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COMPETING ORDER PARAMETERS IN A SELF-ORGANIZING CITY

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In this paper we consider the city as a complex, open, and thus self-organized system, and describe it by means of City-1: a cell space model specifically designed to examine the impact of international migration on the urban dynamics. Our specific case study concerns the recent inflow of new immigrants from ex-USSR countries to Israel's towns and cities. We perceive cities from the perspective of HAKEN's synergetics approach to self-organization in which ordered steady-state in the system is reached as a consequence of a competition among, and enslavement of, some order parameters. In this paper we focus on the interplay among two order parameter which are central to the urban dynamic: the cultural order parameter and the economic order parameter.

Introduction

Self-organization is a property of open, complex and consequently far from equilibrium, systems. 'Open' in the sense that they exchange matter, energy or information with their environment and 'complex' in the sense that the number and properties of their constitutive parts are undefinable (whether quantitatively or qualitatively is a matter of philosophical dispute).

Though the theory originated within the disciplines of physics and chemistry (e.g. HAKEN 1983a, 1983b; NICOLIS and PRIGOGINE 1977), the 'city', from the start, was referred to as an example for a self-organizing system. First, as a metaphor to convey the notion of self-organization (NICOLIS and PRIGOGINE 1977), and later as a subject-matter in the general attempt to expand the notion of self-organization to the socio-human domain (ALLEN 1981; ALLEN and SANGLIER 1981; ALLEN et al. 1985; WEIDLICH 1987; DENDRINOS and SONIS 1990).

HAKEN's synergetics approach to self-organization suggests that since the complexity of such systems constrains our ability to treat them causally and mechanistically, it will be more useful to focus on their morphological behavior. Such an examination revealed that the evolution of self-organizing systems follows a distinct routinized path: long periods of steady dynamics, interfered by relatively short periods of strong fluctuations and chaos. According to HAKEN (1985) while in steady state, the system is governed by a certain order parameter; while in fluctuations and chaos, several order-states compete, until one wins, enslaves the system, brings it to a new steady state and thus becomes the new order parameter.

In two previous studies (PORTUGALI, BENENSON and OMER 1994; PORTUGALI and BENENSON) we have suggested seeing cities and metropolises as open, complex, far from equilibrium, and thus self-organizing, systems. Perceiving cities as such we have developed two models: a cellular automata (CA) model we termed *City* on which various heuristic games could be played as means to study phenomena of sociospatial segregation of national, ethnic, and other groups in the city, and a cell-space model, termed *City-1*, on which the relations between international migration and the internal structure of cities, could be played, with special reference to the recent migration waves to Israel from ex-USSR countries. The aim of the present paper is to use *City-1* as means to study cultural spatial segregation in light of the interrelation between two order parameters which play a central role in shaping the socio-spatial structure of cities: the cultural order parameter (COP) and the economic order parameter (EOP).

The model

The formal description of our model is given in the Appendix. Generally speaking, *City-1* is a *cell-space* (CS) model (ALBIN 1975; COUCLELIS 1988; TOBLER 1979) whose territory is a 2D lattice of cells H_{ij} {$0 < i < n$; $0 < j < m$), each of which might be considered a single house. Individuals occupy or leave the houses and thus participate in generating the migration dynamics of the city and its socio-spatial structure. One individual only can occupy a house. Each individual is characterized by *status and tendency. Status* refers to the individual's economic ability, while *tendency* his/her potential to improve status. Individuals are of two *origins*: *Veterans* and *Olim* (Hebrew for Jewish new immigrants; singular *Ole*). Depending on *status* and *tendency,* each individual can either buy or rent a house, that is, a house can be in two *forms* of occupation: rented or privately owned.

