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Research on Simulation and Performance Evaluation of Open Source Design Process based on Multi-agent

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Abstract: Open source design is a new mode which is composed of many agents who spontaneously cooperate to complete product design. A process model of open source design based on multi-agent is proposed in this paper with the purpose of studying the dynamic characteristics of product evolution and the ability of design-agent in the process of product design. A set of indexes which can evaluate the process of product evolution and the ability of agent is developed, including the weight of each module, product maturity, completion time of module for each agent and development ability of the agent. The algorithms of indexes are realized and verified in the simulation program. The simulation results show that the proposed simulation approach and evaluation indexes are effective for evaluation and management of open source design.

Key words: Open source design, performance evaluation, process simulation

INTRODUCTION

There has been an extremely rapid development of open source design from the emergence of OSS (open source software) in 1990s (Lerner and Triole, 2002). The critical factor to make this design model successful is that there are many volunteers with diverse expertise and interests to design every module of product. Compared with traditional design methods, members of open source community have diversity capacity structure, which has a significant advantage in aspects of product innovation degree, technology maturity, customer satisfaction. At present, open source design has a lot of successful applications in the OSS such famous software as Linux, Apache and Mozilla. It also has a positive attempt in industrial design aspects but a lot of design community end up with failure. The main reason is that the operating and evolution mechanism for the open source design is immature. The agents involved in the open source design are cooperative, initiative and creative. Based on these, this study provided a process model of open source design based on multi-agent and quantitative and dynamic indexes to conduct a comprehensive and systematic research of the entire product design process, so as to provide a reference for the study of the dynamic evolution features of open source design and a rationalized direction for the performance improvement.

Concerning open source design, there are a lot of studies. For example, (Li and Wang, 2012) used the theory and method of system dynamics to analyze the boundary and causality of the dynamical mechanism of peer production and then, established the dynamical mechanism model of general peer production based on system dynamics (Li and Wang, 2012; Yao and Yang, 2012). revealed the preferred mechanism is a significant evolution characteristic of peer production virtual community by the analysis on static structure and dynamic evolution of virtual community (Rycroft and Kash, 2004) Rycroft and Kash, 2004 presented a dynamic evolvement model of innovation network based on rational decision-making behaviors of companies in the innovation cooperation and explore the dynamic evolvement laws of innovation network and the relationship between knowledge spillover among companies and the network structure (Rycroft and Kash, 2004); Huang, made a analysis based on Drupal through social network analysis and concluded that the structure of the Drupal community had the characteristics of a scale-free network (Huang, 2010). Huang (2010) used complex network method to analyze the product structure and evolutionary mechanism of OSS (Le and Panchal, 2012). The above models and simulations are mainly concentrated in complex networks and embody the complexity and the autonomy of open source design. It can analyze the macro structure and index of community but lack the evaluation of product and agent.

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And there are also many researches about performance evaluation of design process (Sarin and Mahajan, 2001) established a performance evaluation index system of product development from two dimensions (Sarin and Mahajan, 2001). Zhang and Shi (2009) thought the performance evaluation of product design should not be limited to part of process and then evaluated every stage of product design process (Zhang and Shi, 2009). Li and Guo (2012) focused on the characteristics of IT new product development team and influence factors of its performance and then developed a performance evaluation model of development (Li and Guo, 2012). However, there is still a lot of room to do a further research quantitatively and dynamically about open source design process based on the theory above.

SIMULATION OF OPEN SOURCE DESIGN PROCESS BASED ON MULTI-AGENT

According to the method of modeling based on multi-agent and the analysis for open source design process, firstly this study build a simulation process like Fig. 1 which is divided into five phases: Updating information, newcomers to the community, browsing modules, developing modules or releasing version and completing the project.

