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Space is the Machine, with a Ghost Inside

Agents and space in an urban model

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Abstract: The purpose of this paper is to report efforts towards the construction of a model for urban spatial dynamics simulation, based on multi-agents and space. The underlying idea is to have urban space producers and consumers operating in a two-layer, two-circuit model. The first layer holds urban space and its successive transformations; a second layer contains agents related to space; the first circuit simulates space production, and a second one simulates space consumption. Relationship between layers is represented as objective spatial features that agents are submitted to (the machine) and subjective meanings agents attach to each spatial feature (the ghost). While space works always in the same way, meanings vary according to each agent's background and context. Relationships between circuits are represented by means of a market game in which producers try to maximize their profits by gambling with their risks, whereas consumers try to foresee the spatial distribution of local externalities that maximizes their utilities and investments. Urban Spatial Features are captured through centrality and land use patterns; every single agent's action leads to changes in both patterns. Producers' profit is a function of built form location. Consumers' local externalities are concerned basically with present and future services. The model iteration is twofold: first it generates and allocates a number of built forms within a previously determined spatial system (a cellular matrix, for example), and second it allocates users to built forms. Population of users have its social profile and growth rate externally determined. Built form allocation is decided on the basis of a combination of profitXrisk perspectives. Users' locational choice is supported by accessibility to services and present/future neighbourhood profile. Built form allocation works as parameter for users' locational assessment, whereas users' choices are used as parameters for developers. The model tends to adjust itself, in terms of quantities and types of built forms to be erected, although through a market lag of some iterations. Allocations are always made through weighted draws, so that mutations (non deterministic allocations) do occur.

1. INTRODUCTION

The latest developments in urban modelling follow one of two trends: space or agent based theories. Space based models suppose that space is somehow structured, and such a structure not only creates its inner hierarchy, at each moment in time, but also drives its changes through time. This means that spatial systems have their own transition mechanisms which are only activated by external stimuli, and eventually modified by individuals or social organizations, but remains as the main driver of change. Social agents, in such a context, are quasi automata individuals that, guided by their rationality and self-interest, end up by embodying spatial properties as 'laws', slaves of an unwritten code of spatial behaviour. Agent based models, on the other hand, tend, so far, to assume space as a container inside which agents develop their interaction. Agents do have all this ability to assess and act, to learn and to move along, provided that spatial barriers and adjacencies are observed. Thus far, agents interact with each others in space, and do so by accounting for spatial constraints, but not with space.

Interaction with space is one of the most relevant aspects of agent action, to the extent that space production/transformation embodies a fair part of human initiatives, as well as creates new framework for other sorts of inter-agent interaction. Space usually is a costless resource with which agents count upon, unless it becomes too little for a growing population; when it happens it is the population that is somehow transformed and not space. Short-term processes are consistent with such a framework (flows, activity location, etc) and probably better developed within it. Long-term processes however can't ignore spatial change and, although space based models seems able to provide sound basis for, say, growth simulation, more subtle aspects of inner-urban transformation remains uncovered.

Most human urban decisions are taken assuming a certain spatial configuration, either those more static, such as locations, or those more dynamic, such as movements and individual or collective activities. Such a configuration consists of specific social attributes assigned to certain bits of space, so that space becomes part of a signifying network of social issues. Empty cells, resulting from an activity of space production, or even modified, existing cells, just as the old, occupied and used ones attains part of those social meaning, altering the context upon which new decisions are made. New cells not only allow for new activities location but also prompt agents to reconsider old locations, settled down interaction patterns and daily movements. Space transformation is likely to affect perception and preference of virtually every agent, whose response to those changes will be only restricted by costs and competition.

This work will consider the context of a growing population that do two sorts of things: space making, or production, and activity locating, or consumption. Space making is a result of demand requirements, although it is developed as a profit seeking activity by many agents. Activity location is a result of an evolving scenario of social meanings spatially distributed, involving both agents newly introduced in the system and old ones, already familiar with it.

2. MODEL ESSENTIALS: SPACE PRODUCTION, ACTIVITY ALLOCATION, AND DIFFERENTIATION

Space production is carried out by agents called *developers* that seek profit maximization; under competition and similar production costs, their edge lays on location choice, as in the poorer locations is where the least expensive land are. A poorer location means, however, at the same time lower land cost and higher investment risk, so that developers drive their business by trading them off. Developers must sell their built form units (BFunits) in a real estate market that is where their feedback comes from. Particularly, they will be watching how those most daring locations' sales perform, in order to adjust their next production round: either they will repeat them and even stretch their limits a bit, or will step back to more central locations.