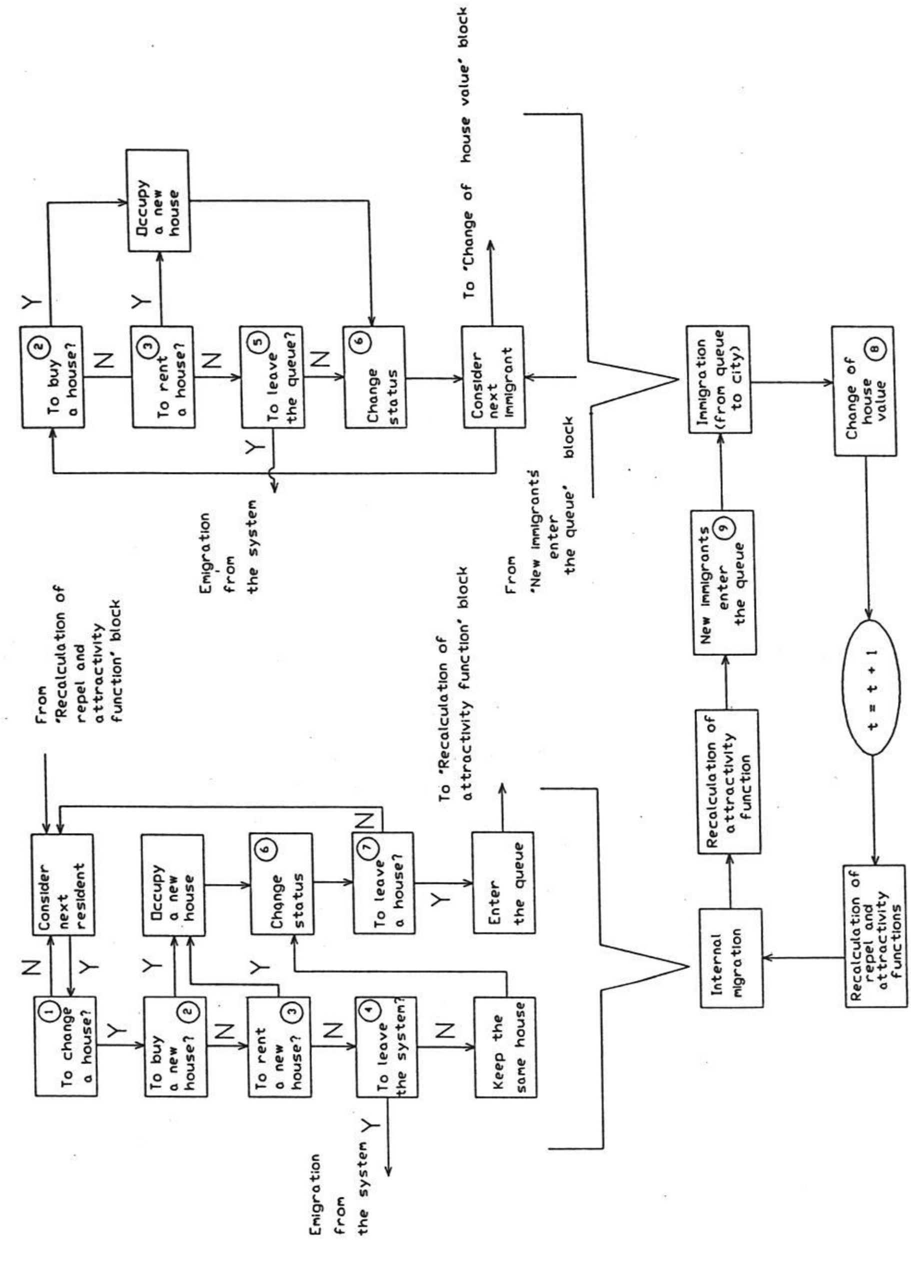
Each house has a *value.* The value of a vacant house is some function of the values of its neighbors. The value of an occupied house is, additionally a function of the *status* of the occupant.

An individual can either rent or buy a house. Both cases imply *payments* which are proportional to the *value* of the house and both also effect the *status* of the paying individual in a way that we define below.

Each sequential time-step every individual takes the following series of decisions (Figure 1): A resident of the city decides whether to stay in, or leave his present house, and in the latter situation, whether to rent or buy a new house in the city, to altogether leave the system, or only to leave his house in the city. In the latter case the resident becomes " homeless", i.e. he or she enters the queue for houses. A new immigrant (veteran or Ole) enters the city by joining the queue and then decides whether to buy/rent a house, further wait in the queue for housing, or altogether leave the queue (and thus the city). The various individuals take such decisions by cormparing their own properties (status, tendency) to the properties of their houses, the vacant houses, and their nearest neighbors.

