Modelling with cellular automata: problem solving environments and multidimensional applications

Naumov, L.A.

Publication date
2011

Summary

In English

The aim of the work in this thesis was to create a general, universal and sophisticated cellular automata modeling environment, suitable for a wide range of research in different theoretical and practical fields, and demonstrate applications for one-, two-, and three-dimensional problems.

In Chapter 2 we study existing cellular automata based problem solving environment. Nine invariant requirements for a general cellular automata based modeling environment are formulated. An overview of existing tools is presented, as well as their conformance to the list of requirements.

As a response to the requirements "CAME$_{\&}$L " ("Cellular Automata Modeling Environment & Library") was developed. CAME$_{\&}$L allows to model an even wider class of systems then "cellular automata". This was achieved with the help of the cellular automata based computational experiment decomposition, which allows to distribute the necessary functionality between five independent components of different purposes: grids, data, metrics, rules, and analyzers.

Chapter 3 is divided into two parts, both of which present an application of the modeling environment for theoretical oriented research. In Sect. 3.1 a classification of structures generated by one-dimensional binary cellular automata from a single seed has been performed, focussing on the question how many and what kind of classes of equivalence can be distinguished for this kind of structures? Seventy variants of classifications have been performed. In addition, it was shown that it is possible for a structure generated by the automaton with cells, which have memory, to belong to the same class as a structure, generated by an automaton with memoryless cells.

Another theoretical application is presented in Sect. 3.2. Thanks to the detachment of a metrics into a separate part of the computational experiments definition, it is possible to use non-standard coordinate systems. We call a mapping of multidimensional grids into one-dimensional coordinates "generalised coordinates".

CAME$_{\&}$L allows to test and study different methods of such coordinated usage, providing a universal way of data storage for completely different grids. When using generalized coordinates, the grid can be easily enlarged if necessary, because appending of cells to the end of a chain is much simpler than reallocation of a multidimensional block structure. Moreover, in this case the state always presents a serial data and can be serialized straightforwardly.

Chapter 4 demonstrates an application of CAME$_{\&}$L for three-dimensional tumour modeling. First several approaches to tumour shrinkage modeling are presented and compared. In addition we presented a tumor cells mitoses rate study. Having no ability to measure such microscopic parameter as the successful mitoses rate in real biological system, we can draw some conclusions about its magnitude, based on the simulation performed with CAME$_{\&}$L and in vitro experiments of larger scale [164]. Our results suggest that at least

55% of inner proliferating tumour LoVo cells are dividing.

Presenting $CAME_{\&}L$ applications for the theoretical and practical research, we have also demonstrated its usability for one-dimensional (Sect. 3.1), two-dimensional (Sect. 3.2), and three-dimensional (Chapter 4) problems. This proves the fact that $CAME_{\&}L$ is a universal and powerful problem solving environment.