PERGAMON

Computers, Environment and Urban Systems
28 (2004) 45–64

Computers, Environment and Urban Systems

www.elsevier.com/locate/compenvurbsys

CityDev, an interactive multi-agents urban model on the web

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Abstract

In this paper we present CityDev, an interactive multi-agents simulation model of the development of a city. The model is based on agents, goods and markets. Each agent (family, industrial firm, developer, etc.) produces goods by using other goods, and trades the goods on the markets. Each good has a price, and the monetary aspects are included in the simulation. When agents produce goods and interact in the markets, the urban fabric is built and transformed. The computer model (simulator) runs on a 3-D spatial pattern organized in cubic cells. CityDev allows interactive users to get involved in the functioning of the model. In fact, they can manage agents generated by the simulator, as well as new agents created by themselves. Agents managed by users interact with agents managed by the simulator. In addition, an administration board interactively controls the development of the city trough the urban plan, the building of new roads and the location of public facilities. In the present paper the model is described and some results are shown.

Keywords: Dynamic urban model; Multi-agent; Human–computer interaction

1. Introduction

Gaming simulation has anticipated some of the basic ideas of the multi-agent simulation approach (Hiroyuki, 2001). Usually, in urban games, the goal is to let human players learn the rules underlying the building of the urban fabric. In turn, in the multi-agent model, the main goal is the simulation of a real situation (Batty and Jiang, 1999) (Portugali, 1999). The present model, called CityDev, which was conceived for

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0198-9715/03/$ - see front matter
doi:10.1016/S0198-9715(02)00047-9

the teaching of urban planning, integrates the two approaches, namely the gaming simulation and the multi-agent, by using the web as a site where human users may interact and play with artificial agents. This particular architecture allows the model to be used both as simulation and as an interactive system. In fact, CityDev concerns both the functioning, and the planning and the management of the urban spatial-economic system. The functioning is based on the multi-agents model, while planning is enforced by an administration board. Agents can be managed both by the simulator and by human users, while the role of the administration board is performed only by human users. Hence the model may be used both as a simulation model of the urban dynamic and as a decision support system. In this latter scenario, it allows the administration board to evaluate alternative policies, and agents managed by human users, such as developers, to experiment the realization of projects concerning their core business (e.g. real estate development).

CityDev simulates the economic system of a city in its real and monetary aspects. It is based on agents, goods and markets. Each agent produces goods by using other goods and trades the produced goods in the markets. Agents are usually located in the physical space. In this simulation the evolution of the urban fabric results from the agents' interaction. A grid of 100×100 squared cells, each 100×100 m sized, is the spatial pattern of the simulation. Built 3-D cells can be over-posed in case of a multi-floors building, up to a maximum of 10. In other words buildings of the city are considered as composed of indivisible 3-D cells (Semboloni, 2000b). The morphology of the ground and the road network are similar to that of Prato, a city of about 160 000 inhabitants near Florence (Italy), whose economy is based on textile industry.

In the following sections we first show the core structure of the model: agents' strategies, markets, and interaction among agents. Second, we describe the role of the administration board, the phases of the simulation and the web interface. Third, we discuss the results of simulations including an example of interaction with human users. Finally, we discuss our model with respect to similar researches.

2. Agents' strategies and goods

Agents are the subjects, the actors of the play, while goods are the objects, the basic elements which are utilized, produced and traded by agents on the markets. Agents include: families (a group of inhabitants living in the same 3-D cell), industrial firms, commercial firms, private service firms, public services, and developers. Goods include: land, labor, buildings (residential, industrial, and commercial), exported goods, imported goods, consumption goods and services.

Each agent produces a good by using other goods as input. The goods produced by an agent are not necessarily utilized by the same agent. For this reason agents trade goods they have produced. Markets are the virtual places where these exchanges occur. In markets agents offer the goods they have produced, set a price for each good and sell it to the first buyer agreeing with this price. All these actions require choices among alternatives, i.e. decisions. An agent chooses the alternative which is supposed to yield the best result i.e. the maximum increase of its earnings.

Each agent is characterized by incoming and outgoing flows of goods. The relationships among agents and goods are shown in Table 1. Columns show the production function of each agent, whereas rows show the origin and destination of goods. From another point of view, a row shows the functioning of the markets. In fact, if one considers—for instance—the row of consumption goods, it appears that these goods are the input for families, and the output for commercial firms. In other words, commercial firms put the consumption goods into the market and the families get these goods from the market. As Table 1 shows, all agents, except developers, need a building where to live or work in. A building is a 3-D cell having a floorspace of 100×100 m. The number of inhabitants grouped together in a family is related to the size of this 3-D cell. In fact, a family is considered as a set comprising one hundred people (about 25 real average families). Hence, each inhabitant is supposed to occupy an average of 100 squared meters for housing, including all the surface utilized for secondary roads, private gardens etc. Among these people, forty are considered being active workers. Consequently, an industrial firm employing two families should be compared with a real firm having about 80 employees. This simplification has been introduced to ease the programming and to reduce the computing time required by the simulation, which depends strictly on the number of agents.

From the perspective of the economic system, agents can be divided in four groups: consumers (families), the export sector (industries), the service sector (commercial and private services firms, and the public services) and, last but not least, the developers, which are the builders of the city. Relations among agents are shown in Fig. 1, while agents' strategies are analyzed in depth hereafter.

