Cellular Automata, Agents with Mobility and GIS for Practical Problems

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Abstract. Some real applications of improved cellular automata models are considered. Considered improvement of models concerned the using real data applications from GIS and incorporating the concepts from other methodologies – especially neural networks and learning. We describe models which allow considering different processes in the case of Ukrainian capital Kyiv. Migration processes and voting processes have been considered. New ways of cellular automata development are discussed.

Keywords: Cellular automata, urban planning, multiagents, GIS, opinion formation.

1 Introduction

Since the origin at 50th years of past century cellular automata had many developments and applications in physics, biology, mathematics, technique (see the books J. Von Neumann, Toffoli T.&Margolus S., Chopard B.&Droz M., Langton C., Wolfram S., Illiachinski A., L. Chua etc.). But now new fields of cellular automata theory and applications are in the processes of intensive development.

Although the papers with applications of cellular automata to the social systems have been proposed at 80th – 90th years recently many questions still are open. For example, important and prospective are idea on binding cellular automata approach with multi-agent approach (especially of moving agents) (see [1, 2]); idea of incorporating learning approaches for deriving the parameters of transition functions in cellular automata; investigations of the role of anticipation in cellular automata models of social systems ([3, 4]). The development and merging of such concepts are still continuing. But the formal classical frames of existing approaches and tools sometimes restrict the applications of concepts to real systems and problems. The strict abstract frames also involve frequently the difficulties in interpretation of received results in the common for practical user's descriptions of social systems (for example, by maps, useful tables, networks structures etc.). As the authors suppose the solution of such problems will be find in the using recent practical tools for data representation [5]: special data bases, geo-information systems (GIS), 3D visualization in time. So in the

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next subsection of proposed paper we at first will describe some problems, which has a practical importance and which use combination cellular automata models with some kind of mobility accounting. At first we describe the modeling of scenarios of harmful manufacturing remouting from the city. Then we remark the problem of migration scenarios of country population and epidemic modeling for Ukraine. Also we describe the problem of modeling political preferences of population (especially of political election) in the case of Ukraine.

Then in the last subsection of the paper we discuss some ways of cellular automata development which follows from analysis of current state of investigations and from our experience of solving real practical problems. Opinion formation problem, political elections and team sportive games are proposed as the background for investigation the problems with multi-agents nature of the systems.

2 Examples of Cellular Automata Modeling for Real Problems

2.1 Modeling of the Isolating of Harmful Manufactures Out of the Borders of the City of Kiev

Here we briefly reproduce the main concept of models from ([6]). The model is made so that it shown as spatial distribution depends on preferences of agent situated on the grid. In simplest variant the agent (the people or company) lives on lattice $N \times N$. Irregular lattice (and special Voronoy cells) may be used for actual geography. The set of agents is $M = \{1,2,...,m\}$. The agents choose the locations. More than one agent can occupy the same location on lattice. The level to usefulness of the agent and need of its using the site depends on distribution agent on lattice and many other parameters: social, economical, geographical and cultural. Allow F to mark distribution an agent on set of the locations. F_{ij} has marked the number an agent, living in i-th row and j-th row of the lattice. Utility function $u : N \times N \times F \to R$ is one of the key components of current approach. Considering identical agents, initial distribution F, the final distribution should be determined which maximize usefulness $F_{ij} \times u(i, j, F)$. Usefulness of the agent depends of all factors: population in its initial location and average distance from its initial location before the other agent.

We have applied the models for different processes. We had considered in details one of the important problem – the scenarios of harmful manufacturing relocation from the city with use the real data [5]. In such case each agent corresponds to single harmful manufacturing. Using such improved models we had considered the processes of relocating of harmful manufacturing in Kiev in dependce on ecological, financial, infrastructure conditions. Scenarios correspond to different utility functions.

2.2 Modeling of Migration Scenarios at Ukraine

Other important class of problems is investigation of migration processes of large scales – regional, country, trans-regional. Fortunately the approach from previous

subsection allows also considering such problems, for example modeling of migration scenarios, different attitudes of population, merging of multiagent and cellular models. All such models allow using of Geoinformational systems and real data base.

2.3 Modeling of Epidemic Scenarios by Cellular Automata

In some previous work (see [7]), it is proposed to use the Stochastic Cellular Automata paradigm to simulate an infectious disease outbreak. The simulation facilitates the study of dynamics of epidemics of different infection diseases, and has been applied to study the effects of spread vaccination cells izolation. Fundamentally the simulator loosely simulates the SIR (Susceptible Infected Removed) and SEIR (Susceptible Exposed Infected Removed) models.

Then, a Cellular Automata model for disease spreading have been developed, implemented and studied in some details. This has been performed on abstract level, but nevertheless with some surprising results: even a simple spreading model can exhibit a sharp transition between controlled situation and devastating epidemics.

2.4 The Problem of Opinion formation and Political Elections

Other very important part of real society is different social and political processes. Here we very shortly describe the problem which is interesting for cellular automata applications. Very important part of social structure is election of different representative authorities and governmental structures. Our implementation of such services had been concentrated mainly around the elections at Ukraine. During our research and information system development we had used different models for election considering: simple algebraic; neural networks; differential equations of diffusive type; models with associative memory; cellular automata.

The choice of models for implementation in the information system depends on the goals of modeling, the processes under investigation, complexity of the models, existing of computer and financial resources etc. One of the basic models of system is the model for the dynamics of voter preferences. Simplest models already had been used in forecasting of last president election campaign in Ukraine at 2010 year.

