The economic aspects of internet of things for a public transport system

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Abstract

This paper study the economic aspects of the application of Internet of things (IoT) for vehicle used to support operations in the public transportation system. A vehicle will experience deterioration (decreased reliability) with the rate of use and age. To maintain high availability and improve vehicle reliability, condition-based maintenance is used to reduce the occurrence of damage and downtime. The degradation process is considered to be influenced by age, usage and operating condition. The use of the IoT has been proved to be economically feasible in reducing the cost of maintenance.

Keywords: Automation; iot technology; condition-based maintenance

INTRODUCTION

The Internet of Things (IoT) has been increasingly used in almost every aspect of life. Nowadays even the IoT is regarded a must to be implemented in many industries due to the impact of Industry 4.0 [1]. Authors such as [2] argue that the use of IoT in replacing the conventional maintenance mode guarantees the safe and efficient operation for industrial equipment. Looking at the close connention between the two – the IoT and the Industry 4.0 - some authors pointed out that it is the time to do a radical change of industrial process by Integration of AI with recent merging technologies which coined as the IIoT [3], and Transportation is no more an exception.

The IoT in transportaion industriy becomes a one stop solution to many problems [4]. There are at least five cases in which IoT is used in transportation, i.e. fleet management, public transit manaagement, smart inventory management, optimal asset utilization, geo-fencing [5]. There is a review on the use of IoT in public tranportation such as those written in [6] to see how important is the IoT and artificial intelegence in public transport system. Some authors also see that the appearence of the Intelligent Transport Systems (ITS) is becoming apparent in which public institutions, private operators and citizens are deeply connected since means of transport are virtualized in mobility resources and provided to users through the Internet [7].

In this paper we present the use of the IoT in managing equipment maintenance of bus public transport. As an example we look at the maintenance of bus air condition (AC) problem by installing a sensor to the equipment so that monitoring can be done in realtime. This may result in an accurate data of the equipment so that appropriate maintenance action can be done. Theoretically this make a more effective and efficient maintenance decision for the maintenence manager. Predictive maintenance can be done in more robust manner. Among other thing is the preventive maintenance, which is generally cheaper than corrective maintennace, can be implemented effectively. In the long-run this will reduce the total cost of maintenance. This is among the economic benefits of the implementation of the IoT in public tranport system.

In general, there are two different methods of maintenance strategy, i.e. time based and predictive based methods. In this paper we use the predictive based method which implemented. We will explain how predictive maintenance based on IoT helps to optimize the availability of vehicle in public transportation system. Maximum availability is critical to provide public support.This paper is organized as follows. Section 2 provides the description of model description and assumptions. Second 3 describes case study in CBM . Finally, we gives conclusions and future research in Section 4.

METHOD

In this section, we introduce two approaches:(1) Mathematical Model and (2) Neural network for CBM of vehicle in public transportation system.

Mathematical model

We propose a condition based maintenance (CBM) policy with periodic inspections, in order to control the level of degradation. Degradation process is considered to be influenced by age, usage and operating condition of the vehicle. The operating condition is represented by a number of condition variables (wear, lubricant quality, contamination, vibration, etc.) and influenced by age and usage. Let Z_t denote the degradation level at time t. In this model, the vehicle is inspected regularly at time $k\tau, k = 1, 2, ..., m$, where $L = m\tau$. The maintenance decision at $k\tau$ is defined as follows:

If the degradation level at $\tau_k (= k\tau)$, exceeds a predetermined threshold L_f (i.e. $Z_{\tau_k} \geq L_f$), then the vehicle fails. Note that the vehicle is still functioning even if $Z_{\tau_j} \geq L_f$ (in the failed state defected at time τ_k), and this reduces the availability of the vehicle. As soon as the failed state is defected, then CM action is done. After CM the state is restored to $Z_0 = 0$ (or the state at time τ_0).

If $L_p \leq Z_{\tau_k} < L_f$, the vehicle is preventively maintained. After PM the degradation level is brought back to $Z_0 = 0$ If $0 < L_p \leq Z_{\tau_k}$, then do nothing.

Adaptive resonance theory-2 neural network

Idea of using an Adaptive Resonance Theory-2 Neural Network (ART-2 NN) for CBM in this research is that in real time there will be a pair of condition where doesn't match with the condition-maintenance action matrix, but it is used reference to take action-1, action-2, action-3 or action-4. ART-2 NN is one of neural network method in artificial intelligence, which can classify a nonlinear relationship with specific training [8].

In case of electricity transmission system – two inputs are clamp temperature and conductor temperature and 1(one) output which is the condition of the clamp connector either good or not. Table 1 shows the condition-maintenance action matrix.