The decisions have probabilistic and deterministic components. They are probabilistic in the sense that the larger the gap between the properties of the individual and his/her neighbors, the higher is the probability that he/she will decide

Figure 1 Structure of Decision Making



to leave the house, and visa versa with respect to occupying a place. They are deterministic in the sense that the individual can buy or rent the house when his/her status is sufficiently high compared to the value of a house, or when he/she cannot afford paying the rent, or the mortgage, of a house in the city and has to leave the city. The result of the latter is a *queue* of individuals who want to occupy a house within the city territory, but cannot afford doing so.

Competing order parameters in the city

Cultural (ethnic and/or national) and socio-economic spatial segregations are typical phenomena in cities in general and in cities which are subject to international migration processes, in particular. This came out also from our previous study (PORTUGALI and BENENSON) in which we have used City-1 as means to simulate and study the implications of the recent migration wave of Jews from ex-USSR countries, to Israeli cities. We have found that cultural relations and socio-economic relations, as formulated in our model, act as two order parameter which compete and interact in a complex way in the evolution of the city. While the aim of our previous paper was to study spatial segregation in the city, our present paper aims, as noted above, to study the complex interplay between the cultural order parameter (COP) and the economic order parameter (EOP).

For this purpose we have played on City-1 three scenarios which described the dynamics of the city and the interplay between the EOP and COP when (i) the EOP is dominant in a certain way, (ii) the COP is dominant in a certain way, and (iii) both the COP and EOP act together. In the following we will describe each scenario in a sequence and examine their evolution by means of three devises: segregation indices (Figure 3), three moments (T=20, T=40, T=120) of the evolving spatial cultural segregation (Figure 4), and the same three moments of the evolving land value surface (Figure 5). Note that Figure 5 can be seen as a surrogate to the evolving spatial economic segregation of individuals in the city. In all scenarios the initial mean value and STD of the status of veterans is four times higher than that of Olim; mean tendency of Olim is four times higher than that of veterans; STD of Olim tendency is four times lower than that of veterans.

(i) When the EOP is dominant in a certain way

The EOP is dominant when we assume two forms of economic antagonism: First, the probability for an individual to leave his house increases with the growth of the difference between the individual's and his neighbors' economic status. Second, the attractivity of a house increases with the increase of the economic improvement of its environment (Figure 2). As can be seen in Figure 3 and 4, in this case the city evolves with no cultural spatial segregation. The city's evolution is thus dominated by the EOP as some economic segregation can be observed (Figure 5). It is important

