DATA-DRIVEN UNSUPERVISED ALGORITHM FOR ANALYZING SENSOR DATA TO DETECT ABNORMAL VALVE OPERATION

BACKGROUND

Aspects described herein relate to valves in aircraft, and more specifically, to a method and system for detecting abnormal valve operation based on a data-driven, unsupervised algorithm for analyzing sensor data. Often, abnormal operation of valves in an aircraft is difficult and time consuming to diagnose. Furthermore, conventional approaches are targeted at diagnosing abnormal operation of a specific valve, or type of valve.

SUMMARY

According to a first aspect of the present invention, there is provided a method, comprising: identifying from a plurality of maintenance messages (MMSGs) a threshold value indicating abnormal operations of a shut-off valve; capturing, during a first predefined time period after the shut-off valve is opened, a first plurality of sensor readings related to the shut-off valve; capturing, during a second predefined time period after the shut-off valve is closed, a second plurality of sensor readings related to the shut-off valve; identifying a first maximum value from the first plurality of sensor readings and a second maximum value from the second plurality of sensor readings; and in response to determining that a difference between the first maximum value and the second maximum value satisfies the threshold value, generating an alert indicating that the shut-off valve is operating abnormally.

According to a second aspect of the present invention, there is provided a system, comprising: a processor; and a memory containing a program which when executed by the processor performs an operation comprising: identifying from a plurality of maintenance messages (MMSGs) a threshold value indicating abnormal operations of a shut-off valve; capturing, during a first predefined time period after the shut-off valve is opened, a first plurality of sensor readings related to the shut-off valve; capturing, during a second predefined time period after the shut-off valve is closed, a second plurality of sensor readings related to the shut-off valve; identifying a first maximum value from the first plurality of sensor readings and a second maximum value from the second plurality of sensor readings; and in response to determining that a difference between the first maximum value and the second maximum value satisfies the threshold value, generating an alert indicating that the shut-off valve is operating abnormally.

According to a third aspect of the present invention, there is provided a computer readable storage device including instructions that when executed by a processor enables the processor to perform an operation comprising: identifying from a plurality of maintenance messages (MMSGs) a threshold value indicating abnormal operations of a shut-off valve; capturing, during a first predefined time period after the shut-off valve is opened, a first plurality of sensor readings related to the shut-off valve; capturing, during a second predefined time period after the shut-off valve is closed, a second plurality of sensor readings related to the shut-off valve; identifying a first maximum value from the first plurality of sensor readings and a second maximum value from the second plurality of sensor readings; and in response to determining that a difference between the first maximum value and the second maximum value satisfies the threshold value, generating an alert indicating that the shut-off valve is operating abnormally.

As disclosed, a computer-implemented method includes identifying a plurality of maintenance messages (MMSGs). Each of the plurality of MMSGs is associated with at least one shut-off valve of a plurality of shut-off valves in a vehicle. The method further includes identifying a first sensor parameter based on an analysis of a plurality of sensor parameters associated with the at least one shut-off valve associated with each MMSG. In addition, a first threshold value for the first sensor parameter is identified as being associated with abnormal operation of the respective at least one shut-off valve. A first sensor associated with a first shut-off valve of the plurality of shut-off valves captures a plurality of values for the first sensor parameter during: (i) a first predefined time period and (ii) a second predefined time period, the first and second predefined time periods associated with a respective one of an opening and a closing of the first shut-off valve. Upon determining that a difference between a maximum value of the plurality of sensor values captured during the first predefined time period and a maximum value of the plurality of sensor values captured during the second predefined time period exceeds the first threshold value for the first sensor parameter, a determination is made that the first shut-off valve is operating abnormally.

