Chinese Journal of Aeronautics, (2014),27(2): 280–290

Chinese Society of Aeronautics and Astronautics
& Beihang University

Chinese Journal of Aeronautics

cja@buaa.edu.cn
www.sciencedirect.com

A multi-agent based intelligent configuration method for aircraft fleet maintenance personnel

Feng Qiang, Li Songjie, Sun Bo *

School of Reliability and Systems Engineering, Beihang University, Beijing 100191, China

Received 18 September 2013; revised 27 October 2013; accepted 6 December 2013
Available online 28 February 2014

KEYWORDS

Aircraft;
Configuration;
Fleet;
Maintenance-planning;
Multi-agent system;
Personnel

Abstract A multi-agent based fleet maintenance personnel configuration method is proposed to solve the mission oriented aircraft fleet maintenance personnel configuration problem. The maintenance process of an aircraft fleet is analyzed first. In the process each aircraft contains multiple parts, and different parts are repaired by personnel with different majors and levels. The factors and their relationship involved in the process of maintenance are analyzed and discussed. Then the whole maintenance process is described as a 3-layer multi-agent system (MAS) model. A communication and reasoning strategy among the agents is put forward. A fleet maintenance personnel configuration algorithm is proposed based on contract net protocol (CNP). Finally, a fleet of 10 aircraft is studied for verification purposes. A mission type with 3 waves of continuous dispatch is imaged. Compared with the traditional methods that can just provide configuration results, the proposed method can provide optimal maintenance strategies as well.

1. Introduction

As one of the key maintenance recourses, maintenance manpower is the subject of equipment maintenance. With the rapid development of technology, for instance, high velocity maintenance is becoming a trend,[1] and three level maintenance is being transferred to two level maintenance;[2] maintenance systems need improving and optimization. A maintenance system involves multiple factors, and all maintenance actions are performed by personnel. Therefore, the number of maintenance personnel is affected by multiple relevant factors,[3] and is difficult to determine. Meanwhile, aviation unit maintenance (AVUM) is directly related to combat effectiveness, while resources are limited. Therefore, the configuration of maintenance personnel of AVUM is very important.

At present, AVUM oriented fleet maintenance personnel configuration methods can be classified into 3 categories. The first is historical methodology.[3,4] For instance, the empirical formula:[4] the total maintenance time equivalent is first acquired, and then the maintenance time of each task is predicted, finally, the number of maintenance personnel is determined by judging the available maintenance time of a single person.

The second is mathematical programming.[5–9] For instance, the mixed integer linear programming:[5] an enumerative algorithm with bounding is proposed, in which each node of the enumeration tree represents a mixed integer linear problem (MILP), then the MILP is reformulated such that it becomes

* Corresponding author. Tel.: +86 10 82313214.
E-mail addresses: fengqiang@buaa.edu.cn (Q. Feng), sunbo@buaa.edu.cn (B. Sun).

Peer review under responsibility of Editorial Committee of CJA.

Production and hosting by Elsevier

1000-9361 © 2014 Production and hosting by Elsevier Ltd. on behalf of CSAA & BUAA. Open access under CC BY-NC-ND license.
http://dx.doi.org/10.1016/j.cja.2014.02.016

tractable for commercial MILP solvers. Ant colony algorithm:[8] a multi-objective mathematic optimization model for time and personnel is established by using the multi-objective constraint theory, then the model is studied based on the theory of modified ant colony algorithm. And genetic algorithm (GA):[9] business objective and process models are established, while the problem of deciding service staff is pointed out. A three-phase approach to decide service staff is put forward, applying an improved GA and a specific evaluation pattern.

The third is simulation:[10] a discrete event simulation model is presented for aircraft maintenance operation, which involves various characteristics and behaviors of an aircraft maintenance system. Optimization modules of the simulation software generate an optimum maintenance plan, and the optimum number of maintenance personnel to match the increased workload in the future.

Of all these approaches, the empirical formula is the most widely used in practice, but the result is far from reality due to its excessive simplification, and it needs to be adjusted according to the maintenance personnel of similar equipment. Mathematical programming is more accurate due to more consideration of various factors, but it is still far from precise and is difficult to solve. Simulation can account for even more factors and avoid complex theoretical derivation. Therefore, simulation is a more promising method.