Table 1
Relationships among agents and goods

Goods	Agents						Outside
	Family	Industrial firm	Commercial firm	Private services firm	Public service	Developer	
Land plot	–	–	–	–	–	In	–
Labor	Out	In	In	In	In	In	–
Building	In	In	In	In	In	Out	–
Export goods	–	Out	–	–	–	–	In
Consumption goods	In	–	Out	–	–	–	–
Public services	In	–	–	–	Out	–	–
Private services	–	In	In	Out	–	–	
Raw materials for industry	–	In	–	–	–	–	Out
Raw materials for building	–	–	–	–	–	In	Out
Wholesale goods	–	–	In	–	–	–	Out

"In" means that a good is utilized as an input by the agent; "Out" that a good is produced and supplied by the agent.

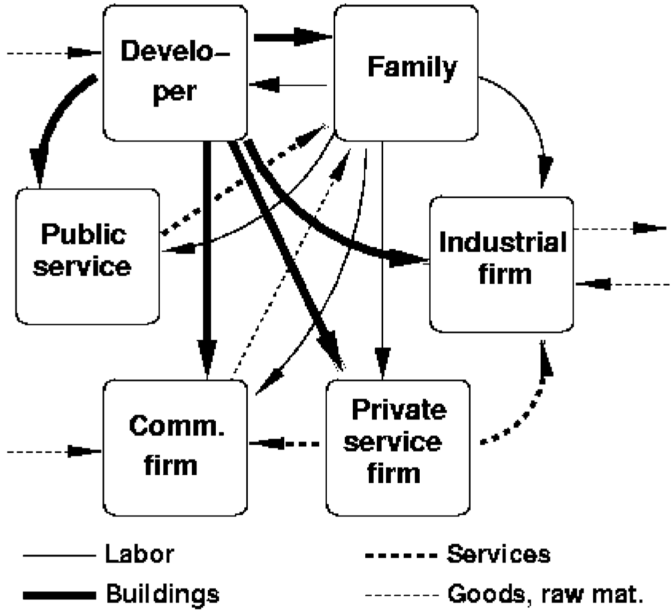

Fig. 1. The network of interactions among agents.

2.1. Families

Families are the final consumers. Their task is to consume goods and to supply labor. The decision areas for families are: where to work, where to live, where to buy consumption goods, and where to utilize public services. Expenditures for housing rent and for transportation are proportional to family income: at least half of the salary. Given this constraint, the strategy of a family is quite simple and consists in choosing the cheapest goods (including transportation costs):

$$\min(\text{price of the goods} + \text{transportation costs}).$$

2.2. Industrial firms

Industrial firms produce export goods that are consumed outside the city. The main decision areas of an industrial firm are: where to produce, the profit rate, and the quantity of production. In order to choose the location, a new industrial firm follows the example of the existing industrial firms. This is a method that has been adopted also for other agents. In fact, a firm with a limited forecasting capability follows the decision of similar agents if the results of this decision are positive, i.e. if these agents' activities are profitable. In other words he calculates the expected profit on the base of the profit of the surrounding existing firms, compares this expected profit with the price of the industrial building and chooses the best offer. In order to simulate the real limited knowledge, a random factor is included in the evaluation of the performances of the other firms:

max(expected profit-price of the building).

Location is not easy to change because some costs are connected with this changes. Instead, a firm can easily change the profit rate (i.e. the price of the product) and the quantity of the planned production. In fact, even if a standard quantity for production is provided, the firm may increase this value. According to the strategy established, an agent increases the quantity of produced goods if all the supplied quantity in the previous step has been sold and increases the profit rate if the goods have been sold at the price established by the firm. In fact, if a good is not sold during a simulation step, its price is automatically lowered by the market. This mechanism allows the market equilibrium to be reached.

2.3. Commercial and private service firms

Commercial firms sell consumption goods to the families, while private service firms provide private service which are exploited by industrial and commercial firms. Their main decision areas comprise: where to locate, the establishment of the profit rate, and of the quantity of production. The strategy for location is based on the example of the existent commercial or private services firms, as for industrial firms. In this case, however, location is more important because it directly affects the amount of sales of commercial and private services firm, due to the transportation costs paid by consumers:

max(expected profit-price of the building).

2.4. Public services

Public services provide families with such facilities as schools, hospitals, and public administration. Public services receive public funds in relationship to the number of families in the city. The main discretionary power of a public service concerns its location. This decision is connected to a spatial analysis of the relation of supply and demand of public services. In other words, a public service decides to locate in the worst serviced area. In fact, the strategy of public services is oriented to the maximization of the social utility:

max(demand of public services-offer of public services).

2.5. Developers

Developers build the urban fabric. They construct buildings in which families, private firms and public services live or work. Hence, they have an important role in the establishment of the shape of the urban fabric. The decision areas of developers are: which land plot to buy, where and which type of building (residential, industrial or commercial) to build.

Land plots are owned by an external entity. A land plot can be sold if it is suitable for the urban development, which usually happens next to already built ares or near roads. In other words, if it is bordered by a built cell or if it is bordered by a road and is located at a distance from a built cell not longer than 300 m. Among all the cells candidates to be sold, only a part chosen at random is offered in the land marked. The price is set according to a basic land price plus a term depending on its characteristics: accessibility of roads, services and jobs, quantity of built cells admitted by the urban plan.

