellular automata and agent-based models. Cars and pedestrians are indeed defined as agents, situated on an active grid, with which they interact. Then, agents have to perform specific tasks, interacting locally with other agents

and with their environment. Figure 5 shows the prototype developed in order to observe and test these interactions, as well as emerging parameters, such as speed of cars or proportion of cars/pedestrians collisions.

While being a work in progress, SAMU already provides an ergonomic platform useful to test the behaviour of the system under different configurations of parameters and to run 'what-if scenarios'.

Anyway, reaching such a modelling level, without being flooded with microscopic details, requires an ad-hoc procedure. Crucial principles like reductionism and parsimony may therefore constitute main guidelines, in our quest for the identification of the micro-specifications sufficient to generate macrostructures of interest.

### Conclusion

Exploring and understanding the swarming city is a major challenge today, especially if our aim is to provide tools useful and relevant enough to assist decision-making processes. Given the complexity of the phenomenon we are talking about, these tools must be flexible enough to reveal different but complementary views of the city on the move. They should highlight various issues of crucial importance, from global trends affecting the whole city to much localized interactions.

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