This Is How I Feel About Complex Systems

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Abstract. It has been around for nearly 40 years since I joined with the academic world in computer science related areas. Because I prefer to concrete real world topics, I, as a system scientist, usually research and develop challenging cutting-edge applications on complex systems. By complex systems, I do not only mean such areas as complex adaptive systems, chaotic, nor fuzzy systems, but, seemingly complicated systems required to be socially implemented. In this short paper, based on my final lecture at Tokyo Institute of Technology, I would like to present how I feel about complex systems and discuss principles of agent-based modeling, interdisciplinary research, and system creation. The paper concludes some comments on what we must do in the future.

Keywords: Complex systems · Agent-based modeling · System creation

1 Introduction

"Complex systems," as used in the title of this chapter, refers to all social systems. Despite its small scale, I believe that the most challenging social system is household management; it is much easier to debate matters on national or even international scales. "Complex systems" in the broader world are generally complex adaptive systems, but those are slightly narrower in meaning. Chaotic systems also exhibit complex behavior, but describing them is quite simple.

We have an innate desire to simplify any complex matter we face, and through a long history of such self-delusion, we come to believe that we understand the world. Witness the myriad mythologies describing the creation of the sun and the moon; these are merely delusional philosophies designed to provide a sense of understanding. A similar phenomenon occurs in academia. In truth, however, these matters—household issues included—retain their complexity.

My position is that we should actively use the concepts of agent-based modeling and evolutionary computation as new approaches to understanding complex systems. Using these two principles, we can understand complex systems. For further details on how I reached this conclusion, see the description in [1], for example.

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2 An Approach to Agent-Based Modeling

Let us discuss the micro-macro links in agent-based modeling. First, an agent is an entity that has an internal state and decision-making and communication functions. Agents can model humans, organizations, or even objects such as molecules. Through the microinteractions of agents, a macroscale order with bottom-up effects emerges. From the standpoint of creating models through which to view the world, we cannot view microscale conditions in detail. Therefore, academia has advanced to the point of observing macroscale phenomena and creating models involving macroscale variables.

Take economics as an example. Currency was created as a result of barter between agents. Currency is continuous and therefore allows for the creation of various equation-based models, which have led to econometric models. I consider this an example of re-creation from zero through agent-based modeling.

Up to this point, natural and social phenomena work in the same way. Go further, however, and they differ. Because agents have internal states and communication functions, they can observe the macroscale order. As a result, top-down influences from the macroscale are transmitted to the micro level, where they alter agent behavior. This is the complex behavior that is generally seen in social phenomena. Once microscale agents begin to observe macroscale phenomena, complex interactions that form micro-macro links arise (Fig. 1).

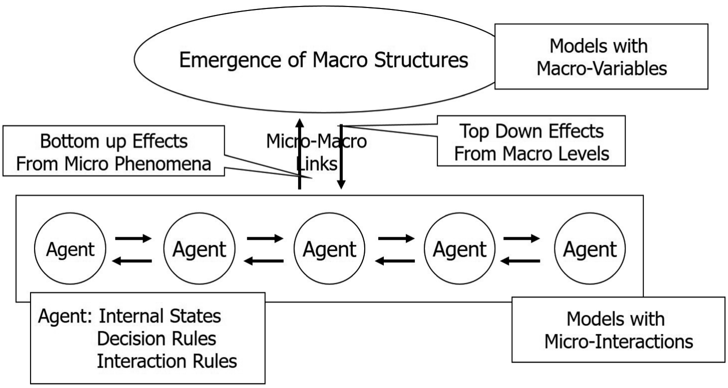


Fig. 1. Framework of agent-based modeling

The desire to program directly in this manner, if possible, led me to agent-based modeling. The programming itself is not all that difficult—the difficulty lies in what comes afterward, in three particular areas.

First, there is a need to skillfully connect theory and reality. For example, game theory experiences problems when applied to the collective behavior seen in real-world social media. Modeling must therefore consider both theory and reality.

As a second issue, this method lies on a disciplinary boundary; therefore, we must be conscious of the differing time scales of the natural sciences, the social sciences, and engineering technology. In the natural sciences, theories are required to be eternally correct within the scope of measurement technology, whereas in the social sciences, we are happy with a theory if it holds for one century. As engineering technicians, however, we expect new technologies to last perhaps a decade; beyond that, they will have been modified to the point of being something else. Such differences in scale become extremely troublesome when creating models.

