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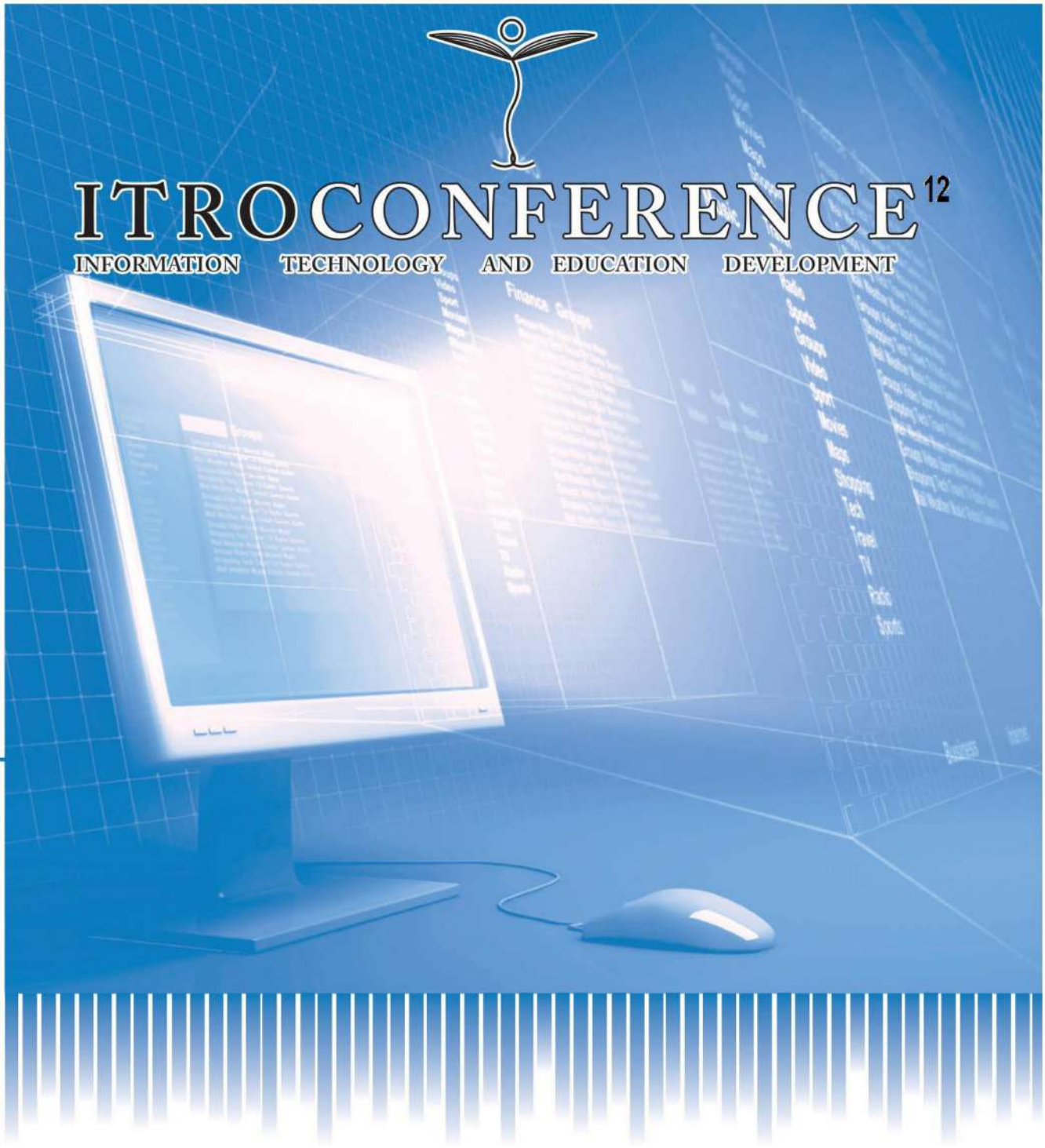
INFORMATION TECHNOLOGY AND EDUCATION DEVELOPMENT



PROCEEDINGS

ZRENJANIN, November 2021

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TECHNICAL FACULTY "MIHAJLO PUPIN"
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With this publication, the CD with all papers from the International Conference on Information Technology and Development of Education, ITRO 2020 is also published.

