2015 3rd International Conference on Applied Computing and Information Technology/2nd International Conference on Computational Science and Intelligence

Project Based Learning with Multi-Agent Simulation in Liberal Arts Education

Masashi Miura
Department of Mechanical and Aerospace Engineering
Tottori University
Tottori, Japan
miura@icee.tottori-u.ac.jp

***Abstract*—Complexity science is a new field of science that help us to understand complex social phenomenon such as economies, traffics, wars, epidemics, mass actions, etc. On the other hand, multi-agents simulation (MAS) methods are useful and powerful tools for complex system science. They come to be applied to studies and analysis of complex systems along with the development of computers. It can be said that the perspectives of complex systems and the skills for MAS are very useful knowledge for students who should live and work in the complex modern society. Then the author tried to design and conduct an education program dealing with complex system science and MAS as liberal arts targeting at students from all faculties. It's a project-based learning program in which students investigated and discussed "What is complex systems?" and develop MAS. In general, it is difficult for students who haven't gained the any special knowledge of computing to build MAS. Then the author applied the generic multi-agent simulation platform "artisoc" to this program. With artisoc, students can build MAS easily. In this paper, the practical example of PBL program with artisoc and its result are introduced.**

***Keywords*—Project Based Learning; Multi-Agent Simulation; Liberal Arts Education; Complex system science**

I. BACKGROUND AND PURPOSE

Complexity science is a new field of science studying how parts of a system give rise to the collective behaviors of the system, and how the system interacts with its environment [1]. It is a research approach to problems in various fields including anthropology, artificial intelligence, artificial life, chemistry, computer science, economics, evolutionary computation, meteorology, molecular biology, neuroscience, physics, psychology, sociology, etc. Complexity science can be correlated with almost all disciplines and it can be used as interdisciplinary approach to the problems in the modern and future complex society. So to learn the basis of complexity science is much meaningful for students who belong to any faculty.

In complexity science, Agent-Based Modeling (ABM) and Multi-Agent Simulation (MAS) are frequently used for understanding and analysis of complex phenomena. ABM is the modeling of phenomena as a collection of autonomous decision-making entities called agents [2]. MAS is the simulation method using agent-based model which is derived from ABM method. They come to be the main tool for studies of complex systems along with the development of computers. When students learn the basis of complexity science, they should also learn about ABM and MAS approach.

Then the author tried to design and conduct an educational program dealing with complex system science and MAS as liberal arts targeting at students from all faculties. The program is designed as a Project-Based Learning (PBL). PBL is a student-centered approach in learning. This method is to learn a subject through the experience of project solving. This educational approach is superior for cultivating "flexible knowledge" and "effective problem-solving skills" of students [3]. In the suggested program, students tackle two subjects. One subject is investigating and discussion "What is complex systems?" and another is developing a multi-agent simulator related to the theme chosen by their own. In ordinary, developing a multi-agent simulator is difficult for students who haven't taken any classes concerned with programming. Then the author used the generic multi-agent simulation platform "artisoc" in this program. With artisoc, students can develop a multi-agent simulator easily. The details of artisoc is introduced in the next section.

The purpose of this study and practice is offering the chance to learn complexity science, agent-based modeling and multi-agent simulation for lower grade students from all faculties as liberal arts education. This paper introduce the PBL program designed by the author and the result of trial practice.

II. PLATFORM FOR MAS

In order that students who don't have enough skill of programing can learn and construct MAS, the author introduced "artisoc" which is developed by KOZO KEIKAKU ENGINEERING Inc. It is a powerful platform for developing multi-agent modeling and simulation [4][5]. With artisoc, researchers and users can develop multi-agent simulators easily by simple operations in the Graphical User Interface (GUI). Then artisoc is utilized in various studies on complex and distributed systems. For example, the author used artisoc for his research on a distributed real-time pricing system for a power grid [6]. Fig. 1 shows the captured image of the simulator for the distributed real-time pricing system

978-1-4673-9642-4/15 $31.00 © 2015 IEEE
DOI 10.1109/ACIT-CSI.2015.51

developed with artisoc. This section explains the features and functions of artisoc. In the explanations and figures, version 3.0 of artisoc is assumed.