Figure 2 Repel/Attractivity Functions for Economic/Cultural Interactions

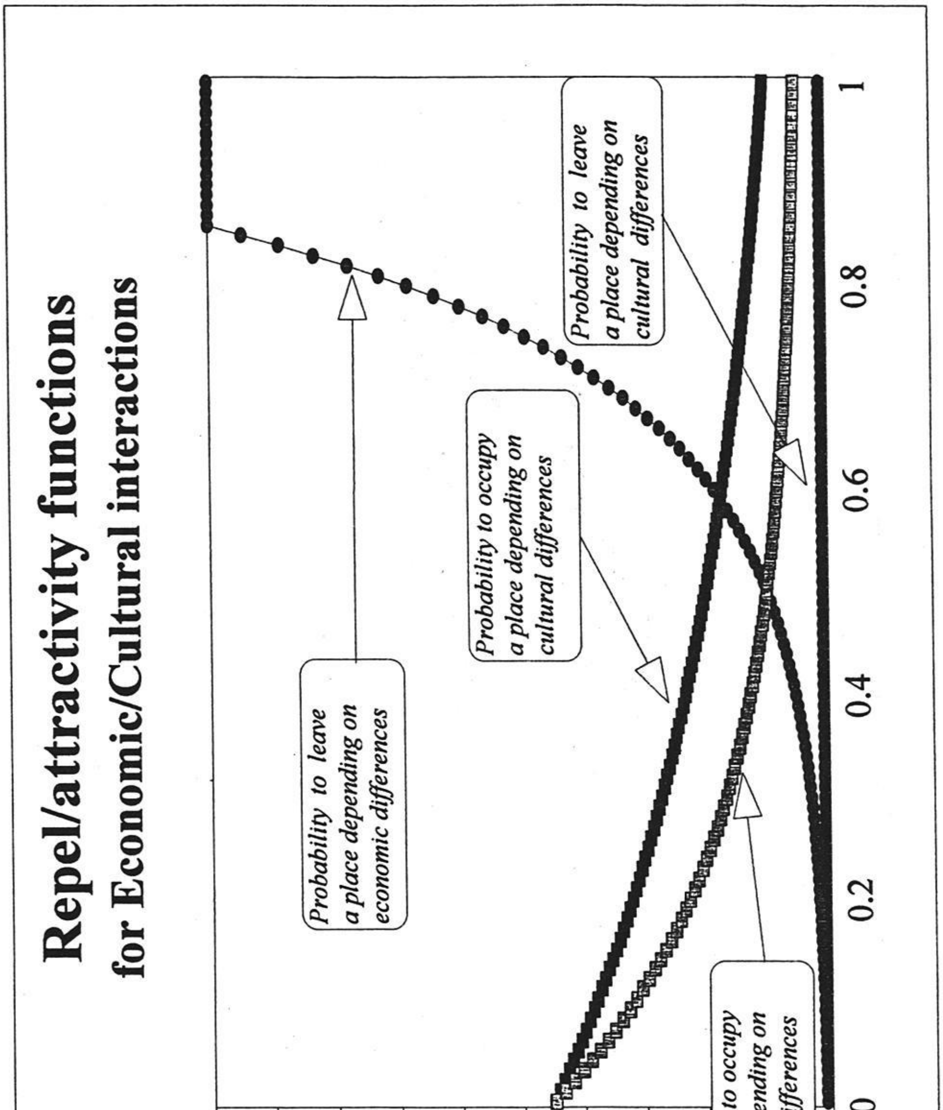
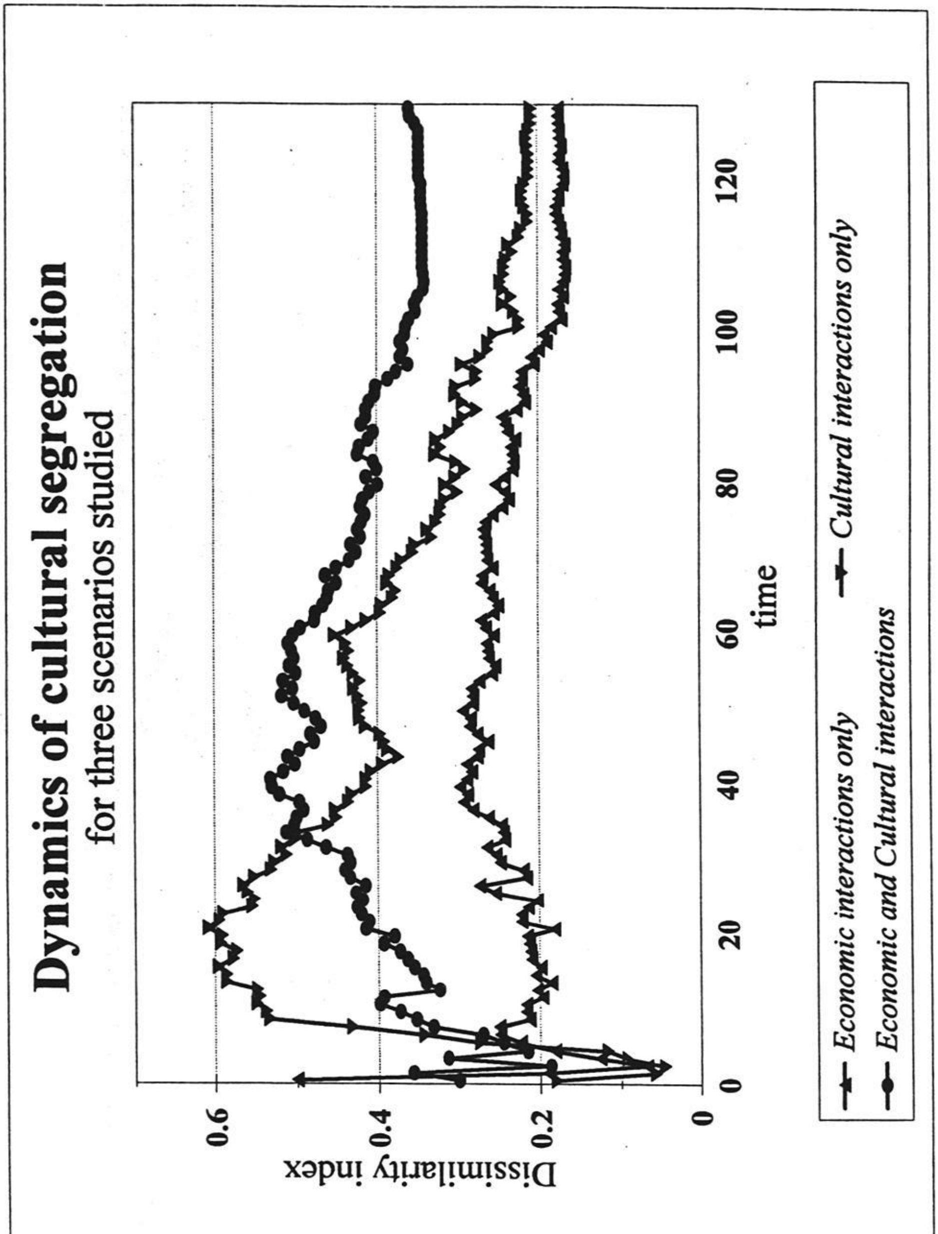