INTRODUCTION

This Proceedings of papers consists from full papers from the International conference "Information technology and development of education" - ITRO 2021, that was held at the Technical Faculty “Mihajlo Pupin” in Zrenjanin on November 26th 2021.

The International conference on Information technology and development of education has had a goal to contribute to the development of education in Serbia and the Region, as well as, to gather experts from natural and technical sciences’ teaching fields.

The expected scientific-skilled analysis of the accomplishment in the field of the contemporary information and communication technologies, as well as analysis of state, needs and tendencies in education all around the world and in our country has been realized.

The authors and the participants of the Conference have dealt with the following thematic areas:

- Education in crisis situations
- Educational challenges
- Theoretic and methodology questions of contemporary pedagogy
- Digital didactics of media
- Modern communication in teaching
- Curriculum of contemporary teaching
- E-learning
- Education management
- Methodic questions of natural and technical sciences subject teaching
- Information and communication technologies

All submitted papers have been reviewed by at least two independent members of the Science Committee. There were total of 94 authors that took part at the Conference from 12 countries, 3 continents: 52 from the Republic of Serbia and 42 from foreign countries such as: Macedonia, Bosnia and Herzegovina, Hungary, Slovakia, India, Bulgaria, Rumania, Albania, USA, Canada, Malaysia. They were presented 49 scientific papers.

The papers presented at the Conference and published in Proceedings can be useful for teachers while learning and teaching in the fields of informatics, technics and other teaching subjects and activities. Contribution to the science and teaching development in this Region and wider has been achieved in this way.

The ITRO Organizing Committee would like to thank the authors of papers, reviewers and participants in the Conference who have contributed to its tradition and successful realization.

Chairman of the Organizing Committee

Snežana Jokić, Ph.D, Ass. Professor

CONTENTS

INVITED LECTURE

SCIENTIFIC PAPERS

Agent-based Modelling and Simulation

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Abstract -One of the most important methods in the educational process, is modelling and simulation of real-world problems. In many situations it is not possible to experiment with real objects to find the right solutions: building, destroying, and making changes may be too expensive, dangerous, or just impossible. Modelling and simulation can be used to build model to represent the real system.

Agent based modelling is a relatively new method compared to system dynamics and discrete event modelling. That are computer simulations used to study the interactions between people, things, places, and time. The agents are programmed to behave and interact with other agents and the environment in certain ways.

In this paper, the agent-based modelling simulation is considered. In simulation software Anylogic are given some examples of agent-based modelling.

I. INTRODUCTION

The modelling and simulation can be used for building models in order to represent the real systems. A simulation is the imitation of the operation of real-world process or system, over the time. In many cases, when it is not possible to experiment with real system for finding the solution, the simulation models are used. For example, building, destroying, and making changes may be too expensive, dangerous, or just impossible. In this case, it is better to build model that uses modelling language to represent the real system.

On the one side, a model should be a close approximation on the real system, and it should contain the most of its important features. On the other side, the model should be simpler for understanding and experimenting, [1], [2].

The simulation modeling is appropriate tool in the following cases [2]:

- when the problem can not be solved analytically.
- Simulation allows the study of internal interaction of subsystems in the complex system.
- Informational, organizational and environmental changes can be simulated in order to be seen their affect in the real system.
- By changing of the simulation inputs and observing of the resulted outputs, can be determined which variables are important and how those variables affect on the system.
- Verification of analytical solution.
- A plan can be visualized with animated simulation.
- Simulation models designed for training make learning possible without incremeting of the cost.

The simulation of the models has advantages and disadvantages. The advantages of the simulation refer to the operations in the real system which are not interrupted, and not used real resources. Also, the time can be compressed or expanded to allow speed-up or slow-down of the phenomenon. In the simulation the variables are controlled. It also provides testing of the hypothesis about why and how certain phenomena are occurred. In the simulation questions in the form “What if” questions can be asked with obtaining appropriate answers. The disadvantages of simulation are that the building of the model requires special training. The obtained simulation’s results often are difficult for interpretation. The process of simulation can be long and expensive because many simulations require special software which have output analysis, [2],[4].