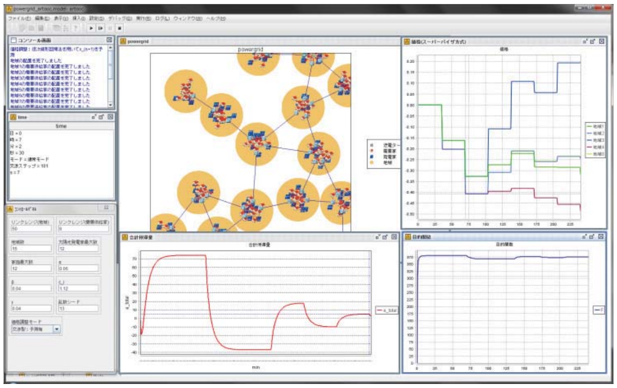

Fig. 1. Captured image of the simulator developed with artisoc

A. Graphical user interface

One of the biggest features of artisoc is that it enables developers to build MAS with GUI operations.

In artisoc, spaces, agents and parameters are managed in the tree diagram as shown in Fig. 2. Users can add, delete and modify the elements with mouse operations on the tree diagram.

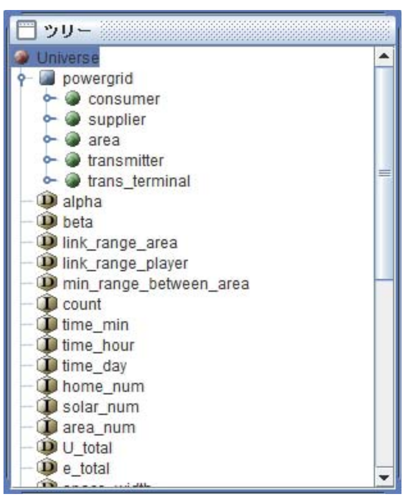

Fig. 2. Tree diagram for management of spaces, agents and parameters

Not only the developing environment but also the simulator built in artisoc has the graphical appearance and interface as shown in Fig. 1. Simulators built with artisoc run on the JAVA platform graphically. However, developers don't have to write any JAVA codes for the graphical expressions. Developers can manage the graphical expressions of spaces or parameters' time series with operations in the GUI of artisoc. For examples, you can see the graphical outputs of the space and the time series graph of parameters in Fig. 8 and Fig. 9 in the section IV.

Moreover, developers can easily make the graphical control panel for setting and changing the parameters. Fig. 3 shows an example of the graphical control panel. By these functions, users can conduct simulations under various conditions and see results graphically. Then it becomes to be more easy for users to consider and discuss results.

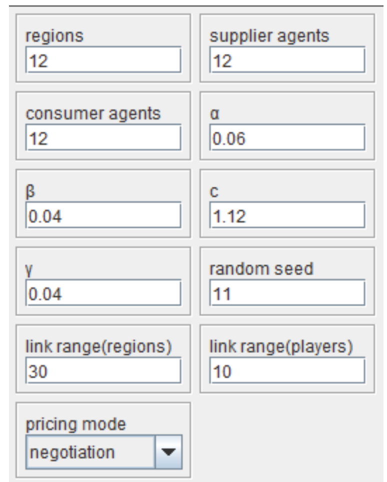

Fig. 3. Example of control panel

B. Management of the time steps and agents

Artisoc provides many functions and libraries for the multi-agent simulation. It manages the time step proceedings, each agent's processing and variables instead of developers' codes. Then developers don't have to write codes for time inclement loops and agents switching loops, but they should write only codes which rule the behavior of each agent. The code shown below is an example. With the example code, the agent walk in the space randomly.

```
/* EXAMPLE CODE */
Agt_Step{
    My.x = My.x + 0.5*(1-2*rnd())
    My.y = My.y + 0.5*(1-2*rnd())
}
```

In the example shown above, "My" means the object equivalent for a prosumer agent. With ordinary simulation coding, the developer must consider the order number of the agent now handled. On the other hand, with artisoc, he should write only "My" in order to indicate that the variable belongs to the agent now handled.

