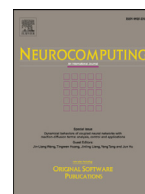




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# An evolutionary agent-based framework for modeling and analysis of labor market<sup>☆</sup>

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## ABSTRACT

This paper presents an agent-based model of labor market to investigate the relationship between company and worker. Contrary to most of previous studies of labor market we apply a game theoretic approach to defining entities in labor market: companies and workers. A company can choose the level of wages, and workers can select the level of effort to increase the productivity in response to the wages. Company and worker agents are designed to possess the basic attributes in order to reflect the real labor market and their activities are adaptively changed using evolutionary model. Our approach is illustrated with four simulation results: the effect of workers resignation, sick leave, dismissal of companies, and productivity growth. Various experiments were conducted to analyze the interactions between worker and company, indicating that performance-based reward strategy and non-greedy strategy in job changing are necessary for companies and workers. The experimental results confirm that the balanced power between worker and company is important in maintenance and extension of labor market, and Nash equilibrium can be maintained in all the cases.

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## 1. Introduction

In a real-world labor market, the behavioral characteristics expressed by worksite individuals, diligence or lazy, depend on who is working for whom [1,2]. A behavior pattern of each individual may heavily affect the state of the labor market such as stability or productivity. There have been many studies on the analysis of the behavioral patterns of the individuals and estimating future in economic or social phenomena by using agent-based computational models [3–6]. This paper investigates the possible interactions between employees and employers, and constructs a framework for modeling such strategic interactions. In this framework, there are two types of agent such as companies and workers that are principal members of the labor market. Both agents have their own strategies, status, memory, attributes, and behaviors. Their relationship in the labor market is formed in cooperative and defective. Such relations are adaptively decided by the current situation and evolved over time. Based on the co-evolutionary computation framework, we discuss the variation of mutual interaction between firms and workers.

We have studied on the evolutionary agent-based modeling for explaining the labor market [10], but they have limitation on the realistic simulation for specific topics in detail. In this paper, we set up a framework of evolutionary simulation of labor market based on the preliminary study, and attempted to reveal the economic phenomena there by analyzing the variation of interactions between employee and employer by changing various market parameters. The power between companies and workers is controlled in term of the four policies: resignation, sick leave, dismissal, and growth of productivity (as a measure of the worker's experience). Considering the basic relations between companies and workers, it is the best to choose selfish behavior for a short period of time. We investigate in what condition can lead to mutually beneficial results in the labor market.

The rest of this paper is organized as follows. Section 2 presents the related work to give better understanding of the difference of our approach compared with the previous studies. Section 3 describes in detail the framework of labor market proposed, and Section 4 illustrates the design of experiments. Section 5 analyzes the experimental results, and the final section presents a conclusion.

## 2. Related works

There are various related works using agent-based modeling. Mostly, evolutionary computation focuses on the prediction of

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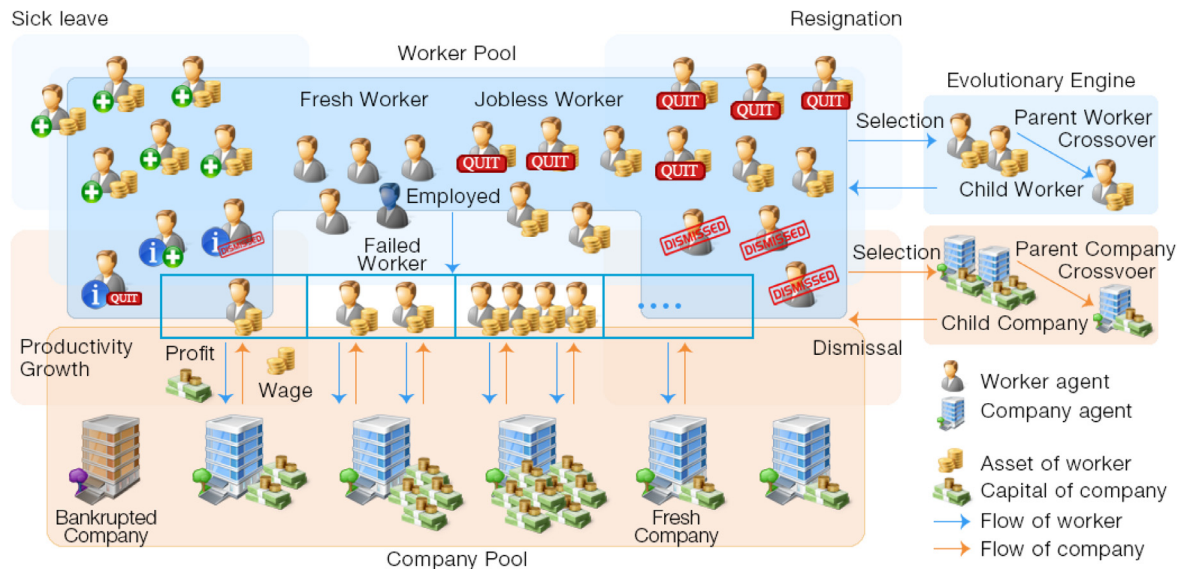
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**Table 1.**