A developer chooses to buy the land plot for which the difference average price of the surrounding buildings minus the price of the land plot is the highest:

$$\max(\text{average price} - \text{land rent}).$$

The decision where to build and which type of building (residential, commercial or industrial) to build is more complex, because two aspects are involved: the demand and offer of each type of building and the local convenience in relation to the land plots owned by the developer. In essence a developer chooses to build the type of building for which the demand is higher and in the land plot surrounded by the more successful agents which are potential demander of this type of building. The success of the agents is evaluated by using their profit. In conclusion a developer decides to built in the land plot for which the difference profit of the surrounding agents minus building cost is the highest:

$$\max(\text{agents' profit} - \text{building cost}).$$

The rent of a building is considered to be equal to five percent of the cost of the building. However, upon completion of the building, developers receive the total price of the building. In other words we have supposed an outside entity (bank or a real estate society) to become the owner of the building stock. This entity pays the developers and rents the buildings to other agents.

3. Markets

Interaction among agents takes place in the markets. Different markets exist for different types of goods available in the simulation: land market, building market, labor market, export goods market, consumption goods market, private service market, and public services market.

On each market the sellers offer goods or services and set their prices. A good or a service is sold to the first buyer who agrees with the price. In addition, the markets are in charge of lowering the price if the good is not sold during a step of the simulation.

The building market has special characteristics which are discussed in depth. Three types of buildings are considered: housing, industrial buildings (sheds), and commercial or service buildings (stores and offices). Each type of building has its specific sub-market. Buildings are allowed to change their intended utilization (from residential to commercial, for instance) and consequently the sub-market in which they are offered, if they are not sold after a given number of steps of the simulation. In other words, they are supposed to be upgraded in order to fit the demand, as it occurs in real situations. In addition, since buildings are bought only for a direct utilization, an agent can rent only one building. If an agent finds a building that better meets his needs, he may change the building where he lives or works. Consequently, he will change the location of his activity.

4. The economic aspect of interaction among agents

The basic parameters of the interaction among agents considered by the model concern production and consumption, salaries, and the prices of basic goods. Parameters that control production and consumption are shown in Tables 2 and 3.

In order to understand the economic interaction produced by the previous set of parameters we consider first, a developer. A developer utilizes the labor of two

Table 2
Parameters related to production and consumption (the first eight rows show the units of goods utilized for production or consumed by agents, while the last part the units of goods produced by agents)

	Family	Industrial firm	Commercial firm	Private services firm	Public service	Developer
Land plot	–	–	–	1	1	–
Labor	–	2	1	5	6	2
Building	1	1	1	1	1	–
Raw materials	–	5	–	–	–	4
Wholesale goods	–	–	10	–	–	–
Private services	–	2	1	–	–	–
Consumption goods	1	–	–	–	–	–
Public services	1	–	–	–	–	–
Produced goods	1	1	10	10	20	1

Table 3
The basic monetary values (in Euro)

Salary of a family in a commercial firms	600 000
Salary in a building firm (developer)	400 000
Salary in an industry	480 000
Salary in a private service	800 000
Salary in a public service	600 000
Basic price of a land plot	1 000 000
Price of wholesale goods	25 000
Price of raw material for building firm (developers)	160 000
Price of raw material for industry	250 000

families, raw material and land to build a cell during a step of the simulation, which is supposed to be equal to 1 year. The cost of a building is variable because of the varying density and of the different prices of raw material depending on the type of building: residential, commercial or industrial. However, the salary of a family, which is supposed to be a group of 100 individuals comprising 40 workers, is set equal to 400 000 Euro per year. The basic price of a land plot is set to 1 000 000 Euro, and the quantity of raw material per built cells is 4 units, each one costing 160 000 Euro. Because the average number of built cells in each land plot is 5, the resulting average cost of a built cell equals to 1 640 000 Euro. The final price is the actual cost multiplied by the profit rate which is established equal to 1.5, yielding about 2 460 000 Euro. The rent for this building is equal to five per cent of its price, i.e. about 123 000 Euro (see Fig. 2). Considering that a family agent represents about 25 real families, the rent is about 4 920 Euro per year per real family.

Given the rent of a building, it is easy to show the interaction of a private service. In fact, a private service agent requires a building whose rent is about 123 000 Euro and utilizes the labor of 5 families each earning 800 000 Euro. The quantity of units of private services produced by the agent is 10. In other words the cost of each private services unit is about 412 000 Euro, and the price, assuming the profit rate equal to 1.5, is about 618 000 Euro (see Fig. 3).

Private services are utilized by commercial and industrial firms. For the production of a unit of export good, this last type of agent utilize 2 units of private service, the labor of two families, whose salary is 480 000 Euro, five units of raw material, whose cost is 250 00 per unit, and a shed whose rent is about 100 000 Euro, yielding a final cost of the unit export good of about 3 540 000, and a final price of about 5 310 000, assuming that the profit rate is set to 1.5 (see Fig. 4).

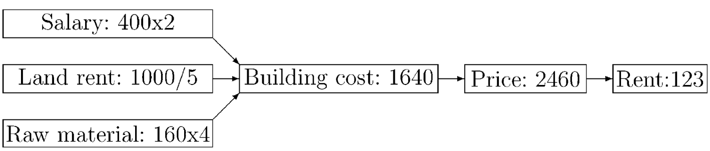

Fig. 2. The interaction giving rise to the building rent. Values are in thousand of Euro.

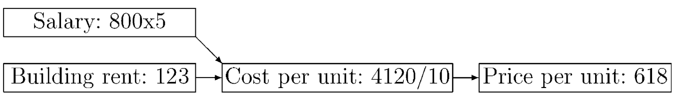

Fig. 3. The interaction giving rise to the price of a unit of private service. Values are in thousand of Euro.