The main aim of the simulation modelling is creation of the framework in which by using of methods we map a real-world system to its model. There are three methods in simulation modelling:

- System Dynamics
- Discrete Event Modeling
- Agent Based Modeling, [5].

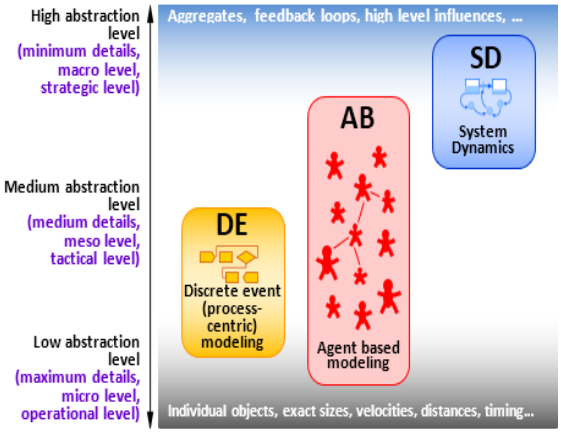

Fig 1. Methods in simulation modeling

Each method has a specific range of abstraction levels. System dynamics assumes very high abstraction, and it is typically used for strategic modeling. Discrete event modeling supports medium and medium-low abstraction. Agent-based modeling does not assume any particular abstraction level. Agent based models, can vary from very detailed models where agents represent physical objects to the highly abstract models where agents represent competing companies or governments.

The selection of the simulation method should be appropriate to the goals of modeling and the system which is subject of the analysis. At the Figure 2 is shown how the modelers are deciding which is the best way to build a model of a supermarket. They can build a process flowchart where customers are entities and employees are resources, an agent-based model where consumers are agents who are affected by advertising, communication, and their interactions with agents and employees, or a feedback structure where sales are in the loop with ads, quality of service, pricing, and customer loyalty. But the best way to model the different parts of a system is the modeling when the different methods are used, and in these situations a multi-method model will best meet the needs.

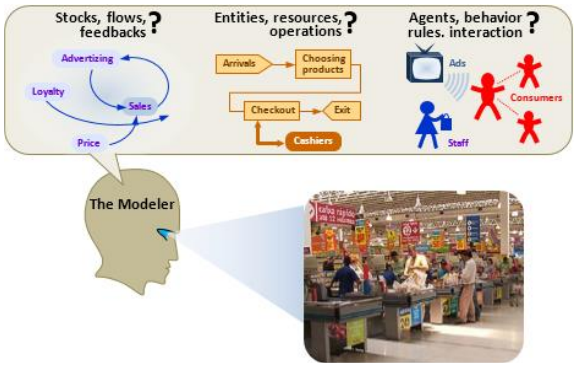

Fig 2. The modeler chooses a modeling method

In this paper we are considering the agent-based simulations and their application in the educational process. It will be shown how the agent-based simulation methods can help in the process of modelling. This refers especially for the students at the mathematical study programmes and computer sciences who study the subjects related to the mathematical modeling, in order to understand the basic concepts for creation of simulation model. The models which are described in this paper, are done in AnyLogic Simulation Modeling Software. This software was primarily chosen because of the availability of ready basic models and its simplicity. In this paper we will describe simple mathematical models like cinema model, SIR epidemiological model and model for transport system. With studying of these simple models, the students can easily understand the basic concepts of agent-based simulations in order to obtain the agents, their activities and mutual communications between the agents.

II. AGENT BASED MODELLING

Agent based modeling is a relatively new method in comparison with system dynamics and discrete event modeling. In fact, agent-based modelling, firstly was accepted as an academic topic. The adoption of agent-based modeling by simulation practitioners started in 2002-2003.

It was triggered by:

- A desire to gain deeper insights into systems because traditional modeling approaches do not capture well.
- Advances in modeling technology make possible modeling by computer science, such as object oriented modeling, UML, and state charts.
- The rapid growth of CPU power and memory. Agent based models are more demanding models than system dynamics and discrete event models.

