Computers & Industrial Engineering 95 (2016) 97–110

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

A mission execution decision making methodology based on mission-health interrelationship analysis

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ARTICLE INFO

Article history:
Received 23 March 2015
Received in revised form 17 December 2015
Accepted 24 February 2016
Available online 2 March 2016

Keywords:
Decision processes
Mission-health analysis
Mission execution decision making

ABSTRACT

In this paper, a mission execution decision making methodology is proposed based on the interrelationship between mission requirements and system capability. A mission–system correlation model is established after analyzing mission–function and function–system separately to determine the connections between mission and system. A detailed contrastive analysis between mission requirements and system capability, including transforming intrinsic health into mission health and modules interrelationship analysis, is then conducted for the given mission, which provides quantitative suggestions for objective and timely mission-execution decision making. A case study on a cruise is used to illustrate the performance of the methodology.

1. Introduction

The enhancement of product performance causes an increasingly complex structure in product design. System, device or even a unit constantly affects mission execution. A tiny fault inside the system or some uncontrollable factors can worsen the whole system. Recently, a large quantity of relevant studies has indicated that Prognosis and Health Management (PHM) technology, a comprehensive solution for product life-cycle support, significantly improves product availability and reduces testing and maintenance costs (Hess & Fila, 2002; Kalgren, Byington, & Roemer, 2006; Orsagh et al., 2006; Scanff et al., 2007; Vichare & Pecht, 2006). Dynamic and real-time information from PHM systems reflect the working condition and provide a feasible way to monitor the health of a system through continuous tests and analysis of each module (He, Zhao, & Xu, 2011; Ming & Ying, 2011; Peter & Chris, 2007; Tan, Qiu, & Liu, 2013). Take, for example, the flight data system of a combat aircraft, in which hundreds of data that reflect the flight performance are recorded for further analysis, such as the design capability test, flight accident investigation, flight training and examination, and necessary maintenance support. Few investigations are performed in this analysis that is related to the trend effect on mission control and planning. Hence, the disconnection between data monitoring and mission-execution decision-making exists objectively.

Generally, assessing product suitability for a mission control is determined through simple detection and experience, which tends to hide failure and results in an incomplete mission or even accidents. The health of modules affects the realization of corresponding functions and therefore influences mission execution. Aside from other group strategies, real-time health condition diagnosis and adaptation to failed condition are important control-level trends (DoD, 2002). Monitoring information and results may benefit decision making for mission execution. Establishing internal relations between monitoring data and system performance is essential to confirm product state and plan mission execution.

Industrial engineering (IE) applies modern system theory in plant capacity planning and efficiency promotion. From the perspective of the development tendency of society, resources, power and technology, product systems, and subsystems are reorganized and rearranged such that they become measurable and controllable based on the principle and method of control theory. Traditional IE focuses on manufacturing industry. Aside from the necessary industrial technologies, the latest achievement in science and technology (i.e., operation research), random theory, and computing technology have been applied in modern IE for management, quantification, and assessment. IE achieves optimization through the rationalization, standardization, efficiency, sequencing, and high quality of product systems, and production factors can be brought to their best performance level for efficient and coordinated operation. The fundamental principle, central

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http://dx.doi.org/10.1016/j.cie.2016.02.022
0360-8352/

theme, and corresponding methodology of IE significantly guide mission control and planning.

Moreover, a mission-execution decision-making problem focuses on the best execution option in a set of possible missions, and mission control is expected to operate safely and robustly under external and internal disturbances and to be able to accommodate fault conditions without significant degradation of their performance (Clements, 2003; Clements, Heck, & Vachtsevanos, 2001). Given the complexity and limitation of considering all factors when making decisions on mission execution, such as system degradation and degraded missions, decision makers have difficulty formulating an objective decision regarding practical operations (Herrera, 1995; Lan, Sun, Chen, & Wang, 2013; Xu, 2004).

The present study proposes a mission-execution decision-making methodology through basic acquisition analysis between mission and module health to provide quantitative assessment information and necessary suggestions for mission execution planning (Fig. 1).

A degraded submission in the actual execution process that is caused by the deterioration of module health directly affects subsequent submissions. For instance, a fighter can climb to a height of 30,000 feet if the engine thrust reaches 100 kilo newton (kN) under healthy condition and can climb to a height of only 20,000 feet if the engine thrust provides 80 kN under a degraded condition. Hence, the fighter lowers the demand when the current capability cannot satisfy normal execution. As such, the two conditions of normal and degraded executions are considered in mission execution decision making.