Figure 3 Dynamics of Cultural Segregation for Three Scenarios Studied



to note, however, that despite the fact that this scenario is governed by economic forces only, economic segregation is not very distinguished.

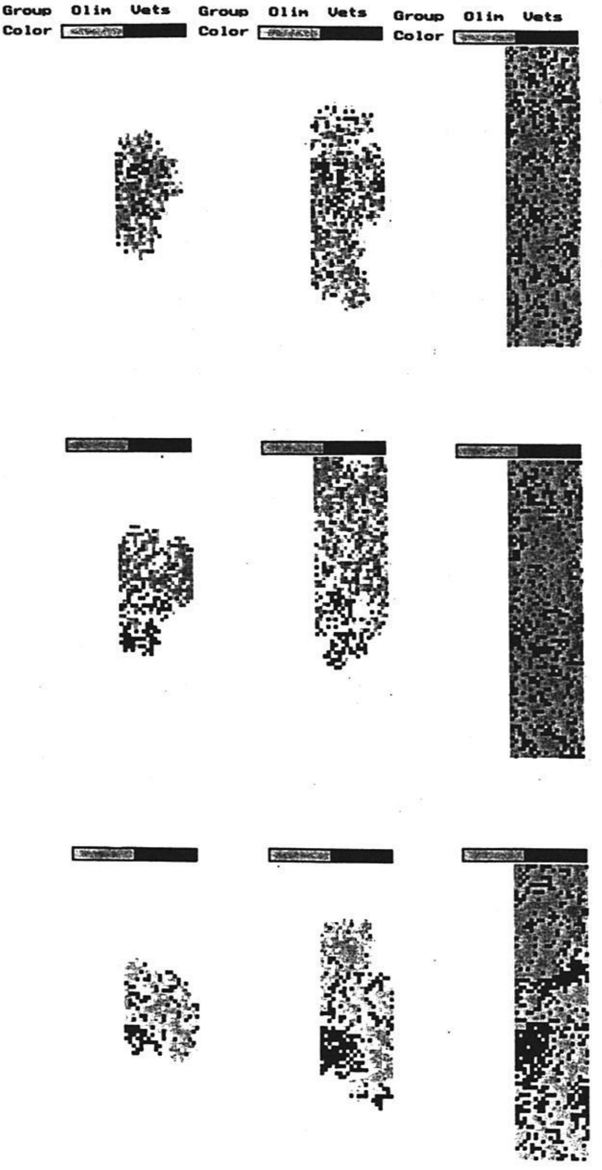
(ii) When the COP is dominant in a certain way

Here there is no economic antagonism and the COP is dominant in the sense that we assume a "mild" cultural antagonism between veterans and Olim. The latter shows up, first, in that the individual's decision to leave a house does not depend on the characteristics of his neighbors, and second, in that when choosing a new house the individual prefers neighbors of his/her own kind. "Prefers" implies that the attractivity of a fully friendly environment is 0.45 compared to 0.1 of a fully strange one (Figure 2). In this case the evolution of the city and the interplay between EOP and COP is more complex than in the previous scenario: At the beginning (0< T<40), the COP slaves the EOP and dominates the city's evolution: the city is segregated culturally (Figure 3 and 4) and economically (Figure 5). Then gradually the EOP and the COP neutralize each other, until in T=120 no cultural segregation (Figure 4), nor economic segregation (Figure 5) can be observed. Apparently this is a result of the higher economic tendency of Olim relative to the veterans.

