A Simple Sensor Fault Detection Algorithm

Wongeun Oh

Abstract**—**This paper propose a simple algorithm for sensor fault diagnosis and data processing using multiple sensors. The proposed sensor systems composed of multiple sensors for measuring the same quantity. If a sensor output is different than other sensors, the sensor will be marked as 'fault' and the output of the whole sensor system will be the average of the remaining normal sensors.

This algorithm can improve the reliability of the sensor systems but has shortcomings such as increased node manufacturing costs and power consumption. Therefore, it should be suitable for the applications where high reliability is essential.

Keywords**—**Sensors, sensor fault, sensor diagnosis, multi-sensors

I. Introduction

RECENTLY, the sensor systems(e.g. wireless sensor networks or IoT) have been widely used for various areas such as environmental monitoring, facility monitoring, fire watching, security, and military purposes[1]. In these applications, the reliability of the measured data is critical. However, the sensors can be damaged by various reasons. The possible causes of the sensor malfunctions are as follows.

- Sensor failure or aging
- Node damage due to impacts
- Node battery exhaustion
- Other errors on the board

Therefore, to secure the reliability of the entire sensor systems, an algorithm that can detect the inaccurate sensor data and sense abnormalities are needed.

Most of the previous studies for detecting sensor errors used complicated techniques such as neural networks, fuzzy, and Kalman filters to enhance the accuracy of the detections[2]-[6]. However, these techniques are not suitable for use in the sensor systems equipped with low performance microprocessors.

In the present paper, we develop a simple sensor fault diagnosis algorithm that uses multiple sensors. The proposed method use multiple sensors to measure the same physical quantities and compare the sensor outputs with each other to detect the fault sensors.

The main advantage of the method is the low complexity compared to previous algorithms while the number of sensors increase. Therefore, the algorithm can be useful in applications where the reliability is important.

The structure and operation algorithm of the proposed sensor systems are explained in chapter 2, the results of the experiments are presented in chapter 3, and conclusions are drawn in chapter 4.

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II. Structure And Algorithm

A. Structure of the sensor node

The structure of the proposed sensor system is shown in Fig. 1. The sensor part is composed of multiple sensors in measuring the physical quantity instead of one sensor. With this structure, reliable data can be generated even when one sensor becomes abnormal, using the results of other normal sensors.

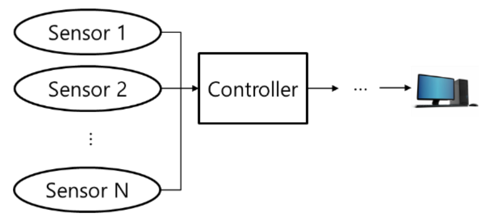

Fig. 1 The structure of the multi-sensor systems

B. Sensor diagnosis and processing algorithm

In the multi-sensor scheme, the sensor normality is determined by comparing the values of individual sensor outputs. For example, if an output value of certain sensor is much different from the values of other sensors then the sensor data are not reliable. That is, if differences in the measured values from individual sensors are within the predefined error range, the data from the whole sensor system are reliable. And the average of the each sensor's measured values is transmitted to the next stage, e.g. computers.

However if the difference exceeds the error limit, the sensor is designated as a fault sensor and the average of the remaining normal sensors is transmitted to the next stage with the information of error sensor. The detailed fault diagnosis and processing algorithm is as follows.

① Calculate the weighted sum $p_i(\cdot)$ of the i th sensor output $s_i(\cdot)$.

$$p_i(k) = \sum_{n=0}^{N_h-1} w(n)s_i(k-n) \quad \text{for all i} \qquad (1)$$

Where $w(n)$ is the weighting coefficient, and N_h is the number of the past values of the sensor.

② Calculate the difference measure. If the output value of the i th sensor satisfies (2) below, then the sensor s_i will be judged as a fault sensor.

$$\text{abs}\left(p_i(k) - p_j(k)\right) > Th, \quad \text{for all j, i} \neq \text{j} \qquad (2)$$

Where *Th* is a threshold value to be set by the user.

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③ If (2) is satisfied in multiple sensors, the sensor node itself should be classified to a damaged node and a fault signal will be transmitted to the computer to discard the whole sensor system.

III. Experimental Study

A. configuration

To verify the validity of the proposed method, experiments using 4 temperature sensors were conducted. The sensors are HT-01DVs that can measure temperatures in a range of −40℃ to 120℃ with an accuracy 0.5℃[7]. The experimental setup is configured so that four temperature sensors are arranged in a line, and the outputs of individual sensors are converted by the National Instrument's NI-6008 DAQ. Figure 3 shows the photos of the sensors used in the experiment.