Previous studies on agent-based modeling (0 means incorporation; X means non-incorporation).

Researchers	Topic	Agent modeling	Game theory	Evolutionary computation
Goh et al. [5]	Macroscopic behavioral dynamics of civil violence	0	0	0
Farahani et al. [8]	Behavioral pattern of predator-prey (Ecosystem)	0	X	0
Maniadakis [9]	Mechanism of human brain working	0	X	0
Kim and Cho [10]	Relationship between companies and workers	0	0	0
Makowsky and Rubin [32]	Social network technology and revolution	0	X	X
Fonoberova et al. [33]	Urban crime and violence	0	X	X

**Fig. 1.** Evolutionary labor market framework.

future or is used to analyze social phenomena. Table 1 summarizes the previous studies on agent-based modeling. Maniadakis introduced a novel agent-based co-evolutionary computational framework for modeling assemblies of brain areas. Quek focused on the design and development of a spatial Evolutionary Multi-Agent Social (EMAS) network to investigate the underlying emergent macroscopic behavioral dynamics of civil violence. Grass investigated the complexity level of agent-based predator/prey ecosystem simulation.

This paper investigates the possible interactions between workers and companies, and constructs a framework for modeling such strategic interactions. In this framework, there are two types of agent, worker and company. Workers and companies, who are principal members of labor market, act as agents having one's strategies, status, attributes, and actions. Their relationship in labor market is formed in cooperative and defective. Such relations are adaptively decided by the current situation and evolved over time. Base on the evolutionary labor market framework, we discuss the variation of mutual interaction occurred by workers and companies.

This paper uses game theory to define the interaction formalized between workers and companies. The game theory has been used widely to model multi-agent environment such as social and economic phenomena, where the primary purpose is not to model a dynamic system, but to study how co-evolution can be used in learning strategies for agents [7]. In labor market, unemployment occurs when people who do not have job are actively seeking work. However, the cause of unemployment can be divided into dismissal and resignation, which can be clearly different in accordance with the agent's position. Also, the relationship between

sick leave and productivity growth is inverse proportional. Sick leave seemed to lead to considerable loss of zest for work [31]. Mackowsky developed an agent-based model to study the mechanism of large-scale social and institutional change, as well as the influence of the level of connectivity on the size of the resulting cascades, in an attempt to explain phenomena such as the "Arab Spring." In this model, there are three types of agents: citizens (heterogeneous), a central authority (government) and non-central authority (police forces) [32]. Fonoberova used Epstein's model for the simulation of crime and violence in urban settings. The purpose of the model was to determine the number of police agents required to keep crime and violence levels under a certain threshold in urban settings [33]. In contrast, we utilize the game theory to define the interaction formalized between workers and companies.

### 3. Agent-based labor market model

All agents coexist in the artificial market with its own behavioral strategy determined by the current status and circumstance, and interact with each other repeatedly. Once a worker has been hired in a company, he provides labor for wages until resignation from the company or elimination from the system. The amount of wages and earnings is decided according to behavioral tactics of both companies and workers agents. Overall concept of the proposed labor market is depicted in Fig. 1.

Each agent decides its current behavior, cooperation or defection, depending on their own strategies encoded in the chromosome, and evolves its worksite strategies over time on the basis of its assets earned by past worksite interactions. The worksite

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