Proposal on Mutual Cooperation Between Simulation Research and Field Research in Archaeology

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Abstract. In this paper, we propose a methodology to collaborate the research using agent simulation and the research using conventional method (field research) in archaeology. The main stream researches using Agent-Based Simulation (ABS) are unidirectional cooperation with the results of field research as input and the results of simulation research as output. In our proposed method, by presenting the hypothesis verification method from ABS result, the simulation result can become the input of field research. As an application example of proposed method, we discuss the problem of whether native Jomon people or Chinese-Korean immigrants played the major role of agricultural culture in Yayoi period by ABS.

Keywords: Agent-Based Simulation · Archaeology · Collaboration

1 Introduction

In this paper, we propose a methodology to collaborate the research using agent based simulation (ABS) and the research using conventional method (field research) in archaeology. As for the application examples, we will discuss the results of using ABS for "Who played the major role of Yayoi agricultural culture in Northern Kyushu?"

With the rapid increase in ABS research in archeology, there is concern about the lack of arrangements the lack of feedback between archaeologists and modelists [1]. One of the reasons for this is the deficiency of comprehensive textbooks and handbooks for archaeologists about simulation technique. In reference to this, a guide to the creation of a simulation model for archaeologists has been created [1]. Also, the complexity of software has been pointed out as an obstacle to the adoption of ABS by archaeologists. Therefore, it is mentioned that a software system that does not require advanced programming knowledge is required [2].

However, we do not believe that archaeologists will be able to collaborate on simulations and field studies because they learn to build models and create programs. We believe that in order to collaborate between simulated and field research, we should not link researchers together, but rather link research results together.

As an archaeological study using ABS, the most popular study is to examine the factors of demographic dynamics of ancient Anasazi people from 800 to 1350 in Long House Valley in Arizona, USA [3, 4]. These studies examined factors influencing the

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population dynamics in Long House Valley by using several parameters including paleoenvironment variables from social unit and empirical data. Such researches are said to account for about 30% of all archeology studies using ABS [2]. That is, such researches can be said to be the mainstream of current research.

In these studies, scenario simulation is performed using historical facts based on anthropological and archaeological materials as input data, and in the simulation results according to historical facts, knowledge as to which parameter among the decision-making factors was effective is obtained. In other words, these researches are unidirectional cooperation with results of field research as input and results of simulation research as output.

2 Proposed Method

2.1 Concept

In this paper, we propose a method for bidirectionally linking research using ABS and field research.

The proposed method is the same as performing scenario simulation using historical facts based on anthropological/archaeological data as input data. However, it observes what kind of social phenomena occurred in the simulation results according to historical facts, generates a hypothesis about the problem. Moreover, it differs from these researches in that it presents what kind of archaeological materials at what time can verify the hypothesis. As an advantage of ABS, by attaching various attributes such as anthropological morphology, DNA, Food production system, culture etc. to the agent and observing the composition ratio of each attribute of the agent as the result of the scenario simulation in chronological order, based on the pattern of combination of attribute diffusion, it is possible to present materials that can verify the hypothesis. In other words, the proposed method could generate a working hypothesis that leads to the discovery of new remains and analysis of remains by presenting what kind of archaeological materials at what time can verify the hypothesis as the verification method of the hypothesis. That is, simulation can be input for research.

2.2 Procedure

The procedure of the proposed method is as follows.

1. Adopt a theme that seemingly inconsistent between materials corresponding to agent attributes.
2. In solving the above theme, consider necessary constituent elements at the minimum.
3. Create an agent model in which the rules are made based on the above and the inputs and constraints based on archaeological materials are attached as agent attribute variables.
4. Make cases by combining inputs based on archaeological materials and other variable parameters, and conduct simulation at many runs for many cases.
5. Extract the simulation case that satisfies the constraint condition.

6. If there are multiple cases with different parameters in the case, find the difference in the time series of the attribute variables of the agent between the cases.
7. Because attribute variables conform to archaeological data, the age and contents of the archaeological material are obtained for verifying which of the hypotheses are correct as the difference of the attribute in the time series of the simulation result.

3 Application Example

When applying the procedure of the proposed method to "Who played the major role of Yayoi agricultural culture in Northern Kyushu? [5]", it is as follows.

1. The theme about the major player of Yayoi agricultural culture in northern Kyushu was adopted as the theme of solving the conflict between the archaeological hypothesis that the native Jomon people played the major role of Yayoi agricultural culture and the anthropological hypothesis that the immigrants played the major role [6–9].
2. The above theme was defined as the problem about population increase due to the diffusion of agricultural culture and genetic, and as a component element, the food production system and trait genetic allele (Jomon trait and Immigrants trait) were set as the attribute variables of the agent.
3. The rule of diffusion of agricultural culture was made based on an infectious disease model, and the rule of inheritance of trait genes was made based on Mendel's law (Immigrants trait dominance).
4. 441 cases were created with variable parameters such as the propagation speed (range and introduction rate) of agricultural culture, and run ten times per case.
5. Of 441 cases, 111 cases could satisfy the constraint condition that 300 years after the initial state where a small number of immigrants migrated with agricultural culture to the place where many large numbers of native Jomon people were living, immigrants became the majority.
6. The 111 cases were divided into cases where the diffusion speed of agricultural culture is more slow and more fast. In each case, there was a large difference in the "trait gene" history of agent's attribute variable "agricultural culture" holder 50 years after the start (see Fig. 1). In the former cases, immigrants were the majority of agricultural culture holder. On the other hand, in the latter cases, native Jomon people were the majority of agricultural culture holder. On the problem about the major player of Yayoi agricultural culture, we generated the former hypothesis that immigrants played major role and the latter hypothesis that native Jomon people played major role.
7. Archaeological data corresponding to agents holding both agricultural culture and Jomon trait genes at the time of 50 years from the start, i.e., discovering of human bone showing Jomon trait and accompanying archaeological remain showing agricultural culture is an archaeological material that can verify which hypothesis is correct (Fig. 2).

