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Video games and urban simulation: new tools or new tricks?

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Abstract: Video games allow complex systems modelling, revealing retroaction loops, replicating self-organization and the emergence of hierarchical organization, functional differentiation and social segregation through multi-level interactions. Recent trends focus on improving modelling tools' graphic quality and interface attractiveness and on using video games to facilitate urban studies teaching and research. This apparent convergence between simulation and video games is addressed through a selection of strategy and city builder video games. Comparisons reveal that simulations and video games point to similar results: they both allow the simulation of complex urban processes, like hierarchical urban networks or urban segregation. Games seem to allow going one step further, being often more "fun" to use. However, the main limitation of video games emerges from their didactic power: video games and simulation software implement rules and models in almost opposite means. Games induce players to learn the model but not to challenge or to produce new knowledge.

Keywords: video games, modelling, simulation, models, representation, self-organisation, emergence, urban studies

Jeux vidéo et simulations urbaines : trucs ou astuces?

Résumé : Les jeux vidéo permettent de modéliser les systèmes complexes en révélant les boucles de rétroaction, en reproduisant l'auto organisation et l'émergence de structures hiérarchiques, en répliquant la différenciation fonctionnelle et la ségrégation sociale au travers d'interactions multi niveaux. Les travaux récents insistent, d'une part, sur l'amélioration de la qualité graphique des outils de modélisation et de l'attractivité des interfaces, d'autre part, sur l'utilisation de jeux vidéo pour stimuler l'enseignement et la recherche. Cette apparente convergence entre outils de simulation et jeux vidéo est analysée à l'aide d'une sélection de jeux de stratégie et de *city builder*. Ces comparaisons révèlent des ressemblances frappantes: les outils de simulation et les jeux vidéo aboutissent à des résultats similaires : ils permettent tous deux de simuler des dynamiques urbaines complexes (réseaux urbains hiérarchisés, ségrégation urbaine). Les jeux semblent même plus complets, leur utilisation étant souvent plus attrayante. Cependant, la principale limite des jeux vidéo découle de leur pouvoir didactique: les jeux vidéo et les logiciels de simulation accordent une place presque diamétralement opposée aux utilisateurs dans la production des règles et des modèles. Les jeux vidéo poussent les joueurs à s'approprier et à comprendre les modèles, mais pas à les dépasser, ni à produire de nouvelles connaissances.

Mots clé : jeux vidéo, modélisation, simulation, modèles, représentations, auto organisation, émergence, études urbaines

"Of course simulation models can be conceived as entertainment tools, and designed for building games, or imagining fictive worlds, as utopias always did. But we want to learn something about the real world from such exercises, by confronting the results of simulation with observation" (Bretagnolle et al. 2006).

The *SimCity* video game series, created by Will Wright in 1989, is unanimously appreciated among geographers, urban-planners, and teachers. Aside from its playful aspects, a didactic role is often attributed to this game series. In the United States, several urban studies and town planning trainings are using video games (Adams 1998, Squire 2004, Gaber 2007, Gordon & Koo 2008, Nesson & Nesson 2008). Like models (Haggett 1965), video games can be both heuristic and didactic tools. Furthermore, the development of modelling tools enhances their similarities to video games. They use video games' graphic models in order to improve their own user interfaces. Moreover, some modelling software have shifted into games for didactical purposes, such as *MacSim* (Augier *et al.* 2001), a macroeconomic simulation software. The *Simpop* (Bura *et al.* 1997, Bretagnolle *et al.* 2006) regional declinations and predictive scenarios have drawn it closer to the multi-level interactions and urban network emergence proposed by the *Civilization* video game series (Microprose & Firaxis 1991-2010). Finally, some agent-based modelling software, like *StarLogo TNG* or *MASON*, are also presented as game conception tools.

Batty and Torrens underline that “*models with emergent properties based on evolutionary principles are increasingly being adopted in game simulations. There is evidence that what is state-of-the-art game design today is often incorporated into the e-science of tomorrow*” (2001). From the perspective of these two authors, is it possible to consider some video games as simulation tools, allowing complex systems' modelling? Do modelling tools have something to learn from video games besides graphic quality and user friendly interfaces? Could we consider video games as efficient modelling tools, and what do they teach us about the real world?

This paper discusses the convergence between video games and urban systems modelling by focusing on emergence as a recurrent notion in both complex systems modelling and video game design. Juul distinguishes two major kinds of video games: “games of progression that directly set up each consecutive challenge in a game, and games of emergence, that set up challenges indirectly because the rules of the games interact” (Juul 2005: 67). Games of emergence, as chess, are based upon a small number of simple rules which can lead to a number of possible states that defy description (Juul 2005). In both video game design and complex systems science, emergence is based upon an asymmetrical relationship between the simplicity of the rules and the extent of the space of the different outcomes proposed by the video game or the model. However, video games and models do not interact in the same way with the player/user and do not share the same goals. In games, different outcomes and emerging properties arise from the interaction between the core code and the different choices of the player; in modelling, exploring the model commonly leads the user to reshape the rules and structures in order to fine-tune or to calibrate the model.

We first explore the relationships between video games, models and representations. Then, we consider video games as geographical meta-models able to simulate emergence. This is followed by case studies of emerging properties in various video games at different levels. Finally, we explore the limitations of using video games as modelling tools.

VIDEO GAMES AS MODELLING TOOLS

Traditional and more recent research have shown how challenging it is to define a game (Huizinga 1938, Caillois 1958, Koster 2005). Three main dimensions characterize video games: multimedia, fun and interactivity (Juul 2005). Video games are spatial simulations designed for entertainment that require user participation through graphics, audio and mechanical interfaces.