Thus far, developers enjoy a choice surface defined by location alternatives; assuming a simulation starting from scratch, there will be virtually no locational differentiation before the first BF allocation (just an empty cell grid). After that, however, hierarchy builds up under the form of a land value structure, and subsequent allocations should be strongly influenced by it. The expected urban form trend is a constrained fragmentation. The other choice surface available for developers is the BF differentiation, which could both derive from demand – a segmented socio-economic society – and arise from the space production itself, as a result of land value structure. The first case would generate BFs of different unitary values, whereas the second would generate different BF densities.

The complementary process is of activity allocation. All agents' locational decisions are based on two issues: spatial opportunity to services (for residents) or consumers (for services) and neighbourhood effect. It could be devised a range of different attitudes towards each factor ('near the services, but not too near'; 'near a sort of service but not others', or 'together this sort of people but that one', etc), steaming out of a segmented society, demanding a complex and heavy simulation process. Nevertheless, what is of utmost importance here is the idea that each agent's allocation decision is based on the decision of others, and frequently on the anticipation of others' decisions. Each new resident will choose its location trying to guess how that neighbourhood will look like, or in other terms, whether others will make the same decision and so contribute to the neighbourhood consolidation or not. To that extent, users will also have two concomitant choice surfaces to decide upon; although being somehow virtual, they are nevertheless the only support for decision.

A supposed early stage simulation would present a number of BFs placed around a territory, each of them representing a possible seed for further aggregation. In the absence of previous directions, services and even population, the first activity allocation will have only the BFs relative positions to help to decide, and in such a context, either it will be random if BFs are scattered, or will prefer those BFs that present some proximity to each other. Preference for eventually clustered BFs will prompt, on one hand, a urban pattern to emerge, and on the other hand, the reproduction, at a finer scale in subsequent iterations, of the same process.

In this way, the process of space production and activity allocation contains simultaneously centrifugal and centripetal forces, in which population flocks around clustered built form, services flocks around clustered residents; both together get reinforced land and location value structure, which spreads BFs around. Such a system could get very volatile, with people and services moving around endlessly, unless some rigidity is admitted. One rigidity factor is precisely the availability of BFs that limits the allocation process.

3. MODEL DESCRIPTION

The model has been thought of as a two layer, two cycle recursive model in which the layers hold the spatial base and the agents respectively, and the cycles allocate built form units on the ground and activities in the built form units successively. Its main features are:

3.1 Spatial Base (layer #1)

This is a cellular grid and an attached database, initially empty. Cells will have unlimited capacity for bearing built form units, although some BF<>CELL area relationship adds rigidity to simulations. Subsequently, built form units, defined as objects, will be added to the spatial base. Allocated BFs will be registered in the database as specific cell attribute, such as number, age and state (occupied, empty). Apart from local attributes, cells will have locational attributes as well: immediate neighbourhood and centrality indices.

3.2 Social Base (layer #2)

This is a virtual space that mirrors the spatial base and manages the activities. There is also a database in which agents – service providers and residents, all of them represented as objects - are mapped. Residents are distributed along a socio-economic scale, their initial number e subsequent growth rate are determined externally. Services are of three types, according to specific levels (level 1 local range, level 2 medium range, level 3 urban range), and are fed into the model proportionally to population. Ranges are measured as areas of influence determined by a radius from the cell under consideration.

3.3 Constraints

Trying to keep the minimum number of constraints, the model would still have to take into account the following constants, referred to spatial and social basis respectively:

Land / BF relationship: search for cheap land is one of the main drivers of the model, so the relationship between land and other components of a real estate investment is relevant. In fact, the equation "*costs = land + all-other-components*" has little elasticity and is very sensitive to the proportion of costs due to land. Considering that a land value structure develops together with the process of urbanization, land values will change (increase) in the entire system with every new development, the equation, in order to continue to match, will see its other variables change along it. This change could either occur in the unitary cost (more expensive BFs) or in global costs (more density of BFs). Land/BF relationship, in this way, will allow for differential distribution of densities, basically.

