Cellular world simulation: A collaborative model for spatial visioning and Territorial Intelligence.

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CELLULAR WORLD SIMULATION: A COLLABORATIVE MODEL FOR SPATIAL VISIONING AND TERRITORIAL INTELLIGENCE

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Abstract: Urban sprawl is a typical problem that cannot be correctly understood and resolved because it relies on several different fields and concerns different actors. With traditional approaches, the whole process cannot be apprehended. This context partly explains the inefficiency of traditional planners' works, and asks for urban planning considered through the idea of collaborative projects. The CamDeus (Cellular Automata Models to Design Environmental and Urban Systems) project is an operational decision-making software giving cartographic and mathematical solutions in order to harmonize and share data and knowledge among scientists, territorial or administrative technicians or elected people. It consists in simplifying the modelling process, so that it can be understood by persons with different technical languages and different scientific qualifications. Thus, the question of urban dynamics is decomposed into three simple and operational questions associated with a particular and relatively simple model : "How many?" (how many hectares will be concerned by urban sprawl in the future?) ; "Where?" (where are the surfaces that will move to another landuse category?) ; "What?" (what is the land use category of the spaces quantified in the first step and located in the second one?). This global modelling is then relatively complex and allows the study of urban changes with efficiency. Its decomposition into three steps appears simplified enough to be simultaneously understood by all the actors concerned with urban planning. CamDeus then allows different points of view to be put together and concrete actions to be modeled for the development of urban territories in the perspective of sustainable development.

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INTRODUCTION

In the "Risk society" defined by U. Beck (1986), the old idea of "danger" is partially opposed to the post-modern notion of "risk": in the past, it was possible to identify and localize the danger, while currently the risk is anonymous, diffuse and omnipresent ; this way, the "enemy" (political, ecological, epidemiological, etc.) is everywhere and nowhere at the same time ; it depends on many actors, possibly conscientiously interacting, possibly not. For geographers in charge with planning, this idea is relied by a new epistemological approach claiming to face up the paradigm of complexity (Chamussy 2003). Concretely, this conceptual changes suggest to explore different ways and new methods for managing daily actions so as to reach the *utopia* of "zero risk". Recent modifications of the French legislation confirm this fact, asking for more complete and integrated reasoning before answering the complex question of urban or regional planning. The CWS[55] project initially started from here ; it tries to release discussion pools between most of the actors concerned with planning decisions for better simulating the consequences and the level of efficiency of their project. Finally CWS can now be considered as an operational decision-making tool (software) and an interesting mediation for sharing environmental knowledge in the context of territorial intelligence.

RELEASE DISCUSSIONS ABOUT PLANNING DECISIONS

The *Nouveaux principes de l'urbanisme* (Ascher 2000) offer a good example of the changes and the new principles that appeared since the end of the 20th century in the realm of urban planning. As the majority of planners, F. Ascher works on the assumption that French administrative procedures usually take place in a bulk-heading context that reduces the efficiency of any action. This is particularly true in the case of (urban) planning issues. Urban sprawl, for example, is a typical problem that cannot be correctly understood and resolved because it relies on several different fields and concerns different actors: a minister in charge with transportation, a property developer who buys and sells building lands, a lawyer or a territorial technician employed to determine and apply local environmental and urban legislation, and a simple citizen (unaware of any other) that only wishes to build a house of his own. Globally, all the goals, all the points of view, all the administrative procedures associated to these actors appear divided into opaque sectors and do not allow to build a project crossing everybody's objective.

It ensues two major lacks: on the one hand the information related to urban planning is not shared from one administration (or one administrative service) to another; on the other hand, the knowledge and the solutions proposed by scientists or experts are not correctly transferred to concrete possibilities of action for planners. Lots of examples show that traditional approaches do not allow to comprehend the whole urban sprawl process. This context partly explains the inefficiency of traditional planners' works, and the new deal imposed since 2000 by the French legislation: "*Solidarité et Renouvellement Urbains*" (Solidarity and Urban Renewal). This law claims to consider urban planning in a way that partially corresponds to the idea of "collaborative projects" or transversality. Japanese (Shen 2003) and Dutch (Stouffs 2003) experiences of "decision collaboration systems" appear thus as excellent examples of achieving concretely such a difficult goal. The principle consists in using web-based technology to communicate with clients, officials and partners about urban planning projects, by the way of interactive on-line cartography and dialogues. The computer-assisted interface which is supporting these communication processes appears then as an interesting technological development for sharing (possibly contradictory or conflictual) information and co-building solutions for each other project.

In urban planning and territorial management, most of the projects can rely on such kind of virtual simulations. But concretely, these simulations always rely on modelling (as P. Haggett defined it[56]

[55] CWS (Cellular World Simulation) is a Land Use and Cover Change (LUCC) model developped by J.P. Antoni and G. Vuidel. First developments were made in the Laboratory Image et Ville (CNRS UMR 7011) in Strasbourg.