There is virtually no video game without representation of space, from the road that scrolls in front of a car to the recreation of Earth through imaginary universes. Spatial representations are central to various levels of video games. Video games open a distinct space of play; space is also simulated by software, mediated by interfaces, represented by players, and can become the stake of play (Stockburger 2006, Nitsche 2009). Representations of space within a video game must be considered to be at least “redoubled”: player’s spatial practices and representations are based on a simulated space (Rufat & Ter Minassian 2011). Thus, the analysis of the in-game space of video games can help us to deepen the comparison between modelling and representation.

From the game to the model and back

From a process rather than an interface point of view, video games similar to *SimCity* are close to the modelling tools used in research. They use similar models, and the simulation relies on feedback loops, conditional loops and cellular automata. Many video games are based on simple spatial models (gravitation, diffusion, centre/periphery, land market, etc.), the combination of which lead to the emergence of archetypal forms of spatial organization at the meso or macro level. They also offer diagnostic tools to evaluate ongoing processes and their spatial results.

For twenty years, the *SimCity* video game series has allowed users to play an all-powerful mayor who builds from scratch, modifies and manages a city. In *SimCity*, simple spatial rules are reproduced by cellular automata similar to *Conway’s Game of Life*¹. *SimCity* uses a combination of

¹ In 1970, the mathematician John Conway suggested this game as the exemplar cellular automata. It is a cellular grid where any cell can be “alive” or “dead”, and there are two rules: a cell is giving birth if there are exactly three live cells in its neighborhood; a cell remains alive if there are two or three live cells adjacent to it. Fewer than two adjacent cells implies the cell dies from isolation, more than three and it dies from overcrowding. This game allows exploring the

gravitational models and cellular automata to model urban growth and the competition for space through the following:

- the attractiveness of different parcels, which can affect their development;
- the parcels' value, which determines the type of population (poor, medium and wealthy) or activities they are likely to accommodate;
- segregation, which homogenizes residential districts and activities;
- the invasion/succession of populations and activities over time.

The player may specify the destination (either residential, industrial, or commercial) of these cells, but he or she cannot operate directly their development, the type of population or activities established in these cells. The actions of players therefore have indirect effects through the choice of the location of amenities, transport infrastructures, and through budgetary constraints. Amenities have an influence or effect zone on neighbouring cells, at different scales. For example, the effect zone of a conference centre on commercial clusters' attractiveness has a radius of 32 cells against only 22 cells on the residential clusters. Or the effect of a small park on residential clusters' value has a radius of 15 cells; that of a large park is 45 cells.

The total attractiveness of a cell results from the combination of the effects of all its amenities (Fig. 1). Their evolution over time as well as network and environmental quality determine the cell's land value, which in turn affects its attractiveness, population or activity.

	effect value on commercial zones	effect distance for commercial zones	effect value on residential zones	effect distance for residential zones
small park	30	15	50	15
large park	35	15	75	45
conference centre	100	32	- 50	22
research centre	50	22	- 50	22
stock market	70	26	0	0

Fig. 1: Effect zone on neighbouring cells of different amenities in *SimCity 4* (2003)

Therefore, *SimCity* is not based on a cellular automata *stricto sensu* but on a *cell-space model*, to follow the distinction made by Michael Batty (2005), since it incorporates remote effects, not only action on neighbouring cells. Furthermore, *SimCity* is based on bottom-up retroactions: neighbouring effects and local interactions are the ones that generate the emergence of urban structures at the meso scale. The software also includes top-down retroactions. The emergence of highest rank activities and services in the more attractive cells depends on the size and the general

countless kinds of complexity that emerge from such simplicity and to find the self-perpetuating configurations. Its popularity lead to numerous variations: *Day & Night*, *HighLife*, *Immigration*, etc. (Holland, 1998: 136-142).

level of education and health of the population of the entire city. Since *SimCity 4* (2003), the game has offered the ability to manage an ensemble of cities at the regional level. The vertical growth and the higher service level that can appear in this game depend on the neighbouring cells, on the size or attributes of the whole population, and also on the evolution of these settings across the urban area.

Finally, video games such as *SimCity* enable simultaneous viewing or overlay of diagnostic tools (maps, graphics, etc.) offering significant amounts of information. In *SimCity 4*, it is possible to overlay arrows showing real-time traffic, route, and transport modes. The player is therefore led to use GIS-like tools to read urban processes and assess its choices regarding the model outcomes (Fig. 2).



Fig. 2: Diagnostic tools in *SimCity 4* (2003)

SimCity illustrates the modelling capacities of video games. By offering urban simulations that simulate self-organization and emergent properties such as hierarchical organization, functional differentiation and social segregation through multi-level interactions, it can be regarded as a modelling tool.

Models and video games as both simulation and representation

A model is a “*formalised representation of a phenomenon*” (Brunet 2001). By definition, models are a simplification of some reality to some lesser representation (Batty & Torrens 2001).

“Of course, this representation passes through several filters, which all have their traps: the perception of the phenomenon; its representation; the construction of a model; the interpretation of the meaning of this model,

its social logic; the ability of the model to take account of the phenomenon; the communication of the results. But who ever said research was meant to be easy?" (Brunet 2001).

