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Complex Project Schedule Risk Simulation Based on Multi-agent

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***Abstract*—In order to solve the problems of complex projects schedule risk assessment, a project schedule risk assessment model based on the multi-agent was established by the Anylogic software in this paper. In this model, a "process" agent, a "process flow", a "risk factor" and a "control" agent were designed by taking into account the process state, transformation conditions and the internal processing behavior of the state. Multiple nested relations between the process flow and the process were formed, which was caused by the risk factors. The model presented in this paper can analyze the equipment risk and order the importance of risk control, the experiment result shows that the model for complex projects schedule risk assessment has a certain reference value.**

Keywords*—*multi-agent; complex project; schedule risk; risk assessment

I. INTRODUCTION

The characteristics of complex project include a wide range, many contents, long period and strong correlation of processes. In the process of implementation, the risk factors of technology, resources and environment are of high uncertainty and the project schedule is difficult to control. Therefore, identifying and assessing the risk factors affecting the progress are crucial for the successful management of the project [1]. The existing evaluation methods are network planning technology [2], discrete event system simulation [3], system dynamics model [4] and so on. But network planning plans and discrete events can not achieve good assessment results. In this paper, we use the message components and state transition components of multi-agent to model complex projects, and divide the process, process flow and risk factor into different object types so that the complex problems are classified as a single object, so that each object achieve good independence and autonomy, and better solve the complexity of process logic in the rework path, and verify the applicability and practicability of the model by simulating specific problems.

II. MODELING ANALYSIS

Multi-agent system is a collection of multiple agents, which is autonomous, distributed and coordinated, and has self-organizing ability, learning ability and reasoning ability [5]. The goal of using multi-agent modeling techniques is to build large, complex systems into small, easily managed systems that communicate and coordinate with each other, and therefore it has great robustness and reliability to use this method to solve complex project risk assessments, and has higher problem solving efficiency [6]. Each agent in the model is independent and autonomous, modular, scalable and flexible in design. It overcomes the difficulty of management and expansion caused by building a huge system. It can effectively reduce the total system cost and complexity, it also reduces the complexity of solving each agent problem and effectively improves the ability of solving problems [7].

The research establishes three named types of agents by dividing the objects in the schedule risk assessment of construction projects into processes, risk factors and process flows, and establish "control" to control the simulation and record the simulation data.

(1) "Process" Agent: each process is considered as the same type of object independently. The "Process" agent only needs to consider the relevant parameters of process status and the existing risk factors.

(2) "Risk factor" agents: take the risk factors as a kind of object, and the occurrence of the risk leads to the rework, so the risk is in one-to-one correspondence with the "process flow" of the rework.

(3) "Process Flow" Agent: the process sequence is regarded as a kind of object, among which "Process Flow" can be divided into main "process flow" and rework "process flow". The main "process flow" is controlled by the "control" agent, and the rework "process flow" is guided by the "risk factor" agent.

(4) "Control" Agent: control the progress of simulation experiment and coordinate other agent.

Among them, the relationship between agents as shown in Figure 1.

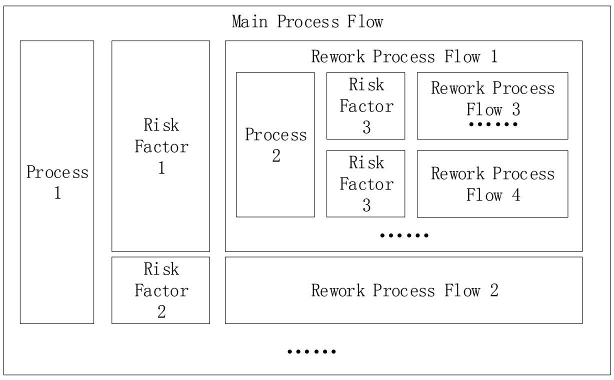

FIGURE I. AGENT RELATIONSHIP BETWEEN THE OBJECT DIAGRAM

The main "process flow" includes several "processes" that constitute the construction sequence under the sequential process. There are several different "risk factors" corresponding to the "process", and the "risk factors" trigger different rework "process flows", rework "process flow" contains a number of different "processes". If the "process" in the main "process flow" is the same as the "process" in the rework "process flow", then the structure of the rework cycle is formed. The nested relational model can better reflect the rework of the project in the actual situation.

III. MODELING BASED ON MULTI-AGENT

According to the requirements of process modeling and simulation, "Process" agent, "Process Flow" agent, "Risk factor" agent and "Control" agent are established. The specific modeling elements are as follows:

A. *Process*

Process is the main part of the project. The following describes the logical behavior of "process" agents from the three aspects: status, branches, and transitions.