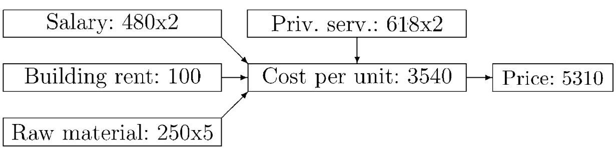

Fig. 4. The interactions giving rise to the price of a unit of export good. Values are in thousand of Euro.

It's worth mentioning that the transportation costs are included in the price of the private services and depend on the distance from the industrial firm to the private service firm. In fact, transportation cost have been set equal to 500 Euro per km per year. Transportation costs are also paid by families in order to buy consumption goods and to work. Transportation costs are a crucial parameter for the generation of the urban cluster, whose shape depends on it and on the rules governing land market.

The above mentioned parameters have been derived from a rough observation of the real world. In essence the main issue with these parameters is their internal coherence i.e. the balance in the budgets of agents between debit and credit.

5. Administration board

The multi-agents system is managed by a group of web users playing the role of the administration board in charge of the management of the urban development (Payne & Sycara, 2000). Tasks of the board include: town planning, setting values for the strategic variables of the simulation, and the location of public services. The latter task can also be accomplished autonomously by the simulator, while the first two tasks can be performed only by the administration board.

The goal of the planning activity is to establish the urban code and to design the new roads that are necessary for the urban development. The urban code concerns:

- the maximum number of cells that can be built on a land plot;
- the allowed land uses. Possible land uses are: housing, industry, commerce and services, public services, or unbuilt.

The strategic variables are:

- the basic price of a land plot;
- the amount of the outside demand for export goods produced by industrial firms;
- the price of export goods;
- the price of import goods (raw materials for industry and building, and wholesale goods).

The administration board may also be charged with the management of the public services agents, i.e. decides their location, which is strategic for the suitability of a zone in relation to the urban development.

6. Phases of the simulation

The model is jointly controlled by the computer simulation and by users. The simulation runs by steps. Each of these steps is supposed to represent 1 year of the real life of the city. Each step has six phases: generation and elimination of agents, management of agents by users, trading in the markets, production, update of the agents' budget, and administration of the simulation.

During the first phase, new agents are generated by the simulator if in the previous step the demand for the output produced by the agents has been greater than the supply. In turn, an agent is eliminated if his budget is negative.

In the second phase, human users can interact with the model by managing one or more agents. These agents, similarly to agents managed by the simulator, receive some initial funds. By using these funds, a user can buy goods, that are needed by the agents he, or she, controls. The user is in charge of taking strategic decision on behalf of his/her agents.

During the third phase, agents offer goods they produced in the previous step, in the market. Agents check at random all the markets in order to find goods they need. Agents may check a market more times if their needs have not been satisfied during previous visits.

In the fourth phase, agents that have all the necessary inputs, produce their outputs. Usually this phase is entirely managed by the simulator. Only users managing developers can decide the kind of building to construct and the location of this building. Obviously, developers must decide according to the urban code, avoiding to build a number of cells higher than admitted, or to construct a forbidden type of building.

In the fifth phase, the budget of each agent is calculated by summing up all the transactions that took place during the step. Transportation costs are also calculated and added to the expenses of each agent.

Finally, the administration board manages public services, and possibly modifies the urban code. In addition the board may establish the price and quantity of the outside demand and the price of imported goods.

7. The web interface

User interaction relies on a web interface (URL: http://fs.urba.arch.unifi.it:8080/suncity), which is an essential part of the simulation (Page, 1998; Ravid & Rafaeli, 2000). The web interface includes a home page, trough which web users can register or login. When a user enters the simulation, he or she has to choose the agents to control and consequently to perform the tasks allowed for these agents. The structure of the interface is shown in Fig. 5. In essence, a user playing the role of an agent has to choose in the markets the goods to buy. For each market a list of available goods, including location and price, is shown (see Fig. 6).

The location is identified with spatial coordinates and a map is available in order to help the location of the good.

Agents can choose the profit rate and the amount of production. Developers are allowed to decide which land plot to buy. In addition, among the owned land plots, a developer may decide where and which type of building (residential, commercial, or industrial) to build.

Some information is available to users: This concerns the development of the current simulation and includes various maps at different scale, along with graphs displaying

