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Multi-agent Simulation System Study on Product Development Process

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To study designers' subjective initiative in the product development process, at first a multi-agent simulation model of product development process was established; second, a relevant multi-agent simulation system was developed based on the model. The realization principles of multi-agent simulation and function structure to describe the system were given, and key technologies of agent packaging, agent behavior function and graphical interface of simulation model were studied. At last a multi-agent simulation model on development process of a motorcycle engine project was built, and simulation experiments were carried out. The instance shows that the multi-agent simulation provides a quantitative and dynamic analysis method of human and organizational factors during the collaborative product development process.

Keywords: Product development, multi-agent model, multi-agent simulation.

1 Introduction

Nowadays, the characteristics of product development are increasingly outstanding, such as integration, complexity, dynamics, distribution, and so on. It has become a key problem in product development process management to predict, evaluate, and improve the process through dynamic simulation. In the research field of product development process modeling and simulating, the remarkable characteristics are building task-focused models based on activities decomposition principle, and running the simulation system through task triggering rules [1, 7, 8]. The product development is a typical kind of knowledge work, which is deeply impacted by human initiative, autonomy and collaborativity, as well as organization structure, control strategy, and collaborative methods of product development team. However, it's too hard to reflect human and organizational relationships in task models, due to the difficulty of quantitative analysis for influence on the process by human initiative and organizational factors. In recent years, it provides us a new way to our study with wide application of multi-agent-oriented dynamic simulation. For example, the operation of multi-agent-oriented simulation system was achieved in literatures [4, 5], and corresponding problems on cooperation were discussed as well, but the mentioned studies didn't concern product development process.

As a result, in combination with complex adaptive system theory and model building principle of multi-intelligence-agent system in artificial intelligence [3, pp.7-9, 30-36], a designer-centered multi-agent model orienting to product development process was set up in this paper. In the following text, the multi-agent simulation system was developed and the main technologies were mentioned, at last, an application case was given to describe the human initiative and organizational factors in product development process.

2 Multi-agent simulation model of product development process

In multi-agent simulation of product development process, designers are continually changing product information to achieve the whole product development through their initiative and collaboration behaviors. Based on the principle, a multi-agent simulation model for product development process was built, shown as Figure 2.1.

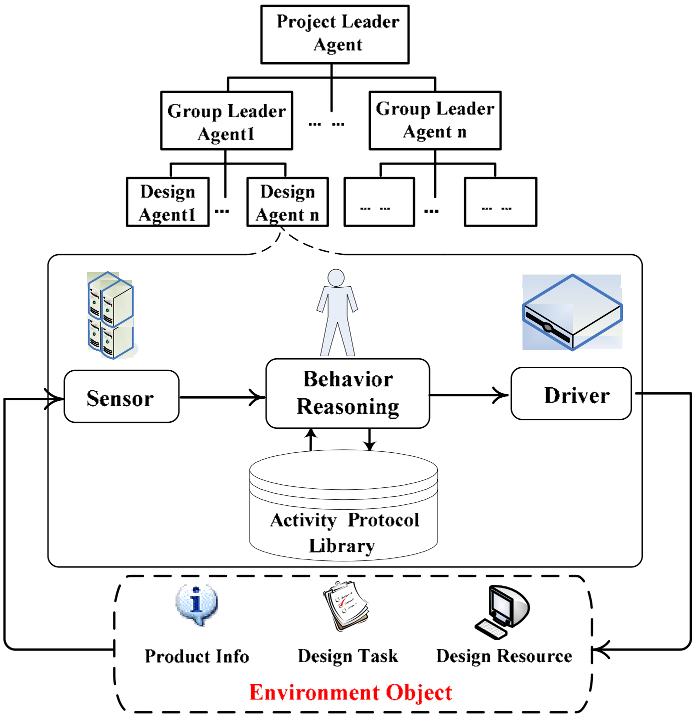

Figure 2.1: Integrated designer-centered simulation model in product development process

In this model, product information, design resources and design tasks were attributed to environment object. Correspondingly, the product development team was built according to each designer's characteristics like organizational relationship, functional scope and capacity. Besides, design agents were endowed with autonomous characteristics such as initiative, autonomy and collaboration. As predicted in the model, firstly design agents obtained environment object information by sensor, then analyzed the gained information by calling activity protocol library, so as to put forward processing scheme, and finally conveyed it to environment object by driver. In this way, the characteristics of design agent like initiative, autonomy and cooperation, as well as organizational behaviors in product development process, could be described well and truly in the model.

3 The multi-agent simulation system development of product development

Based on the model, a multi-agent simulation system for product development process was developed as Figure 3.1.