Cell / BF relationship: cells will have no limited capacity to bear BFs, so that any one could be occupied by a single BF unit or a number of BFs piled up. In order to save processing time during the various search procedures involved in the simulation, which relates each cell to a certain neighbourhood, cells could be thought of as capable to bear several BF units at the ground level.

BF ageing: opposite to land, whose value increases continually with development, buildings devaluate along time, creating this conflict between actual and expected rents. BF values will be decreased horizontally at a flat rate every iteration, and BFs beyond a certain age would be disposed off, opening ground for fresh development.

Developers, inhabitants and service providers: it is expected that the number of developers, as well as service providers will be automatically adjusted during the process, through the feedback procedures that are explained ahead. As the whole process must begin with the deployment of some BFs on the ground, developers come first; their number could be arbitrated by the operator or randomly determined inside the algorithm. Every new developer entering the system will have an initial production capacity that is supposed to grow up, or at least be maintained along the iterations. Initial population also is arbitrated or randomly determined. Service providers' nominal number is determined in relation to the total population; their actual existence, however, depends on performance (see ahead).

Growth rate: for the time being, growth rate is informed externally, either as a constant or as a new figure informed before each iteration.

3.4 Production Cycle

Each iteration is thought of as a three-step loop, where the first one allocates built forms on cells (production cycle), the second one allocates services, and the third one allocates residents inside the built forms (activity cycles).

The production cycle simulates the action of developers. Their action is prompted by the already introduced idea of risk/profit trade off; to this extent, each single developer is able to see and understand the entire spatial system, but do not know about each other's decision, so that their action is uncoordinated. The spatial system is apprehended through two factors: land value structure and built form differentiation. Land value structure arises from spatial distribution of cells over the territory and of built form units over the cell system, so that the value of every piece of land would change after any change occurring anywhere in the system; considering a growing system, land values will tend to increase. Land values, moreover, will grow exponentially in the most central locations.

Every land plot, on the other hand, will define a BF-limit type, which is that built form unit matching exactly the relationship land <> built form costs. Each land plot's limit BF type would be the one that satisfies the minimum viable proportion between land and total investment costs. In this sense, BF type is in fact defined as a unitary built form of a certain cost, considering cost as the sum of land and all other components and services necessary to erect it. It is called BF-limit because it is located precisely at the point where land cost is maximum and consequently profit is zero.

Developers will never locate an isolated BF type in its limit location. As a first alternative they will consider to move out to lower land cost locations; however moving out means to increase the risk of getting no buyer, so the move should not be too far out. The second alternative is to move in, increasing density; moving in depends upon certain conditions, such as his own business scale, as well as land value profile. Considering distributed systems that as consequence present a relatively flat land value structure profile, the movement towards the centre could be done without too much density increase, although every new development will make that profile steeper.

As a third alternative, developers could move out **and** increase density, which is doubly convenient, as foreseeable profit would exponentially increase, together with a risk decrease. Risk lowering would occur due to 'location invention', the process of creating an attractive new location by investing in larger scale built form clustered production. This alternative turns out to be the best one, and points towards a globally fragmented and scattered, although locally dense, sort of city. Considering many BF types coexisting and being produced in the same way at the same time, overlapping bands of different BF types will form and create the environment for diversity.

3.5 Activity Allocation Cycle

It helps to think of two different BF users: residents and service providers. Resident groups should differentiate from each other, mirroring the spatial and value differentiation occurred in built form structure. Resident individuals will prefer to locate themselves by other of the same or similar social group. Individuals entering the system will look for already established clusters of group-matching people; in the absence of such evidence, they will try to guess 'suitable' people of the kind will prefer to locate. Future social location is hard to anticipate, being the only possible hint the type and size of BF clusters already in place. Residents will shoot at the highest value BFs possible and at the most prospectively exclusive places available. In this way, locations of similar BF types will have similar probabilities to be picked up by residents, but those that are chosen first will have their probabilities to be chosen even further increased.

The other factor presiding residential choice is service provision; in order to examine this, let us first discuss service allocation. Services of different levels are defined by a certain radius taken around its location, representing each level's reach. Service providers will try to choose their locations in terms of maximum accessibility found out within that radius. Service providers will also pay attention to other services' locations, as service clustering increases everyone's catchment areas, as well as will prefer to be near high income social groups. To that extent, service providers, in the attempt to locate near of as many wealthy consumers as possible, as well as near other services, will provide a pattern of service agglomeration in the proximity of higher income, dense residential areas.

