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A Cellular Automaton as a Model to Study the Dinamics of an Industrial District

by

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Abstract

A Cellular Automaton represents a model of a complex dynamical system with a high number of small interacting units. The global properties of the system come from the Automaton evolution subject only to local interaction rules. An Industrial District can be considered as a system with a high number of small firms usually acting without a global strategy. Each firm interacts locally with other firms within a cooperation/competition framework. One of the most important elements of an industrial district is the information transparency, i.e. the information diffusion through the system. In the following paper, we describe a dynamical cellular simulation of an industrial district with respect to its information transparency rate.

1 Introduction

Cellular Automata (CA) represent a class of complex dynamical systems composed by a large number of mutually interacting units. The evolution of the Cellular Automata, within a discrete space-time coordinate system, comes from local interactions between first neighbor units. A Cellular Automaton is a discrete and finite lattice of identical cells where each cell represents an evolving unit. A vector, x_i^t, describes the status of the *i-th* cell at time t. Usually the state vector can assume values within a small set of integers $Z_k = \{0,1,2,\ldots\ldots,k-1\}$. The dynamical evolution of the Automaton changes the value of the state vector of a cell at time t according to the state of the neighbor cells at time $(t-1)$. The term neighbor indicates all the cells belonging to an apriori defined Interaction Neighborhood, U_{x_i}. The interactions are local in the sense that only cells belonging to the same Interaction Neighborhood can mutually interact (see S. Wolfram 1986, H. Gutowitz 1991, L.A. Zadeh 1997).

A one-dimensional lattice, a chain of identical cells, represents a 1D-CA where the Interaction Neighborhood, U, can be defined as all the r cells on the right and on the left interacting with the central one. In this case we can write the transition rules in this way:

$$x_i^{t+1} = f(x_{i-r}^t, \ldots, x_i^t, \ldots, x_{i+r}^t) \qquad (1)$$

with:

$$f : Z_k^{2r+1} \rightarrow Z_k \qquad (2)$$

where x_i^t is the state of the cell *i-th* at time t, f represents the interaction rules and r is a non negative integer specifying the extension of the Interaction Neighborhood on which f is defined. The simplest *1D-CA* is a chain of cells with $r=1$ and $k=2$. In this case, the

cells are binary systems interacting only with the two first neighbors (one on the left and one on the right) (E. Jen, 1990). Starting from this definition a generalization to nD-CA is a straightforward exercise (S. Wolfram, 1986).

A Cellular Automaton can be seen as a paradigm for a complex system with a high number of simple and identical units subject only to local interactions. The global properties of the system come from a computer simulation of the stochastic evolution dynamics where the most detailed description of the local interactions and transition rules is included into the Cellular Model. This approach has been widely used to study systems intrinsically local where the dynamics strongly depends from short-distance interactions. Moreover, because of the computational efficiency of the discrete cellular models, with respect to the continuous partial-derivatives based models, the Cellular Automata have been used as simple models to investigate complex systems in physics, biology, sociology and economics (D. Farmer et al. 1984, E. Domany and W. Kinzel 1984, U. Frisch et al.1986, B. Boghosian and D. Levermore 1987, T. Toffoli and N. Morgolus 1990, E. Fredkin 1990, C. Bruun 1996).

An Industrial District is, usually, a set of small firms geographically strongly localized with relationships of mutual cooperation and competition. Although all the firms act within a stationary framework on the same market (the "local" or "internal" market) the entrepreneurs in the district are continuously looking for new opportunity such as: new markets, new products, new technologies. In a typical Industrial District, this search is not driven by a Development and Research Office but often is based on intuition, industrial emulation among the firms in the district, gossip among firm-managers or to the news coming from the media while the strong geographical localization helps a continuous information exchange among the agents in the district. If the information exchange is null each agent can rely only on its personal intuition or experience. On the other side, we can consider systems where the information is immediately broadcast to each agent in the district and obviously all the intermediate cases. In these last two situations, the agents combine the information coming from other agents with information coming from media, personal intuition and personal experience (S. Brusco 1989, G. Becattini 1998).

In this paper, we propose a Cellular Automata based stochastic model to simulate the dynamical evolution of an Industrial District with respect to the information transmission among the single units.

2 Simulation Results and Discussion

The model is defined on a *(20x20x10)*-3D Cellular Automaton where each cell on the *(20x20)* basal plane represents an industrial unit (the *agents*) interacting with 10 gain opportunities or scenarios (the *markets*, i.e., new markets, new products or new technologies). In the model, we defined a set of *agent-agent* interaction rules describing the information exchange and *agent-market* interaction rules related to *investment decisions* and *investment returns*. The goal of the cellular simulation is to investigate in detail the role of the information transmission among the agents on the performances of the whole district in terms of global industrial growth and richness concentration. In the proposed model, the amount of exchanged information depends upon the number of contacts within the defined U-neighborhood topology. The *agent-agent* interaction rules modify (depending on the U-topology) the agents' knowledge about the *markets*. This

knowledge will be used to decide to invest or not on a given *market* (*investment decisions*) while the *investment yields* depend upon the intrinsic property of the interacting *agent* and *market*. Obviously the more information available to an *agent* the less is the risk to take a wrong decision (i.e. investing on a unfavorable market or not investing in a rich market).

