The application of cellular automata in modeling of opinion formation in society

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Abstract

In the recent years it has been shown that behavior of the human social activities can be successfully simulated by quite simple models. Among them, very interesting due to its discrete representation, seems to be cellular automata. In the presented paper we would like to deal with this approach introducing some corrections to the model of cellular automata with two absorbing states. The simple version of this model has already been used in simulations of the opinion formation by Bagnoli and the obtained results were very promising. Our modifications lead to the new phase diagram shown in the paper. We present also general differences implicated by the Bagnoli's model modifications.

1. Introduction

Simulation of the social opinion formation is a very difficult and complex process [1]. Usage of a lot of small, simple models has been common in this discipline recently. Especially cellular automata models [2] are very widely used in this branch of science as models of homogeneous population where the same rule is applied to all elements of the system simultaneously. Referring to such models we can, for instance call Sznajd-Weron's model [3] or Galam's model [4] as a typical representative.

The next section presents a brief introduction to our model. We have shown the basis of models and ideas used to create the model rule. Next we have shown the results of our computations, i.e. phase diagram with quality discussion.

2. Model

Usually totalistic cellular automata models have been used for computations which means that all elements of neighborhood have the same influence on the state of the cell in the next temporary step. In our model we have broken this

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assumption by introducing the rule depending on localization of active cells in the neighborhood.

Such a point of view we have borrowed from real society where obviously the pressure of society has very strong influence on the decision of a single person in election. But we can not forget that each of them has his own political inclination and very often such an inclination is built from a lot of small factors (beginning with origin and finishing with health condition). It would be very interesting to analyze each of the mentioned factors but in our model we have gathered all of these in two coefficients p_1 and p_2.

We have built our model on the one-dimensional lattice, where each cell can be occupied (value is 1) or unoccupied (value is 0). In the meaning of opinion formation each cell represents one person (but in another case we can assume that cell represents family or another group of people) and if it is active it means that its political beliefs are rightist and if it is inactive its beliefs are leftist. Periodic boundary conditions have been used.

Let's assume that neighborhood radius is equal 1 (it means that neighborhood has three elements). Let's assume also the model will be symmetric (change of left and right neighbour should not change result).

Such a model can have six possible configurations of the neighborhood:

$$
\begin{aligned}
&(000) \\
&(100) = (001) \\
&(010) \\
&(110) = (011) \\
&(101) \\
&(111)
\end{aligned}
\tag{1}
$$

In the creation of the rule we tried to make use of the following ideas:
1. If all elements of the neighborhood have the same state, nothing should be changed with the cell.
2. If only one neighbor (left or right) is unoccupied, the cell will be occupied in the next temporary step with the probability p_1.
3. If only one neighbor (left or right) is occupied, the cell will be occupied in the next temporary step with the probability $(1-p_1)$.
4. If only the central cell is active, it will stay active with probability p_2.
5. If only central cell is inactive, it will become active with probability p_2.

Summing up the above ideas with representation (1), leads us to the following form of rule:

If neighbour configuration is

$$(000)$$
$$(100) = (001)$$
$$(010)$$
$$(110) = (011)$$
$$(101)$$
$$(111)$$

cell will be active with probability

$$0$$
$$1 - p_1$$
$$p_2$$
$$p_1$$
$$p_2$$
$$1$$

In the meaning of opinion formation rule 1 means that if all beliefs in the vicinity of people are the same, there is not any pressure and people's beliefs remain the same. Rules 2 and 3 represent the case where only one neighbour presents other beliefs. Coefficient p_1 represents the ability to stay with old beliefs if such a case occurs. Rules 4 and 5 represents the case where whole exerts pressure on people vicinity. Coefficient p_2 is the numerical value of ability to stay with old beliefs in spite of such pressure.