Modelling is an activity for testing, exploring, creating and communicating knowledge about certain urban phenomena. Over time, it involves testing hypothesis through a series of iterations, shifting from approximation to approximation (Bretagnolle *et al.* 2000 & 2006). However, these models may have opposite philosophical backgrounds (Sanders 1999) and expose the epistemological problems underlying the analysis of urban problems: complexity is an intrinsic feature of phenomena but also depends on the knowledge of the observer (Occelli 2002). Furthermore, the use of modelling in social sciences often relies on arbitrary choices and intuitive rules rather than testable assumptions (Batty & Torrens 2001, Epstein 1999).

For more than fifteen years, the relations between the model and the real world (Batty 1994) and the mere sense and effectiveness of urban modelling (Wegener 1994) have been discussed:

"One is forced to conclude that most models that we are working with are arbitrary, based on a loose consensus of what seems plausible but not on any definitive evaluation of the appropriateness of model structures. Until we are able to move beyond this, then all complex systems model will remain contestable and inconclusive" (Batty & Torrens 2001).

Complex urban models will always contain more assumptions about reality than are testable and involve contextual assumptions that remain implicit. These increasing difficulties in testing and validating models, and the fact that some arbitrary mechanisms have to be imposed so that realistic outcomes emerge, have raised serious concerns about the ability of models to predict or even reflect the real world. It has been argued that models are still useful, because every kind of model can be used for every purpose. It may depend on users, not on the models; urban models still largely remain didactical vehicles that are valuable to engender discussion and debate (Batty & Torrens 2001). These concerns are not specific to modelling. Barnes and Duncan underline that "writing about worlds reveals as much about ourselves as it does about the worlds represented" (1992: 3). Writing (or modelling) reflects more our representations than the world itself. In short, urban modelling can be seen as story telling (Guhathakurta 2001), like video games (Frasca 1999).

Video games are spatial representations that teach us the impacts of representations and ideologies on spatial practices (Ter Minassian & Rufat 2008). So, are video games better stories, better representations or better models? This is not a rhetorical question: Johnson made the game *SimCity* (Maxis 1989) one of the pre-eminent examples of complex systems:

"SimCity would also inaugurate a new phase in the developing story of self-organising; emergent behaviour was no longer purely an object of study, something to interpret and to model in the lab. It was something you could build, something you could interact with (...) It is both the promise and the peril of swarm logic and the

higher-level behaviour is almost impossible to predict in advance. You never really know what lies on the other end of a phase transition until you press play and find out... And then you see what happens” (Johnson 2001).

Hence, the differences between video games, models and simulation tools may become unclear, even if *SimCity* is arguably a borderline case. It is open-ended, surprising the player with emerging properties, and has no clear goal. This has led to the assertion that it is not a “pure” video game (Juul 2005). In addition, it has been used worldwide by city planners and mayors for prediction or to explore the effects of various projects, budget choices and adjustments or public policies (Starr 1994) and more recently for urban hydrology modelling (D’artista *et al.* 2007).

Unfolding the representations behind the models

By playing such video games, the player is made to adopt the same experimental posture as the researcher exploring a model, asking “What if I act in such a way?.” All of these games propose a playground wide enough to explore the different conditions for self-organisation and the emergence of socio-spatial hierarchical and functional differentiation. This study analyzes the model underlying each game. Understanding the model requires playing a video game a multiple times in an attempt to reach the implicit or explicit objectives of each game. In a video game, the spatial structures’ emergence may depend on player’s choices. It is also the case of the user’s choices when exploring a model:

“The lines between the modeller, the modelled, and the user are increasingly blurred. This is no more or less than the idea that the user is part of the system to be modelled and is often no different in behaviour from the rest of the system that is being modelled” (Batty & Torrens 2001).

The possibilities granted to the player are limited by game rules (Salen & Zimmerman 2004), interaction degree, details and the elements with which the player can interact (Juul 2007). Jesper Juul shows that this level of abstraction does not depend on the technical capacities but on the choices made by the designers. Indeed, they have to reduce information and the possible interactions in order to turn a set of possibilities into a game. From this point of view, game design can be compared to modelling.

Our hypothesis is that the underlying model of video games does not depend solely on rules and game design but also on incitements framing the player choices and behaviours. Player’s behaviour is oriented by the goals, when clear goals exist, and by some incentive and coercive mechanisms of the game that we called “regulations” (Ter Minassian & Rufat 2008). Responding to these regulations, the player has to develop a reflexive analysis of his/her successful choices, effective behaviours, and painful failures. For example, in city builder games, the player has the freedom to experiment with different strategies in order to develop a city and to choose different goals.

Nevertheless, choices in accordance with the model coded by the designers into the software will ensure faster growth and more diversity, thus raising funds. The *SimCity* series favour an urbanization type very close to conventional representations of the North American city². The city in the *SimCity* series is an urban model, both as an ensemble of simple spatial rules and as an ideological representation of the flourishing city based on functional zoning and urban sprawl.

These choices are gratifying, because they grant more possibilities, so the player may tend to fold up the model even if he/she does not consciously understand it. On the other hand, those rules and regulations have to be sufficiently subtle so that the scope of winning strategies will not be too narrow. The player should not identify too easily or too quickly which strategies are to be led to win almost every time in order to ensure game length (Koster 2005). Consequently, one has to play a video game many times in order to understand its underlying model.

To test our different hypotheses, we analyzed the interactions between urban system models and game mechanics in some commercial video games.