Residents do have varied levels of dependency towards services, generally inversely proportional to income, so that lower income residents will prefer to locate next to services, whereas high income ones will not care too much for that, or even will prefer to stay away. Proximity preferences, both for services and various income level population groups, will give the activity system both the attraction and repulsion forces already identified in space production.

Residents will also want to re-locate when their respective BF unit reaches an advanced age and their vicinity/service nucleus looses quality, particularly those in the higher income end. Built form ageing recording is a model's automated task and re-location can be triggered by a constant; neighbourhood quality is a feedback procedure, as described below. Different social groups will have particular thresholds for that purpose.

3.6 Feedback and Recurrent Automated Tasks

The system must be surveyed before every iteration for land cost structure; this is proceeded with the use of centrality model. Briefly, centrality model is a measure of spatial differentiation based on betweenness and built form that can be used as a proxy of land value distribution. The system's stocks must also be devaluated after every iteration, in order to appropriate the loss of value due to BF ageing. The whole system must be monitored for cell and BF occupancy, as well as BF particular values.

Developers will also survey the system in order to discover whether each one's BF have been occupied (sold) and which ones have remained vacant. They also want to know which BF type has been most successfully sold. Resulting from this sort of feedback, the following factors are determined:

- BFs not occupied are devaluated
- BF types most successful will be produced further; the ones not picked up by residents will not be produced in the next iteration
- Successful developers will have their capacity increased, the opposite occurring to those who fails to sell out their whole production. Developers will then grow, shrink and disappear from the system.

Residents will also want to know how each one's neighbourhood performs, and therefore will look at how updated the stocks are, how socially homogeneous it has been, and also how well served by services. Social homogeneity could be looked at from different basin areas (different radius) and also particular tolerance to other social groups. High-income groups will present lower tolerance towards the co-presence of other groups in the vicinity, whereas other groups will tolerate and even require some heterogeneity. Distance to service centres is also a matter of social group consideration, varying according to each one's dependency. Results of this feedback will derive the trend of high end, although ageing BFs being likely to be abandoned by original residents, opening room for lower income residents or services, who will increase social heterogeneity. Neighbourhood performance, or quality, is carried out through a search routine around each residential cell, according to a determined radius, in which occupation is registered and compared with previous measures.

Service providers must have their performance evaluated, in order to determine whether each one stays in business and grows, or decreases and disappears. This is measured through convergence, whose calculation is presented ahead, that considers how concentrations of services at particular locations, split resident location in different catching areas.

Summarising, the model is almost entirely defined in spatial terms, even the agents are very simple creatures who behave according to elementary spatial rules, or laws; nevertheless, as each one's actions are likely to generate externalities and to affect the others, the result is not a linear accommodation of people along the spatial rules, but a unstable system that changes constantly. Changes in the system are externally prompted by population growth, stocks ageing and eventually income changes, their causes, however, are internal ones. The magnitude and intensity of changes can be proportional to external forces, however their nature is entirely due to the system's own characteristics and dynamics. This dynamics are based on centripetal and centrifugal forces, as in Fujita and Mori (1997). Agents have limited learning capacity, represented by their ability to change behaviour as a result of a bad feedback; however changes are merely adjustments in risk (for developers) and tolerance (for residents) parameters.

4. MODEL DELINEATION

The process of model construction is still on the way; a preliminary version of it, containing some of the routines, has been published recently (Bordini et al, 2004), as part of a research on artificial intelligence. Its main parts and routines are the following:

4.1 Spatial Base

Within the domain of the spatial base layer there is an empty cell grid and a directory of built forms, also empty at the beginning of any simulation. Spatial base contains some basic assumptions, such as the constant relationship between land and built form, as well as between cell and built form ground areas. The grid directory will keep track of cell occupation, centrality and other attributes, whereas BF directory will control BF attributes such as type, value and status, as well as demand vector. Cell occupation refers to the number of BFs located inside it, and must register this both as a total number and as number of clusters. BF cluster is a group of BF piled up. Centrality is a measure of spatial differentiation adjusted to simulate land value distribution (Krafta, 1994). An empty grid attains very low levels of centrality, or even no centrality at all in the case of a *torus*, but will develop as built form units are located. BF type is in fact each BF value at the moment of its initialisation, actual value is the type updated after each iteration which will determine a time-related devaluation, as well as a possible devaluation due to lack of occupation. Status is related to occupation and activity, and has three possible states: empty, residential and service.