However, current research is still far from being able to solve an actual maintenance personnel configuration problem. For example, new equipment that lacks historical data is not suited to historical methodology. Meanwhile, more attention is paid to the overall view of fleet maintenance problem, while individual pieces of equipment and person are largely ignored, which does not match the reality very well, nor is appropriate or accurate. Besides, in literature, maintenance tasks are usually regarded as time equivalent, while the effect of human error is not fully considered. Finally, current configuration methods usually follow certain rules to solve the optimal number of personnel and/or estimate the strategies, but the optimal maintenance strategy is not so easily obtained.

As an advanced modeling technique, multi-agent modeling has been successfully applied to maintenance modeling and optimization.[11–17] Agents can imitate the interaction and collaboration in the process of fleet maintenance, and can improve the accuracy of fleet maintenance model. The application of multi agent modeling can be divided into two aspects.

The first is maintenance optimization. For instance, Bouzidi-Hassini and Benbouzid-Sitayeb[15] proposed a joint production and maintenance scheduling that takes into account human resources availability and skills to propose realistic schedules, where multi-agent systems are used for modeling the floor shop.

The second is maintenance influence factor analysis and evaluation. For instance, Feng et al.[17] established a carrier aircraft operation and maintenance support model, and analyzed the influence of RMS level on the dispatch capacity of the carrier aircraft fleet.

Although multi-agent has not been applied to maintenance personnel configuration, it has laid a good foundation for the fleet maintenance personnel configuration problem, and can provide reference for its model framework and corresponding modeling elements. Compared with maintenance personnel configuration, the gap lies in: (A) the description of maintenance personnel is not detailed enough; (B) the analysis capacity of the model is not sufficient because generation of strategy is not very well achieved.

Based on multi-agent modeling, an intelligent aircraft fleet maintenance personnel configuration method for field maintenance is proposed in this paper. The multi-agent model can imitate the detailed behavior of the maintenance personnel, including their major, capability level, personnel cooperation, human error, and the result is more accurate; moreover, the number of personnel and personnel dispatching strategy can be solved at the same time, which can provide more support for maintenance system optimization.

2. Problem descriptions

2.1. Analysis of the maintenance process

An aircraft contains multiple parts which may fail. When a combat mission instruction is delivered to an aircraft, the aircrew conducts a pre-flight inspection, and once an aircraft returns from a mission, the aircrew conducts a post-flight inspection. If failures don't occur, the aircraft conducts the mission, or the aircraft is sent to the maintenance process. During the maintenance, human errors[18] may occur, so a test is required before the maintenance task is completed. Once the maintenance is done, the aircraft waits for mission instructions again. The detailed process is shown in Fig. 1.

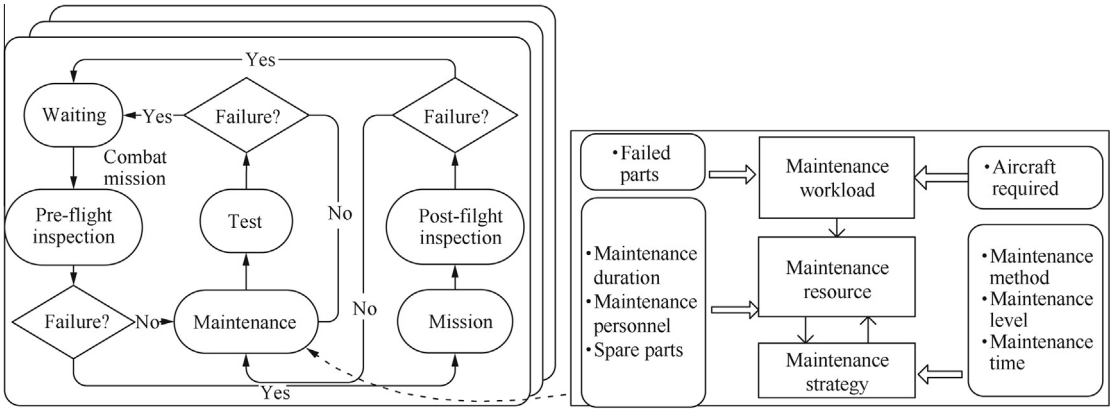

Fig. 1 Fleet maintenance process.