Remark that the next useful step at improving the solutions of such problems consists in using cellular automata models but with the cells which have non-square shape and which correspond to the real distribution of populations in geographical environment.

3 Discussions

Described above results are interesting as the examples of important problems solutions. But analysis of such examples (and other investigations and papers) allows considering some already existing tendencies and anticipating the new possibilities for cellular automata development.

The first tendency consists in merging the cellular automata approach with using real data base. This will follow to weakening the useful requirement on regularity and homogeneity structures accompanied by adjusting real data from geoinformational system (GIS).

The second tendency is related to the idea of considering moving elements on the regular space subdivision. Following [1, 2] it is useful to name it 'situated moving agents' where 'agent' understands as some elements which have own preferences. Remark that traffic and pedestrian movements are the good examples of such systems. Also many such problems supply ecology, political and social sciences, economy.

Now also relatively new tendency may be found in the theory and applications of cellular automata approach – namely, correct accounting of different properties of the objects of modeling on the base of cellular automata approach.

First of all we should remark the spreading ideas from the field of artificial intelligence, especially the different kinds of learning, including reinforcement learning. Of course some investigations in this field exist more then third years (especially in social modeling: emerging of social norms, rules, order and power). But now new possibilities emerges for cellular automata models by more extensive use of recent data mining approaches, multi-agent modeling, decision-making theory and computational neuroscience, including using of computer models for brain processes.

Because of such presumable expanding of cellular automata modeling more involved models will be useful. Here we remark only some evident possibilities. The first consists in using more complex structure of cellular automata – especially by hierarchical models. The second tendency is using more complex dynamics for each cell states evolution, by the rules for transition of cells states for the next moments of time. This may include as the models for internal dynamics of cell's states as the modified internal descriptions of the environment and neighbor cell's dynamics. Remark that for these goals (description, dynamics and reinforced models) may be useful the neural networks models with internal representation of the systems in elements (see [4]). The next direction for cellular automata models improvement consists in more detailed accounting of evolutionary aspects of dynamics in the rules of the models. Following the general outlines from physic the first example consist in accounting the memory (delay) effects in cellular automata. Relatively few papers on such investigations have been published before.

But recently the accounting of strong anticipatory property by D. Dubois in cellular automata opens the new prospects in the theory and applications of cellular automata. Since the of 90-th by D.Dubois [8] the idea of strong anticipation had been introduced: "Definition of an incursive discrete strong anticipatory system …: an incursive discrete system is a system which computes its current state at time t, as a function of its states at past times $,..., t-3, t-2, t-1$, present time, t, and even its states at future times $t+1, t+2, t+3,...$

$$x(t+1) = A(..., x(t-2), x(t), x(t+1), x(t+2),..., p)$$

where x at future times $t+1,...$ is computed in using the equation itself".

We already had been investigating some such effects in game 'Life' models and in some traffic problems [3, 9]. The main new peculiarity by accounting strong anticipation is the possibility of multivaluedness of element's state at given moment of time. Remark that recently we have found the way for using such multivaluedness for description of intrinsic uncertainty in the traffic problems.

4 Conclusions

Thus in proposed paper we have discussed some presumable ways for development of cellular automata which follows from analysis of some concrete models and applications. May be the most interesting is the intensive using of real geography and geometry of considered objects and systems especially with geoinformational systems; exploiting idea of situated cellular agents and using more complex representation of cellular automata structure, description of rules and states and more complex dynamics of cells, especially with accounting memory and anticipation.

References

1. Bandini, S., Manconi, S., Vizzari, G.: Agent based Modeling and Simulation. In: Encyclopedia of Complexity and System Science, pp. 184–197 (2009)
2. Bandini, S., Manconi, S., Vizzari, G.: Situated Cellular Agents a Model to Simulate Crowding Dynamics. Special Issues on Cellular Automata E87-D, 669–676 (2004)
3. Goldengorin, B., Makarenko, A., Smelyanec, N.: Some Applications and Prospects of Cellular Automata in Traffic Problems. In: El Yacoubi, S., Chopard, B., Bandini, S. (eds.) ACRI 2006. LNCS, vol. 4173, pp. 532–537. Springer, Heidelberg (2006)
4. Makarenko, A.: Anticipating in modeling of large social systems - neuronets with internal structure and multivaluedness. International Journal of Computing Anticipatory Systems 13, 77–92 (2002)
5. ISGEO 2012 WWW Intelligence Systems GEO (2012), http://www.isgeo.kiev.ua
6. Page, S.: On the emergence of cities. Working Paper Santa- Fe Institute n. 98 -08- 075e, 28 p (1998), http://www.santa-fe.edu/sfi/publications/working-papers/98-08-075E.ps
7. Venkatachalam, S., Mikler, A.R.: Towards Computational Epidemiology Using Stochastic Cellular Automata in modeling spread of diseases, Department of Computer Science and Engineering, University of North Texas, Denton, TX - 76207, USA (2005), http://www.cerl.unt.edu/publications/2005/ps/Paper_hawaii.ps
8. Dubois, D.: Introduction to computing Anticipatory Systems. International Journal of Computing Anticipatory Systems (Liege) 2, 3–14 (1998)
9. Makarenko, A., Krushinski, D., Goldengorin, B.: Anticipation and Delocalization in Cellular Models of Pedestrian Traffic. In: Proceed. of INDS 2008, Klagenfurt, Austria, pp. 61–64. Shanker-verlag, Aachen (2008)