(iii) When COP and EOP interact

Here we assume the existence of both economic and cultural antagonism as above, and the repel and attraction functions are thus the sum of both antagonisms as defined in the Appendix. This scenario is rather interesting. At first, the evolution of the city is governed fully by the COP - a strong trend towards cultural segregation can be observed in Figure 3. Then segregation decreases but do not disappear, and in fact it can be observed all the way to T=120. The interesting part is the role played here by the EOP. Indeed, as can be seen in Figure 3, it acts to moderate cultural spatial segregation, but at the same time it does not eliminates it, but actually acts as a catalyst and reinforces it: the COP enslaves the EOP and the city becomes culturally (Figure 4) and economically (Figure 5) segregated in line with the COP.

Figure 4 Dynamics of Olim/Veterans Spatial Distribution



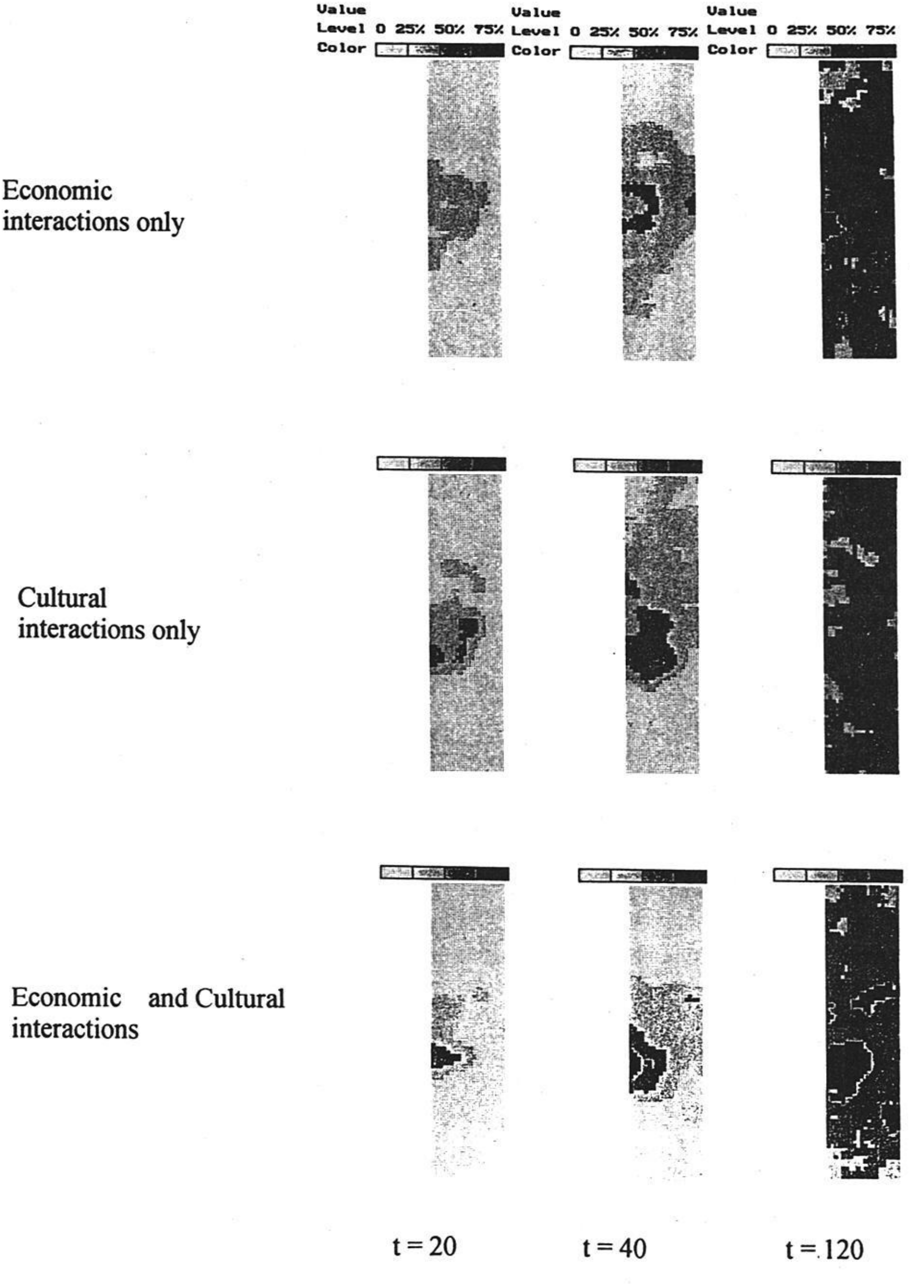
Economic interactions only

Cultural interactions only

Economic and Cultural interactions

t = 20   t = 40   t = 120

Figure 5 Dynamics of Land Value Maps



Appendix

CS model City-1 consists of *territory, transformation rules* , and *immigration-emigration* rules. Transformation rules define the properties and occupants of each house at the next time-step depending on properties and occupants of all the neighboring houses. Immigration-emigration rules define the flows of the individuals into- and out of the city.

Consider individual **P** with status S_p $(0 \le Sp \le 1)$, tendency T_p $(0 \le T_p \le 1)$, and origin O_p $(O_p \in \{Veteran, Ole\})$. When **P** occupies a house/cell H_{ij} whose value is V_H $(0 \le V_H \le 1)$, we denote an occupation form as F_p $(F_p \in \{Owner, Renter\})$. The payment of an individual occupying house **H** is W_H $(0 \le W_H \le 1)$. The status of an individual and the value of a house depend on time. We shall mark it explicitely, when necessary.

We consider as neighbors individuals and houses in the 5x5 square around a house, that is, individuals occupying houses from the set of