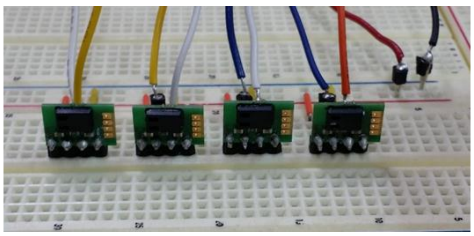

Fig. 2 The temperature sensors for the experiment

A computer program to monitor the sensors outputs and to test the proposed fault diagnosis algorithm was made using the Labview. This program is comprised of a graphs display of the four sensors' output, a function to display abnormal sensors, and a function to calculate and display the current temperature.

B. Experiment results

Fig. 3 shows the program's screenshot when there is no sensor abnormality. The outputs of sensor 1(S1) ~ sensor 4(S4) are 21.7℃, 21.3℃, 21.4℃, and 21.6℃. Although the values show slight differences, the differences in outputs from the sensors are below the threshold. Then the sensors are judged as operating normally, and the final output value is 21.4℃ that is the average of each sensor output. Moreover, it can be seen that even if there is no severe sensor error, the errors of individual sensors can be mitigated.

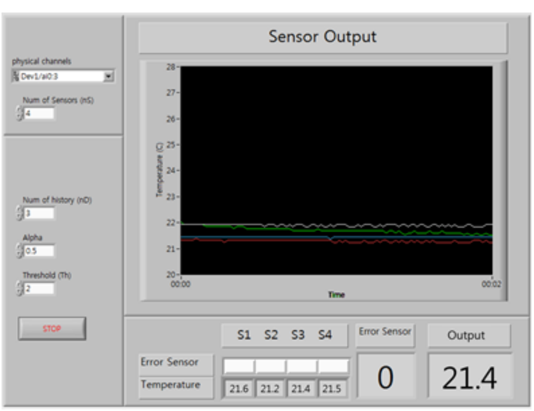

Fig. 3 Normal operation without any error sensor

Fig. 4 shows a case where the sensor 3(S3) malfunctions. The outputs of sensor 1(S1) ~ sensor 4(S4) are 22.5℃, 21.5℃, 24.4℃, and 21.5℃. The temperature measured by S3 is higher than the other sensors and the difference measure (2) is satisfied when the threshold(*Th*) is 2. In this case, the value of the S3 is discarded and the fault alarm is indicated on the screen as a red LED. The final output value of the sensor system is 21.8℃ which is the mean of the remaining sensors excluding the fault sensor S3.

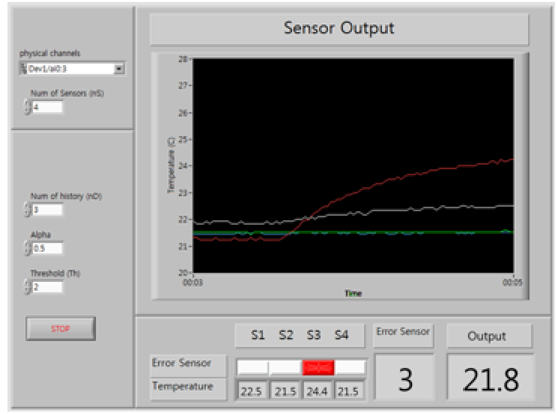

Fig. 4 Fault operation of S3 sensor

As can be seen here, if only one malfunctioning sensor such as S3 had been used in the sensor system, data with errors might have been transmitted to the server, causing problems. However, in the proposed method, even when there is an error sensor, accurate values can be transmitted using the information from the remaining normal sensors.

Fig. 5 shows a case where two or more sensors have errors. In this case, the temperatures cannot be measured accurately because the normal sensor cannot be distinguished. In this cases the sensor system itself is regarded to have been seriously damaged and sensor system fault signals are transmitted to the server together with the average temperature of all the sensors.

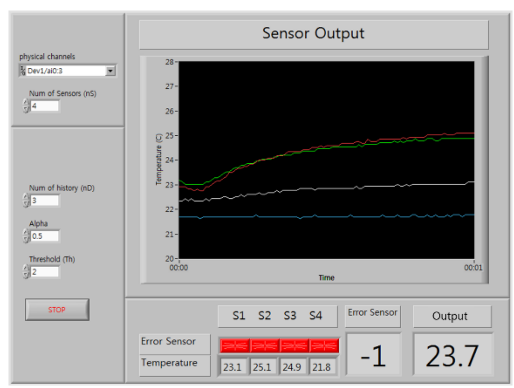

Fig. 5 Fault operation of multiple sensors

V. Conclusion

In this paper the multiple sensors structure for increasing reliability and the fault diagnosis algorithm have been proposed. The sensor system has multiple sensors for measuring and transmit the average value of the multiple sensor outputs if the differences between measured values from individual sensors are within the threshold. If the differences between measured values exceed the threshold, the average value of the remaining sensors excluding the fault sensor is transmitted.

To verify the proposed algorithm, the experiments using 4 temperature sensors has been conducted and showed promising results. The proposed algorithm has an advantage that reliability can be improved compared to the single sensor system but has shortcomings such as increased node manufacturing costs and more power consumption. Therefore, it should be suitable for the applications where high reliability is essential.

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