A New Challenge in Predictive Maintenance Analysis for Aircraft

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ABSTRACT

JAL Engineering Co., Ltd. (JALEC) has been challenging to develop the predictive maintenance by big data analysis using the flight sensor data and the maintenance data as one of our initiatives to improve our aircraft reliability. Our analysis method is to verify hypotheses based on mechanics and engineer expertise with the data. Furthermore, in order to enhance our predictive maintenance, we introduced a new analysis method to search for hypotheses based on the information obtained from the data with AI technology. This article describes how JALEC has succeeded in developing a new analysis method with AI technology in the predictive maintenance and what we want to realize in the near future as a total engineering company.

1. INTRODUCTION

The use of big data to identify the signs of mechanical failure and to take countermeasures before actual failure can greatly contribute to the improvement of the quality of the machine, which is one of the most promising areas of data utilization. That's no exception in the aviation industry.

JALEC is a JAL group's subsidiary maintenance company that provides maintenance, repair and overhaul services for aircrafts, engines and components. Our company has been focusing on measures to analyze big data from the large amount of flight data acquired from sensors equipped on aircrafts, and to detect signs of failures, and to take preventive maintenance actions before reaching actual failures, which is what we call "Predictive Maintenance". We started data analysis to create our own predictive models with hypothesis-testing approach based on the experience and knowledge of mechanics and engineers. This approach has steadily produced success results and is still our primary method. However, there were some cases that it was difficult to establish failure prediction models using hypothesis-testing analysis. Therefore, we are challenging to develop a new data-driven analysis approach to create predictive models. In this article, we introduce the results of data-driven analysis using AI technology newly introduced by JALEC for failure prediction analysis with examples.

2. OVERVIEW OF AIRCRAFT PREDICTIVE MAINTENANCE

Aircrafts have systems that record and monitor various sensor data during flight. The varieties of sensor data range from hundreds to thousands depending on aircraft type, including, for example, temperature and pressure of the air being bled out of the engine, the speed of the motors used in various systems. JAL has been storing those flight sensor data for over years. By analyzing those historical sensor data as well as historical maintenance data, if we find any relationship between specific behavior on sensor data and aircraft failures, we can predict that the same failure would happen by monitoring on present flight data to take preventive maintenance actions. Predicting the aircraft failures in advance enables airlines to perform appropriate maintenance actions in a planned manner and to avoid unplanned actions causing flight schedule interruptions and cancellations. Furthermore, this approach can help reduce the need for excess inventory of spare parts for repairs. Figure 1 shows the overview of our predictive maintenance concept.

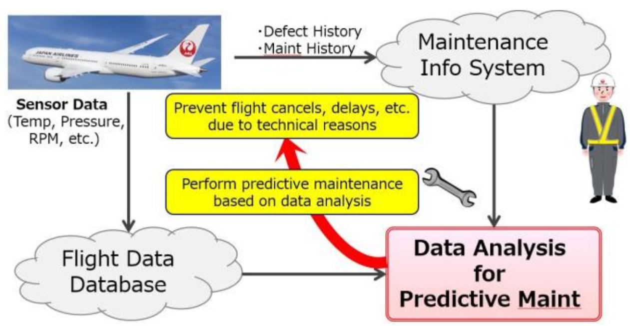

Figure1. Overview of Predictive Maintenance

3. CONVENTIONAL APPROACH: HYPOTHESIS-TESTING ANALYSIS

In order to achieve accurate failure prediction, we found it was important to develop some hypotheses of scenarios leading to failure based on our expertise and experience about the system obtained through daily maintenance work, and to statistically verify them one by one through data analysis.

We call this approach "Hypothesis-Testing Analysis" and the specific steps are as follows (refer to Figure 2):

1. Based on the expertise of maintenance engineers and system engineers, we consider scenarios leading to target failure and develop hypotheses. Then, consider which parameters (sensor data) should be focused on.
2. Visualize the parameters of interest for several flights before and after a failed flight, and thoroughly observe if there is any feature and behavior of the data that emerges before the failure.
3. Create appropriate features to express the observed data changes, as like maximum, minimum, mean, etc. of certain parameter under certain conditions.
4. With the created feature, verify whether there is a significant difference statistically between the normal flights and the flights prior to the failed flight. If the differences are found, it could be a failure prediction model after setting an appropriate threshold for the feature.