Part 1 – A mission system correlation model is established to understand the relationship between mission and system based on the relationship between function requirement and function availability. Part 1 of Fig. 1 shows the three parts of the model: mission decomposition, mission–function analysis, and function–system analysis. Mission decomposition decomposes a given mission into submissions to provide information for mission–system relations analysis. Mission–function analysis focuses on the function requirement of each submission, whereas function–system analysis focuses on the module requirements of corresponding functions. The mission–system correlation model obtains the basic modules for a particular mission through function requirement analysis, which provides fundamental and reliable information on mission-execution decision making.

Part 2 – Acquiring a collection of possible mission sequences is necessary for mission-execution decision making because the methodology produces an execution sequence for a given mission. Mission execution information can be obtained from product designers, maintenance supporters, and mission executors. A mission has various possibilities of submission execution based on the different health conditions of modules and considering the normal and degraded conditions. The information provides several discrete conditions of submission execution: different flying heights, detection approaches, and different methods of attack. However, not all possibilities of submission can be linked to finish the mission because of the interplay of submissions, as illustrated in the preceding paragraphs. Part 2 of Fig. 1 shows that the possible executions of submissions A, B, and C are A1–A3, B1–B2, and C1–C3, respectively. The effect of the two adjacent submissions on each other should be analyzed whether or not the former submission affects the latter one after all the possibilities of the submissions are confirmed. If the current health condition fulfills the normal execution of the former submission, then we should determine whether or not the health condition after the execution of the former submission could fulfill the latter one. The health condition may be worse for the latter submission if the former submission is executed degradedly. For instance, the degraded health condition may be suitable only to B2 if A2 is adapted in submission A; and only C2 is probable for submission C after the execution of B2. All the possibilities are analyzed step by step based on the health condition of the modules from the PHM system to acquire a collection of possible mission sequences, which include all the linking possibilities of the submissions to execute the mission. The green line in the illustration links the normal execution, whereas the yellow and red lines link the degrade execution.

Part 3 – The confirmation of the mission health (MH) of the modules and analysis of their interrelationships are processed based on mission–system incident relations and possible execution

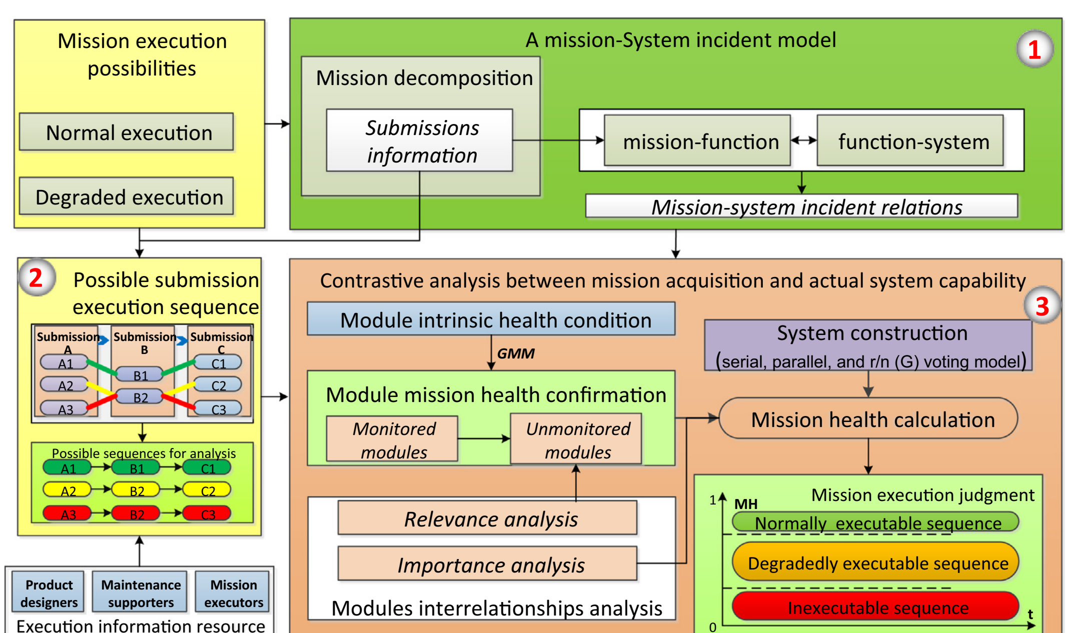

Fig. 1. Main process for mission execution decision making (considering normal and degraded execution, the main process mainly covers three parts namely mission–system incident module, possible submission execution sequences, contrastive analysis between mission acquisition and actual system capability).