C. Coding blocks and processing oder

Artisoc provides some coding blocks and the developer should only write codes into those blocks. Then artisoc manages processing orders according to the coded blocks as shown in Fig. 4. In the below, each block is explained briefly.

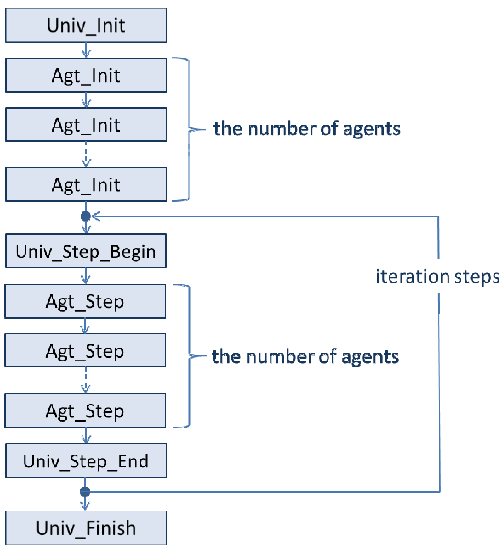

Fig. 4. Processing order in artisoc

"Univ_Init" block:

In this block, initial processes of the simulation are written. In ordinary case, The initial processes include agents creation processes and parameter setting processes.

" Agt_Init" block:

In this block, the processes of setting parameters to each agent are written.

" Univ_Step_Begin" block:

In this block, initial processes for each step are written. The processes written in this block are executed in the beginning of every step.

" Agt_Step" block:

This is the most important block for the simulator. The behaviors of each agent are written in this block like the example code which is shown in the previous page.

" Univ_Step_End" block:

In this block, final processes for each step are written. The processes written in this block are executed in the end of every step.

" Univ_Finished" block:

In this block, final processes of the simulation are written. The processes written in this block are executed in the end of simulation for only once.

III. INSTRUCTION DESIGN

In this section, the instruction design of the suggested program is explained. The program is designed assuming a class of 2 credit (16 weeks, 90 minutes per a week). The 1st or 2nd grade students are assumed as target of the class. It is basically PBL program and has factors of reverse-learning. For example, students work on developing the practice simulation as homework. In the class, they get only basic explanation of how to use artisoc and work on the basic and small practice subject for MAS.

A. Schedule

TABLE I shows the schedule of the program. The program consists of manly three parts: the discussion part, the practice of MAS part and the project activities. In the first half of the program, the discussion week and the MAS practice weeks are arranged one after the other. As homework, students read the assigned part of the textbook between the discussion week and the next discussion week. So students have 2 weeks for reading. Students work on developing the practice simulator with artisoc also as homework between the MAS practice weeks. In this phase, students learn what are complex systems, what is complexity science and how to build MAS with artisoc. In the latter half of the program, students work on the project activities in a group. The goal of the project is to develop the prototype MAS which simulates a complex phenomenon based on students' idea. At the last of the program, students make a presentation about their MAS.

TABLE I. SCHEDULE TABLE

Week	Activities
1	Orientation
2	Discussion based on reading the textbook
3	Tutorial and basic practice of artisoc
4	Discussion based on reading the textbook
5	Tutorial and basic practice of artisoc
6	Discussion based on reading the textbook
7	Tutorial and basic practice of artisoc
8	Idea generation for MAS project
9	Role assignment and planning
10	Project Activities
11	Project Activities
12	Project Activities
13	Project Activities
14	Project Activities
15	Project Activities
16	Presentation
	Final Report

B. Activities

Discussion based on reading the textbook:

In this activity, students discuss what is complexity science, what are complex systems, how complex systems behave and what phenomenon in real world is corresponding to complex system. The discussion is based on the textbook.