VIDEO GAMES AND THE EMERGENCE OF HIERARCHICAL AND SOCIO-SPATIAL DIFFERENTIATION

We focused on city builder and strategy games to examine the self-organisation and the emergence of hierarchical, functional and socio-spatial differentiation through bottom-up and top-down interactions. These two categories of video games involve multi-level urban development and offer great flexibility for experiment³. Then, we set a typology of the outcoming urban structures in the selected video games to show that, despite some similarities, they rely on different modelling choices and different representations of urban areas.

Strategy games and city builders are the two categories of video games that most closely reflect geographical issues (Ter Minassian & Rufat 2008). In the former, played at the scale of an urban system, a continent, or even an entire world, the player must control the land and resources in order to win. Game mechanics are directly inspired by traditional wargames; geography is about “making war” (Lacoste 1979), and space is mainly presented as a battlefield. In the latter, the game is played at the intra-urban scale, the player acts as both the mayor and the urban planner⁴. For the

² One can also take the example of the *Grand Theft Auto* series (Rockstar Games 1997-2008), although they are not city builder's games. Although these games allow the player to act as a criminal, they re-enact the values of the Western legal system by teaching him the futility of crime (Chess 2005).

³ This article will not discuss multi-player games, because they present specific issues due to their game design (particularly in the case of “persistent worlds”) and the socialization contexts in which players interact in the game.

⁴ City builder's games are sometimes called “god games”: the player with his overhanging vision of the playground and the capacity to freeze the in-play time acts more as a god than as a mayor. But this is not a specificity of city builders.

geographer, the distinction seems relevant; geography is about urban planning, and space is a kind of territory that the player must urbanize from scratch. The video games on which we focus can be sorted in two groups:

- Open-ended games with no clear goal, in which the player can build a city by controlling planning, budget, transport, etc. The atmosphere and graphic representations may change from game to game, from Antiquity in *CivCity Rome* (2k Games 2006) and *Caesar IV* (Sierra 2006) to Western contemporary urbanism in *SimCity 4* (Maxis 2003) and *City Life* (Monte Cristo 2006). The similarities and differences between these games allow the identification of basic trends in the simulation choices as well as in the attempts of designers to make games more original than their competitors.
- Strategy games with an explicit goal: to develop an urban system in order to master resources and to slay opponents: These games repeat the same simulation principles but for an entire country, as in *Civilization IV* (2k Games 2006) and *Rise of Nations* (Microsoft 2003).

A cross-study of all these games allows varying the analysis from the intra-urban micro level to the networks of cities macro level.

Micro-management, from the meso scale to entire countries

The examples of *City Life* and *Civilization* show that video games can simulate the emergence of structures at various scales: from urban structures to the organization of full city networks.

In *City Life*, the player must ensure the social cohesion of the city, but the underlying definition proposed by the game mechanics in *City Life* is clearly problematic, far closer to social segregation than to social mixity. Social cohesion, along with competitiveness and governance, has become the new *credo* of mayors, public authorities and urban planners since the beginning of the twenty-first century (Gordon & Buck 2005). Social cohesion is a key component for a successful urban growth, although it can take multiple definitions (Parkinson & Boddy 2004). Indeed, the main interest of the video game *City Life*, graphically close to the *SimCity* series, is to promote social cohesion by considering the inhabitants' social profile as a genuine parameter. There are six profiles: elite, yuppies, white collars, artists, blue collars, and unskilled workers. The player has to guarantee the pacification of their social relations through physical separation, although they have to team up at their workplace. Indeed, it is not enough to build cities uniformly occupied by some yuppies or to separate homogenous neighbourhoods by several kilometres of buffer zones as in other city

Other games actually offer to play a divine character, as *Populous* (Bullfrog, 1989) or *God of War* (Sony Computer Entertainment, 2005).

builders. Development is based on companies that require the collaboration of several types of social classes.

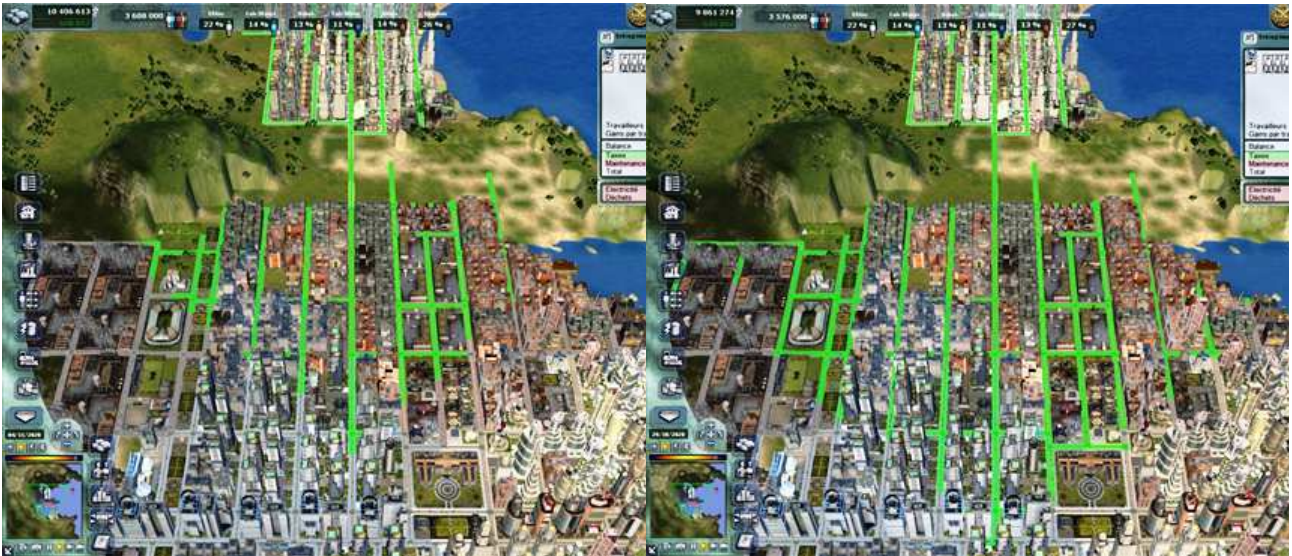


Fig. 3: Accessibility in City Life (2006). Increase of the employment zone of a single company (in green) when shifting its connection to the city from a 2-line road (left) to a 4-line highway (right).

