

Supercomputer Technologies in Agent - Based Models

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Experience of Some Scientists and Practical Experts Well-known examples of launching agent-based models on supercomputers

- EURACE Project
- FuturICT
- ABM++ EpiSims
- EpiFast
- A Flexible, Large-Scale, Distributed Agent Based Epidemic Model
- Agent-based modeling and Simulation for EXASCALE Computing

Software for HPC ABM

- Microsoft AXUM
- RepastHPC
- CyberGIS
- MUSE (Miami University Simulation Environment)
- Pandora
- SWAGES
- HPABM (A Hierarchical Parallel Simulation Framework for Spatially-explicit Agent-based Models)

Our approach: Supercomputer Technology for Agent-oriented Simulation (STARS)



The model was launched on the supercomputer “**Lomonosov**”, which simulated the socio-economic system of Russia for the next **50 years**. This ABM is based on the interaction of **100 million agents**, which hypothetically represent the socio-economic environment of Russia. The behavior of each agent is set by a number of algorithms, which describe its actions and interaction with other agents in the real world.

The initial agent -based model

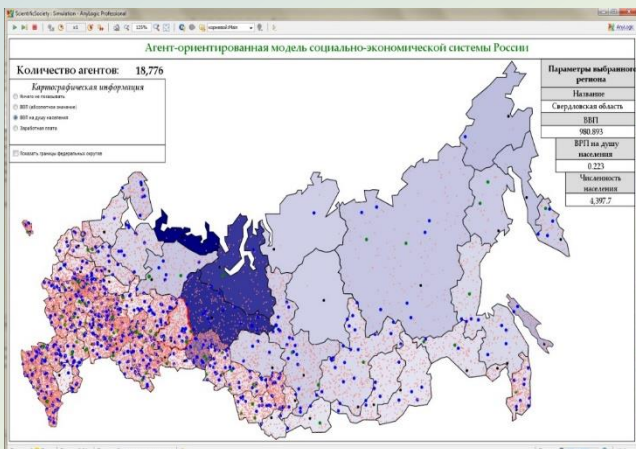
The specification of the agents of the model was carried out taking into consideration the following parameters: **1) age; 2) life expectancy; 3) specialization of parents; 4) place of work; 5) region of residence; 6) income and others.**

The specification of regions was carried out, taking into consideration the following parameters: **1) geographic borders; 2) population; 3) number of workers (by type); 4) GRP; 5) GRP per capita; 6) volume of investments; 7) volume of investments per capita; 8) average salary; 9) average life expectancy; 10) index of population growth, etc.**

The major actions of agents are:

- aging (change from the category «children» to category «working age adults», and then - to «pensioners»);
- creating family;
- giving birth to a child;
- acquiring profession;
- religious activity;
- change of job;
- migration to other regions (or countries).

These actions are accompanied by the change in the number agents within corresponding groups with respect to (a) ethnicity, (b) religion, (c) nationality etc.



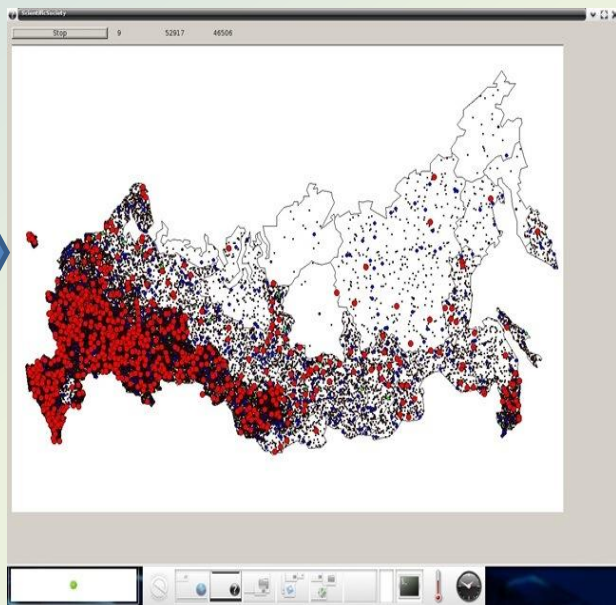
The initial agent -based model

The first stage of development of the ABM, is to construct a tool that effectively solves the problem of research on conventional computers, as well as adjusting the parameters of the model. After its successful testing with a small number of agents (about 20 thousand - is the number of agents, with which conventional computers are able to perform calculations at a satisfactory rate and with good productivity, given the complexity of agents) it was decided to convert the model so that it could be used on a supercomputer – this was the second stage of development. During the first stage the AnyLogic product was used, the technical capabilities of which, allowed to debug the model at a satisfactory speed and to configure its settings.