As disclosed, a computer program product comprises a computer-readable storage medium having computer-readable code embodied therewith. The computer-readable program code is executable by a processor to perform an operation comprising identifying a plurality of maintenance messages (MMSGs). Each of the plurality of MMSGs is associated with at least one shut-off valve of a plurality of shut-off valves in a vehicle. The operation further includes identifying a first sensor parameter based on an analysis of a plurality of sensor parameters associated with the at least one shut-off valve associated with each MMSG. In

addition, a first threshold value for the first sensor parameter is identified as being associated with abnormal operation of the respective at least one shut-off valve. A first sensor associated with a first shut-off valve of the plurality of shut-off valves then captures a plurality of values for the first sensor parameter during: (i) a first predefined time period and (ii) a second predefined time period, the first and second predefined time periods associated with a respective one of an opening and a closing of the first shut-off valve. Upon determining that a difference between a maximum value of the plurality of sensor values captured during the first predefined time period and a maximum value of the plurality of sensor values captured during the second predefined time period exceeds the first threshold value for the first sensor parameter, a determination is made that the first shut-off valve is operating abnormally.

As disclosed, a system comprises a computer processor and a memory containing a program. The program is executable by the processor to perform an operation comprising identifying a plurality of maintenance messages (MMSGs). Each of the plurality of MMSGs is associated with at least one shut-off valve of a plurality of shut-off valves in a vehicle. The operation further includes identifying a first sensor parameter based on an analysis of a plurality of sensor parameters associated with the at least one shut-off valve associated with each MMSG. In addition, a first threshold value for the first sensor parameter is identified as being associated with abnormal operation of the respective at least one shut-off valve. A first sensor associated with a first shut-off valve of the plurality of shut-off valves then captures a plurality of values for the first sensor parameter during: (i) a first predefined time period and (ii) a second predefined time period, the first and second predefined time periods associated with a respective one of an opening and a closing of the first shut-off valve. Upon determining that a difference between a maximum value of the plurality of sensor values captured during the first predefined time period and a maximum value of the plurality of sensor values captured during the second predefined time period exceeds the first threshold value for the first sensor parameter, a determination is made that the first shut-off valve is operating abnormally.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a block diagram illustrating components of a system which implements a data-driven, unsupervised algorithm for analyzing sensor data to detect abnormal valve operation, according to one aspect.

Figures 2A-2B illustrate example techniques for detecting abnormal operation of valves based on a data-driven, unsupervised algorithm for analyzing sensor data, according to various aspects.

CLAIMS

What is claimed is:

1. A method, comprising:

identifying from a plurality of maintenance messages (MMSGs) a threshold value indicating abnormal operations of a shut-off valve;

capturing, during a first predefined time period after the shut-off valve is opened, a first plurality of sensor readings related to the shut-off valve;

capturing, during a second predefined time period after the shut-off valve is closed, a second plurality of sensor readings related to the shut-off valve;

identifying a first maximum value from the first plurality of sensor readings and a second maximum value from the second plurality of sensor readings; and

in response to determining that a difference between the first maximum value and the second maximum value satisfies the threshold value, generating an alert indicating that the shut-off valve is operating abnormally.

2. The method of claim 1, further comprising:

transmitting, while a vehicle in which the shut-off valve is included is operating, the alert to a remote computing device via a network; and

scheduling, by the remote computing device, maintenance for the shut-off valve.

3. The method of claim 1, wherein identifying the threshold value from the plurality of MMSGs further comprises:

identifying, in each MMSG of the plurality of MMSGs, a first plurality of MMSG sensor readings related to a respective shut-off valve that were captured during a first MMSG predefined time period after opening the respective shut-off valve;

identifying, in each MMSG of the plurality of MMSGs, a second plurality of MMSG sensor readings related to the respective shut-off valve that were captured during a second MMSG predefined time period after closing the respective shut-off valve;

identifying, for each MMSG of the plurality of MMSGs, a first MMSG maximum value from the first plurality of MMSG sensor readings and a second MMSG maximum value from the second plurality of MMSG sensor readings;

computing, for each MMSG of the plurality of MMSGs, a MMSG difference between the first MMSG maximum value and the second MMSG maximum value, to produce a corresponding plurality of MMSG differences;

identifying a value from the plurality of MMSG differences that is a specified number of standard deviations from a mean of the plurality of MMSG differences; and

setting the value to the threshold.

4. The method of claim 1, wherein the plurality of MMSGs are identified based on a determination that a respective date of each MMSG of the plurality of MMSGs occurred within a specified number of days from a current date at which the first plurality of sensor readings and the second plurality of sensor readings are captured.