4.2 Social Base

Social base is organized in a grid that mirrors the spatial one, and will have directories to handle the agents. The developer directory manages each developer’s accountancy, which involves the location of each and every BF that has been built by him and is still unoccupied. These are, usually, the ones that have been produced in the latest iteration, and eventually those remaining unsold from previous iterations. It also involves the calculation of developer’s actual building power, established according to his performance in the previous one or few iterations; performance being taken as sales success, that can make his capacity to build up less or more BF units in the next iteration.

The resident directory keeps track of every agent who inhabits the system, in terms of location, and registers each one’s socio-economic profile. Service provider’s directory does a similar job, registering the location and level of every service providers. Level refers to a service hierarchy that should differentiate local scale, middle range and urban scale services in terms of reaching radius.

4.3 Parameters

The elements that should be informed before a simulation is set off, as required above, are land<>BF relationship, Cell<>BF relationship, service level categories and service<>residents relationship. Land<>BF creates a proportionality between the whole cost of a BF unit and the cost of its parts, particularly land. Cell<>BF creates a capacity for cell to bear BF juxtaposed horizontally, beyond which BF should be built up vertically. Service level categories specify which are those levels, while service<>residents will specify how many inhabitants are required for a service to exist. As it will be seen ahead, when the population reaches a certain number, services of different levels are allowed to exist. As for population, parameters are required to define relationship between socio-economic profiles and BF types, degrees of dependence of social groups to services and degrees of social groups' tolerance towards other groups.

4.4 External Vectors

The only external element to be introduced is population, both the initial and the additional fraction to be added up at each new round. Population should have a socio-economic profile informed, which could either come up as a distribution between two extremes or be informed before each iteration. Population composition is a key issue in here, because land values in a growing spatial system is likely to increase, and consequently, from a certain moment on, the land market will offer locations impossible to be occupied if the socio-economic profile is fixed, even considering high density developments at the most central ones. This could be solved either by considering a floating socio-economic scale that adjusts itself to the land value structure, or using an open-ended socio-economic scale that is updated when the population reaches previously determined figures.

4.5 Developers Decision Making Process

Developers are introduced in the system randomly, with building capacity equals one; the resulting space production will be adjusted by space consumption, and unsuccessful developers are expelled in the case of overproduction, or new ones will be introduced otherwise. Each developer should know the land value structure, which is calculated as a feedback after every iteration. They should also know which BF types demand has been larger than production and which locations were most sought out, all feedback procedures.

Decision on which BF type to produce is through a weighted draw-selection among the ones which demand was larger than supply. Having decided which BF type to build, developers have to decide where to do it, considering as reference the limit situation (the location where the relation land<>BF costs is limit). The outward option will be always the best, despite the risk involved, so the decision is about balancing profit and risk prospects. As profit prospect is a function of location and goes up as location goes out, the actual restriction to the outward movement is given by spatial contextual factors that could encourage or discourage it. Starting from the limit locations the cell system should be searched for existence of BFs of the same and higher types (positive factor) and of lower value types (negative factor). In this way, existing built forms of a certain type will prompt new ones of the same type to occur, and built forms of other types will prevent new ones of higher value to occur.

The procedure for space production simulation involves searching the cell system from the limit location outwards, looking for positive and negative signals of risk taking. A positive one will prompt the search to go on to the next outward cell neighbourhood; a negative one will stop the search.

In rigorous terms, locations are unique, so there will be as many BF types as cells in the system, although in practical terms little differences can be relaxed by adjusting the precision with which land value structure is calculated. In this way, land value categories can be formed and a clearer BF type structure of as many type categories as desired is also obtained. Developers will make their search of an acceptable location from a randomly selected limit location.

Between the limit location and the reference that has stopped the search will have a number of cells, encompassed by a radius of *n* steps, which comprises the field inside which location is to be carried out. In such a field, the existing BFs of the same type are positive attractors, whereas the limit location and lower type BFs are the opposite. All empty places comprised by the field are valid options for location. Within the valid options, the actual choice is carried out by submitting the land cost to the parameters of attraction. Positive and negative attraction parameters work as land cost multipliers that regulate each developer's willingness to take risks, and will be adjusted after each round according to the demand behaviour.