[56] For P. Haggett, a model is a "simplified version of reality built in order to demonstrate certain properties of reality".

(Haggett/Chorley 1967)). The CWS program is an example of modelling that tries to facilitate the dialogues and the comprehension of the global stakes linked to territorial projects. Then, it can be considered as a decision-making software conceived to reduce the two precedently identified lacks, i.e. to increase the possibilities of sharing from one group of people to another and to create a bridge through different fields of competence, everybody making one's contribution to the global solution.

HARMONIZE DATA TO COMPARE POINTS OF VIEW

Firstly, CWS approach gives methodological and technical solutions to harmonize different sets of disparate data within a spatio-temporal way. At first, several data is needed for taking into account all the fields and topics connected to urban dynamics: landuse modifications, networks structure and capacity, economic situation of the city in its region, political goals, administrative procedure for acting, etc. But moreover, it must be considered within a temporal dimension to be understood as a global process. In the French case of urbanization for example, considering the rural depopulation (1950-1970) and the massive peri-urbanization (1970-2000) which are statistically measured by specialized institutes, seems interesting in order to study what happened from the 50's, in order to anticipate the most expected future changes. The major problem consists in harmonizing this disparate raw data to obtain comparable information in space and time

Using a simple cartographic method – a tessellation – appears as an interesting solution to construct and store the information. For example, grid mapping makes it possible to compare data issued from various sources and constructed or collected through different points of view, with different goals, by different people. Concretely it consists in transforming continuous original mapped data into discreet spatial data within regular square polygons and then in studying what happens inside each cell: what is the past and actual landuse of the cell? Which kind of legislation must be applied on it? Does it correspond to a future development project area? etc. All this information can be coded for each cell and stored in a GIS cellular database. Tessellation produces then a grid that makes it possible to consider the geographical information inside its cells, whatever the date and the source of information. As shown on the Figure 1, it can be cartographic data as well as legislative or textual information concerning the past or the actual state of each cell.

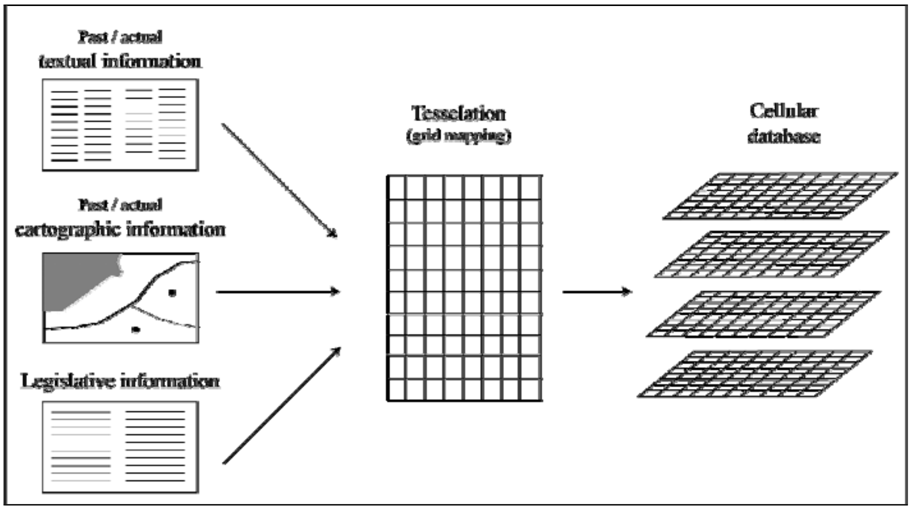

Figure 1
Grid mapping for building a cellular database
Source: J.P. Antoni, 2003

Within this cellular lattice which is grouping together many information layers based on the same data structure, grid mapping effectively allows to visualize global or precise land use transformations of urban and peri-urban areas, and to compare these transformations from one location to another and from one time to another. These layers can be used together to improve our knowledge about urban dynamics. Thus they can help to simulate specific objectives and scenarios of territorial development.

SIMULATE OBJECTIVES *VIA* SIMPLE METHODS

But, for simulating planning objectives within a prospective approach, lots of methods can be used, from the simplest to the most complex or technical. And the multiplicity of actors concerned with planning will not have the same capacity for understanding or using it. The second goal of the CWS project consists then in creating a platform between scientists, territorial or administrative technicians or elected persons, i.e. persons who usually do not use the same kind of methods and reason following different objectives and points of view. The concrete idea is then to create a "simple" modelling process generating the simulations, so that it can be understood by persons with different technical languages and different scientific qualifications. In the CWS project, the problem of urban dynamics is then decomposed into three simple and operational questions : how many hectares will be concerned by future changes? (question 'how many?'); where are located these changes? (question 'where?') ; and to which kind of land use will they belong? (question 'what?'). The experiences developed *via* this approach effectively show that phenomena as complex as urban sprawl or urban renewal can probably be better considered if they are decomposed into different parts, corresponding to a particular aspect of the phenomenon. Each one also corresponds to a specific step of the modelling and is associated with a particular and relatively simple model (Figure 2). Such a decomposition allows to discern correctly the meaning of this modelling and appears a necessity for the construction of simple models, i.e. models which are not designed *ad hoc* and finally too complex to be clearly understood by non-specialist users.