1. According to the four states of the process, set the status as follows: "waiting", "proceeding", "rework" and "fulfillment".

2. There is a branch in the "process" agent, used to determine whether the risk is generated.

① Branch: Used to judge whether the defect occurs or not, provided that the risk occurrence rate of each "risk factor" agent existing in the process is compared with the random generation factor to generate an array structure and sequentially trigger the corresponding rework "process flow" and transfer to the "rework flow" state. If the risk factor in the process is not triggered, then transferred to the "fulfilment" state.

3. According to the transfer process conditions and simulation requirements, designing a process state diagram shown in Figure 2.

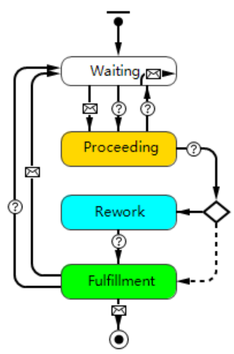

FIGURE II. PROCESS STATE DIAGRAM

The following figure shows the role of the changes.

(1) Reset the completion status of the process in the database when the "process" agent is generated.

Execute Statement ("UPDATE completion status table SET completion status = 0 WHERE name = "' + get Name () + "'");

(2) Message transition from the "waiting" state to the "proceeding" state is the start of this process instruction issued by the "control" or "process flow" agent.

(3) Conditions transition from "waiting" to "proceeding", with the condition that the number of pre-processes equals the pre-process completion and the status is adjusted when all the pre-processes are "completed".

(4) Condition transition from "proceeding" to "waiting", with the condition that the number of pre-process is not equal to the completion of pre-process. The change does not exist in practice. However, considering that the transmission of messages between agents is asynchronous, the order of transmission is not controlled by programming, it may happen that some agents are triggered by the pre-process conditions, while the multi-process rework instruction has been "proceeding" state, then the pre-process of the agent has not been completed. So we need to add further changes from the "proceeding" state to the "waiting" state.

(5) Condition transition from "proceeding" to branch ①, with the condition that the remaining construction period is less than or equal to 0, and the condition of less than 0 is to solve the problem of simulation accuracy defects. When calculating the remaining period, it has become a number less than zero. Transferred to the judgment of the occurrence of the risk after the procedure is finished.

(6) Condition transition from "proceeding" to "rework" state, provided that the risk in the risk factor agent does occur.

(7) Conditions transition from branch ① to the "fulfillment" state are as follows: the probability of the random generation factor being greater than the risk factor.

(8) Conditions transition from "rework" state to "fulfilment" state, conditions for the process corresponding to the risk factor of rework "process flow" all completed.

(9) Message transition from "fulfillment" to "waiting", which is a "reset" command sent to other agents to receive commands issued by "control" agents or other agents and then transferred to initial state.

(10) Conditions transition from "fulfillment" to "waiting", provided that the number of pre-process is not equal to the pre-process completion. Through this transition, we can form a state transition chain structure, and finally enable the multi-process rework in the main simulation environment to form a sequential rework loop from the rework point.

(11) Message transition from "Fulfillment" state to "Final" state, the message is received "simulation end" command, then the agent's operation is forced to end.

B. *Process Flow*

Process flow is the environment of process operation. The "process" in the same "process flow" can interact with each other through the message components. Therefore, the main function of the "process flow" is to isolate the influence of "process" messages in different "process flows". The parameters include the process start sequence number, process termination sequence number and the "process" agent connection structure. "Process Flow" state transition diagram shown in Figure 3:

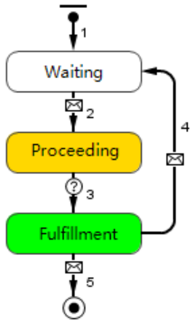

FIGURE III. PROCESS FLOW" AGENT STATE DIAGRAM

The effect of the transitions indicated by the numbers in Figure 3 are as follows:

(1) Create a "process flow" agent.

(2) When receiving the process flow start instruction issued by a "risk factor" agent, the "process flow" transitions from the "waiting" state to the "proceeding" state and the "starting" instruction is sent to the internal initial "process", then it started working.

(3) When the "process" in the "process flow" is completed, the completion status of the final process is triggered. When the conditions are satisfied, the "process flow" is switched from the "proceeding" status to the "fulfillment" status.

(4) When the "process flow" receives the "reset" command, it will be transferred from the "fulfillment" status to the “waiting” status.

(5) "Process Flow" becomes the final state when "Simulation Fulfill" command is received.