Students read the assigned part of the textbook as homework and make a document which summarized the assigned part. In the class, students explained the contents of the textbook and their opinion with each other. Fig. 5 is the picture of discussion.

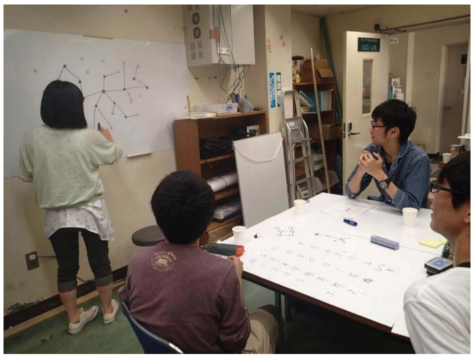

Fig. 5. Discussion

In this time, Ref. [7] is used for the textbook. In this book, the author who is leading complex systems scientist Melanie Mitchell explains how large-scale complex, organized, and adaptive behavior can emerge from simple interactions among myriad individuals with abounding examples based on her work at the Santa Fe Institute. This book does not contain difficult formulation and it is appropriate textbook for lower grade students.

Tutorial and basic practice of artisoc:

In the tutorial week, the lecturer explains the basic of how to model phenomena with agent-based method and how to build multi-agent simulator with artisoc. And students work on the small subject of building MAS. For example, they build MAS in which agents move about randomly. After the class, students work on the practice subjects of building MAS as homework. Fig. 6 shows the captured image of the tagged model MAS which is assigned to students for the one of practice subjects. In the tagged model MAS, hunter agents chase after the nearest people agent and people agents run away from the nearest hunter.

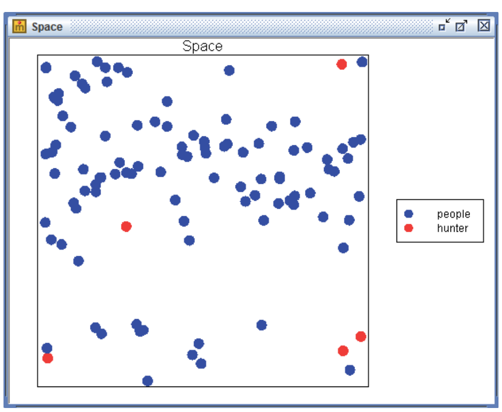

Fig. 6. The tag model MAS

Idea generation for MAS project:

In the latter half of the program, students get at modeling, designing and building MAS as group work. For the first activity, they provide and select ideas of what phenomenon they should model and simulate. For generating and selecting ideas, we introduce the brainstorming method and dot-voting method [8]. Fig. 7 is the picture of brainstorming for idea generation.

Fig. 7. Brainstorming for providing idea of MAS

Role assignment and planning:

After students decide the theme for MAS, they should assign role for each member. And they should make a schedule for building MAS and making a presentation.

Project Activities:

In the project activities, students work on developing their unique multi-agent simulator, considering the simulation results and preparing the final presentation. To achieve the goal, they should work on the activities not only in the class but also out of the class. So it promotes their reverse-learning. For the files and information sharing and the distributed work, “Google Drive” is utilized in our practice.

Presentation:

At the last class, students make the presentation about the results of their project activities. The presentation should contain the demonstration of the multi-agent simulator they built.

IV. RESULT OF PRACTICE

The author practiced the program explained in the previous section for trial as the liberal arts class of Tottori University in the first semester of 2014. Because it was the trial practice, the capacity was limited to 5 students (corresponding to one group). Then 4 students took the class. Two of them are the 1st grade students from Faculty of Engineering and the other two are the 1st grade students from Faculty of Medicine.

A. Discussion and MAS practice

The activities of the first half of the program went on as scheduled. The circumstances of the class can be seen in Fig. 5 and Fig. 7. In the tutorial and practice of artisoc, Ref. [4] is used for the textbook.