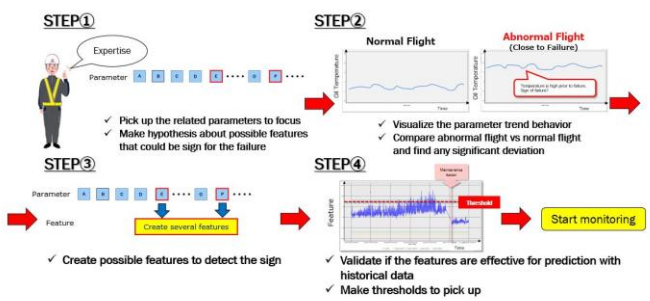

Figure2. Process of Hypothesis-Testing Analysis

To date, with this approach JALEC has steadily produced successful results by creating over 100 prediction models that can detect signs of failures. However, we also have experienced many cases that it is difficult to establish failure prediction models using hypothesis-testing analysis. To break through this difficulty, we thought a new approach should be necessary in addition to the conventional one.

4. New Approach: Data-Driven Hypothesis Analysis

As a new approach, JALEC addressed an approach called " data-driven hypothesis analysis", which derives possible hypotheses for predictive logic from a given set of data. By developing this new approach, we think there is a possibility that some signs of failures can be detected on trends in sensor data, even for failures the hypothesis-testing analysis couldn't find the sign.

To realize this approach, we focus on a new data analysis software called dotData, an Automated Machine Learning platform featuring automated feature engineering. The key to data-driven hypothesis analysis is finding significant features in the given data. At the time, other AI and machine learning tools and products existed, but in most of them, the feature values had to be designed and provided by humans, and the results tended to be black boxes. In contrast, dotData automatically extracts features and visualizes them on the software, so it exactly meets our needs of the "data-driven hypothesis" failure prediction. In figure 3, the concept of the new approach is shown.

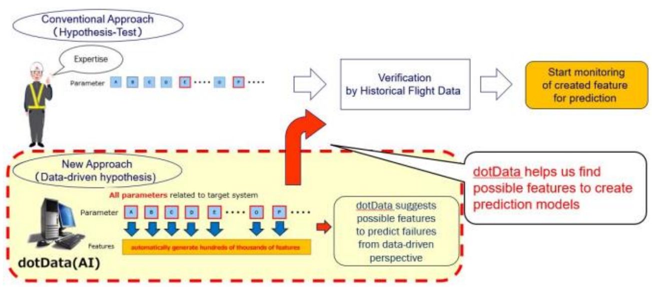

Figure3. Concept of Data-driven Hypothesis Analysis

In 2019 JALEC carried out Proof of Concept (PoC) in order to validate if dotData could realize our data-driven hypothesis analysis concept. In this PoC, we took up failure on Boeing 787 Hydraulic Spoiler PCU (Power Control Unit) as the subject, where our conventional analysis methods had already detected signs of failure. This challenge would be successful if the features dotData automatically created include the one we already had known or new feature that could lead to predict the failure.

Figure 4 shows the process of analysis in this PoC. First, we prepared a group of "Normal" flights (=no failure condition included) and a group of "Abnormal" flights (= possibly failure condition included), and picked up the parameters related to Hydraulic Spoiler PCU from those two groups of flight data. After four times of analyses, including changing the set of normal/abnormal flight data, dotData automatically generated hundreds of thousands of features, from which a cumulative total of 268 statistically significant features were selected. Finally, we confirmed the 9 common features selected in all four analyses and one of them matched the feature that were initially found by the hypothesis-testing analysis. This result proves that dotData can automatically generate effective features for predictive analysis and that our concept of data-driven hypothesis analysis is successful.

Since the success of this PoC, JALEC has continued data-driven hypothesis analysis using dotData as well as conventional hypothesis-testing analysis. At present, there are only several successful cases, but we developed failure prediction logics using this new approach for some failure events. In one successful case, the experience of the mechanics and engineers indicated that possible feature for prediction would appear while the subject system was running, however, dotData revealed features while the subject system was not operational could lead to the prediction model. In this way, we can say that this new approach has enhanced our company's predictive maintenance capabilities.

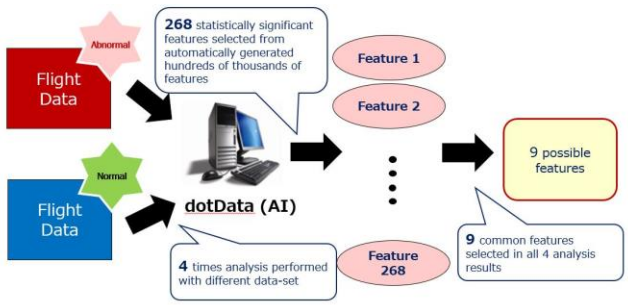

Figure4. Analysis Process in Proof of Concept

5. CONCLUSION

JALEC has introduced one new data-driven predictive analysis approach by using Automated Machine Learning technology for aircraft maintenance. Though we consider that our primary method for predictive analysis is still conventional hypothesis-testing analysis, however we believe that this kind of challenge to incorporate new advanced analytic technology will bring us to strengthen our maintenance capabilities for aircraft quality improvement.

Going forward, we will continue to take on many challenges to combine of further advanced analytic technologies with our maintenance expertise for improving the quality of aircrafts.