Thus, the evolution of employment across the whole city has effects on the local demand for housing. It is a top-down retroaction. Furthermore, the effect zone of any building is determined by its accessibility, which varies according to the transport infrastructure type. A plant or a company located too far does not succeed in attracting employees, even if its attractiveness can be improved through higher level infrastructures (Fig.3).



Fig. 4: Urban segregation in City Life (2006). The organization of the 6 classes in more or less homogenous zones (left) and a zoom on a building at the border of two zones (right), with “intellectuals” (little men in red) and “unskilled workers” (in black) annoyed to have to coexist.

In *City Life*, the spatial proximity of two communities automatically generates conflicts, called “cultural tensions”. Tensions appear as soon as different populations coexist in contiguous housing, but not at their workplace⁵. The game is based on bottom-up retroactions. Each social class has specific needs in terms of jobs, leisure and equipments. At the scale of each neighbourhood, the localisation of companies, services and leisure is therefore a powerful tool to shape the socio-economic fabric. This leads to the social segregation of the entire city, which is also a spatial segregation by neighbourhoods (Fig.4). Thus, the game generates a segregated city through micro level interactions, according to MAS derivate from Schelling’s model (1978), as proposed by Batty (2005), and taking networks into account, as suggested by Banos (2010).

In the *Civilization* series, the player is the leader of a country called “civilization” and has to ensure its development from 4000 BC to present. Player actions are conditioned by the cities’ performance, measured through manufacturing output or wealth. City development is therefore crucial in the success or failure of the game. The emergence of a national, hierarchical, and specialized urban network relies on the actions of the player which intervene at multiple and intricated scales, from the micro-scale of the cities to the international scale of the geopolitical relationships between “civilizations”.

In *Civilization*, each city controls a production area (Fig.5). The more resources located within its production area, the better they are used, and the more powerful the city becomes. A first specialization level begins at the micro level: a city that has many mineral resources will benefit from specializing in industrial development.

At a higher level, the player must consider the best options for national territory development. A compulsory minimum distance avoids overlapping production areas (Fig.5). The regulations of the game discourage significant distance between cities: a huge territory is harder to defend; transport infrastructures are more difficult to build; and each city’s productivity is inversely proportional to its distance to the capital city. Players are free to build roughly the same equipment in all cities, but regulations lead to specializing cities, thus saving resources. For example, environmental determinism is a strong regulation toward specialization: industrial investments will be more effective in cities near mineral resources, and rivers and ocean will favour commercial activities.

⁵ It was not possible to reveal the exact algorithm that manages those social tensions. Our testing established that tensions spring up as soon as two different classes coexist in the same building or in contiguous housing. The more these populations are different and numerous, the faster conflicts become violent (from quarrels to riots).

Moreover, it is possible to place the national stock exchange in the smallest city, but this is utterly counterproductive. It is better to build it in the wealthiest city in order to maximize funds and use them to develop other cities.



Fig. 5: Cities' network in Civilization IV (2006). Each city controls a 21 cells production area (left), the model and regulations lead the player to specialise cities and to create a hierarchical cities' network (right).

Finally, international geopolitics is a major factor with a direct impact on the micro or urban scale. Degraded diplomatic relations can incite the player to strengthen his defences in border cities. This may lead to increasing the density of the local transport network and to constructing military equipment and infrastructure at the expense of economic growth. Eventually, cities are progressively specialised into a hierarchical network, depending on their size and their functions (Fig.5). The results appear to be convergent with the Christaller's model, despite the environmental determinism of the game's model (Fortin *et al.* 2006, Ter Minassian & Rufat 2008).

Distinct spatial differentiations according to modelling choices

Previous examples have shown that video games tend to model the emergence of identical geographical phenomena. However, a more detailed analysis highlights dissimilarities between video games. For example, three types of urban hierarchical organization and functional differentiation can be observed according to modelling choices: centralized, tiered, polycentric.

In *CivCity Rome*, the game's model and regulations determine the emergence of a centralized urban area. In this Roman Empire urban simulation, the growth of cities is based on equipment, amenities and services proximity (e.g. barber, school, temple, etc.) and certain products availability (wine, olive oil, etc.). The more diverse products to which inhabitants have access, the higher they climb

the social ladder, which is graphically shown by the improvement of their dwelling. This improvement is also rewarded by an increase in local taxes levied; they will directly feed public funds and hence increase the player's options. Like in *City Life*, product availability and services proximity depend on the accessibility of catchment areas (mainly markets) or equipment, measured by Euclidian distance and by the presence of roads. In order to get the most cost-effective outcomes and faster development, the player needs to favour neighbourhoods where the first signs of quality emerge. In *CivCity Rome*, the distance is tied to dwelling: the better a house is, the further its residents can travel to obtain products and services (Fig.6), thus accessing more diversity and increasing their chances to upgrade again. This creates a positive feedback loop: the presence of a wealthy population encourages demand in higher level amenities and products, to which the player responds by developing them, in turn consolidating the emergence of wealthy neighbourhoods, all increasing financial revenues and player possibilities. A centralized urban area emerges, because regulations make the player concentrate its efforts in areas that are already well equipped and supplied (Fig.6), especially since the game allows the player to move houses to the best equipped neighbourhoods.