B. Project Activities

The result of brainstorming and dot-voting, students decided to model and simulate the siege warfare: the battle of attacking armies and defending armies. In Tottori, the siege warfare of Tottori castle was occurred in 1581. That warfare is famous as one of the few in which starvation tactics were used to a successful completion of the siege. The forces of Toyotomi Hideyoshi cut the castle's supplies and surrounded it for 200 days. The siege ended when the lord of the castle, Kikkawa Tsuneie, surrendered and committed suicide. So students focused the historical event of Tottori.

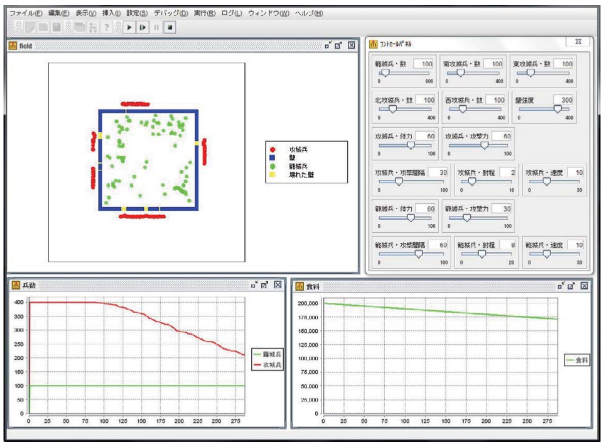

Fig. 8. The captured image of the simulator developed by the students

In the project activities, students developed the siege warfare simulator as shown in Fig. 8. In their MAS, the attacking soldier, the defending soldier and the wall of the castle are treated as agents. Soldiers are assumed to have no central commander and each soldier decides his behavior with information from the neighboring agents. And neighboring agents interact with each other. So they constitute a complex system. The captured images of the space output are shown in Fig. 9. The red points show the attacking soldiers, the green points show the defending soldiers and the blue lines show the wall agents. In Fig. 9, some attacking soldiers entered into the castle and the broken wall agents are expressed with yellow lines.

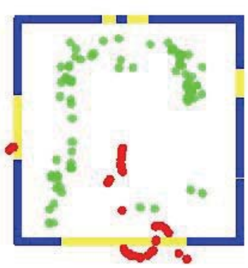

Fig. 9. The captured images of the space output

Students introduced the food parameters to the simulation. If there are many defending soldiers, they get advantage in the battle. However, many defending soldiers consume much food. When food parameter reach to zero, it is considered that the defending soldiers lose. So there is a trade-off relation between the number of defending soldiers and the consuming speed of food. Using the simulator developed by students, we can see the trade-off effects. In the final presentation, students discussed the trade-off relation with the results of the simulation.

C. Evaluation

To evaluate the educational effectiveness, the questionnaire study was carried out. The students answered the pre-questionnaire in the beginning of the first class and the post-questionnaire after the last class. In this subsection, the results of questionnaires are showed. Though all questions and answers were written in Japanese in actuality, the author translated them into English in this paper. It should be paid attention that the aggregate results have not the statistical meanings because of the so small number of respondents (4 students).

The pre-questionnaire has some simple questions and they are intended to know the initial levels of understanding and the initial skills of the students. The question items and the results are shown in TABLE II. The result of the pre-questionnaire shows that the students have no knowledge of the complex systems, MAS and programming before the start of the class. That is usual for the 1st grade student. In spite of student’s inexperience with programming, they achieved the modeling of the siege warfare and the developing of the multi-agent simulator by their own as shown in the previous subsection. That indicates the educational program is very effective in learning the complex system, MAS and programming skills.

TABLE II. RESULT OF PRE- QUESTIONNAIRE

question	yes	no
Do you know what the complex systems is?	0	4
Do you know the words “multi-agent system” or “multi-agent simulation”?	0	4
Do you have experience with programming?	0	4

The post-questionnaire was assigned to the students as part of the final paper. In each question of the post-questionnaire, a student choose an option about the level of understandings and skills in each question. And he should describe the reason why he chose the option. TABLE III shows an example of a question in the post-questionnaire.