Translation of the model

- ❑ The models in the **AnyLogic project** are kept in the format of an XML-file, containing the tree diagram of the parameters necessary for the generation of the code: classes of agents, parameters, elements of the presentation, descriptions of the **UML-diagrams** of the behavior of agents.
- ❑ During the work of the converter this tree diagram is translated into code **C++** of the program, calculating this model. The entry of the tree is executed “depth wise”. At that, the following key stages are marked, and their combination with the translation process is carried out.
 - 1. *Generating the main parameters.*
 - 2. *Generating classes.*
 - 3. *Generating the simulator.*
 - 4. *Generating shared files of the project*

Result of the work of the supercomputer program in graphic format



Supercomputers available for calculations

At the moment of making the calculations three supercomputers were available to us, which were in the top five of the supercomputer rating of the Top-50 supercomputers in the CIS countries.

Position in Top -50	Supercomputers	Nodes	CPU	Kernels	RAM/ node	TFlops
1	«Lomonosov» (Moscow State University)	5 130	10 260	44 000	12GB	414
4	MVS-100K (Interagency Supercomputing Center of the RAS)	1 256	2 332	10 344	8GB	123
5	«Chebyshev» (Moscow State University)	633	1 250	5 000	8GB	60

Results

By using supercomputing technologies and optimizing the program code we were able to achieve very high productivity.

The optimization of the code and the use of C++ instead of Java allowed for the increase in speed of execution of the program. The model was tested in the following initial conditions: **1) number of agents – 20 thousand; 2) forecasting period – 50 years**. The results of the calculations showed that the count time of the model using ADEVS amounted to **48 seconds** using one processor, whereas the count time of the model using AnyLogic and a single processor amounted to **2 minutes and 32 seconds**, which means that the development framework was chosen correctly.

As has already been noted before, an ordinary personal computer with high productivity is able to carry out calculations with satisfactory speed with a total number of **20 thousand agents** (the behavior of each is defined by around **20 functions**). At that the average count time of one unit of model time (one year) amounts to around one minute. When dealing with a larger number of agents, **100 thousand** for example, the computer simply **“freezes”**.

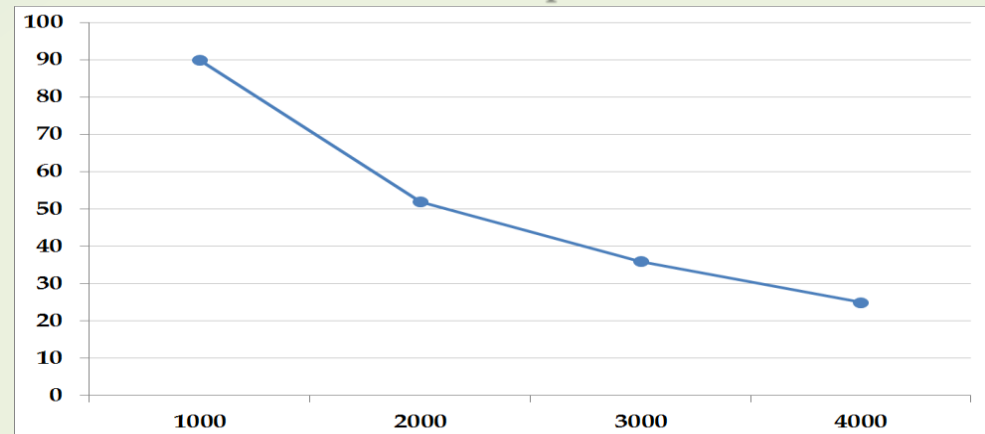
Using the **1000 processors** of the supercomputer and executing the optimized code, allowed to increase the number of agents to **100 million**, and the number of model years to **50**. At that, this enormous volume of research was carried out in a period of time, which approximately equaled **1 minute and 30 seconds** (this indicator may slightly vary depending on the type of processors used).

Results of the modeling showed, that if the current tendencies ensue the population of the **Siberian** and the **Fareast Federal Districts** will significantly decrease, while in the **Southern Federal District**, on the contrary, there will be a significant increase in population. In addition to that, the modeling carried out gives reason to predict a gradual decrease of the GDP, as well as several other macroeconomic indicators.

The results of the experiments carried out using the developed ABM revealed that the scaling of the model in itself has certain meaning. For example, when launching the same version of the model for **50 model years** using the same parameters (except for the number of agents: in the first case there were **100 million agents**, in the second – **100 thousand agents**) the results received, that is the scaled number of agents, had a difference of about **4,5%**.

It can be assumed that in complex dynamic systems the same parameters (birth rate, life expectancy etc.) may produce different results depending on the size of the community.

Time for calculating the model as a function of the number of processors



(X axes– number of processors, Y axes – time in seconds)

This work is supported by Russian Science Foundation (grants № 14-18-01968).