3. Results

Before we started working with the model, it was a very important thing to discover the period of time, which model needs to get stability, simply a transient period. The information about the dependence of the transient period on the value of parameters p_1 and p_2 are important for us. Preliminary simulations have brought us to diagram 1. There is drawn the dependence of density of active cells in the function of time. We chose for the simulations four points from the range of p_1 and p_2 i.e. (0.2; 0.8), (0.5; 0.2), (0.5; 0.8), (0.8; 0.5).

From the diagram if can be seen after about 200 time steps, the system is stabilized. In our next computations we chose 600 steps as a transient period, just in case.

The phase diagram for our system is presented in Figs. 2 and 3. Fig. 2 shows the structure of the system in the three-dimensional space. However, Fig. 3 is projection on the plane where the third dimension is represented by the gray scale.

If we try to compare our phase diagram with the phase diagram of model with two absorbing states [5, 6], the first thing which distinguishes both is the fact

that for our model in the diagram it is a region which depends on the initial state density. In the model with two absorbing states such a relationship does not exist.
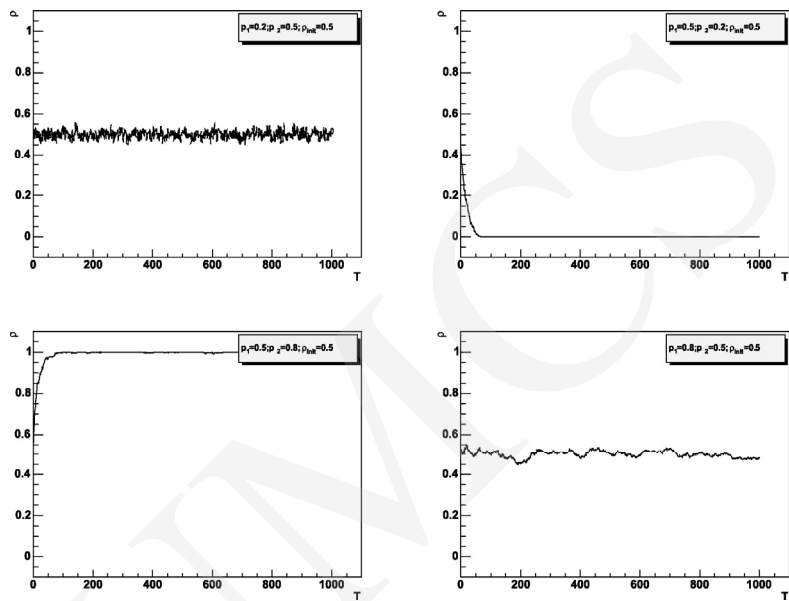

Fig. 1. Diagram shows the model with the occupied cells density in the function of temporal steps. The initial density in all cases is ρ_{init} =0.5, (top left) p_1 =0.2 p_2 =0.5, (top right) p_1 = 0.5 p_2 = 0.2, (bottom left) p_1 = 0.5 p_2 = 0.8, (bottom right) p_1 = 0.8 p_2 = 0.5.
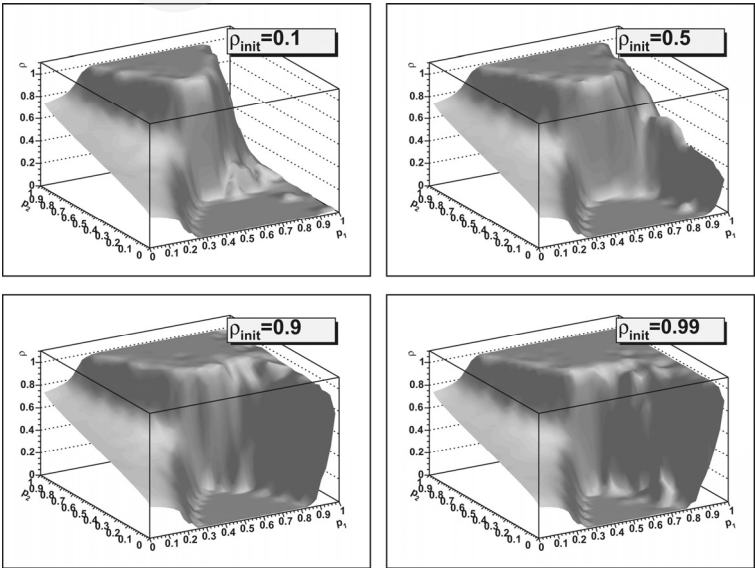