Fig. 6: Centralized urban space in CivCity Rome (2006). Dwellings near the equipments concentrated in the centre upgrade (left), and the better a house is, the further its residents can travel to catch products and services (right).

This process is related to the choice of designers to base the calculation of accessibility on the position and the quality of the housing in an urban area. This generates an organisation in concentric areas, with higher-ranking equipments and services located around the most luxurious housing, while those of lower rank are found on the outskirts, surrounded by the poorer dwellings.

In *City Life*, a few settings are enough to model from a blank game map a city with socially differentiated neighbourhoods, sometimes separated by buffer zones, and with a central area concentrating social diversity. The game is based on a subtle balance between spatial proximity and urban segregation to ensure both proximity of a diverse labour force for each type of activity and social homogeneity inside each neighbourhood. The emerging organisation stems from the definition of centrality as both a dense and socially diverse area' this diversity can only exist around specific equipments: city hall and cultural centres. The cultural or neighbourhood centres have a smaller effect radius than the city hall, which is always the first building to be found. The result is a city polarized by a few hierarchized centralities, ensuring density and diversity, at the fringe of the homogeneous zones (Fig.7).



Fig. 7: Hierarchical urban space in City Life (2006). Dense and diverse central area around the city hall (left) and smaller centrality spot around the nearby “cultural” centre (right).

The same is true for *Caesar IV*, although the modelling is based on different factors. In *City Life*, hierarchical differentiation and socio-spatial segregation emerge from the interaction of residential choices and amenities distribution, which works because all dwellings are potentially available to all inhabitants. In *Caesar IV*, however, there are three types of dwellings which correspond to the three population categories (plebeians, equestrians, and patricians). Each type must exist in sufficient number in order to accommodate the labour force needed by the developing city. The spatial distribution of these different housings leads to emerging properties such as urban segregation. Collective facilities such as hospitals or baths are suitable for all population categories, but recreation is indispensable for patricians. Urban space tiering stems from the distinction between common devices and markets, which form the city’s core, and specialization of higher rank housing and amenities for each population, which are structured in poles of variable importance.

Conversely, in *SimCity*, the measure of distance is tied to amenities. During the game, interactions between land zoning (housing, industrial, and commercial) and distance to amenities and services first generate concentric urban areas, as in the Burgess model. Depending on its level of development, the city can then be structured in multiple kernels, as in the model of Harris and Ullmann, and some edges-cities may emerge (Fig. 8).



Fig. 8: Polycentric space in *SimCity 4* (2003).

During the game, the consolidation of this polycentrism is ensured by progressive provision of equipments or specific amenities, which ensures a sometimes-considerable attractiveness bonus for the spots located in their area of influence. Since *SimCity 4*, high-ranked amenities must be unlocked, for example, when the city reaches a certain population size or level of education. This new system allows the player to accelerate the emergence of a hierarchal and specialised urban area around the different levels of centrality generated by the presence of these particularly attractive amenities.

Observing the emergence of different urban hierarchical organization and functional differentiation, resulting in European, North American or hybrid situations, seems very close to the exploration of urban simulation models. For example, the agent-based *Urban Economics model* (Lemoy *et al.* 2010) includes choosing the location of different amenities and adjusting the inhabitants' utility functions in order to monitor the resulting city structures. Playing games and exploring or fine-tuning models require the same operations: locating amenities, monitoring self-organisation and inspecting the emergence of urban structures and segregation. Moreover, the limitations admitted by this model's designers are actually addressed by video games: vertical growth, spatial competition

between firms and household, impact of transportation network, etc. Video games can appear as more complete representations or more efficient models of urban life. So, what does that mean that video games can be used to explore possible future issues in complex urban systems?

THE LIMITS OF USING GAMES AS MODELS OR SIMULATION TOOLS

Obviously, it is possible to have fun exploring models and video games present convergent results with simulation tools; they even seem to go one step further. However, the use of video games as simulation tools has some limits. First, the code of video games is protected by intellectual property, and only few settings of the software are editable. Second, other limits arise from the aims, practices and user possibilities in video games.

Playing a game is not conceiving a model

The video game market is highly competitive; the legal protection of the code restrains the precision that may be reached in the analysis of modelling processes. Only explanatory factors and some mechanisms can be isolated, not the exact algorithms underlying them⁶. However, online forums publish reports of experiments by some players trying to understand the underlying models of their favourite game in order to improve their strategy⁷. Some video game settings are editable, but players cannot intervene in the core-code of the software, which is held by designers. For example, the very definition of centrality is hard-coded in the games' software and seems to vary depending on designers' culture: in *SimCity*, the central criterion for the American designers was density, whereas in *City Life*, the European designers considered both density and diversity. As a consequence, the players who do not have access to the core-code of the game are not in the same position as scientists designing models.