The *markets* are characterized by: *the success probability*, i.e. the probability for an *agent* to obtain positive yields if he will decide to invest in that *market*, *the profit margin*, i.e. the maximum investment multiplier that an *agent* can obtain if he invests on a *market* and obtains a success, and *the market dimension*, i.e. the total gain offered by a *market*. All the *market* parameters are unknown to the *agents*. They can obtain information about them from the three information channels: personal intuition, personal experience or neighbors' experience. Moreover, the *success probability* and the *profit margin* dynamically evolve depending upon the agents' investments. The more the agents investing in a market and the higher is the associated competition. This will introduce saturation effects causing a reduction of the effective success probability and profit margin. On the other side, if only few agents, compared with the market dimension, are investing in a market, the associated level of competition is low and the saturation effects will not be activated.

Each *agent* is characterized by: *the firm size, S*, i.e. the financial resources that a firm can use to invest on the markets (we suppose the whole value of the firm), the *animal spirit*, the *risk aversion* and the *managerial skills*. The animal spirit represents the tendency of an agent to over-estimate a market: a measure of optimism. If the animal spirit is null than the agent is very pessimistic about every investment opportunity and he will never invest, while if the animal spirit is high the agent optimistically overestimates the markets and he will invest and operate more often. The risk aversion is the propensity to face the investment risk associated with the new markets. The managerial skills measure the ability of an agent to obtain a success investing in a market. If an agent invests in a market and he obtains a success, he will increase his managerial skills. This will increase the success probability associated to the interaction with that market.

In the Cellular Model, we characterize an Industrial District by its *transparency*, a measure of the *information diffusion rate and precision*. In our case, the transmitted information regards the agents' knowledge about the markets in terms of experienced occurrence of success and profit margin while the information transmission rate is represented by the number of agents contacted in each time period.

The agent-agent interaction rules impose that in each period the agent transfers information on his investment performances (occurrence of success and profit margin) to N_c (number of contacted agents) neighbors agents. Non-linearity and feed-back control directly derive from the transmission mechanism. The U-topology, I_c, defines the agents to be contacted to exchange information with and N_c represents the number of cells in that neighborhood. In this sense, N_c is an approximate measure of the information diffusion rate. The agent-market interaction rules (investment decision and investment yields) depend upon the agent knowledge of the markets and the agent and market properties. Dynamical evolution coming from saturation effects, competition, know-how acquiring, prime-moving has also been included in the agent-market interaction rules.

We performed parallel simulations, with the same starting conditions and the same succession of events, on twelve *(20x20x10)* cellular lattices the only difference being
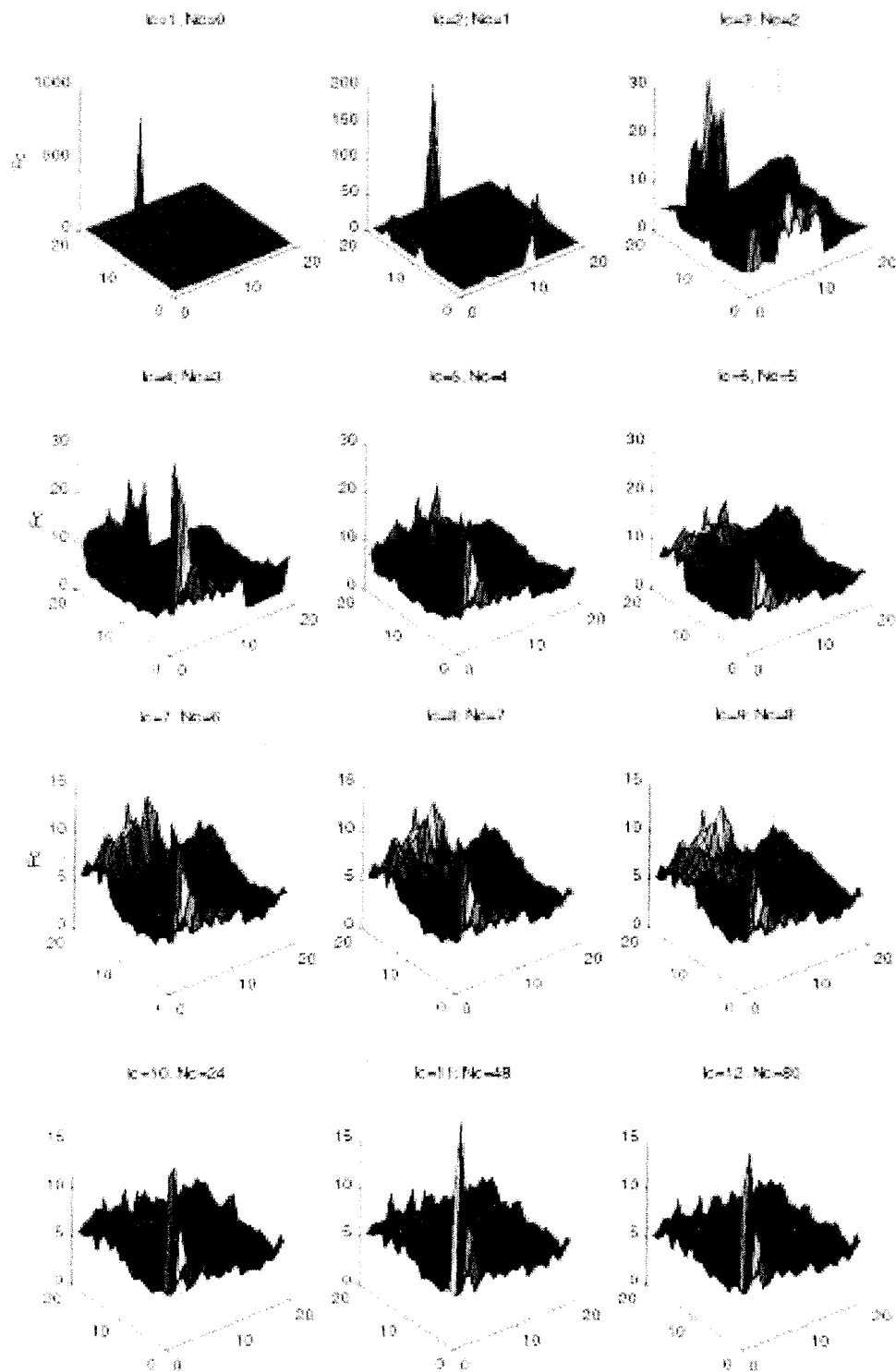
Figure 1 Single Agent Growth Rate (Fr) with respect to the Communication Neighbourhood (Ic) and the Number of Contacts (Nc) within a time period. Each peak represents the growth rate for a single agent in the 20×20 Cellular Lattice after 120 time periods. Note the Fr rescaling from 1000 to 200, 30 and 15 going from Nc=0 (No Information Transmission) to Nc=80 (Broadcasting Information Transmission)