Agent based modeling offers a modeler another way to look at the system:

With this modeling it is known how the system behaves, which are the key variables and their dependencies, how the process flows, and how the system's objects behave. So, the building of this kind of model is starting by identifying the objects (agents) and defining their behaviors. Afterward, it is needed to make connections between the agents which are created and allow them to interact or put them in an environment which has its own

dynamics. The system's global behavior emerges from many (tens, hundreds, thousands, millions) concurrent individual behaviors.

There is no standard language for agent-based modeling, and an agent-based model's structure comes from graphical editors or scripts. In agent-based modeling a system is modeled as a collection of decision-making entities called agents. The agent evaluates its situation and makes decisions on the basis of certain rules. There are many ways to specify an agent's behavior. They may execute various behaviors appropriate for the system.

In many cases, the best way to capture the agent's internal dynamics is to use system dynamics or a discrete event approach, and then place a stock and flow diagram or a process flowchart inside an agent. Similarly, outside agents the dynamics of the environment where they live is often naturally modeled using traditional methods. It is why many agent-based models are multi-method models.

Agents in an agent-based model may represent very diverse things: vehicles, units of equipment, projects, products, ideas, organizations, investments, pieces of land, people in different roles, etc.

Academics still debate which properties an object should have to be an "agent": proactive and reactive qualities, a spatial awareness, an ability to learn, social ability, "intellect", etc. In applied agent-based modeling, however, all kinds of agents are present: some communicate while others live in total isolation, some live in a space while others live without a space, and some learn and adapt while others never change their behavior patterns.

The advantage of agent-based modeling over other modeling techniques can be captured in three statements: Agent based modeling captures emergent phenomena, it allows a natural description of the system and its flexible.

III. AGENT BASED MODELLING IN MATH MODELING COURSES

With advances in computing, agent-based modelling has become a feasible and appealing tool for studying of different systems. Agent based modeling are used as powerful modeling tool for modeling of stochastic processes, for modelling of process that involve nonlinear interaction and heterogeneous spatial structures.

Agent-based modeling has been used for studies in economics, biology, political science, business and management, medicine etc.

The inclusion of agent-based modelling in math courses generally are performed in two ways. The first way is when the agent-based modelling is studied as one modeling technique in a course that contains more modeling techniques, the second way is when exist the special course of agent-based modeling, and in this course the agent based modeling is the only type of modeling that is used.

The formal description of an agent-based model requires more than just writing of the computer code. This can be problem for many students from computer science and math. Often description of the simple agent-based model is not easily and require more time and labor. This can make, agent-based modeling to look difficult for the students when they are starting with the study of agent-based models.

In the courses for modeling and simulation, the professors should take care not to introduce the computer code implementation simultaneous to the model description. Courses for studying methods in mathematical modeling must start with a discussion of the modeling cycle, which can be presented as a flow diagram, representing it as a mathematical model, analyzing the model and then using the results for next tasks. On the Figure 3 example of a modeling cycle diagram is represented. [7].

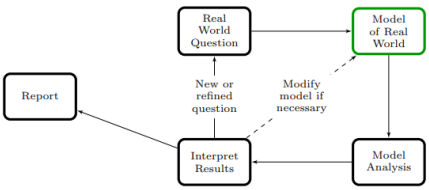

Fig 3. Diagram of the modeling cycle

When the mathematical models are represented with equations (more often differential equations), the time spent on representing the real world as a mathematical model is relatively short. The building of an agent-based model can be a long process, because the models are designed to simulate interactions between individuals and the local environment.

When students are in the middle of constructing their first agent-based model, they often lose sight of where they are in the modeling cycle. Because the model implementation is one cycle, writing of the code is other cycle. After that, the students should test the code and if it runs and produces good results. This process should be repeated too slowly and add all the components needed for the full algorithm of the agent-based model.

There are many different software tools for constructing, simulating, and analyzing agent-based

modelling. When the agent-based modelling is used in mathematics courses software should be chosen according to the pedagogical objectives of the course.