C. Risk Factor

The risk factor of each process has different numbers and different types, each of the risk factors as a "risk factor" agent. The "risk factor" agent connects "process" and "process flow" as a parameter object throughout the simulation. Its parameters should include the corresponding rework "process flow" serial number and risk distribution.

Therefore, the "risk factor" agent parameters include:

(1) The risk occurrence rate: the type is "double".

(2) Rework process flow: the type is "Process Flow".

D. Control

The role of the "control" in this simulation is to control the main process flow, the number of simulations, recording the simulation results and send "reset" instructions to coordinate the operation of the process agent. The state diagram of the "control" agent is shown in Figure 4:

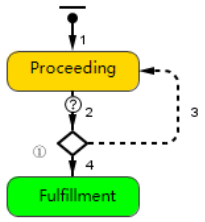

FIGURE IV. CONTROL" STATE DIAGRAM

The effects of transitions in the diagram are illustrated as follows:

(1) Empty the database time table:

Execute Statement ("TRUNCATE TABLE time table");

(2) Condition transition from "Proceeding" state to branch ①. The condition is whether the final procedure completion state is completed or not.

(3) Condition transition from branch ① to "Fulfillment" state. The conditions for the current number of simulations and the total number of simulations equal.

(4) Default transition from branch ① to "Proceeding" state.

IV. CASE SIMULATION AND RESULTS ANALYSIS

At present, there is a common phenomenon of budget overruns and a delay in progress in warship maintenance projects, resulting in warships failing to complete training tasks expectedly and equipment funding has not been used reasonably and effectively [8].Therefore, this paper selected a type of marine diesel engine minor repair projects for the case of simulation and analysis, with the key consideration of duration, through the gap between the actual average total duration and the average duration after control to reflect the influence level of complex project risk factors, and then analyze the major risk factors that have an important impact on the duration of maintenance and need to take priority measures to control, so as to provide a reliable basis for the schedule risk management of complex projects.

Combined with the characteristics of diesel engine maintenance and learn from relevant experts’ experience in the field to take the initial parameters of each process shown in Table 1.

TABLE I. INITIAL PARAMETERS OF DIESEL ENGINE MAINTENANCE PROCESS

ID	P_{init}	ID_{pre}	Risk	$Flow_{re}$	P_{re}	ID	P_{init}	ID_{pre}	Risk	$Flow_{i}$	P_{re}
S1	8		0.02	S1	6	S14	5	S12	0.01	S14	1
S2	9	S1	0.03	S2	7	S15	6	S12	0.02	S15	3
S3	10	S2	0.02	S3	9	S16	6	S12	0.01	S16	1
S4	5	S2	0.03	S4	3	S17	7	S5;S9;S10	0.03	S17	3
S5	6	S2	0.03	S5	3	S18	8	S13;S14;S15;S16;	0.02	S18	5
S6	12	S3	0.05	S6	10	S19	7	S18	0.04	S19	5
S7	11	S3	0.01	S2;S3;S7;		S20	8	S18	0.02	S20	4
S8	10	S3	0.01	S8	8	S21	4	S11;S17;S19;S20;	0.001	S21	1
S9	15	S3	0.02	S9	5	S22	4	S21	0.01	S22	3
S10	10	S4	0.02	S10	6	S23	3	S21	0.01	S23	2
S11	3	S1	0.01	S11	1	S24	5	S21	0.01	S24	2
S12	3	S6;S7;S8;	0.01	S12	1	S25	0	S22;S23;S24;	0	S25	0
S13	7	S12	0.02	S13	3						

Take the parameters of each process as shown in Table 1 to establish “process”, “risk factor”, “rework process flow” agent, set the initial process and process parameters in the main process flow interface, and output the process status diagram, the process remaining time line chart, the average duration line chart and the average time, simulation interface shown in Figure 5.