the interaction neighborhood, I_c, related to the information exchange. Since I_c defines the number of contacted agents per period, N_c, the parallel simulation gives a picture of the evolution of the district with respect to the information diffusion rate. Considering Automata with $N_c=0,1,2,3,4,5,6,7,8,15,24,80$ the simulations run over 120 periods. Although we do not include a temporal calibration, this will cover ideally a 10 years evolution. With a stochastic dynamic, the same initial conditions generate a probability distribution over a space of possible final states. The dependence of the model with respect to the starting conditions has been tested by repeating 50 times the simulation keeping the same starting point with a different succession of events, and other using the same succession of events but different starting points. Repeating 20 complete different simulations has tested the robustness. Although the distribution of the quantitative results shows a high standard deviation (about 30% respect to the mean values) the qualitative interpretation of them in terms of macro economical behaviors are quite similar.

At the end of each simulation, the state of the agents and of the district has been summarized by two sets of indices: the growth factors (individual and global) and some resources concentration indicators. The agent growth factor, $F_c=S_{120}/S_0$, represents the firm size at the end of the simulation with respect to the initial size. The results, for a typical simulation, are displayed in Figure 1 where a $3D$ representation of the agent growth factor with respect to the number of contacts, N_c, shows a strong evidence of a steadying influence from increasing the information exchange. It is evident that a monopolistic state will establish in a situation where the information exchange is nil ($N_c=0$). As the information exchange rate increases, we obtain a more uniform distribution in the agents' growth factor. We also note that the district leading position is assumed by the prime mover while the exchange rates is low ($N_c \leq 8$) and by the most skilled agent when the exchange rate gets higher ($N_c \geq 25$).

Figure 2 summarizes the global properties of the system. The average growth factor and some concentration indices are displayed with respect to N_c. The average growth factor, $\overline{F_c}$, shows a monotonically increasing behavior with an asymptotic regime in the limit of the high information exchange rates. The asymptotic behavior comes from saturation effects in the information diffusion. The transmission rate is so high that all the information will be almost immediately available to each agent in the lattice. These results seem to indicate that a higher information flow within the district helps the global growth of the system favoring the richness diffusion.

This last aspect is evident in the curves (figure 2) of the percentage of richness concentrated on the biggest 4, 10 or 15 firms, C_i, $i=4, 10, 15$. The C_i values represent, from an economic point-of-view, a set of concentration indicators more meaningful than the usual statistical ones.

In conclusion, the cellular agent-based approach applied to simulate the dynamic of an industrial district permitted us to analyze the role of the information exchange rate on the system industrial and commercial growth in terms of both diffusion and absolute value. The simulation results indicate a positive effect of the information exchange on the industrial development of the whole district.

Despite the accurate description of the agents, markets and interaction rules involving a large set of parameters the parallel simulation, fixing everything except the information exchange rate, show an acceptable degree of robustness and stability.

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