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Advanced human resource management model based on complex system and agent-based modeling

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Abstract
Managing human resource of a company efficiently is always a popular topic all the time. Former researches usually use qualitative methodologies. Therefore, we design a model based on graph theory, statistics, team science, complex system and agent-based modeling.The structure of our model is a multi-layer network. We use probability theories to evaluate the value that the individual with different abilities can make in different positions, and utilize Kuhn-Munkres algorithm to find the optimal match between individuals and positions.

Key words:*multi-layer network, Kuhn-Munkres algorithm, probability theory, human-capital network, agent-based modeling*

1 Introduction

The reasons that many big companies succeed are varied. For instance, the talented, well-educated and experienced individuals are welcomed in such good enterprises[1,2]. However, how to organize these kinds of people and encourage them to achieve the group's targets is a great challenge.

In order to efficiently manage employees of a company, many different theories have been put forward. Most former theories or models base on experiences and qualitative analysis while our model can analyze this kind of problem quantitatively. First, we use the traditional matching algorithm – Kuhn-Munkres algorithm (KM algorithm), to adapt the relatively complex conditions of human resource management. Then, individuals will be matched to most appropriate positions by this improved algorithm and a human capital network will be built automatically[3,4]. After that, we utilize two dynamic processes to demonstrate how the network evolves[5]. Up to now, model has been designed successfully, and afterwards we will apply this model to solve several tasks[6,7]. Afterwards, we perform simulation-experiment by agent-based methodology[8]. Each node in network will be represented as an agent in multi-

agent system, and event-oriented methodology is applied to realize dynamic processes[9,10]. Finally, it is necessary to assess the performance of the model in pragmatic utilization and an objective conclusion is also essential.

2 Methods

2.1 Network structure

The human capital network structure is mainly based on the organizational structure of the company. We assume that the company has 12 offices and 46 divisions, and each office or division has 4 or 7 employees respectively. It is reasonable to assume that each office or division has a supervisor, and different offices or divisions communicate with each other by their supervisors. Each office or division is a sub-network and employees in each sub-network connect with everyone else in the same sub-network. Similarly, we can build friendship network, trust network, information flow network and many other kinds of networks and bind them with the human capital network to compose a multilayer network. Therefore, we can build a multilayer network by connecting different networks. Each type of networks represents a layer in multilayer network. The network structure is shown in Fig 1.

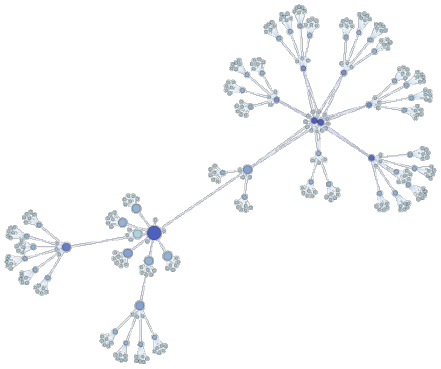


Fig.1 -Network structure.

2.2 Matching algorithm

KM algorithm is a strong tool to solve assignment problem in bipartite graph. This algorithm can find an optimal solution, which satisfy that the sum of the weights of edges in the match is the maximum. Thus, we can get a bipartite graph adapting to pragmatic conditions. Nodes in the left side are employees who will be assigned while nodes in right side are opening positions. Therefore, the main task is to determine the weights of each edge.We classify all individuals into seven levels, and we also classify all positions into the same seven levels

(Senior Manager, Junior Manager, Experienced Supervisor, Inexperienced Supervisor, Experienced Employee, Inexperienced Employee and Administrative Clerk) according to pragmatic situation.

Naturally, if an individual who has a high working level, the edge between him and the positions that need high-level employees will have a high weight. Weconsider a general situation: an individual with ability μ wants a position. We assume that the value curve obeys Gaussian distribution. The equation of value that an employee creates can be deduced in Eq. (1).$v(p)$ means the value an individual creates at position p. A is the scale coefficient who decides the maximum value. And μ is the individual's ability level,and σ is standard deviation. The value of A depends on individual's ability μ since different levels of employees can make different values. We assume that the top level creates maximum value, which equals to M. And the bottom level creates minimum value m. Thus, the expression of $A(\mu)$ is shown in Eq. (2).Therefore, by synthesizing Eq.(1) and Eq.(2), we can calculate the value created by an individual with ability μ at position p. The expression is shown in Eq. (3).

$$v(p) = Ae^{-\frac{(p-\mu)^2}{2\sigma^2}}, \tag{1}$$

$$A(\mu) = me^{\frac{\ln\frac{M}{m}}{6}(\mu-1)} = me^{\frac{\ln M-\ln m}{6}(\mu-1)}. \tag{2}$$

$$v(\mu, p) = A(\mu)e^{-\frac{(p-\mu)^2}{2\sigma^2}} = me^{\frac{\ln M-\ln m}{6}(\mu-1)-\frac{(p-\mu)^2}{2\sigma^2}}. \tag{3}$$

Obviously, function $v(\mu,p)$ indicates the weight of edge between individual (employee) μ and opening position p. Then, matching algorithm can be used to assign individuals to corresponding positions.

2.3 Multi-agent system

It is necessary to build a multi-agent system to combine two results that we have got before. Agent-based methodology is usually utilized in complex system that is difficult to get analytic solution. In this multi-agent system, each agent, who has several attributes, represents an individual in the company. Attributes include loyalty, ability-level and position of agent, which can affect the whole productivity of the company and individuals' leaving rate.Evolvement rules are key elements of the model and rules can be divided into two parts – recruit rules and churn rules. Recruit rules indicates the mechanism of recruitment, and churn rules means how the network evolves when someone leaves or retires. It is not pragmatic that

the company recruit new employee once an old employee leaves. Therefore, we assume that HR manager recruits new ones monthly. Recruitment schedule is shown in Fig 2.