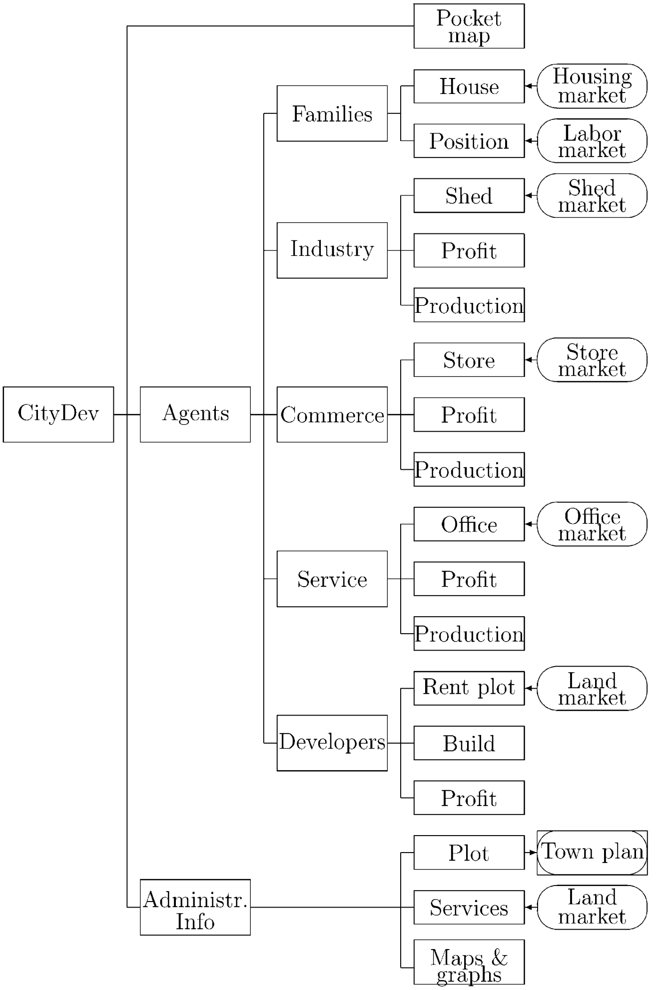

Fig. 5. The structure of the interface of CityDev. The items included in boxes are the functions available for user interaction.

the dynamics of the main variables (number of agents, buildings, prices etc.). In addition, an interactive map is also available to provide users with all the information concerning a specific land plot—i.e. the current urban code: allowed land use and built floors—the type of cell for each floor and the agents that live or work in these cells.

Additional facilities are available to the administration board. These include changing the urban code for a given land plot and the creation of new roads as well as the management of public services.

Usually, interaction with users happens after the simulation has run for at least 100 steps, beginning from a seed of only one building located in the city center. Currently the interaction has been simulated by authors with a student course in

Fig. 6. The store market: an example.

urban planning at the Faculty of Architecture in Florence. From this experience has resulted that human users can interact individually or organized in a group. This second type of interaction is needed at least in a first phase in order to explain the functioning of the model and of the interaction. In this case users interact during a period of half an hour. After this period the administration board can start the running of a new step of the simulation. The interaction may be pursued individually when the human users are well aware of the rule of the simulation.

8. Estimation of parameters

One of the positive aspect of this multi-agent model in relation to the estimation of the parameters lies in the fact that the values of some of the parameters is connected with aspects of real life. In other words one can find the price of the raw material for buildings, but it is more difficult to find in the reality the value of an exponent controlling the range of a random factor. In fact, we can identify two classes of parameters: Parameters that can be estimated independently by he model and parameters whose estimation depends strictly by the formulation of the model.

All the parameters pertaining to the interactions among agents are of the first class. In other words they can be easily extracted from the observed reality. These parameters are the quantity of floor space per inhabitant or per employee, the price of the export goods and consumption goods etc.

The second class of parameters are related mainly to the strategy of an agent. In fact, the strategy is based on the expected profit which is estimated on the basis of the profit of the similar surrounding firms. A random factor is added in order to consider the uncertain knowledge of the situation, as in the following equation:

$$P_i = P_i^{\mathrm{l}} + \alpha \overline{P_{\mathrm{t}}}[-\ln(r)]^{\beta} \tag{1}$$

where P_i is the expected profit in cell i, P_i^{l} is the local profit calculated by using the budget of the agents located in the surrounding cells, $\overline{P_{\mathrm{t}}}$ is the average profit, and $0 \leqslant r \leqslant 1$ is a random value, and α and β are parameters. These parameters are more diffcult to calculate trough direct observation, because they are related to the model, and should be calibrated by using an optimization algorithm, such as simulated annealing, reducing the error between observed and calculated data (Semboloni, 2000a). This method asks for spatio-temporal data that were not available. For these reasons, we have changed manually some parameters and we have compared the results with the map of Prato till we obtain the more similar shape.

It is not possible to consider this procedure as a calibration but only as an estimation of the starting point for a true calibration based on land use data when available.

9. The experiments

Experiments concern the two simulations with two different values related to evaluation of the expected profit, and a simulation in which human users have interacted with the functioning of the model. These simulations have an explorative character. The experiments consider the evolution of the city from the beginning to year 150. In fact the city grows from one seed comprising two families one industry and a commerce. The dynamic is due to a constant growth rate applied to the demand for export goods. The result is an exponential growth of the population, which do not correspond with the real data but produces an urban cluster that can be compared with the real observed cluster.

Let us consider the first experiment. The outputs of the simulation are the growth of the number of agents, the variation of the prices in the markets and the expansion of the city on a 3-D spatial pattern.

The overall growth is due to an exogenous increase of the demand of export goods which influences the variation of the related quantities. At the end of the simulation, the total number of agents is equal to 984. Families are 623, corresponding to 62 300 inhabitants (see Fig. 7). In addition, because the construction of buildings depends on the variation of these quantities, the number of developers represents something like a derivative of the growth process.

