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Dynamics of human innovative behaviors

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HIGHLIGHTS

- The model is proposed to investigate the dynamics of human innovative behaviors.
- Our model combines the evolutionary game with the spreading process of innovations.
- We assume that the relative benefit of innovators drives innovative activities.
- Quasi-localized effects and rich non-Poisson properties are shown.
- The relative cost of innovative activity deeply impacts on its dynamics.

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ABSTRACT

How to promote the innovative activities is an important problem for modern society. In this paper, combining the evolutionary games with information spreading, we propose a lattice model to investigate dynamics of human innovative behaviors based on benefit-driven assumption. Simulations show several properties in agreement with peoples' daily cognition on innovative behaviors, such as slow diffusion of innovative behaviors, gathering of innovative strategy on "innovative centers", and quasi-localized dynamics. Furthermore, our model also emerges rich non-Poisson properties in the temporal–spatial patterns of the innovative status, including the scaling law in the interval time of innovation releases and the bimodal distributions on the spreading range of innovations, which would be universal in human innovative behaviors. Our model provides a basic framework on the study of the issues relevant to the evolution of human innovative behaviors and the promotion measurement of innovative activities.

1. Introduction

The research on socio-economic systems rises to be a popular issue and attracts a great amount of researchers during the recent decade [1–4], due to its inherent complicated dynamics and macroscopic phenomenon as the traditional physical system. The foundational methods and models of statistical physics, nonlinear physics, complex network, numerical simulation have been applied to the problem of diffusion dynamics [5–7], opinion dynamics [8–11], traffic flow [12–14], cascading failure [15–17], evolutionary game [18–20] and so on. In social development, innovative activities have been regarded as the source of human culture and play an important role on social advances. How to promote the innovative activities of people effectively is a critical factor for the success of a social system. Here, innovations always refer to new

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products, goods, services, ideas, online creations, social norms and institutions and so on if they are unknown within a particular group.

After an innovation emerges, it will probably face a tough diffusion situation contrasting to the dominative mature technology owing to kinds of reasons, such as its imperfection or people's stubbornness. The competing course of two different kinds of products or information is a popular topic [21–23]. Based on a continuous model put forward in 2000, there are a serials of work [24–29] concerning on the technological developing process which discuss but not limited to discuss the following problems: when and where the technological development takes place, how the agents response to neighbors' technological change, and how their reactions contribute to the global enhancement of technological level of system.

However, the innovative activities are not only suppressed by difficulties in its spreading, but also in the production of innovation which is the first step of innovative process. Despite extensive discussion on innovations' spread, the evolutionary dynamics of innovative behavior is not clear. How the innovative behavior evolves in an interaction system? How the two procedures of innovative activity (innovative behavior and innovation diffusion) affects each other? Most significant, how to promote people's innovative behaviors and the spirit of ingenuity? These relevant discussions still lack in previous studies. The process of innovation bursting has been studied by introducing a technology space in view of percolation theory [30,31].

A typical model inspiring us greatly is proposed by S. Bornholdt, et al. [32] based on the framework discussing the competition and coexistence of multi-opinions. In this model, innovation is introduced with three basic rules: majority rule when accepting neighbors' opinion, no repeating of old ideas, and tiny chance to raise new idea. The model clearly shows the characteristics of "rapid rise, slow decline, difficulty to be replaced" of innovation in scientific paradigms' development, and excites our curiosity in the innovative behavior itself. In reality, from the development of discipline and technology, to companies launching new products, or the decision of the topic of a news report, blog, etc., there are at least two choices for people: to go into a brand new way, or just to improve or follow an existing one in the system. Thus, a problem concerned with multi-choices should be considered.

When facing multiple choices, agents always decide their strategies by comparing the payoff from different choices [7,33–35]. The representative example is evolutionary game [18–20], in which one makes different gains according to his own and neighbors' choices, states, or strategies (e.g. to cooperate or to betray), and adopts his next strategy according to the incomes after each play, mostly longing for lower cost and future higher yield. This idea has also been extended to learning process during innovation spread [21,24,25,28,29,36,37]. No matter adopting innovative or following behavior, one has to pay cost (in the form of spending time, money, energy, etc. and taking a risk) and can obtain reward (in form of proceeds, reputation, growing interest, etc.). Generally speaking, comparing with the conventionalism and the copycat, innovative behaviors usually face much higher risks and cost but can obtain some extra benefit from the successful innovation, such as the patent income and wide reputations. The following behavior is just the opposite situation with lower risks and lower benefit. Thus the most successful agent (taking highest profits) in a local group may be an innovator or a follower. All in all, the innovative and following behavior is just the two choices contradict but interdependent with each other.

In this paper, we propose a modeling framework to study the general feature in the evolution of innovation behavior. Different to most of previous works that mainly discuss the spreading of new technologies or new cultures, we focus on the dynamics in the evolution of innovative behaviors under the assumption that innovators have to pay more price, and that innovative intention is stirred up by huge rewards from the spreading of its innovations. We try to provide new insights to understand the factors which impacts on peoples' innovative behaviors and the way how to encourage innovative behaviors effectively.

2. The model

To investigate the basic feature on the evolutionary dynamics of innovative behaviors, our model discards much of detailed and particular factors, such as the differences on innovative ability, the application values of innovations, and so on. For simplicity, the individuals choose binary strategies: to be innovators (I) or to be followers (F). The innovators bring about significant progresses, and the followers make smaller improvement by following innovators. Two basic assumptions are considered in a general way: (i) Comparing with the activities of just copying or following other's innovations, innovative activities have much more cost. (ii) From a general perspective, while someone's result is accepted by more individuals, it is considered to be more successful and gains more rewards. And thus we assume, for an individual, no matter it is the creator of innovation or not, it can obtain some benefit from its spreading. This benefit is proportional to the spreading range of the innovation from the individuals.

Based on the above two assumptions, the evolution algorithms of our model can be described as follows:

(i) In $L \times L$ lattices with periodic boundary condition, each node i represents an individual who holds an arbitrary type of information, and adopts binary strategies $s(i, t)$ to update its information: to be a follower (F) or an innovator (I).

(ii) The dynamics can be seen as two parts and has two timescales: τ and t. One stage timed by τ is the asynchronous update of agents' information, containing two forms of behavior: the innovative behavior and the following behavior. Each completed information updating stage is followed by once synchronous update of strategies which is timed by t. That is to say, each time step t includes several sub-steps τ.

(iii) At each sub-step τ during a time step t, we select an arbitrary agent i who has not updated its information in the current t, with initial information state $m_i(t, \tau) = m_i(t - 1)$. If i is an I agent, it puts forward new information (or say