5. The method of claim 1, wherein the first predefined time period lasts for a given window of time during a given operational phase of a vehicle in which the shut-off valve is included and the second predefined time period lasts for the given window of time during the given operational phase of the vehicle.

6. The method of claim 1, further comprising:

identifying from the plurality of MMSGs a second threshold value indicating abnormal operations of the shut-off valve;

capturing, during the first predefined time period after the shut-off valve is opened, a third plurality of sensor readings related to the shut-off valve;

capturing, during the second predefined time period after the shut-off valve is closed, a fourth plurality of sensor readings related to the shut-off valve;

wherein the first plurality of sensor readings and the second plurality of sensor readings relate to a first parameter of the shut-off valve and the third plurality of sensor readings and the fourth plurality of sensor readings relate to a second parameter of the shut-off valve different from the first parameter;

identifying a third maximum value from the third plurality of sensor readings and a fourth maximum value from the fourth plurality of sensor readings; and

in response to determining that a second difference between the third maximum value and the fourth maximum value satisfies the second threshold value, generating the alert indicating that the shut-off valve is operating abnormally.

7. The method of claim 6, wherein the first parameter and the second parameter are selected from the group consisting of:

temperature;

pressure;

altitude;

airspeed; and

humidity.

8. A system, comprising:

a processor; and

a memory containing a program which when executed by the processor performs an operation comprising:

identifying from a plurality of maintenance messages (MMSGs) a threshold value indicating abnormal operations of a shut-off valve;

capturing, during a first predefined time period after the shut-off valve is opened, a first plurality of sensor readings related to the shut-off valve;

capturing, during a second predefined time period after the shut-off valve is closed, a second plurality of sensor readings related to the shut-off valve;

identifying a first maximum value from the first plurality of sensor readings and a second maximum value from the second plurality of sensor readings; and

in response to determining that a difference between the first maximum value and the second maximum value satisfies the threshold value, generating an alert indicating that the shut-off valve is operating abnormally.

9. The system of claim 8, the operation further comprising:

transmitting, while a vehicle in which the shut-off valve is included is operating, the alert to a remote computing device via a network; and

scheduling, by the remote computing device, maintenance for the shut-off valve.

10. The system of claim 8, wherein identifying the threshold value from the plurality of MMSGs further comprises:

identifying, in each MMSG of the plurality of MMSGs, a first plurality of MMSG sensor readings related to a respective shut-off valve that were captured during a first MMSG predefined time period after opening the respective shut-off valve;

identifying, in each MMSG of the plurality of MMSGs, a second plurality of MMSG sensor readings related to the respective shut-off valve that were captured during a second MMSG predefined time period after closing the respective shut-off valve;

identifying, for each MMSG of the plurality of MMSGs, a first MMSG maximum value from the first plurality of MMSG sensor readings and a second MMSG maximum value from the second plurality of MMSG sensor readings;

computing, for each MMSG of the plurality of MMSGs, a MMSG difference between the first MMSG maximum value and the second MMSG maximum value, to produce a corresponding plurality of MMSG differences;

identifying a value from the plurality of MMSG differences that is a specified number of standard deviations from a mean of the plurality of MMSG differences; and

setting the value to the threshold.

11. The system of claim 8, wherein the plurality of MMSGs are identified based on a determination that a respective date of each MMSG of the plurality of MMSGs occurred within a specified number of days from a current date at which the first plurality of sensor readings and the second plurality of sensor readings are captured.

12. The system of claim 8, wherein the first predefined time period lasts for a given window of time during a given operational phase of a vehicle in which the shut-off valve is included and the second predefined time period lasts for the given window of time during the given operational phase of the vehicle.