Some of the most used simulation software in education are: EcoBeaker, SimBio, NetLogo and Anylogic.

NetLogo is a multi-agent modeling environment. This software is used by many hundreds of thousands of students, teachers, and researchers from whole world. Its user interface includes a tab where agent-based modeling code is written in the NetLogo programming language, and a tab for the user to view a visualization of the model and user specified outputs as the model is simulated, [10].

EcoBeaker is an ecological simulation program designed primarily for education but also useful for research models. EcoBeaker makes a two-dimensional computer world into which the agents are placed and them behaviors are designed, [8].

SimBio is a simulation software for biological systems such as cardiac cells, epithelial cells, and pancreatic β cells. With this software can be simulated experiments in evolution, cell biology, genetics, and neurobiology. SimBio is written in Java, uses XML and can solve ordinary differential equations, [9].

AnyLogic is a simulation modeling tool developed by AnyLogic (formerly XJ Technologies). It supports agent-based simulation, discrete events simulation, and system dynamics. AnyLogic is a cross-platform simulation software running on Windows, macOS and Linux.

AnyLogic is used to simulate markets and competition, healthcare, manufacturing, supply chain and logistics, retail, business processes, social and ecosystem dynamics, defense, asset management, pedestrian dynamics, and road traffic, [11].

We will consider some examples where AnyLogic software is used.

IV. CASE STUDY IN ANYLOGIC

A. *Seir Model*

SEIR model is the most effective model for explaining how an epidemic is spreading. The SEIR model is consisting of the assumption for totally susceptible population at the starting time of the pandemic. In the SEIR model, the global population of *N* individuals are split in 5 categories: *susceptible S, exposed E, infected I* and *recovered R.*

- Susceptible - people who are not infected by the virus, the started population.
- Exposed - people who are infected but who can't infect others
- Infectious - people who are infected and who can infect others
- Recovered – people who have recovered from the virus.

In Anylogic, *stocks* represent real-world stocks of material, knowledge, people, money, etc. *Flows* define their rate of change - how stock values change and define the system's dynamics. The SEIR model in Anylogic is given on Figure 4.

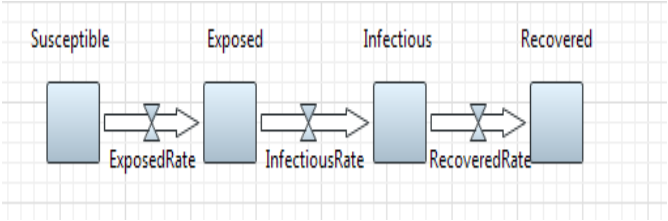

Fig.4 SEIR model in AnyLogic

AnyLogic automatically generates a stock's formula according to the user's stock-and-flow diagram. AnyLogic automatically created these formulas when the flow is added.

After that, the parameters and dependencies are defined. Five parameters: Total Population, Infectivity, ContactRateInfectious, AverageIncubationTime, AverageIllnessDuration are added, and their default values are defined.

- Total Population=2000000
- Infectivity=0.3
- ContactRateInfectious=0.5
- AverageIncubationTime=10
- AverageIllnessDuration=10

Now, the number of infected people is defined by specifying 1 as the Initial Value of the stock Infectious and define the Initial Value for the stock Susceptible: TotalPopulation-1. ,

- ExposedRate=Infectious*ContactRateInfectious*Infectivity*Susceptible/Total population
- InfectiousRate=Exposed/AverageIncubationTime
- RecoveredRate=Infectious/AverageIllnessDuration.