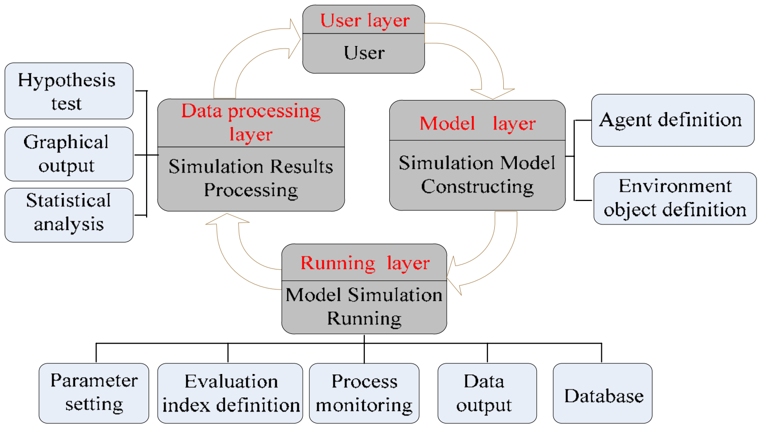

Figure 3.1: function structure of multi-agent simulation system

In accordance with the system structure, the operator should firstly enter user layer to open system interface; secondly, in model layer, he/she need build models, define attributes of design agents and environment object, and set the constraints between tasks and information; after model building, the designer can set parameter, define evaluation index, monitor the process and get output which linked a simulation database to ensure large amounts of data calling and storing in running layer; in data processing layer, simulation results were processed by statistical analysis, graphical output, as well as hypothesis testing; finally as feedback, the processing results returned to user layer, in which the user could adjust and optimize the current product development process, and modify the simulation model as well as parameters for a new round of simulation. The user could analyze these results, until the optimized scheme appeared.

3.1 Subject Packaging

Design agent model and environment object model were realized in the form of class packages, design agent into *Person Class* with environment object into 3 classes: *Task*, *Item* and *Resource*. As described, Person Class packaged all attributions and parameters of intelligent agent required in simulation, and the above 3 classes packaging environment object respectively.

3.2 Design Agent Behavior Function Invoking

Agent activities were implemented by calling behavior functions, based on the previous protocols [2, 6], as shown in Figure 3.2.

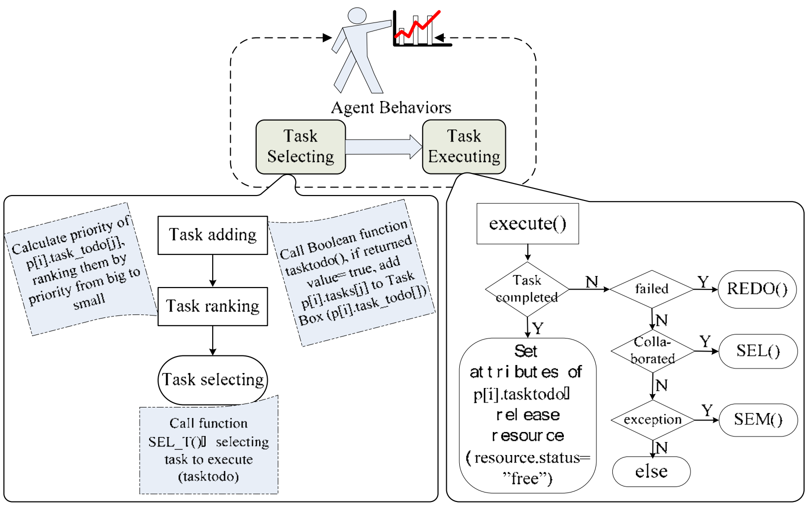

Figure 3.2: function definition to agent behaviors

In each behavioral process, there were 2 *for()* loops for 2 times of design agent traversal, so as to complete 2 phases of task screening and executing in sequence. The concrete process was as follows:

1) In the first *for()* loop, design agent checked array *p[i].tasks[]* for tasks that satisfied executive conditions, and added these screened tasks to array *p[i].task_todo[]* by calling Boolean function *tasktodo()*; after that, calculated priority values of each task from *p[i].task_todo[]*, sorting them from big to small by value; at last, determined task *(p[i].tasktodo) person[i]* would execute, by calling function *SEL_T()*.

2) After confirming the task to be executed, design agent turned into the second *for()* loop to call function *execute()*. In the function, if *tasktodo.work_time (work time of task p[i]tasktodo)* was equal to *tasktodo.normal_time*, the task was accomplished, then set relevant attributes of *p[i].tasktodo* and released the occupied resource *(resource.status="free")*. Otherwise, transferred to *else()* part, in which design agent *(p[i])* executed behavior protocols like cooperation, pause, rework and exception, according to task types *(p[i].tasktodo.type = examine task|| collab temp|| except temp||…)*.

3) With plus of simulation step length *rt (rt++)*, design agent *(person[i])* executed tasks of product development process as above regulations circularly, until all tasks are

completed.

3.3 The Graphical Interface of Simulation Model

The graphical interface of simulation model included 2 parts: agent model definition and environment object definition. Agent model definition consisted of agent attributes and agents' relations, and environment object definition of object attributes, relations between agents and objects, as well as relations among objects. In addition, environment relation definition prescribed 3 kinds of relationships: design agent and design task, input and output of tasks, as well as task and feedback, all of which were represented in the form of line with arrows linking objects.

The operator could drag different kinds of icons onto *Form++* canvas, which severally represented design agent, task, item and design resource, with line representing relations of each module and simulation flows. After simulation model framed, double-clicked left mouse button on each module and line, then input relevant parameters so that the program would call function *OnLButtonDblClk()*, which was programmed with the function of reading and storing module attributes.