$$U(H_{ij}) = \{H_{kl}\ |\max(0, i-3) < k < \min(n, i+3), \max(0, j-3) < j < \min(m, j+3)\}$$

Below $S_{neighbors}$ is an average status of the individuals in the $U(H_{ij})$, $O_{neighbors}$ is a fraction of individuals in the $U(H_{ij})$, whose origin is the same as an origin of individual **P**, situated in the H_{ij}.

Each time step the sequence of decisions and parameters changes is calculated in the following way (equations' numbers correspond to the numbers of the boxes in the flow chart at the Figure 1):

Transformation rules

1. To change a house?

The probability for an individual **P** to leave house **H** depends on the occupant's origin, fraction of his/her neighbors whose origin differs from occupants' one and the absolute value of the difference between occupants' status and the status of his/her neighbors:

$$R_P = \alpha 1(O_P) + \beta 1(O_P)\exp(\gamma 1(O_p)Abs(S_P - S_{neighbor})) +$$
$$\alpha 2(O_P) + \beta 2(O_P)\exp(\gamma 2(O_P)(1 - O_{neighbor})) \qquad (1.1.)$$

We suppose that R_P increases monotonously with the increase of

$Abs(S_P - S_{neighbors})$ and $1 - O_{neighbors}$

2. To buy a new house?

This deterministic condition is applied to queuing individuals who want to enter the city as well as to residents who want to change their houses. An individual **P** can buy house **H** of value V_H if his/her status and tendency are sufficiently high relative to the value of the house. That is

$$S_P > \delta_0 + \delta_1 V_H,\ \ T_P > \tau_0 + \tau_1 V_H \qquad (2.1)$$

where δ_0, δ_1, τ_0, τ_1 are constants.

An individual **P** chooses a house from the set of vacant houses satisfying conditions (2.1). The "attractivity" of a house **H** $(Q_P(H))$ is estimated as follows:

$$Q_P(H) = \alpha_3(O_P) + \beta_3(O_P)\exp(\gamma_3(O_P)S_{neighbors}) + \alpha_4(O_P) + \beta_4(O_P)\exp(\gamma 4(O_P)O_{neighbors}) \quad (2.2)$$

We suppose that $Q_P(H)$ monotonously increases with an increase in the $S_{neighbors}$ and $O_{neighbors}$ and interpret "attractivity" as the probability to occupy (buy or rent) a vacant "house" H_{ij} when it is the only possible choice.