At the initial phase for the product design, community management-agent and core technology-agent launch the open source project, the management-agents update the information on the current project process, what the agents do during the open source design process and even about the what the community is going on right now. All of this information will help the information of the product module transfer to the open source community correctly and facilitate the agents to choose which one to develop next. Until the completion for updating information of modules, agents can attend to the community according to their interest and technique level and then agents browse the whole project, or make judgments about the task box for actual time modules. If the box is empty, the agent chooses which module to put into the box, if not, choose the module directly. After choosing the module, the agents develop it and release the version. Based on the index like completion time, technique level, the manager-agent evaluates and sifts those versions, then chooses the best one to release in open source community; Finally, making a judgment whether all of the product modules are finished, if yes, the project ends, otherwise, continuing the whole process in the next loop until the product design is completed.

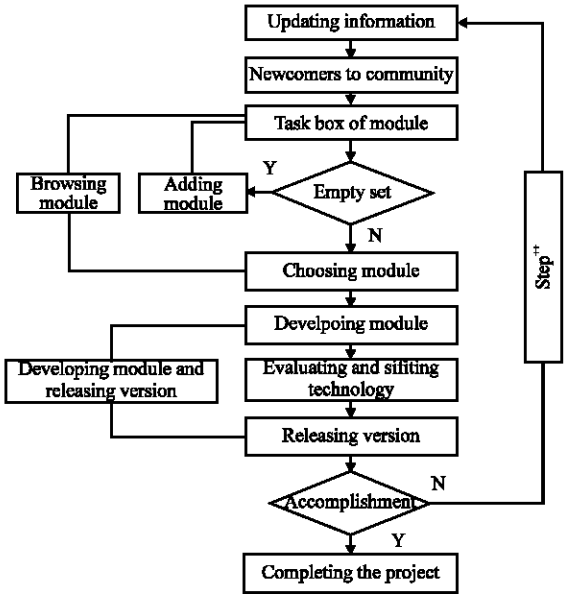

Fig.1: Overall simulation process of open source design

PROCESS EVALUATION INDEX

Product performance evaluation index: Compared with the traditional product design evaluation, product performance evaluation of open source design is real-time and periodic. Real-time performance mainly embodies in the dynamic changes of the product. Periodic performance mainly embodies in the whole process of product evolution, including the initial stage, development stage and mature stage. Periodic indexes need to be controlled in a certain period, so that it can be analyzed. On this basis, this study proposes the following specific evaluation indexes of the product design performance evaluation:

- **Weight of each module:** This index is used to evaluate the module development?s impact on the entire product development process. It is regarded as a ratio between the time needed for module development and the whole time of the product development. Assuming that Ti means the development time of module i and Wi means the weight of module:

$$w_i = \frac{T_i}{\sum_{i=0}^{n} T_i} \quad (i = 0, 1, 2..., n) \tag{1}$$

- **Product maturity:** This index is used to evaluate the degree of product evolution at some point in time. Every module in product has a different level of evolution. Assuming that Pi means the percentage of evolution for module i at some point in time and U means product maturity:

$$U = \sum_{i=0}^{n} P_i * w_i \ (i = 0, 1, 2..., n) \quad (2)$$

Agent performance evaluation indexes: In the open source community, the agents are different in the level of knowledge and technology. So it is necessary to evaluate the agent performance

- **Completion time of module for each agent:** The index is used to evaluate the ability of each agent in one module by comparison with the development time of every agent in the same module
- **Development ability of agent:** The index is used to evaluate development ability of agent in each module

$$M_i = Q_i * U_i \ (i = 0, 1, 2,...n) \quad (3)$$

$$U_i = \frac{\sum_{j=0}^{m} U_{ij}}{N'} \ (i = 0, 1, 2..., n; \ j = 0, 1, 2,...m) \quad (4)$$

$$Q_i = \frac{N'}{N} \quad (5)$$

Assuming that Mi means development ability of agent, Q_i means weight of modules which are developed by agent i, U_i means the average of development speed each module which agent i participates in (the first to complete goals 100, the second goal 90, the third goals 80),U_{ij} means the speed of agent i who develop module j, N' means the number of modules that agent i has participated in, N means the total number of modules.