13. The system of claim 8, the operation further comprising:

identifying from the plurality of MMSGs a second threshold value indicating abnormal operations of the shut-off valve;

capturing, during the first predefined time period after the shut-off valve is opened, a third plurality of sensor readings related to the shut-off valve;

capturing, during the second predefined time period after the shut-off valve is closed, a fourth plurality of sensor readings related to the shut-off valve;

wherein the first plurality of sensor readings and the second plurality of sensor readings relate to a first parameter of the shut-off valve and the third plurality of sensor readings and the fourth plurality of sensor readings relate to a second parameter of the shut-off valve different from the first parameter;

identifying a third maximum value from the third plurality of sensor readings and a fourth maximum value from the fourth plurality of sensor readings; and

in response to determining that a second difference between the third maximum value and the fourth maximum value satisfies the second threshold value, generating the alert indicating that the shut-off valve is operating abnormally.

14. The system of claim 13, wherein the first parameter and the second parameter are selected from the group consisting of:

temperature;

pressure;

altitude;

airspeed; and

humidity.

15. A computer readable storage device including instructions that when executed by a processor enables the processor to perform an operation comprising:

identifying from a plurality of maintenance messages (MMSGs) a threshold value indicating abnormal operations of a shut-off valve;

capturing, during a first predefined time period after the shut-off valve is opened, a first plurality of sensor readings related to the shut-off valve;

capturing, during a second predefined time period after the shut-off valve is closed, a second plurality of sensor readings related to the shut-off valve;

identifying a first maximum value from the first plurality of sensor readings and a second maximum value from the second plurality of sensor readings; and

in response to determining that a difference between the first maximum value and the second maximum value satisfies the threshold value, generating an alert indicating that the shut-off valve is operating abnormally.

16. The storage device of claim 15, the operation further comprising:

transmitting, while a vehicle in which the shut-off valve is included is operating, the alert to a remote computing device via a network; and

scheduling, by the remote computing device, maintenance for the shut-off valve.

17. The storage device of claim 15, wherein identifying the threshold value from the plurality of MMSGs further comprises:

identifying, in each MMSG of the plurality of MMSGs, a first plurality of MMSG sensor readings related to a respective shut-off valve that were captured during a first MMSG predefined time period after opening the respective shut-off valve;

identifying, in each MMSG of the plurality of MMSGs, a second plurality of MMSG sensor readings related to the respective shut-off valve that were captured during a second MMSG predefined time period after closing the respective shut-off valve;

identifying, for each MMSG of the plurality of MMSGs, a first MMSG maximum value from the first plurality of MMSG sensor readings and a second MMSG maximum value from the second plurality of MMSG sensor readings;

computing, for each MMSG of the plurality of MMSGs, a MMSG difference between the first MMSG maximum value and the second MMSG maximum value, to produce a corresponding plurality of MMSG differences;

identifying a value from the plurality of MMSG differences that is a specified number of standard deviations from a mean of the plurality of MMSG differences; and

setting the value to the threshold.

18. The storage device of claim 15, wherein the plurality of MMSGs are identified based on a determination that a respective date of each MMSG of the plurality of MMSGs occurred within a specified number of days from a current date at which the first plurality of sensor readings and the second plurality of sensor readings are captured.

19. The storage device of claim 15, wherein the first predefined time period lasts for a given window of time during a given operational phase of a vehicle in which the shut-off valve is included and the second predefined time period lasts for the given window of time during the given operational phase of the vehicle.

20. The storage device of claim 15, the operation further comprising:

identifying from the plurality of MMSGs a second threshold value indicating abnormal operations of the shut-off valve;

capturing, during the first predefined time period after the shut-off valve is opened, a third plurality of sensor readings related to the shut-off valve;

capturing, during the second predefined time period after the shut-off valve is closed, a fourth plurality of sensor readings related to the shut-off valve;

wherein the first plurality of sensor readings and the second plurality of sensor readings relate to a first parameter of the shut-off valve and the third plurality of sensor readings and the fourth plurality of sensor readings relate to a second parameter of the shut-off valve different from the first parameter, wherein the first parameter and the second parameter are selected as different members from the group consisting of:

temperature;

pressure;

altitude;

airspeed; and

humidity;

identifying a third maximum value from the third plurality of sensor readings and a fourth maximum value from the fourth plurality of sensor readings; and

in response to determining that a second difference between the third maximum value and the fourth maximum value satisfies the second threshold value, generating the alert indicating that the shut-off valve is operating abnormally.