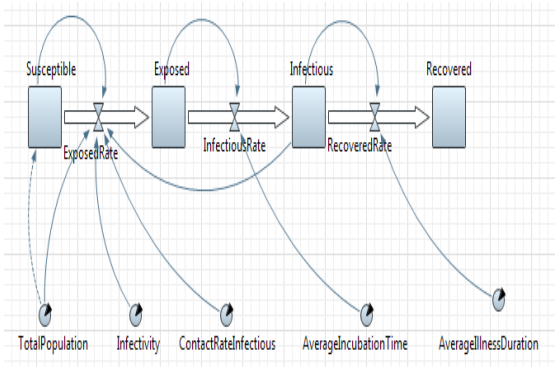

Fig5. SEIR model with parameters

We run the model, and the output is given on Figure 6

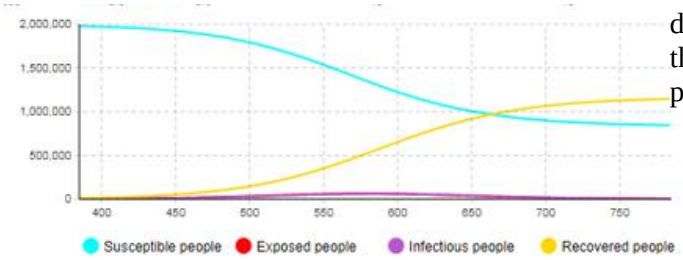

Fig 6. Output from SEIR model

B. Cinema model

An agent-based model of a costumer cinema – one where each costumer will be an agent will be built. The model includes 5000 people who have not seen one movie in the cinema, but a combination of advertising and word of mouth will eventually lead them to purchase the ticket to watch it. It is also represented advertising's influence on consumer demand by allowing a specific percentage of them to become interested in purchasing the ticket during a given day. Advertising effectiveness = 0.1 determines the percentage of potential users that become ready to buy the product during a given day.

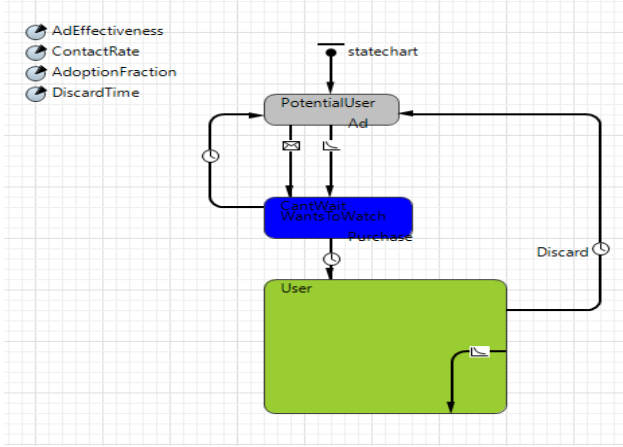

Fig 7. Cinema model

The parameters that are included represent several functions, the first parameter AdEffectiveness defines the percentage of potential users who become ready to buy the ticket and watch the movie during a given day. The second ContactRate represent how many contacts of a person has per day with other PotentialUsers. The third AdoptionFraction is used to show how much the ContactRate (the contact between two PotentialUsers) has affection. The last parameter on the picture represents DiscardTime, how much time will the User wait to become PotentialUser again.

There are two more parameters which test the impatience of our customers. MaxWaitingTime defines the maximum time a consumer will wait for the product (in this case, 15 minutes) and the other parameter, MaxPurchaseTime is 20 minutes.

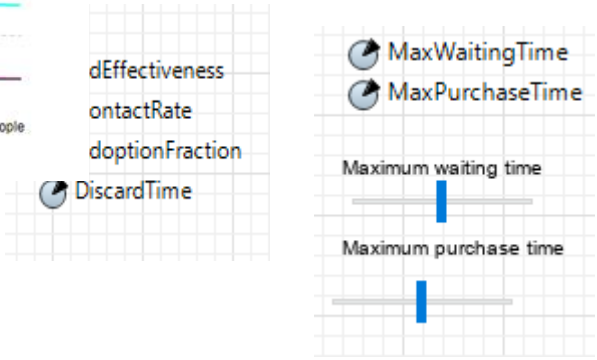

Fig.8 Parameters in Cinema Model

When program is run, 5000 population that is selected above, is obtained and it can be seen that mostly have gray Potential Users because the patience is very low and the max waiting time in our case is 20minutes. The yellowGreen which are the Users are less and when they finished with the watching of the movie, they cannot go back for another 7 days.

