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Agent-based modeling on technological innovation as an evolutionary process

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Abstract

This paper describes a multi-agent model built to simulate the process of technological innovation, based on the widely accepted theory that technological innovation can be seen as an evolutionary process. The actors in the simulation include producers and a large number of consumers. Every producer will produce several types of products at each step. Each product is composed of several design parameters and several performance parameters (fitness components). Kauffman's famous *NK* model is used to deal with the mapping from a design parameter space (DPS) to a performance parameter space (PPS). In addition to the constructional selection, which can be illustrated by the *NK* model, we added environmental selection into the simulation and explored technological innovation as the result of the interaction between these two kinds of selection.

Keywords: Agent-based simulation; Technological innovation

1. Introduction

In recent years, agent-based modeling (ABM) has become increasingly influential in many fields of social science such as economic, political, anthropological, and so on. The examples of such works include [4,6,7,11,17,22]. It is widely believed that ABM is not only a new powerful tool for researchers to challenge complex adaptive systems [16], but also a new way of thinking about the world where we live. The main purpose of ABM is to study the macro-level complexities from the interactions in the micro-level, in other words, ABM tries to challenge complexities in a bottom-up way. Researchers doing ABM, especially in social simulations, always keep in mind that "simple patterns of repeated individual action can lead to extremely complex social institutions" [8].

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Agents in the ABM can be simply defined as autonomous decision-making entities. From a more theoretical view of artificial intelligence, an agent is a computer system that is either conceptualized or implemented using the concepts that are more usually applied to humans [24]. Simply speaking the purpose of this research is to model and simulate the technological innovation process by ABM.

There are good reasons to view innovation systems as complex systems. The actors of the system interact with each other, learn, adapt and reorganize, expand their diversity, and explore their various options [20]. And one of the obvious features of technological innovation in an advanced industrial society is that it involves the coevolution of marketable artifacts, scientific concepts, research practices and commercial organization [25]. Many researchers suggested that technological innovation should be understood as an evolutionary process [9,13,19,25]. Technological innovation is also featured as a complexity challenge [2,18].

Based on the above thinking, many different models about technological innovation have been developed. Roughly, those models can be divided into two groups. The first group focuses on industrial firms, treating them as social organizations driven by market forces to adapt to changing technological regimes. Such models abound in literatures of evolutionary economics [23]. The second group focuses on the essence of technologies themselves. Typical models in this group are Arthur's [5] model of the "lock-in" of a single, but potentially sub-optional technology and Kauffman's [12] *NK* model of hill-climbing which predicts potentially different sub-optima in a rugged fitness landscape. The first group tries to capture the features of technological innovation from macro-level, while the second group tries to explain technological innovation from micro-level. Considering technologies (or its carrier products and services) as species, the first group pays much attention to the environment in which the species live, while the second group pays much attention to how the physical structure of individuals, for example DNA, affects the behavior and future of the species.

This paper presents an agent-based model that integrates the basic ideas of both groups. In our model, there are mainly two kinds of actors (or agents), producers and consumers. Producers design and produce different products. Consumers evaluate and purchase those products. As the carrier of technologies, every product is composed of several design parameters. And as commodities, products have performance parameters which can bring utilities to consumers. The mapping from design parameter space (DPS) to performance parameter space (PPS) is dealt with by using Kauffman's *NK* model. The agent-based model indicates our basic conceptual understanding about technological innovation: an innovation in technology is the result of both constructional selection and environmental selection.

Constructional selection can be seen as a kind of inner selection. In the process of technological innovation, there is some outside pull or pressure, that is to say, the social environment, especially market forces, will play an important role in selection. Corresponding to constructional selection, the impact from the environment is called environmental selection. Constructional selection generates things with high performance, but it doesn't mean these things will be overwhelming in environmental selection. The survivors are the result of both types of selection.

Based on the agent-based model, we developed a platform by using object-oriented programming to simulate the technological innovation process under different situations. The methodology we have adopted accords with Axelrod's description of the value of simulation [9]:

Simulation is a third way of doing science. Like deduction, it starts with a set of explicit assumptions. But unlike deduction, it does not prove theorems. Instead a simulation generates data that can be analyzed inductively. Unlike typical induction, however, the simulated data comes from a rigorously specified set of rules rather than direct measurement of the real world. While induction can be used to find patterns in data, and deduction can be used to find consequences of assumptions, simulation modeling can be used to aid intuition [3].