Even among apparently similar city builder's video games, *City Life* has a social focus, offering to micromanage different populations' localisation through activities and amenities. *SimCity* has an economic focus, allowing to manage activities through transport infrastructures, amenities and differentiated tax levels. Players can change some rules and parameters or fine-tune the model through patches, but they cannot make one game behave as the other. Only game designers have full access to the underlying model. Both video games and modelling can lead to a reflexive approach of urban processes and to adopt the "what if?" experimental posture. Game design can be

⁶ Nevertheless, the core-code of the first edition of *SimCity* (1989) has been edited online; the GPL open source code version is called "Micropolis": http://www.donhopkins.com/drupal/taxonomy_menu/4/49/66

⁷ See for example on the first American on-line fan site dedicated to the *Civilization* series: www.civfanatics.com.

compared to modelling; game patches and mods can be associated with calibrating and fine-tuning the model. However, playing a game is more similar to exploring the model. Moreover, designing and exploring models rest on almost opposite man/machine interactions.

Self-organization theories stipulate that observable structures at a specific scale emerge from interactions between elements at a lower scale. Simple mechanism repetition produces relatively complex organized structures, without an intention to create them (Allen 1997). In a self-organised model, the user sets the starting parameters and fine-tunes the model, but simulation is what supports the dynamics of evolution over time (Pumain *et al.* 2009). Conversely, players can rarely set up the starting parameters and reshape all rules and structures of the game's software. Players' choices only lead them to explore the model, introducing the time dynamics and taking part in feedbacks and bifurcations of the system, without changing initial conditions.

In a video game, the model moves toward the stabilisation of urban structures. However, if spatial differentiations seem to emerge naturally from the interaction of agents and phenomena occurring at different scales, then player choices are oriented toward the emergence of specific socio-spatial structures. So, intentionality appears to be a serious issue in both video games and modelling: once targeted, a behaviour or a property is no longer surprising. The intention exists, from both users and players, to reach hierarchical differentiation and the emergence of socio-spatial new properties. In some sense, once modelled and simulated, a system is thus no longer complex. However, it is trickier in video games, because the main intention of the player may not be to understand or to explore the model.

Beating the model or winning the game?

When playing a game, players are induced to have fun and to try to win the game. Even in open-ended games with no clear goals, players are challenged by emerging problems and swayed to define their own goals in order to make the game more fun or more awkward. Solving the game or simulation is supposed to provoke pleasure (Koster 2005). Paradoxically, video game players cannot do everything; their possibilities are conditioned by goals, rules and regulations. Goals and regulations specific to each game bond players' choices; they push them to learn the model. Therefore, players may be seen as agents rather than as actors⁸ of the simulation (but not of the game). For example, in *SimCity*, the sudden merging of the high-tech industries is dependent on a set of factors (level of fees, average education and health of the inhabitants, crime rates, etc.) on

⁸ Borrowing to sociology and urban studies, the "actor" designates an individual who possesses independent power of decision, whereas an "agent" designates those whose decisions are bounded for a more or less long time (Touraine 1984, Passeron 2001, Lévy & Lussault 2003).

which the player can indirectly act through the game. Players can try to master those parameters in order to facilitate the high-tech industries' emergence, but their choices are mainly determined by their will to reach some goals or to win the game⁹. In other words, the players are themselves played by the game; they are induced to discover, learn and fulfil the underlying model.

The modelling proposed by a video game requires relentless vigilance from its user to constantly adapt choices to the outcomes of the software. This reflexive decision-making process is the key to video games. It conducts the game simulation toward the emergence of hierarchical organization, functional differentiation and social segregation. It also stimulates the didactic power of games: players have to explore their possibilities in order to learn the underlying model and then adapt their choices. In turn, it generates almost immediate gratification, provided that the user/player controls the main mechanisms of the game, which in turn creates the pleasure of playing a video game. Thus, as when exploring a model, there are two different ways of playing a game: by experimenting all possible actions and reflexively observing their outcomes, as when fine-tuning the parameters of a simulation, or by studying what other players have discovered and achieved, as when extracting from surveys the attributes of a model's agents. Nevertheless, the game's goals and regulations lead the player to understand the model, perhaps to learn it, but clearly not to improve or to challenge it.

How are arbitrary choices made?

Video games and models are representations. They rely on arbitrary choices and intuitive rules to offer simplification of some reality. Video games are designed to be challenging and enjoyable over time. According to Sid Meier, designer of *Civilization*, "a game is a series of interesting choices" (Rolling & Morris 2000: 38). For both video games and modelling, the simulation relies on arbitrary parameters or structures that may not reflect, or even try to reflect, reality. The difference is that in the case of modelling tools, those structures are (or at least should be) designed to bring new knowledge or new understanding (Pumain *et al.* 2009). There is also the common assumption that arbitrary implementations should be explicit (Batty & Torrens 2001). Conversely, in a video game, the reason to establish, for example, the power law $(\text{income})^{3/8}$ is that it works fine to balance the game and keep it entertaining and challenging. This arbitrary choice is not apparent to the player; it is buried under the code.

⁹ In some cases, it may be assumed that some settings are deliberately left aside. In *City Life*, if the program took too often into account the presence of some communities in the vicinity at the very moment an inhabitant installs, there would be too high inertia of the social composition of the city, therefore an uninteresting challenge proposed to the player, and actually little interest in the game. Thus, there is a necessarily arbitrary search for balance between the various factors considered, in order to avoid both boredom and frustration, which is critical for game designers.

