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Determination of optimum criteria for condition-based maintenance of automatic ticket gates using remote monitoring data

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Abstract

Condition-based maintenance is effective in improving availability by preventing failure occurrences, especially in the case where the lives of equipment or components are unstable because of varying operating and environmental conditions. However, failure symptoms are not necessarily detected by monitoring systems in an accurate manner. In such cases, we need to determine the proper criteria for the effective execution of preventive maintenance to minimize the total effects, which include both the effects of successful preventive maintenance and those of unsuccessful ones. This paper proposes a method to determine the optimum criteria for executing the preventive maintenance of the mechatronics equipment. The error messages generated from the sensor signals do not have one-to-one correspondence with the component deterioration and failures because the mechatronics equipment usually use sensors, which are equipped for control purposes, to monitoring the failure symptoms. Therefore, we need to devise the method to relate the error messages with the deterioration and failures. We propose a four-step procedure for this purpose, in which a structural and functional analysis is integrated with a history data analysis. The proposed methods are applied to the automatic ticket gates installed in the train stations in Japan to verify their effectiveness.

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Keywords: Preventive maintenance criteria; Remote monitoring; Condition-based maintenance; Mechatronics equipment

1. Introduction

With the growing importance of maintenance in the recent years [1], remote maintenance systems have been introduced in various fields [2, 3]. The remote maintenance system remotely collects information on machine conditions and identifies the deterioration or failure symptoms, which can be used to trigger preventive maintenance (PM) actions. The remote maintenance systems are effective in reducing inspection and diagnosis costs, especially when many machines need to be maintained or when the machines are installed in places that are difficult to access. Machines, such as air-conditioning equipment in large buildings and gas turbine engines in power generation plants spread around the world, are typical examples of these cases.

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The remote maintenance systems are widely applied to mechatronics equipment (e.g., automatic ticket gates (ATG) in train stations and air-conditioning systems in buildings) because they are usually equipped with many sensors for control purposes, which make the implementation of the remote maintenance systems easy. However, the sensors for control purposes cannot directly monitor failure occurrences or symptoms. Therefore, we need to devise the methods for extracting information on the deterioration and failure symptoms from the monitored data and setting the proper criteria for PM executions. In this case, we have to consider the effects of false alarms and overlooking the symptoms. Any monitoring system could make a misjudgment. Therefore, we need to optimize the criteria for triggering PM execution to minimize the effects of the monitoring system misjudgment.

Many studies were conducted on the condition-based maintenance (CBM). They focused on the diagnosis and prognosis of deterioration and failures based on the monitoring data [4, 5] or setting the criteria for PM executions [6]. Most of these studies adopted either the stochastic approach using the stochastic model or the structural approach, in which the behaviors of the machines with defective components are analyzed based on the structural and functional analysis of the machines. However, few studies integrated both approaches. Few studies also dealt with the CBM using the sensors for control purposes, instead of dedicated sensors.

This paper proposes a method to relate the monitoring data with deterioration and failures and determine the optimum criteria for PM execution of mechatronics equipment. The rest of the paper is organized as follows: Section 2 explains the procedure of setting the criteria for PM execution. Section 3 presents the proposed procedure applied to automatic ticket gates installed in the train stations to demonstrate its effectiveness. Section 4 concludes the paper.

2. Determination of the optimum criteria for the PM execution

2.1. Proposed procedure of determining the optimum criteria for the PM execution

The mechatronics equipment are commonly equipped with a monitoring system for detecting the malfunctions. These monitoring systems usually use sensors for control purposes because of the installation cost. However, they do not necessarily and directly monitor the deterioration or failures of the mechanisms. They usually detect the behaviors of the mechanisms or objects to be handled, such as tickets in the case of automatic ticket gates. Therefore, the monitored data obtained by the sensors for control purposes do not have a one-to-one correspondence with the deterioration and failures of the mechanisms, which is why we need to develop the method to set the proper criteria of the PM execution. We assume that the error messages in this study are generated by the controllers of the mechatronics equipment (hereafter called machines) based on the certain logic using the monitoring data. The criteria are expressed as “PM is executed when a certain combination of the error messages is generated for more than a certain number of times N_e during a certain period of time T_c”.

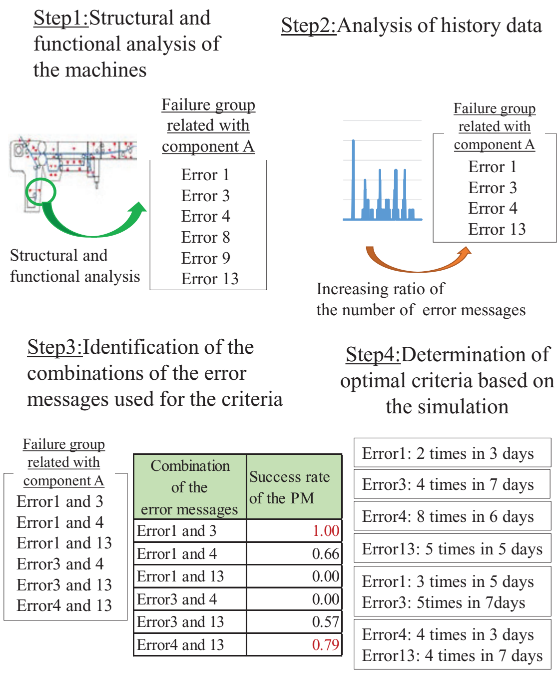

Fig. 1. Procedure for determining the optimal criteria for the PM executions

Figure 1 shows the proposed procedure for determining the optimal criteria comprising four steps. First, the error messages that relate failures are identified based on the structural and functional analysis of the machines. Second, the quantitative relationships between the error messages and the failures are evaluated using the historical data. Third, the proper combinations of the error messages for an effective detection of the failure symptoms are selected. Fourth, the optimal criteria for the PM execution are determined based on the simulation using historical data.

2.2. Step 1: Structural and functional analysis of the machines

We first examine the relations between the deterioration and the failures and the error messages based on the machine mechanisms. Accordingly, the structural and functional relationships among the components of the machines are identified for this purpose. We can analyze the effects of the deterioration and failures of the components on the machine behaviors and the objects dealt with by the machine based on these relations. The effect of the component propagates depending on its structural and functional relations if it deteriorates or fails. Furthermore, the behavioral changes of the machine and the objects, which are recognized as machine failures, are induced. These changes could be detected by the sensors, and the error messages are generated. We can relate the error messages with the component deterioration and failures by analyzing these processes.