Fig. 2. Model phase diagram for the different initial density ρ_{init}.
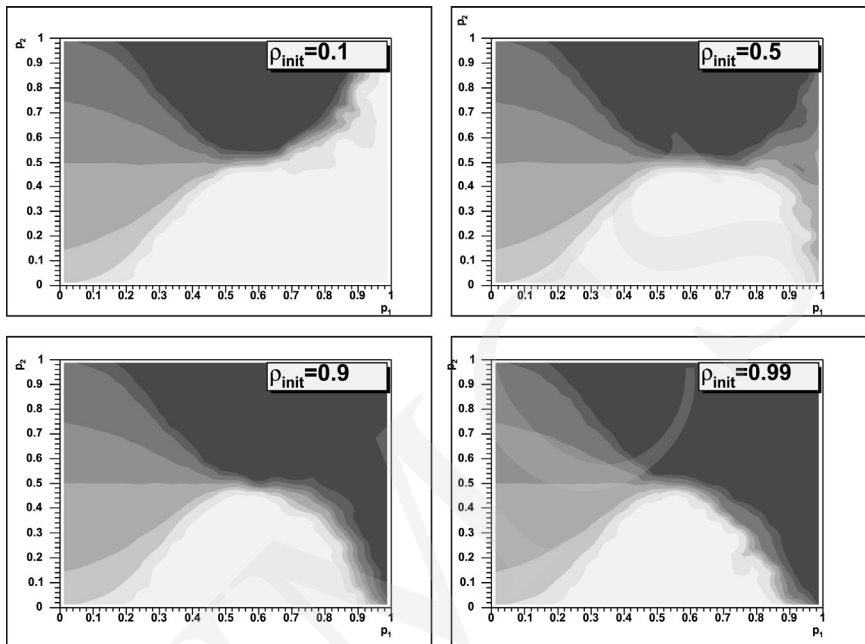
Fig. 3. Model phase diagram (the same as Figure 2 but in the gray scale)

4. Summary

In the diagram we can distinguish four different areas:

1. for the small p_1 the area is rather flat and the state of the system does not depend on the state of initial density,

2. for the middle p_1 and small p_2 there is an absorbing state (to the inactive state),

3. for the middle p_1 and great p_2 there is an absorbing state (to the active state),

4. for the great p_1 the system exhibits a very interesting behavior depending on the initial density.

It is worth stressing that the transient effect in the system does not depend on the area that the system occupies in the diagram. The four mentioned areas of diagram are implicated by proper configurations of the coefficients p_1 and p_2.

Areas 2 and 3 are the after-effect of absorbing states and from the point of view of opinion formation this is the situation in which the society is unanimous. Such a situation takes place when one of political groups has dominant influence on all persons in the society.

Area 4 is more interesting because the final state of the system depends on the initial density which means that in the society, people's consciousness plays a dominant role and it is very difficult to change it.

Finally, area 1 is the most interesting. In this case the final density does not depend on the initial density, so we have a situation in which the society is completely determined by factors (in the model they are represented by p_1 and p_2) like media or political pressure.

Summing up, although the model presented in the paper is very simple, the phase diagram obtained by using it to the simulations is very interesting. In the diagram we can find a lot of interesting regions and there are also a lot of other features (like e.g. boundaries between areas 1, 2, 3 and 4) which have not been explored yet.

In order to use this model in real simulations we ought to create 'bridge' between the coefficients p_1 and p_2 and the real factors (which determine opinion formation). This is what we are going to do soon.

References

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