SIMULATION EXPERIMENT

Experiment design: We designed two projects (A and B) as comparative experiment, to check the effectiveness of the proposed simulation model and the evaluation index. Project A stands for prime community, project B stands for interim community, they both have 8 modules, including 3 core modules and 5 common modules. In project A, there are 50 initial agents, including 1 management-agent, 3 core-agents, 46 common-agents; In project B, there are 100 initial agents, including 1 management-agent, 3 core-agents, 96 common-agents. In project A and B, they both have 8 modules and they have the same development subsequence, the development process is as shown in Fig. 2, TA stands for module, I stands for I/O information.

Results and analysis of the experiment: We will make an analysis according to the results of the experiment.

Product performance evaluation index:

- **index 1 weight of each module:** After the simulation, the simulation program figures out the weight of TA0-TA7 in both project A and B, as is shown in Fig. 3

By comparing the simulation results of project A and B, it is shown that as the community's scale getting larger, module 2's weight is always in a higher level (22 %in Project A, 21% in Project B),that indicates the development of module 2 is important for product evolution. At the same time, we found the module 3 and 7 also important.

- **index 2 product maturity:** Product maturity is a real-time index; it stands for the product's development status and extent at some moment. Here we use the experimental data when time step is 20 and 70, as is shown in Fig. 4

By comparing the simulation results, it is shown that when the step is the same, the maturity of project A and B is different, specially, when the community scale is smaller, the product maturity is higher on the contrary. The reason is that when the community scale enlarges, the module solutions increase, that lengthens the time of module evaluation and selection.

Agent's performance index:

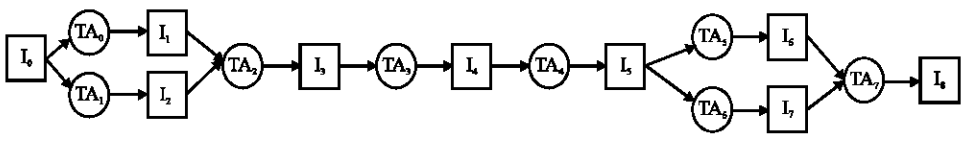

Fig. 2: Development process for product's every module

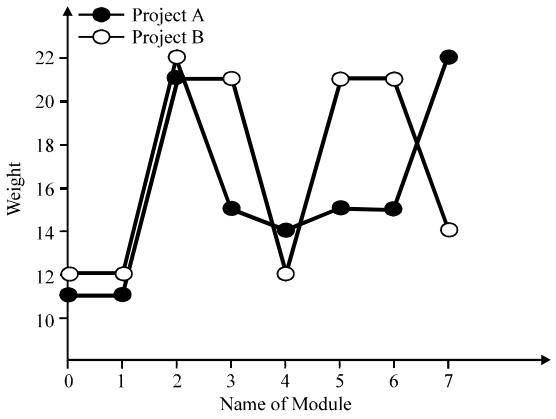

Fig. 3: Weight of each module in project A and B

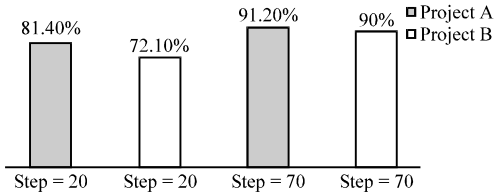

Fig. 4: Product maturity when step is 20 and 70 in project A and B

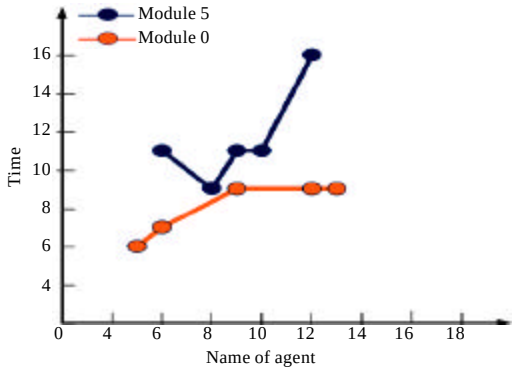

Fig. 5: Completion time of module 0 and module 5 for each agent in project A

Index 1: completion time of module for each agent: We compare agent's completion time in some typical module (module with more agents). We choose module 0 and module 5 to compare in project A and B, as is shown in Fig. 5 and 6.