An individual occupies one of the houses satisfying (2.1) or fails to occupy any of the houses in the following way. Let us denote as Λ the set of the houses, satisfying (2.1), plus some special element H_O, corresponding to failure of the attempt to occupy. We define the probability p_{ij} to occupy house $H_{ij} \varepsilon \Lambda$ as

$$p_{ij} = s_{ij} / \sum_{H_{ij} \varepsilon \Lambda} s_{ij} \quad (2.3)$$

where $s_{ij} = Q(H_{ij})s_0 / (1 - Q(H_{ij}))$, $s_0 = \prod_{H_{ij} \varepsilon \Lambda / \{H_0\}} (1-Q(H_{ij}))$

3. To rent a new house?

If an individual did not succeed to buy a house, he/she tries to rent one. In the same manner as above the individual chooses from the set of houses satisfying condition (3.1) which is similar to the second of conditions (2.1):

$$T_P > \tau_2 + \tau_3 V_H \quad (3.1)$$

where τ_2, τ_3 are constants.

Each vacant house, satisfying condition (3.1), can be rented. The "attractivity" of the vacant houses is estimated according to (2.2). The probability to rent one of the houses **H** satisfying (3.1) is calculated according to (2.3).

4. Change of Status

Simultaneously with the above activities regarding spatial location, the individual's status changes every time-step. The status, at the next time-step, of individual **P** located at house **H,** depends on his/her current status, tendency and payment in the following manner

$$S_p(t+1) = \begin{cases} \max\{0, S_P(t) + T_P(t) - W_H(F_P(t))\} & \text{if } T_P(t) - W_H(F_P(t)) \leq 0 \\ \min\{1, S_P(t) + T_P(t) - W_H(F_P(t))\} & \text{if } T_P(t) - W_H(F_P(t)) > 0 \end{cases} \quad (4.1)$$

where $S_P(t)$, $T_P(t)$ are defined as above, **t** denotes the number of the time-step.

We define payment $W_H(F_P(t))$ as the right parts of formulae (2.1) and (3.1):

$$W_H(F_P(t)) = \begin{cases} \tau_0 + \tau_1 V_H(t) & \text{for } F_P(t) = \text{owner} \\ \tau_2 + \tau_3 V_H(t) & \text{for } F_P(t) = \text{renter} \end{cases} \quad (4.2)$$

Queuing individuals have no payment and consequently the changes in their status are determined as follows:

$$S_P(t+1) = \min\{1, S_P(t) + T_P(t)\} \quad (4.3)$$

5. Change of Value

The value of a vacant house **H** at the next time-step is defined as the average of the status of individuals occupying houses or the value of the vacant houses in the neighborhood **U(H).** That is

$$\mathbf{V_H(t+1) = ((S_1(t) + S_2(t) + S_3(t) + ...) + (V_1(t) + V_2(t) + V_3(t) + ..))/25} \qquad (5.1)$$

where **D < 1** is a decrement of value.

In the first pair of brackets we include status of individuals occupying houses in **U(H)**, and in the second pair the values of the vacant houses in **U(H)**.

Immigration-emigration rules

6. To leave the system?

A resident who could not buy a new house nor rent one, stays at his/her current house in the city or leaves the system. It is supposed that $\mathbf{L_P}$, the probability to leave the system, is:

$$\mathbf{L_P = const} \qquad (6.1)$$

A new immigrant who failed to buy or rent a house either returns to the queue or else leaves the system.

7. To leave the queue?

An individual entering the queue is trying to occupy a house each time-step. If he/she did not succeed to occupy a house during some pre-determined time-steps ($\mathbf{T_{threshold}}$), he/she leaves the system. Below

$$\mathbf{T_{threshold} = const} \qquad (7.1)$$

8. To leave the city?

This is a deterministic rule. An individual will leave the city's territory and enter the queue if

$$\mathbf{S_P(t) < S_{threshold}} \qquad (8.1)$$

where $\mathbf{S_{threshold}}$ is a threshold status level.

9. Inflow of individuals

Each time-step a constant number of Veterans and Olim enter the city. Their initial status and tendency are assigned randomly and independently according to the given normal distributions with

$$\mathbf{mean = \mu(O_P), \ \ STD = STD(O_P)} \qquad (9.1)$$

that is mean and average differ for Veterans and Olim.

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