TABLE III. EXAMPLE OF QUESTION IN POST- QUESTIONNAIRE

Question 1.
Has your understanding about the complex system been improved? <Circle one option> 1.not improved 2. improved 3. improved much <Describe why you chose the option>

TABLE IV shows the result of the post-questionnaire. As seen from the table, all students answered “improved” or “improved much” for all items.

TABLE IV. RESULT OF POST- QUESTIONNAIRE

No.	understandings or skills	not	improved	much
1	What is the complex system?	0	2	2
2	Complex systems in nature, society, and daily life.	0	3	1
3	The importance of complexity science.	0	0	4
4	Skills for programming	0	3	1
5	How to develop malti-agent simulation.	0	4	0
6	How to conshider simulation results.	0	3	1
7	Skills for presentation.	0	1	3
8	Skills for group works.	0	1	3
9	How to learn new things.	0	3	1
10	Motivation for learning at University.	0	2	2

In the below, examples of the students’ description why they chose the option “improved” or “improved much” are listed up. The number written in square brackets is corresponding to the question number in TABLE IV.

- Before taking this class, I didn’t know the concept of the complex system. However, I have now reached to the stage of being able to explain the complex system.[No.1]
- Because I have come to think “this phenomenon could be explained with the complex system science” when I found something in daily life. [No.2]
- I think complex science can be very useful in various fields as healthcare, economics, etc. [No.2]
- Because now I know it is important for developing the simulation to think “What should I do to make the model more realistic?” and “Why is the output of the simulation different from what I had imagined?” [No.5]

From the results of the pre- and post-questionnaires shown above, it can be said that the suggested program is effective in education of complex science and ABM/MAS approach for lower grade students.

D. Activities after the class

After the first semester, the students decided that they continue to work on the project activities. In the second semester, they modified and improve the model and simulator of the siege warfare as the extracurricular activities. Then they apply for the 15th MAS competition organized by KOZO KEIKAKU ENGINEERING Inc. [9]. In the result, they got the excellent award for their presentation and their simulation. Fig. 10 is the picture of the students’ presentation in that competition.

Fig. 10. Student’ presentation in the 15th MAS competition

V. SUMMARY

To learn the basis of complexity science and the methods of multi-agent simulation are much meaningful for students who belong to any faculty. Then the author designed the PBL program with multi-agent simulation as liberal arts. In the program, the lower grade students who don’t have knowledge of programming can build multi-agent simulation by utilizing the MAS platform “artisoc.” In the activities of developing the multi-agent simulator, students can learn about complex systems in a practical manner. As the result of the trial practice of the program, students could develop their unique multi-agent simulation which simulates the siege warfare and they achieved the excellent prize.

REFERENCES

[1] Y. Bar-Yam, “General features of complex systems,” Encyclopedia of Life Support Systems (EOLSS), UNESCO, EOLSS Publishers, September 2002.

[2] 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. 3, pp. 7280-7287, May 2002.

[3] C. E. Hmelo-Silver , “Problem-Based Learning:What and how do students learn?,” Educational Psychology Review, vol.16, no.3, pp. 235-266, 2004.

[4] S. Yamakage. “Modeling and Expanding Artificial Societies : Introduction to Multi-Agent Simulation with artisoc,” KOZO KEIKAKU ENGINEERING Inc., 2009.

[5] Y. Kazuya. “International Relations and Agent-based Modeling: A New User-friendly Simulator? Artisoc,” Proceedings of annual meeting of the International Studies Association 48th Annual Convention, Chicago, 2007.

[6] M. Miura and K. Sakurama, “Graphical and Scalable Multi-Agent Simulator for Real-time Pricing in Electric Power Grid,” Proceedings of The Twentieth International Symposium on Artificial Life and Robotics, GS19-4, Beppu, 2015.

[7] M. Mitchell, “Complexity: A Guided Tour,” Oxford Univ Pr, November, 2011.

[8] K. B. Kahn, “The PDMA Handbook of New Product Development,” Wiley, December 2012.

[9] The website of MAS Competition: http://mas.kke.co.jp/modules/tinyd3/