From the figures above we find that in module 0 of project A, agent 9, 12, 13 develop more slowly; in module 5 of project B, agent 4, 10 develop faster. Besides, agents are usually in the same development level in different

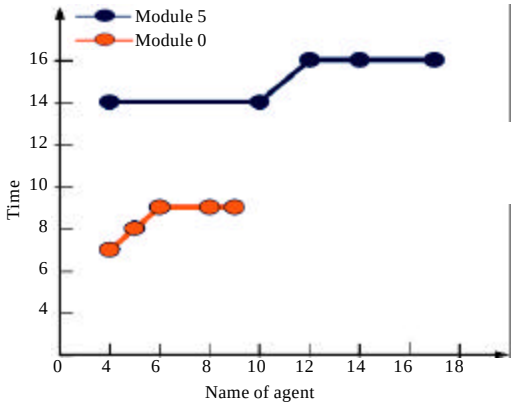

Fig. 6: Completion time of module 0 and module 5 for each agent in project B

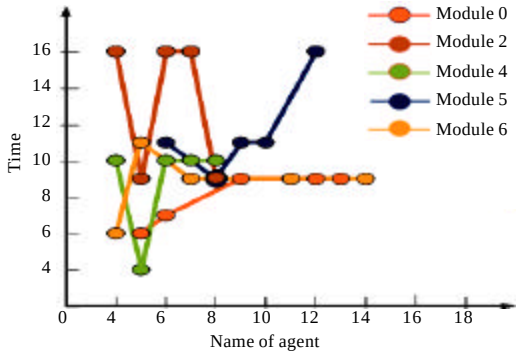

Fig. 7: Agent's completion time used for developing chosen modules in project A

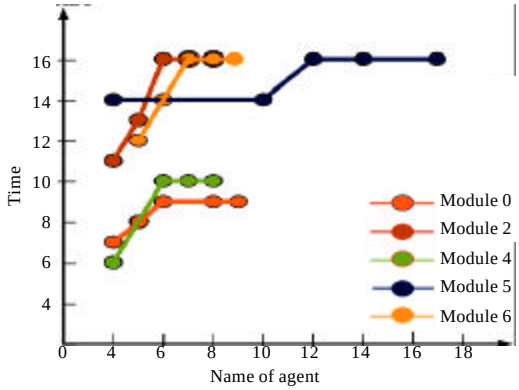

Fig. 8: Agent's completion time used for developing chosen modules in project B

module, for example, in project A agent 12 develops slowly in either module 0 or module 5.

Index 2 development ability of agent: We choose typical modules from project A and B to do research. The typical

ones mean modules with much more agents, such as module 0, 2, 4, 5, 6. The agent's completion time used for developing modules in project A and project B is shown in Fig. 7and 8.

From the figures above we calculated the developing ability score of agent 4, agent 5, agent 6. In project A they are 35, 47.5, 45 and in project B they are 50, 46.25, 41.25. We know from the results, in project A the rank in a descending order is agent 5, agent 6, agent 4; while in project B the rank is agent 4, agent 5, agent 6.

SUMMARY

There is a typical complex adaptive collaborative character in the process of open source design. According to the technology of multi-agent, this paper reveals a simulation program of open source design and a relatively mature evaluation system. Product performance evaluation indexes comprise weight of each module, product maturity; agent performance evaluation indexes comprise completion time of module for each agent, development ability of agent. The simulation results show that the proposed simulation method and evaluation indexes provide a basis for evaluation and management of open source design. On this basis, the future research will focus on developing more simulation experiments, such as comparative experiment about different behavior rules of intelligent agent and management operation mechanism of the community.

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