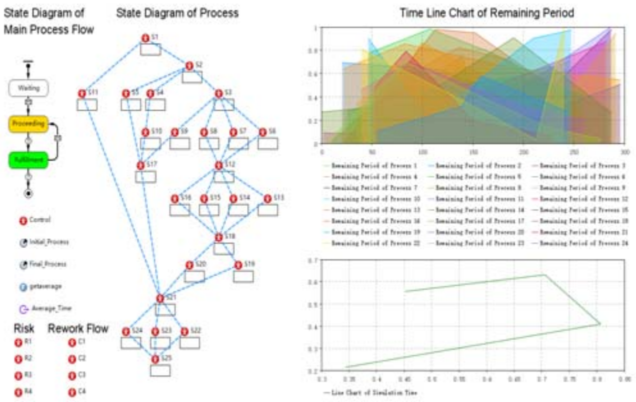

FIGURE V. MAIN PROCESS FLOW INTERFACE DIAGRAM

According to the characteristics of the maintenance process of the diesel engine, the process parameters in Table 1 are obtained, a diesel engine schedule risk assessment model based on multi-agent is established and simulated 100000 times to get the average total duration under risk control, which is 75.565d.Then, the average total duration is obtained by adjusting the defect rate of a single process, and the average total duration is compared with the average total duration without controlling the risk to obtain the variation of the total duration, and then the degree of influence of each process defect rate on the total maintenance schedule is analyzed. Finally, the order of importance of maintenance processes that require prioritized control is obtained. Suppose the cost of reducing the same rate of each process of diesel engine maintenance’ defect rate is the same, thus the average duration of the simulation is shown in Table 2 by artificially adjusting the defect rate of each process to reduce by 30%.

TABLE II. DURATION CHANGES UNDER THE DEFECT CONTROL

ID	$R_{control}$	P_{aver}	P_{change}	ID	$R_{control}$	P_{aver}	P_{chang}
S1	0.014	75.492	0.073	S13	0.014	75.495	0.07
S2	0.021	75.502	0.063	S14	0.007	75.558	0.007
S3	0.014	75.361	0.204	S15	0.014	75.541	0.024
S4	0.021	75.539	0.026	S16	0.007	75.539	0.026
S5	0.021	75.554	0.011	S17	0.021	75.545	0.02
S6	0.035	75.329	0.236	S18	0.014	75.463	0.102
S7	0.007	75.531	0.034	S19	0.028	75.486	0.079
S8	0.007	75.484	0.081	S20	0.014	75.349	0.216
S9	0.014	75.565	0	S21	0.0007	75.477	0.088
S10	0.014	75.517	0.048	S22	0.007	75.471	0.094
S11	0.007	75.545	0.02	S23	0.007	75.538	0.027
S12	0.007	75.441	0.124	S24	0.007	75.471	0.094

According to the above simulation results, it can be concluded that the change of total duration caused by the detect rate reduction of process S6 is the highest, followed by the process S20, process S3, process S12 and process S18, indicating that the adjustment of defect rate of process S6 has the greatest impact on the total duration of the diesel engine maintenance. Therefore, it is more effective to control the defect rate of process S6, S20, S3, S12 and S18 for the average duration of the project, it is feasible to adopt certain control measures to control these processes in priority. In addition, the rework period of each process can be adjusted, and the average timetable under the control of rework period of different processes can be obtained.

V. CONCLUSION

The schedule risk assessment is directly related to the execution efficiency and quality of complex projects. Based on the analysis of the logic conditions of warship diesel engine maintenance process status transition, a method for assessing the schedule risk of complex projects based on multi-agent is proposed. By using this method, we have got the influence of the parameters of each process on the complex project duration, and have completed the schedule risk importance analysis of a type of warship diesel engine maintenance project, which is general network plan can not reach. What's more, the model has some expansibility, it can introduce the hybrid modeling method based on system dynamics, and consider the resource, cost and other factors to make the simulation more practical. In addition, it is more vaguer to consider the defect rate response to the risk and can be studied in a "proceeding" state considering a certain distribution of defect occurrence rules.

REFERENCES

[1] Muhammed Mufazzal Hossen, Sunkoo Kang, Jonghyun Kim. Construction schedule delay risk assessment by using combined ahp-rii methodology for an international npp project. Nuclear engineering and technology. 47(2015):362-379.

[2] GUO Qi, HE Jin-jing, HU Miao. Project network planning schedule risk analysis based on monte-carlo simulation. J. Project Management Technology, 2013, 11(11):66-70.

[3] MAN Qing-peng. Research on modeling and controller method of schedule planning in building construction. D. Harbin Engineering University, 2008.

[4] LI Cun-bing, LU Gong-shu, LI Peng, LI Shang. System dynamics model for grid construction project schedule risk management. J. East China Electric Power, 2012, 40(02):178-182.

[5] B C Draa, B M oulin. Trends in distributed artificial intelligence [J]. Artificial Intelligence, 1992, 56(6):3566.

[6] LIU Jin-kun, ER Lian-jie. Overview of application of multi-agent technology. J. Control and Decision, 2001(02):133-140+180.

[7] Singh M P. Multi-Agent System: A Theoretical Framework for Intentions, Know-how, and Communications. Berlin: Springer-Verlag KG, 1994.

[8] LIU Zhi-qiang. The research of schedule control on the project of ZB vessels middle lever maintenance. D. South China University of Technology, 2011.