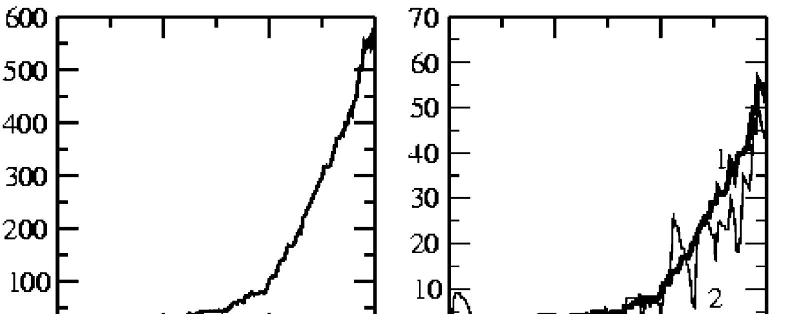

Fig. 7. Dynamic of the number of agents during the simulation. Left side: families. Right side: commercial firms (1), and developers (2).

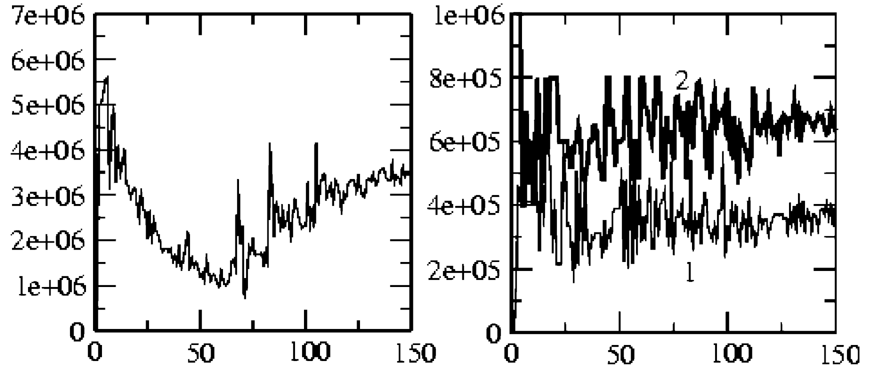

Fig. 8. The variation of prices during the simulation. Left side: average price of residential buildings. Right side: average salary (1) and average price of consumption goods (2).

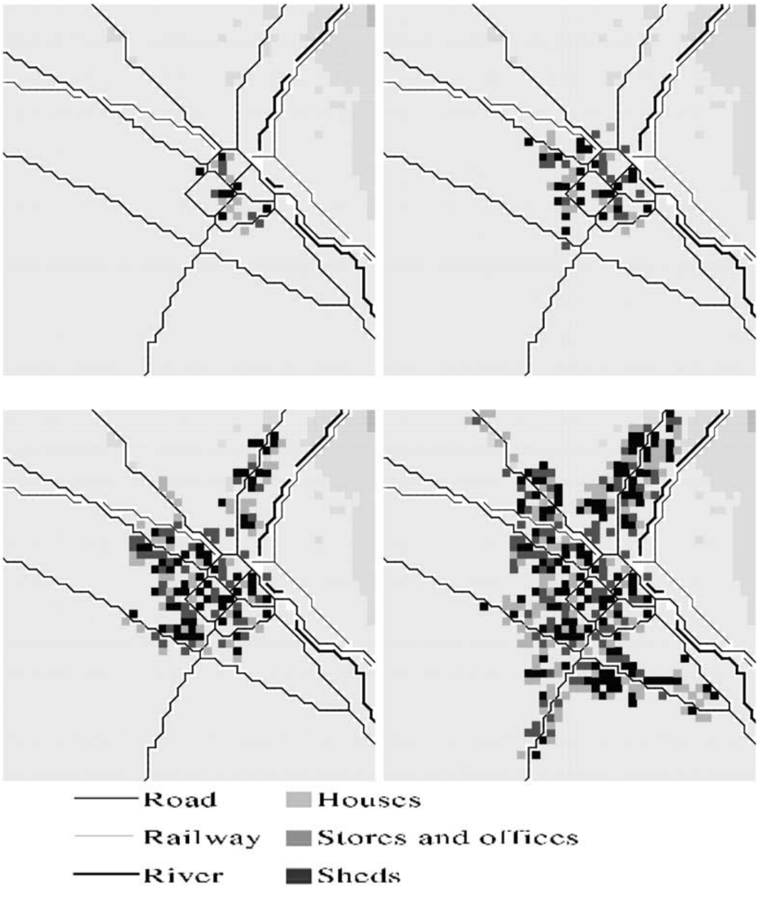

Fig. 9. First experiment. The urban cluster after 50, 100, 125, and 150 iterations.

Concerning the dynamics of prices, (see Fig. 8) salaries are fixed and oscillations are due only to a random factor; in turn prices of consumption goods oscillate around an equilibrium value. Prices of land plots and of buildings have a more complex trend. In fact, since at the beginning developers continue to build on the basis of the expected growth of families, the prices of buildings fall down due to the fact that the supply is greater than demand. After 150 iterations, these prices reach an equilibrium value. The spatial pattern is the result of the growth of the system, of the spatial rule concerning the selling of a land plot and of the transportation costs. The seed is initially located in the center of the map. Hereafter are shown the spatial pattern obtained after 50, 100, 125, and 150 iterations (see Fig. 9). A rough comparison with the map of the city on 1978 (Fig. 10) shows that the form is similar while the industrial firms are less concentrated than in the reality. Fig. 11 shows a 3-D view of the simulated urban cluster.

The second experiment focused on the utilization of a random factor in the calculation of the expected profit. In fact, in the first experiments [see Eq. (1)] $\alpha = 0$, while in the second experiment $\alpha = 0.5$, and $\beta = 2$; in other words we have included a random factor. The Fig. 13 shows the results of the experiment. The random factor yields an urban development featuring less continuity (see Fig. 12). This aspect has been evaluated by computing as measure the spatial autocorrelation

Fig. 10. The map of Prato, 1978. Black bordered zone are the main industrial zones.