4 Simulation example

Under the support of the developed simulation system, the paper carried through simulation modeling and experimental analysis to the product development process of a certain motorcycle engine. A graphical simulation input interface was shown in Figure 4.1. It could easily fulfill input and modification of various simulation parameters, by this approach, the multi-agent simulation model was built.

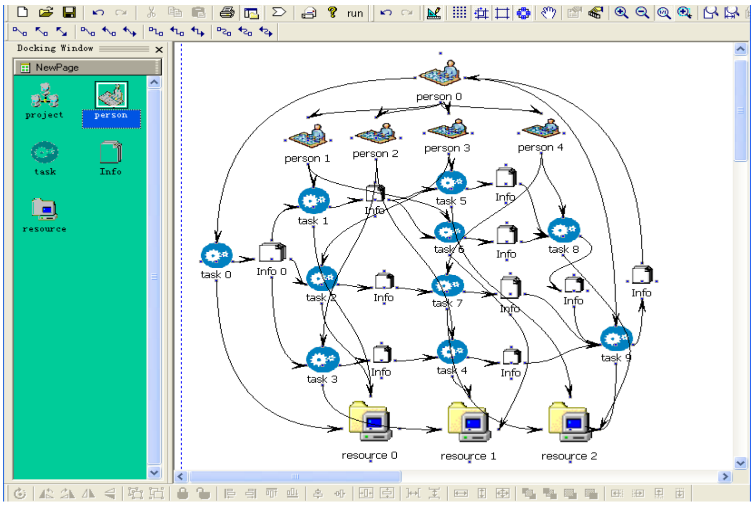

Figure 4.1: graphical simulation input interface

Figure 4.2 was a Gantt chart of output, describing the execution process of tasks Person 1 charged. From the figure, Person 1 was responsible for Task1 and Task 2. At time 6 of simulation step length *(rt=6)*, Person 1 began to implement Task1; however, by time 18 of step length, Person1 wouldn't continue Task1, if only he/she could find collaboration from other design agents. Hence, Person1 sent request for collaboration, and had to wait, remaining Person1's pause *(p[1].status=pause)* for collaboration; by time 24 of step length, the request for collaboration was solved, and then Person1 went on with Task1; by time 29 of step length, after Task1 finished, Person1 turned to Task6, in which some exceptions also occurred such as rework and collaboration.

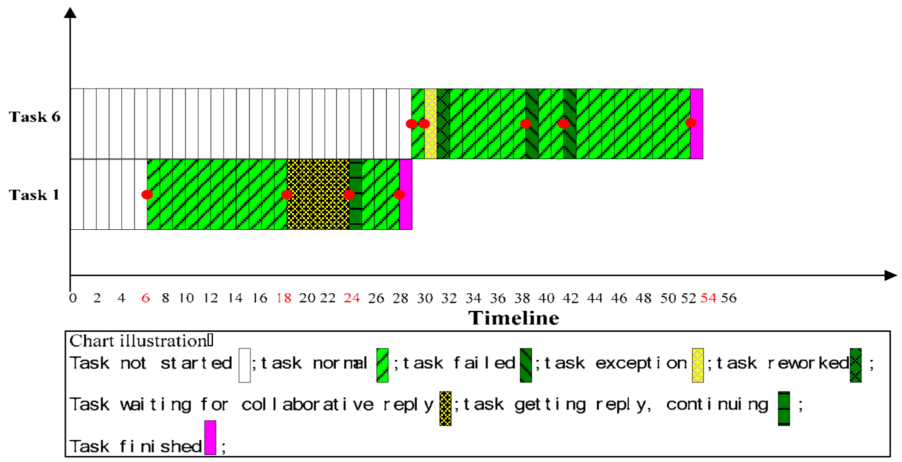

Figure 4.2: work process of Person1 in simulation

By time 54 of simulation step length *(rt=54)*, Person1 finally completed the 2 tasks, under circumstances of *execution, failure, rework, collaboration, exception, etc*. During the above experiment, the simulation described design agents' autonomous and organizational collaborative behaviors in product development process vividly and precisely, furthermore, it could carry out contrastive simulation research on product development team, like individual decision-making behaviors, organizational structures and organizational strategies.

5 Conclusions

In order to reflect dominant position of designers in product development process and embody their autonomy and collaboration in simulation process, the paper constructed multi-agent model of product development process, and developed the corresponding simulation system, using the technologies such as function packing, graphical simulation and so on, The simulation results showed that the proposed simulation model and system were able to make detailed description to autonomy, initiative, and collaboration designers behaved in the process. It provided a quantitative and dynamic research method of optimizing organizational behaviors in the process. For example, we can use this model and system to do some contrast analysis of organizational structure, scheduling strategy, partner selection strategy by the protocols. The further work will go on with pertinent research on personnel allocation, resource conflict and organizational factors in product development process, based on the simulation system.

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Yingzi Li is currently a doctor candidate of Chongqing University. Her research is mainly in the areas of product development modeling and simulation.