In order to balance a game, game designers suppose that the player is a *homo æconomicus* (Smith 2006), that is, a rational agent making best use of the information at hand and trying to maximize his/her gain. This has several limitations. First, not all players behave in a strictly rational manner. Some players do not aim to beat the best score, reach the maximum level or rush to finish the game. Thus, the examination of all possibilities (and their consequences) present at a certain time is difficult in practice; the rationality of agents is therefore bounded (Simon 1956). Also, if regulations are too strong and limit possibilities too much, then players may be frustrated or discouraged by the game. On the contrary, if the regulations have no effect or very little effect, then they break the interactivity and turn the player into a spectator. When extreme, effectiveness and regulations may kill the game, but this threshold is probably relative and may vary from one player to another (Juul 2005).

When designing video games, arbitrary choices and intuitive rules are not meant to simplify some reality or to bring some new understanding; they are designed to ensure player's entertainment and the game length. For example, game balance is used to prevent a choice or a strategy from becoming prevalent, according to the rock-paper-scissors principle (Rolling & Morris 2004), or to favour cooperative behaviours (Smith 2006). Generally speaking, player's sanctions, from point loss to the death of characters and game over, is destined to challenge player's choices and strategies in order to make players confront new challenges, which prolongs the gaming experience (Juul 2009). Furthermore, many of the arbitrary choices made by designers are strongly ideological (Bogost 2008).

Finally, the main difference between modelling and video game is their goals. A game aims to be fun and entertaining, while a model aims to produce knowledge and engender debate. In short, game mechanisms guide player actions without accordance to any spatial model.

Conclusions: are video games really one step further in modeling?

Video games are generally a good approach to complex systems, by stressing feedbacks and retroactions that the user must understand and control. They use classical models and may have didactical applications. They even appear to go one step further than models and simulations used by scholars.

Besides their graphic qualities, video games may be seen as more complete models than existing simulations. Video games appear to be less caricatured simplifications, because they take into account vertical growth, transportation networks, spatial competition, firms, households, environment, etc. Featuring all of these interacting elements at once makes them more efficient

models. This can be illustrated by their implementation of the environmental framework. Video games take into account a wide range of topographical or environmental effects. They constrain constructions and networks as well as the availability of natural resources (*Civilization*). Inversely the presence of rivers facilitates trade (*Caesar*) or offers recreational opportunities (*SimCity*, *City Life*). The *SimCity* and *Civilization* series offer a specific representation of the environment, in which natural determinisms remain strong, and human technology is always triumphant. The environmental framework is malleable virtually at will: its presence in the simulation is mainly cosmetic. A belief in the advance of technology in order to overcome natural limitations, following a technicist vision of human evolution (Baark & Svedin 1988), underlies all of these games. In *SimCity* or *City Life*, for example, to flatten land is very inexpensive, and the environmental framework has no landscape or hedonic value¹⁰ (a private housing estate will not have higher value on a hill with a beautiful view over a river). The physical environment is mostly considered as available land to be urbanized.

This stresses the most essential difference between video games and simulation software: they implement rules and models using nearly opposite methods. Complex systems models are difficult to validate, which is why models and simulation are constructed in an explicit way. Conversely, in video games, most of the simplifications remain hidden to the player, and the underlying models are not explicit; rather, they are buried under the core-code of the software. Players have to discover the rules by exploring the different outcomes of the game in order to establish their own strategy. This is supposed to induce pleasure from the game. However, it is possible to solve the game without taking full notice of the model.

As Krugman puts it, models are metaphors, not truth (1997: 80). The same can be said for video games, even the most realistic city-builder games. Indeed, video games are squared spatial representations and metaphors whose main purpose is to induce pleasure. They are appealing because of their graphic qualities and appear as less schematic simplifications because they feature more interacting elements at once. Moreover, playing at city builder games can lead to a reflexive approach of urban dynamics. This is why urban studies scholarships have recently employed video games.

However, the main limitation of using video games in research emerges precisely from their didactic power: models and rules remain hidden, to be discovered by the player's explorations. In short, video games and simulation software implement rules and models in almost opposite means. Therefore, the game may induce the players to learn the model, but not really to understand it or to

¹⁰ If the presence of trees arises the value of the adjacent land, it is because they contribute to limit pollution, and not for themselves. This is why in *SimCity* an urban park is a more "efficient" amenity than a forest. Furthermore, players may consider their city on aesthetic criteria, but this is not part of the game.

produce new knowledge. Nevertheless, video games could be an invitation to reinsert human factor into models, particularly for online games which rely on interactions between many players. The difference between *City Life* and Schelling's model is the introduction of player diversity as a new uncertainty level; the range of their reflexive behaviour may add a political constraint to the model. Could "serious games", i. e. video games explicitly developed for educational purpose, be the solution? They are already the result of this apparent convergence between video games, models and simulation tools. The response is not so easy. Indeed, the design and exploration of serious games rely on practices other than those related to commercial video games (Alvarez *et al.* 2011). Furthermore, playing is always a serious activity. The software called "serious games" often fail on all accounts: they appear as less compelling, and few studies have shown that they may have better didactic power than commercial video games.

Ultimately, the apparent convergence between video games and urban complex modelling seems to result from the desire to replicate the graphic appeal of video games. It is more a question of making these tools fun in order to widen their public and to sustain the development of simulation software. Even the most powerful or innovating 3D engines bring no new knowledge to their users. Nonetheless, certain resemblances between the design of certain simulations and former video games are striking. For example, many models and simulations of urban growth or segregation have categories close to *SimCity*: three types of population (poor, average, wealthy), a strict zoning (residences, sometimes services and industries), the same kind of amenities, etc. This account leads us to question the possible cultural transfers, conscious or not, between video games and simulation software. If you are using urban models and complex simulations and also playing video games, please feel free to contact us!

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