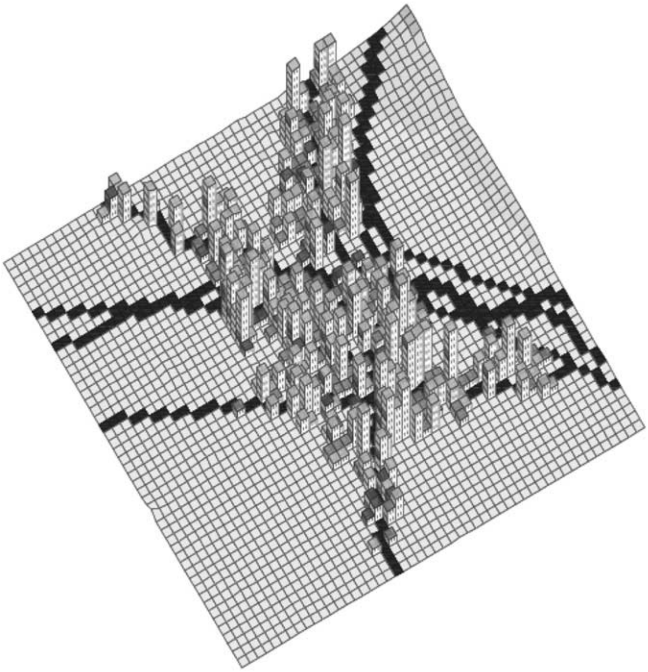

Fig. 11. First experiment. A 3-D view of the urban cluster after 150 iterations.

during the simulation. As Fig. 13 shows, that spatial autocorrelation in the first experiment, after an initial period, is higher than in the second: by using the random factor, different areas evolve more independently.

In addition we experimented interaction with the model: the development of an urban area in the suburb of the city. As human users we have created new developers, we have rent land plots in the areas, and than we have built houses (see Fig. 14). During about 10 steps developers managed by human users, have continued to build, but the building remained vacant, probably because they were considered too much distant from the existing activities. The developers continued to lose money and at the end the most part bankrupted, while the building begun to be occupied. At this step all the buildings were occupied, and a new neighborhood was developed (see Fig. 15). The interesting aspect of this simulation is the possibility to experiment a private plan for the city development. In addition we can estimate how much resources we need to invest or how much time we have to expect for the first earnings.

10. Relation with similar models

As explained in the introduction, the roots of this model can be found in the urban gaming simulation, and especially in the CLUG model (Feldt, 1972). Similarities with this game can be found in the economic base mechanism, in the negotiation in the

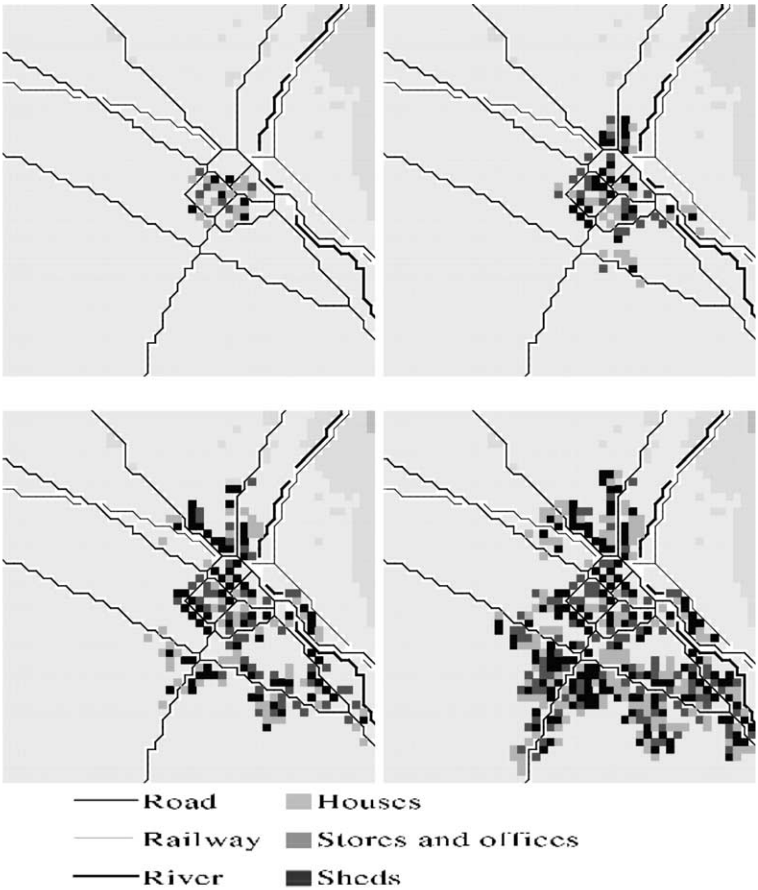

Fig. 12. Second experiment. The urban cluster after 50, 100, 125, and 150 iterations.

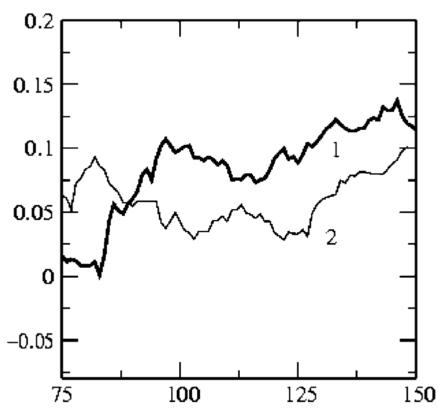

Fig. 13. The spatial autocorrelation of the urban cluster during 150 iterations. 1: first experiment, 2: second experiment.