Attraction and repulsion parameters can be interpreted as the social preferences, or prejudices of groups towards other groups, although it has a clear economic rationale. In effect, residents are also small real estate investors and their location decision, despite its utility, is first of all, an investment decision. The parameters also represent the gambling factor involved in the space production. Parameters are adjusted from one round to the next by market performance of each BF unit and BF type; developers will be encouraged to risk further if their previous gambles paid off, and otherwise if not. Decision on space production is taken by all developers, over many BF types, simultaneously, so that the resulting pattern is an overlapping allocation that changes not only the land value structure and the local factors for the next iteration, but also can affect the activity allocation in the same iteration, as unintended spatial patterns, involving concentration/dispersion of built forms and neighbourhood formation, can be created.

4.6 Service Providers Decision Making Process

Services have precedence over residents in the simulation due to their more competitive approach to location, despite services coming along after residents. In this way, services allocation will be proceeded first, even though it will fail in the first simulation rounds. Provided that the population size is big enough, service units of various levels will be allowed to come into the system. References for locational decision are, in this case, accessibility and proximity to high-income residents and other services' locations. Accessibility can be measured according to different radius, so that each service level will have a particular probability surface in which places highly accessible will hold higher probabilities to be picked up. Similarly, places already holding service units, as well as wealthy people, or next to those that are, also hold higher chances to be selected. A draw-selection, weighted by those three factors, will define where each service unit will be placed. A partially random selection, in this case, will represent both the agent's common sense and inventiveness, as the majority of location decision will fall on 'right' cells – those which really have accessibility and vicinity qualities – although some are likely to fall on unexpected locations.

Vicinity factors are multipliers applied on the accessibility surface, so that they are able to cause minor changes in the probability field on which location is decided. Such a factors are likely to be more relevant for local and mid range services than for global ones.

4.7 Residents Decision Making Process

Allocation starts from the high income residents, who will search the system, first, for homogeneous suitable social groups, and alternatively, for suitable BFs homogeneously grouped and away from lower value ones. Services also should not be included in the tightest buffer (same cell or immediate vicinity). Other lower income resident classes follow, constrained by fewer clauses related to co-presence and more attached to service location. Lower income groups are the more service-dependent ones. The resulting trend is expected to provide a pattern of group homogeneity more or less exclusive according to income.

Residents aiming for re-location will be considered as active part of demand, in the same conditions as newcomers. They get such a status through feedback evaluation of neighbourhood quality; each income group will have a threshold denoting the tolerance to environment quality. Different from service agents that are created inside the system as a function of population size, residents are input externally, so eventually some could not be allocated at all, and should be kept in a pool, waiting for the next round.

4.8 Feedback

Network search is the basic procedure for feedback, applied to different situations. Developers require updated knowledge about land value structure, BF location preferences per resident group and unattended demand. Location preferences are simple BF attributes, recorded in the proper directory; the same goes for unattended demand. Land value distribution can be represented by a measure of centrality. Centrality is a measure of spatial differentiation based on public space configuration and distribution of built form and activities (Krafta 1994). Spatial differentiation is obtained by searching minimal paths between every pair of spaces and finding out which spaces are central to each pair, considering each space's actual built form and activity loading. Although for real, usually highly irregular urban grids, this procedure is hard and timing consuming, in a cell grid, it turns out to be quite simple.

Minimal path search happens to be a standard procedure for some other feedback routines as well, such as convergence, accessibility and neighbourhood homogeneity identification. Convergence is a sort of spatial opportunity measure, seen from the viewpoint of service providers' locations, for it searches the spatial system taking ordered pairs of service-residence locations and considering all other services locations (Krafta 1997). As convergence simulates the distribution of consumers among all service providers, according the their relative position and size/complexity, it can be used as a feedback evaluation for service performance.

Accessibility is also a configurational measure based on minimal path search that, applied on regular grids, measuring distance as adjacencies, is quite simple. Neighbourhood properties is a simple search for certain attributes within a given radius or distance.