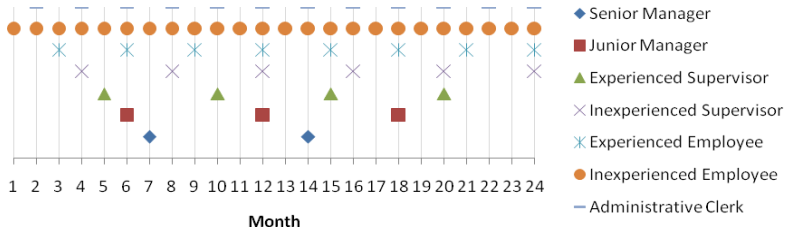
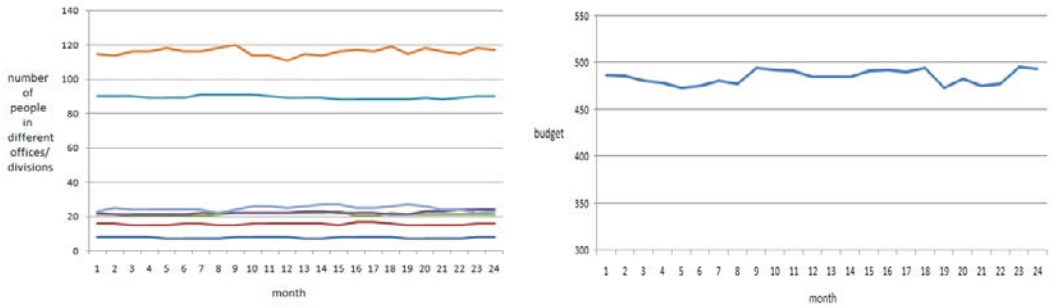


Fig. 2 - recruitment schedule

In terms of the number of employees who will be recruited each time depends on the current vacancies. To be detailed, suppose that HR manager recruits *x* employees for corresponding position each time. Thus, 12*x* employees will be recruited per year, which should equals to about 2/3 current vacancies.Once the company recruits new employees, first select all opening positions which are available to new ones. We assume that the number of people who want new job from company obeys Gaussian distribution. After that, we use matching algorithm mentioned before to assign new employees.

3 Results and discussions

We set the initial parameters (80% of full status and 15% churn rate) and then start simulation for 2 years. Simulation records the temporary data and thus we get the following results. The result is illustrated in Fig 3.



(1) (2)

Fig. 3 - (1) shows that the population keeps stable in the mass. (2) shows that the budget experiences few fluctuate during 2 years and approximately keeps at the same level.

Direct effects of churn rate have been discussed in section 2.5.2. Therefore, we are able to discuss the indirect effects after we get the simulation results. After setting different churn rate (10%, 15%, 20%, 25%, 30%, 35%, 40% and 45 %) and running the model with each churn rate 10 times, we get the maximum, minimum and average value of percentage of full status for positions. The percentage of full status for positions dropped with the increase of churn rate. It is illustrated in Fig 4.

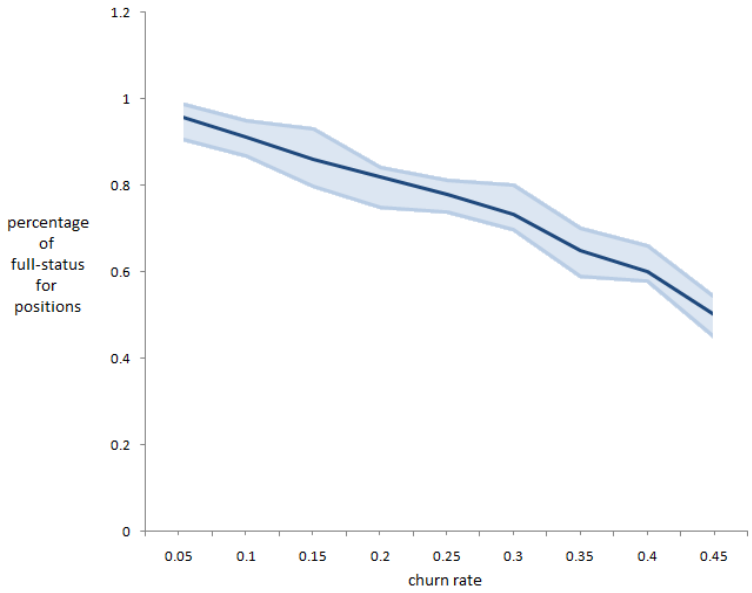


Fig. 4 -Percentage of full status for positions.

We can learn from the Figure 5 that when churn rate is smaller than 20%, the percentage of full status for positions is steadily larger than 80%. However, when churn rate equals to 25%, the maximum percentage is larger than 80% and average percentage is smaller than 80%. Moreover, the percentage cannot be larger than 80% when churn rate is over 30%.

4 Conclusions

In this paper, the model that we proposed has following advantages: (1) we combined human capital network, personal relationship network and influence network. By creating multilayer networks, we took those three factors into consideration and obtained a good conclusion. (2) many technical mathematical methodologies are applied to calculate important parameters such as probability density functions, the value that an employee creates, diffusion equation of churn effects, etc. (3) we applied computer simulation to simulate the process that reflects how the human resource churns and changes. We got many statistical data that could guide us to manage human resource. However, this model still has some problems. For example, we

ignored some factors such as information flow and trust network, which weaken our model and put errors into our conclusion. These problems will be addressed in the future work.

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