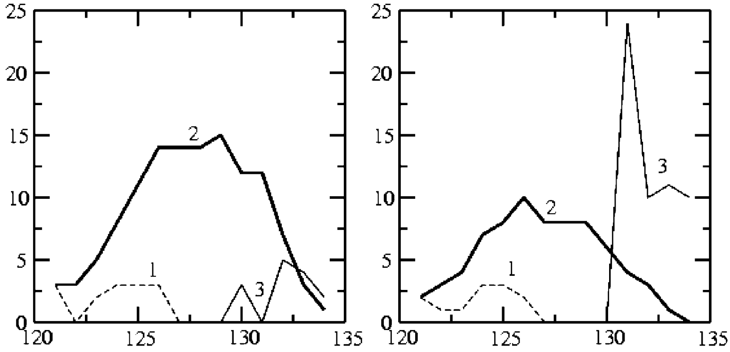

Fig. 14. Left: the developers created at each step (1), the total number of developers controlled by human users at each step (2) and the dead developers (3). Right: the land plots bought by the controlled developers (1), the housing cells built (2), and the housing cells sold (3).

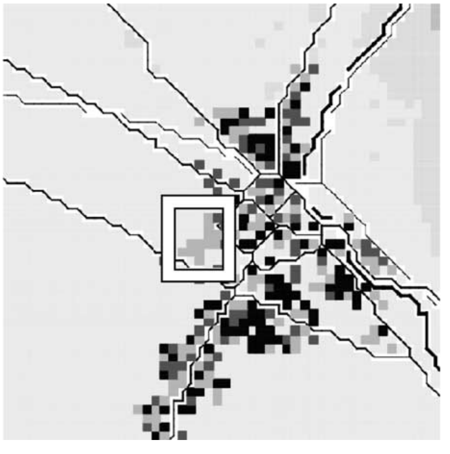

Fig. 15. The new residential zone built by developers controlled by human users, included into the white squared area.

market, and in the role of transportation cost in the establishment of the urban shape. The main difference lies in the fact that CityDev is totally agent-oriented, and for this reason users are obliged to play a role that has been established in the model instead of to be organized in teams that are able to perform various roles.

CityDev is a multi-agent model. From this point of view it is a model similar to that considered by Agent computational economic (Tesfatsion, 2002). In fact the present model simulates the urban economic system with agents interacting in the markets; in this economic system the main concern of agents is the increase of profit while the building of the urban fabric is a secondary aspect, as in the reality. In these economic models agents are supposed to learn in relation to the past experiences, while in CityDev the strategies of agents are based on inference in relation to the situation of other agents.

Some of these models are now experimented trough the web as interactive Computer–human simulation. The interaction with human users is the result of the integration of the gaming simulation and the multi-agents approach. An interactive planning activity which is relevant in the urban dynamic is included in the present model. Planning is considered as a control of the overall dynamic but also as the development of a project of some agents or group of agents. This is a new way to consider planning in relation to the self-organizing character of the urban systems.

In order to better pinpoint this aspect let us consider one of the most famous urban games, SimCity. SimCity is in essence a tool for experimenting the effects of an urban policies facing a complex reality. In fact the aims of SimCity is to make the player Mayor and City Planner (Friedman, 1999). In other words, Simcity is a classical example of a what-if model. In fact the Major can experiment different urban policy and the effects of these policies are simulated. This is a classical way of conceiving planning, i.e. as a constraint to the system dynamic. CityDev allows the users to develop their plans as agents, as in the reality. This is a new way to conceive the planning facing to the aspect of the complexity. In other words we suggest a planning which utilizes more the strength of the system dynamic and less the constraints to its functioning.

11. Conclusion

We have presented an interactive multi-agents model for the simulation of the urban development. Trough the interaction with human users, this model emphasizes the role of agents in the conscious orientation of the urban system. This aspect correspond to a a new necessity concerning the new role of planning in the complex self-organized system. This new role is more related to the autonomous capacity of planning of agents.

The utilization of the web enhances the possibilities of interaction making the model really accessible to a lot of people which wishes to experiment the possible configuration of an urban system.

12. Technical aspects

CityDev is managed by a computer application based on object oriented technologies. The software is written in Java. The basic components of the CityDev interactive simulation are the simulator, the data base, the exchange module, and the Web front-end.

The simulator is the core of the simulation. It is based on a multi-agents platform and is in charge of updating the variables of the simulation, and of the management of agents not managed by human users. Geographical data are stored and organized into the data base. These data comprise: elevation of the ground, slope, rivers, roads, and railway. The exchange module comprises a set of methods which allow the application which manages the web users to interact with the simulator. The

Web front-end is utilized by web-users and by the administration in order to interact with the simulator.

The software has been developed using free software packages. These are Linux (RedHat), as operating system, Apache as web server, Postgresql as database, jdk 1.2.2, Tomcat for servlets and jsp pages, and JDBC for database access.

Acknowledgements

The CityDev has been funded by the University of Florence under a program for the innovation in teaching. Massimo Vassalli (National Institute of Applied Optic, Florence) collaborated at the beginning of the project with useful suggestions and ideas.

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