5. MODEL FLOW

The model iterates, and each iteration is a loop of few intermediate allocation procedures and feedback searches. The first and most important/complex iteration leg is *BF allocation*; it starts by checking whether there are developers enough in the system. "Developers enough" means an overall building capacity (all existing developers added up) to match the unattended demand. In the first round, as there is neither unattended demand nor developers, some of them are created randomly. Developers will check the land value structure, as well as locations and BF types' performances. As many BF types can perform positively in the previous round, a surface of probability can be created for developers' BF choice, based on the proportion of each type's occurrence.

Developers will draw-select a BF type according to that surface of probability and then find their correspondent limit location set. From the limit location set, a cell is selected at random and a search outwards is performed, for similar and dissimilar BF units; similar ones will prompt the search to go on; dissimilar ones will end it. Locational decision is proceed as described earlier on.

The second leg deals with activity allocation; service providers will enter the system proportionally to existing population, according to levels; first level services are local, will have a limited reach and relate to few residents, in the opposite end, third level services are global, will have unlimited reach and require large population. The system will check total population and create as many service providers as required. New services will be located according to the procedure already described (accessibility and vicinity factors), from the global to local level down to the local ones.

Residential activity allocation comes next, from the high to lower income groups. Newcomers and residents wishing re-location will be located by running the respective procedure, that involves to combine group and BF type searches with social parameters – those that relate social groups to others (co-presence tolerance) and to services (dependence).

After each allocation round, the feedback procedures should be run and all directories updated. Resulting from it, each resident, service provider and developer should be aware of each one's actual situation in the system – housing quality, business performance, building capacity, etc – and therefore can develop the strategy for the next round. Strategy development means, for residents, either to stay in or to move on to new location; for service providers, either to go on, keeping the same level of service or growing up, or to shut down, and for developers, to adjust their risk/profit parameters, as well as to choose the type of buildings to develop.

6. FINAL COMMENTS

"*Space is the machine*" is the name of a Hillier's book in which, and after having developed the thesis of the social logic of space, the distinguished author practices a more structuralist approach to space. This idea, further developed in the paper "A theory of the city as object", suggests that urban space, apart from embodying cultural dimensions of society, works as its mould, to extent that land use and co-presence are somehow determined by it. In this way, the expression *machine* is used in an ambiguous sense, meaning at the same time something that society can drive, but also something that imprison it. Spatial configuration becomes a social expression, but, disappointingly quite a predictable one; cities are one means to say how society actually is, but what comes out of it is the message that we are slaves of short X long lines dichotomy. This article has taken – and mended – the expression "space is the machine" to suggest that maybe social actors have more choice and consequently the city has an open future. To this extent, the conceptual model attempts to represent spatial determinations not as laws that are out there to be complied with, but as constraints that can be -and usually are- manipulated by agents in different ways in different situations.

As far the model itself is concerned, one first question it let to arise is about the centre. Considering the developers' logic in the model, built form types will always appear off their limit position in an outwards tendency. Simultaneous built form types will configure an overlapping pattern of urban form that apparently tends to leave a hollow in the centre. This situation is not new in urban theory, as Anas (1978) and Harrison & Kain (1974) have proposed models that produces similar pattern, although for different reasons. One difference is that here stocks can be renewed; another one is that service centres grow together with the residential areas, yet another one is that this model allows global services to locate outside the main centre. Nevertheless, the question on what happens at the very heart of the spatial system remains, and could be addressed in two ways; the first one is that the model, dealing with real estate market, does not include some social agents. In effect, churches, banks, insurance companies, government buildings, sport organizations, public equipments are somewhat out and some times beyond that market. The other way is considering the institutional character of urban societies. Concretely, social agents are not simple and symmetric individuals trying to fulfil their basic needs, in a unregulated world, just on the contrary. All sorts of conventions, regulations, policies and values concerning social organization are likely to interfere in its spatial organization, particularly in the centre.

A further particularity of the model is that, together with the "market thinking" agents develop strong attitudes towards others, manifested in their preferences to group homogeneously and to keep away from other groups. This characteristic, that has been already included in simulations, as in Portugali et al (1997), seems to be representative of Brazilian cities and able to work as locational parameter.

What has been described here is the rough skeleton of a model that, in order to work as a cognitive tool, should go further in the exploration of relationships between agents and space, and in order to do that, agents should develop higher levels of organization, beyond those of simple residential clustering as admitted in the model, as well as a better learning ability. Both knowledge acquisition and collective organization will give the model some of the realism it needs.

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