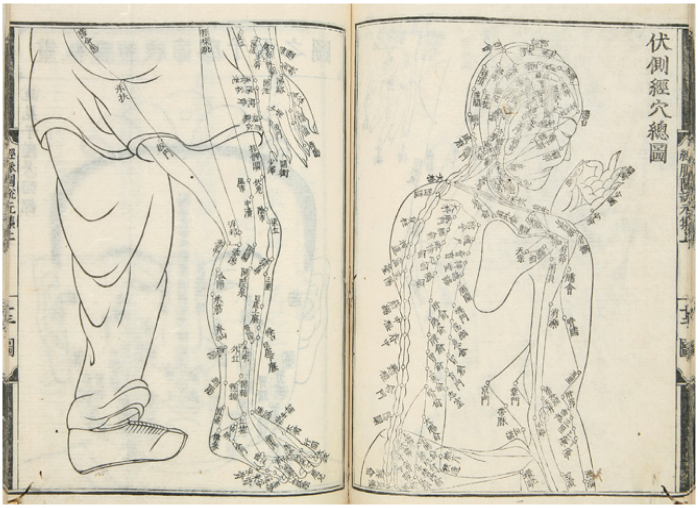
The third problem is the difficulty of receiving general recognition for the models we create. There are two aspects of this: assessing validity and ensuring correctness. For example, securities exchanges set "limit up" and "limit down" prices to restrain volatility, but the extent to which prices are allowed to fluctuate is arbitrary. There are many other such situations. Although it is possible to somehow mesh models with reality, when considering the design of new structures, determining whether a model works correctly becomes a matter of its persuasiveness, i.e., a matter of its ability to convince. This is extremely difficult to accomplish with agent-based modeling.

3 The Necessity of a Common Language

Still, as mentioned above, it is human nature to desire simplification, even if not to the extent of mythology. This is summarized well in Nobel Laureate Daniel Kahneman's Thinking, Fast and Slow [2]. This book assumes that humans cannot think the unthinkable. Indeed, it repeatedly describes how humans continually avoid thinking. This concept implies that, as we progress in our research, acknowledging such laziness becomes more likely to produce results, and therefore, it is easier to remain in our foxholes. I admit that digging a foxhole is necessary for becoming a specialist in academia, but I also believe that this is probably a bad idea. If we are to escape from our foxholes, we must first identify a common language. If no common language exists, we must create one.

An example of this is, curiously enough, the concept of acupuncture points in Oriental medicine. One might consider these points inherent to the human body, but in fact, they are an invented concept. This is demonstrated by the fact that their different names and positions depend on the tradition. However, whereas the treatment may vary slightly according to the school of thought, using terminology related to acupuncture points allows knowledge to be propagated easily. In other words, the act of naming acupuncture points itself has made it possible to describe treatment methods. Being able to describe treatment methods aids propagation and makes it possible to describe incorrect ways of stimulating a given point (Fig. 2). Therefore, I consider a common language necessary for shared consideration of complex problems. This is what I believe, but it is no easy task in academic areas where progress is fast. Therefore, I consider it necessary to consciously make the effort to create a common language.

Based on the above, cross-domain, or interdisciplinary approaches are vital for social issues in general [3]. As an example, statistical physics has a very powerful method called mean field approximation. This method allows various models to be analyzed and approximate calculations to be performed. To that end, however, the simplifying assumptions are important. In contrast, with agent-based modeling, we can use computers to simulate the behavior of agents and the circumstances of the



- Acupuncture Points are Invented
- Explanations with the Concepts of them are Essential

Fig. 2. Explanations of acupuncture points in an old Japanese textbook

surrounding world in a bottom-up manner. Computers can understand these descriptions, as can humans with some difficulty, but experiments modeling a world with no particular first principles require substantial parameter tuning.

For example, gravitational models of population dynamics are based on Newton's law of universal gravitation, but their results can be manipulated in any direction using the parameter corresponding to the gravitational constant. When modeling is performed using agents, the movements of people can be observed. That means the two approaches are complementary and must both be appropriately considered when modeling social issues.

4 Creating Systems

I would like to turn the discussion to system creation. Due in part to the recent boom in artificial intelligence, I hear frequent mentions of "advanced systems." Extremely large, elephantine systems are being created, particularly in business fields. In many cases, however, creating an elephant consumes all available resources, which, in turn, leads to businesses relying fully on the system as-is. If the organization includes many intelligent members, they will forbid individuals from interacting with the elephant and instead take parts from it to create trunk systems and tusk systems and ear systems through which business can be conducted. This is not necessarily a bad approach, as long as the business runs smoothly, but the oncoming tsunami of artificial intelligence and big data require those trunks and tusks to be reattached. The result can easily

Fig. 3. A system as an elephant and users as blind people (Photo: Hubei Museum of Modern Art (Wuhan, China))

become a piecemeal creation reminiscent of Frankenstein's monster (Fig. 3). I believe that this is already happening in large companies trying to use big data correctly.