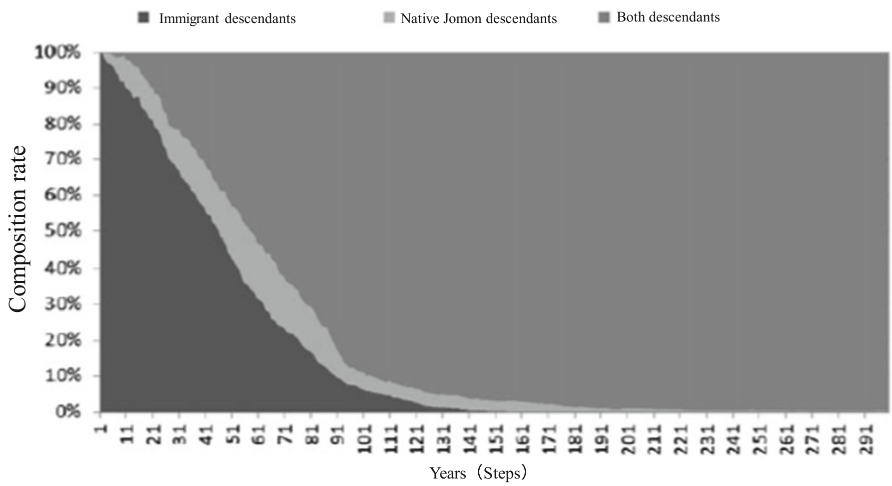

Fig. 1. Comparison on composition ratio of descendants of those practicing an agrarian culture in the cases of slow diffusion of the agrarian culture.

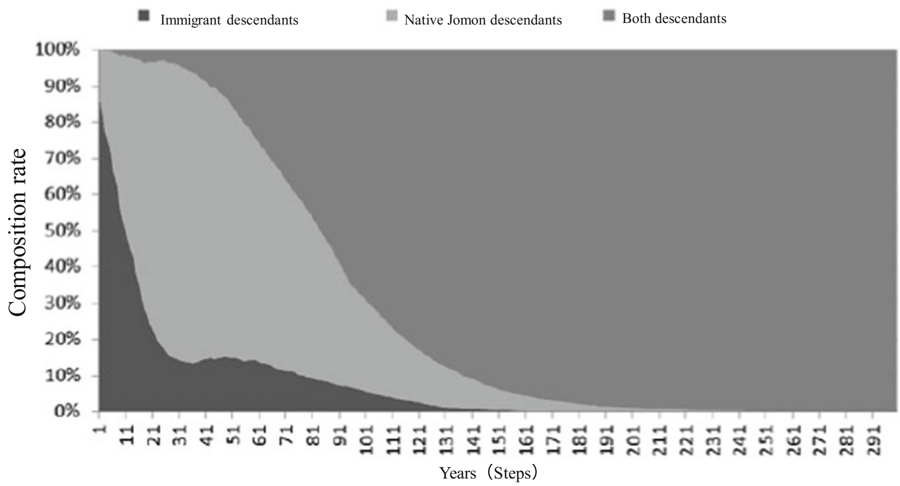

Fig. 2. Comparison on composition ratio of descendants of those practicing an agrarian culture in the cases of rapid diffusion of the agrarian culture.

4 Discussion

Firstly, we acknowledge important prior art in the field of ABS for human systems simulation such as Epstein and Axtell [10] seminal work on simulating social systems; Gilbert and Troitzsch [11] work on the use of simulation by social scientists; the work by Tesfatsion [12] on agent-based simulation for social economics, and; Bonabeau [13] on the utilization of agent-based modeling of human system.

In our work, based on the ABS results, we show work hypotheses that lead to the discovery of new remains and the reanalysis of remains for hypothesis verification, and by simulation being the input of field research, we show it made it possible to link simulation research and field research bi-directionally.

In the application example using the proposed method, it was possible to reproduce past social phenomena and generate a hypothesis by ABS. Then, for these hypotheses, by assigning various attributes (morphology, DNA, food production system, culture) to the agent in multiple, and seeing the component ratio of each attribute of the agent as a simulation result in chronological order, based on the pattern of combinations, we were able to present materials that can verify hypotheses.

Furthermore, we propose to analyze what kind of factors, that is, what rules and parameters are important for classification of many scenarios and many hypotheses. In addition, we think that it is necessary to analyze which microscopic phenomenon at any point in the simulation step is affecting the factors that result in different results even under the same condition. For these, it is effective to use the approximate Bayesian computation, the decision tree of simulation logs [14] and the random forest algorithm that can separate rules and parameter combinations.

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