The first step of the modelling is the question "how many". A Mathematical model relying on Markov chains answers it with the help of transition probabilities measuring the chance of a change from one land use to another. This step (quantification of urban dynamics) is interesting to estimate the proportion of each land use category in the future. But this estimation is not really usable for urban planning without any information about its geographical location. A second step (location of urban dynamics) is then required; it should answer the question "where?": where are the surfaces determined at the first step that will move to another landuse category ? Different spatial models can be used. For instance, we choose to use a potential model (Donnay 1992, Weber 1997, Weber 1998) taking simultaneously into account classical assumptions : the complementarities between each cell and the rest, their respective distances, the intervening opportunities existing on the study area (Warntz 1958, Abler 1972). This way, the potential model assumes that: 1. urban expansion creates an interaction between new and old urban spaces which can be considered as complementary spaces; 2. urban expansion is based on the minimization of the mathematical distances between the concerned cells; 3. urban expansion favors the best solutions by testing all the possibilities of complementarities and distances. These three ideas are very simply exprimed in the mathematical formula of the potential model.

Unique cellular database (cf. Figure 1)	Step and goal	Model	Simulations integer ...
	1. Quantification of urban dynamics	Markov chains	... continuation of the past observed trends ... prospective scenarios ... tested ideas about futur development
	2. Location of urban dynamics	Potential model	... elements of legislation ... particular specificities of the territory ... references to spatial interaction theory
	3. Differentiation of urban dynamics	Cellular automata	... prospective scenarios ... tested ideas about urban composition ... long term running simulations

Figure 2
Three simple steps for a global complex modelling

Source: J.P. Antoni, 2003

The calculation of potential values for each cell demands to determine *m* masses associated to the landuse categories. This determination is one of the major problem of the modeling. In a first time, it can rely on the observation of comparable past periods that the regular cellular structure allows to do. In a second time, it can rely on everyone's experience, goal and project. Then, the masses can be considered as the "attractiveness level" of a landuse category, and exprimed on a defined scale, e.g. from 1 to 10 for example. An engineer can determine it according to his technical goals, a jurist to legal dispositions, a politician to its development project, etc. The advantage of this quantitative modelling is double : 1. Each actor's objective can be compared with another (the mean objectif could then be calculated!) because they all reason with similar tools and rules; 2. Everyone's opinion or will can be understood by each other because it is exprimed on the same graduated scale.

At this stage, the modelling approach allows to locate the future simulated changes, but it cannot describe more precisely the nature of these changes. For instance, it does not allow to know if they will create residential, industrial units or facilities. Last question is "What?": What is the land use category of these spaces (differentiation of urban dynamics). Cellular automata answer this third question through complex rules of transition. Recent works in urban geography, using techniques issued from Artificial Distributed Intelligence, effectively offer a new conceptual framework to treat such kind of problems (White 1994, Langlois/Phipps 1997, Batty 1999, White 2003). Automata should assume that the category of the cells is determined by its neighborhood, actually by the categories of the neighbor cells. The analysis of each cell's cellular neighborhood (grid mapping) allows to define transition rules, explaining why a cell has moved from one landuse category to another. Such kind of rules can then be applied to most of the other cells for choosing their category. As precedently, the biggest problem consists in defining pertinent rules. At first, they can be determined by empirical tests, according to the users' estimation and observation of past periods. Then, a statistical method should be developed to construct a set of rules closely relying on quantified observations.

CONCLUSION

Finally, the global combined modelling appears relatively complex and allows the study of urban growth with efficiency. But its decomposition into three steps appears simple enough to be simultaneously understood by all the actors concerned with urban planning. A complementary document called "scenario sheet" helps to connect these different kinds of actors and to put together there points of view in a sharing process of modelling: everyone writes his ideas about what the future of the urban area could be on the sheet ; then the texts are translated into mathematical coefficients and parameters able to feed the three models. Such a translation can be done by the actors themselves, but can although be confided to a third party. This way, such a modelling really corresponds to an "accompanied modelling", animated by a mediator who collects, translates, and simulates everyone's idea within the process proposed by CWS. As J.M Dziedzicki (Dziedzicki 2003) explained it, this mediation process seems particularly interesting for planning issues, because it leads to a possible participative and evaluation, i.e. a real dialogue based on terrirorial intelligence. It is then an undeniable progress for all the concerned persons and an evolution in our manner to conceive projects (Brunet 2001). According to the notion of reflexivity associated to the "Risk society" (Giddens 1994, 1998), such a kind of deliberative process can be envisaged as a complement for the traditional institutions of our democratic systems. Finally, complex and complete scenarios of urban dynamics can emerge from this collaborative modelling. They could although allow concrete actions for the development of territories in the perspective of sustainable development.

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