Table.1. Initial condition and maintenance action

<table>
<tr><td rowspan="3" colspan="3"></td><td colspan="6">CONDUCTOR CONDITION (9-6-1)</td></tr>
<tr><td rowspan="2" colspan="2">Below Limit-1</td><td colspan="4">Above Limit-1</td></tr>
<tr><td colspan="2">Between Limit 1-6</td><td colspan="2">Above Limit-6</td></tr>
<tr><td rowspan="6">CLAMP CONDITION (1-6-9)</td><td rowspan="4">Above Limit-6</td><td rowspan="2">Above Limit-1</td><td>Emer-gency</td><td></td><td>Emergency</td><td></td><td>Emer-gency</td><td></td></tr>
<tr><td></td><td>Need to be check right away</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Between Limit 1-6</td><td></td><td></td><td rowspan="2" colspan="2">Checked within 30 days</td><td rowspan="2" colspan="2">Good Condition</td></tr>
<tr><td></td><td>Need to be check right away</td></tr>
<tr><td rowspan="2" colspan="2">Below limit-6</td><td></td><td></td><td rowspan="2" colspan="2">Good Condition</td><td rowspan="2" colspan="2">Excellent Condi-tion</td></tr>
<tr><td></td><td>Need to be check right away</td></tr>
</table>

RESULT AND DISCUSSION

Apublic bus AC maintenance system is considered as case study in this research. Temperature and humidity conditions of the engine room and cabin space on the bus are continously monitored. One can use ANN with temperature and humidity as an inputs, and hence we can define actions 1-4 as in Table 1. The system display real information from each bus that is monitored and stored in a database on a mini server. The system can inform the spare parts that are close to the usage threshold, either based on a predetermined time or based on mileage (km) from time of last replacement. Data and informationcan be displayed and printed in reports, such as daily, weekly and monthly reports and transfer report files into Excel format.

Figure 1 shows slave block diagram which starts from the DHT22 type temperature and humidity sensor data input, and the door sensor uses an inductive proximity switch with control using an ATMega 2560 microcontroller unit (MCU). Output of the microcontroller is processed on a mini PC using USB. On a Mini PC, information is displayed on a 7 inch touchscreen LCD screen and the data are sent via the Wi-Fi module to the server and sent to the cloud server. LEDs and buzzers are used for alarm indicators in case of unwanted conditions, such as high engine room temperatures.

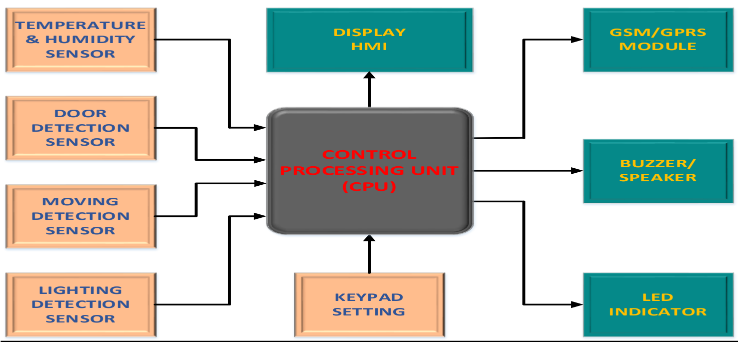

Figure 1. Slave block diagram

DHT11 and DHT22

Temperature and humidity are the two measurement objects included in the data acquisition system. This research applied DHT11 and DHT22 sensors from Aosong Electronics.These sensors can measure temperature and humidity simultaneously with digital output. Information about accuracy is found in both data sheets. Nevertheless this information does not describe the actual conditions when is operated on a particular location or platform. We compare the accuracy of DHT11 and DHT22 in temperature and humidity measurements when are operated indoors and outdoors. Based on testing that has been done, DHT22 has higher accuracy than DHT11 with a relative error measuring 4% temperature and 18% humidity. DHT11, on the other hand, has a wider error range of 1-7% and 11-35%.

AT Mega 2560 MCU

AT Mega 2560 MCU is a microcontroller device that has 54 digital inputs or outputs. In this research, 14 pins are used for PWM output and 16 pins are used as analog input, 4 pins for UART, 16 MHz crystal oscillator, USB connection, ICSP header power jack, and reset button. This module needs power to program a microcontroller such as a USB cable and power supply via an adapter or a battery.

Arduino

DHT22 and AT Mega 2560 MCU are given to support the use of Arduino microcontrollers, which are connected to a computer with a USB cable or electricity with an adapter from AC to DC or batteries to start usage.

CONCLUSIONS

We have studied CBM policy with periodic inspections and an Adaptive Resonance Theory-2 Neural Network (ART-2 NN) for CBM to reduce failures and unnecessary maintenance actions. Hence it will improve the availability and decreases the total cost. This is among the economic benefits of the implementation of the IoT in equipment maintenance management.

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