Cinema model simulates how 5000 people will react if they all are PotentialUsers and waiting to purchase one ticked for the one movie in the Cinema. From the last picture it can be concluded that because 5000 people is too many for just one selling counter and the waiting line is too long, which means that the customers will have high impatience and most of them won't be waiting, and they will eventually quit and go back to PotentialUsers. So, if is needed to sell tickets to 5000 people, more than one selling counter is needed, therefore the waiting line won't be so long, and the people will not wait to purchase the ticket.

The output from simulation in given on Figure 9

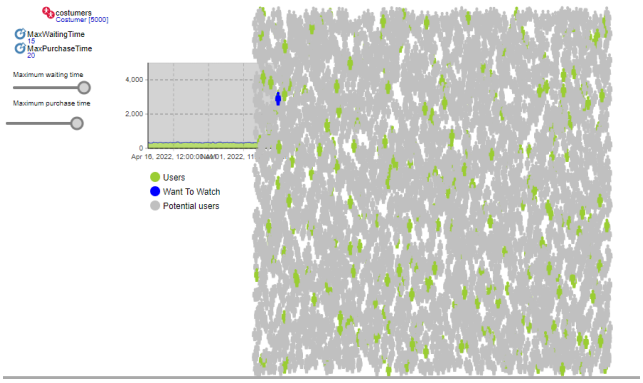

Fig.9 Output from Cinema model

V. CONCLUSION

Agent-based modeling and simulation is a powerful technique in simulating and exploring phenomena that includes a large set of active components represented by agents. Also, agent-based models offer an extensible way to model different systems consisting of autonomous and interacting agents which perform their actions and adapt their behaviors. The computer simulation in AnyLogic software helps the researcher to explore the behavior of a dynamic system. In this paper, we discussed the broad applications of agent-based modeling and simulation.

Because the use of ICT is increasing in all aspects of life as well as the need to optimize different systems and processes using computer models and simulations, in which intelligent agents play a key role, the use of agent-based modeling and simulation tools in education is justified. The paper also outlines the essential features of agent-based tools that, according to our experience, can play a key role in choosing one of them. That is why we believe this paper can be used by the teachers at all levels of the education system when choosing the most appropriate tool for their work.

REFERENCES

[1] A. Maria, "Introduction to Modeling and Simulation," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, 1997.

[2] J. Banks, J. S. Carson, and B. L. Nelson, Discrete-Event System Simulation, Second Edition, Prentice Hall, 1996.

[3] J. M. Aughenbaugh, C. Paredis, The Role and Limitations of Modeling in Systems Design, Proceedings of IMECE2004, ASME International Mechanical Engineering Congress and RD&D Expo November 13-19, 2004, Anaheim, California USA.

[4] G. L. Fenves, F. McKenna Axel, Data Model for Simulation, 2010.

[5] A. Borshchev, I. Grigoryev, The Big Book of Simulation Modeling MultiMethod Modeling with AnyLogic 8, 2020.

[6] E. Bonabeau, "Agent Based Modeling: Methods and Techniques for Simulating Human Systems", Proceedings of the National Academy of Sciences of the United States of America, Vol. 99, No. 10, Supplement 3: Sackler Colloquium on Adaptive Agents, Intelligence, and Emergent Human Organization: Capturing Complexity though Agent-Based Modeling (May 14, 2002), pp. 7280-7287.

[7] E. N. Bodine, R. M. Panoff, E. O. Voit, A. E. Weisstein,"Agent-based Modeling and Simulation in Mathematics and Biology Education", Bulletin of Mathematical Biology volume 82, Article number: 101 (2020).

[8] E. Meir, EcoBeaker 2: Teaching Ecology and Conservation Through Computer Experiments, Proceedings, University of Washington, USA, EdMedia+Innovative Learning, Association for the Advancement of Computing in Education (AACE), Waynesville, NC, 1999.

[9] M. Behr, M. Llari, SIMulation technologies in the fields of BIO-Sciences and Multiphysics: BioMechanics, BioMaterials and BioMedicine, Marseille, France, june 2014.

[10] https://ccl.northwestern.edu/netlogo/

[11] A. Borshchev, "MultiMethod Modeling: AnyLogic Chapter", In book: Discrete-Event Simulation and System Dynamics for Management Decision Making, April 2014.