Creating systems has always been an extremely troublesome task, and furthermore, systems tend to become out-of-date as soon as they are completed. Therefore, they need to be broken up and used in parts or tossed aside and re-created. Such re-creation requires time, money, and energy; therefore, executive decision-making comes into play. Taking on a system requires skills related to analysis, design, and imagination. Analysis lies in the field of science. Design and development are in the realm of engineering. Imagination is a matter of sensibility. If all three are not skillfully combined, a good system cannot be produced. We must be aware that in something akin to the "Red Queen hypothesis" from Lewis Carroll's Through the Looking-Glass, one must continue running to avoid becoming increasingly obsolete.

Note that systemization alone is insufficient for solving social problems. In 2016, the Oxford English Dictionary selected "post-truth" as its word of the year, suggesting that we have entered an era that emphasizes impact over truth. For example, today we see a heavy emphasis on the impact of social media. I cannot help but wonder whether, a decade from now, we will be discussing how we were all taken in by social media. Today, we consider fake news and online bullying social issues, but I consider this a positive trend—in the past, only large organizations were capable of manipulating information, but today, individuals have much more power, and post-truth concepts have become highly influential. There are probably various reasons for this increase in individual power, but one significant factor is the advancing capabilities of computer hardware.

5 What We Must Do in the Future

When I consider the state of academia in Japan, I am troubled by many discomforting truths. University researchers and educators are overworked. There is too much competition due to the selectivity and concentration of research budgets. Few large companies have central research laboratories, and corporate researchers have little freedom in choosing their topics.

In fiscal year 2017, the total amount of JSPS KAKENHI grants-in-aid was US$2.1 billion (just under JPN230 billion). This includes amounts dedicated to research on induced pluripotent stem cells and supercomputers. In comparison, the research budget at Amazon is said to be US$22.6 billion. The largest research budget in Japan is that of Toyota at approximately US$9.3 billion. From admittedly rather old data, the total corporate R&D expenditure in Japan is approximately JPN12–13 trillion. Of that, approximately JPN30–40 billion are transferred from companies to universities. There is no way to overcome such vast funding differences, no matter how skilled the researchers are. Thus, Japanese academics are put in an extremely tough spot.

This leads to the question of what we can do about this situation, and, as powerless as we are, I believe that there are two approaches we can take.

The first approach is internationalization, which is more inexpensive now than ever. Even today, research proposals include words to the effect of “they’re doing this in the U.S., so we should, too” (despite that fact that China is actually more advanced in many fields!). Indeed, declaring that the Black Ships have arrived is a good way to convince one’s superiors of the need for action and a relatively simple way to persuade others of the importance of opening up the country.

However, we cannot wait for the Black Ships to arrive, and pursuing international cooperation is an important part of active manipulation from behind the scenes. When the story hinges on cooperatively sailing the Black Ships, we can find many ways of communicating with researchers overseas. International joint research projects provide a particularly easy way of obtaining funds; therefore, I believe they should be pursued to the extent possible.

The second approach I suggest is “Gundamization”. Indeed, current smartphones empower human beings, making them similar to Gundam. We put on our Mobile Suits when we head out to face our enemies (whomever they may be). In particular, we should use tools such as machine translation and Skype as a way of heading out into the world and communicating with others. “Gundamization” is no longer a big deal.

Next, to promote system creation, it is necessary to always remember that systems are generally invisible and dynamic. It is easy to understand a new computer that runs one hundred times faster than the current one. It is more difficult to understand how a new system can solve problems one hundred times faster. Telling top executives what you want to do and why it is important is likely to be met with confusion due to the complexity of the issue. You will be told to come back with a simpler example, but having gone to the trouble to do so, you will then be told that what you propose is merely common sense. In the end, the first step in creating outstanding systems scientists is to teach field-specific knowledge. Another extremely important task is to learn what you do not understand from others.

6 Concluding Remarks

It is important that systems scientists understand their respective specialized areas and have a cross-disciplinary perspective for dealing with problems that arise. In addition, I believe we should use agent-based modeling. In conclusion, I introduce some statements slides that I frequently use in my lectures.

One is a statement that is engraved in the Picasso museum in Barcelona: “Art is a lie that makes us realize truth”. The other is a book by Duncan Watts, *Everything Is Obvious: Once You Know the Answer* [4]. Slightly adjusting these two phrases provides a good description of how I think about complex systems and agent-based modeling:

– Agent simulation is the lie that helps us realize truth.
– Something will be obvious once you know the agent simulation.

I look forward to seeing future research on complex systems using agent modeling.

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