Develop a Power Detection and Faulty Isolation Module for Mobile Robot

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Abstract: Based on the sensor based detection method; this paper presents a power detection and faulty isolation system for a mobile robot. We measure current and voltage value of the power system, and use four current sensors to measure the current variance of the power system, and use multilevel multisensor fusion method to detect and diagnosis current sensor status, and isolate faulty current sensor to improve the power status to be exact using the redundant management method and prediction algorithm. We design the power detection and faulty isolation module using HOLTEK microchip according to the redundant management method. If the method is faulty, the module can transmit measured value and decision output to main controller using series interface (RS232). The main controller can decide an exact output to control power in the mobile robot using statistical signal detection method. We design a general user interface (GUI) for the power status of the mobile robot. It can display four current and four voltage measured values, maximum and minimum measured range, and power variance status for the mobile robot. Finally, we implement the proposed method on the experiment scenario of power detection procedure for the mobile robot.

Keywords: Autonomous mobile robot, redundant management method, statistical signal detection method.

I. INTRODUCTION

With the robotic technologies changing with each passing year, mobile robots have been widely applied in many fields such as factory automation dangerous environment detection, office automation, hospital, entertainment, space exploration, farm automation, military and security system and so on. Recently more and more researchers take interests in the intelligent service robot. In our lab, we have been designed a mobile robot (ISLR-I) to fight fire source. The power of the mobile robot is lack, and it can not be controlled by the command, and some dangerous event may be happened. We must detect power variance of the mobile robot all the time.

We have designed a power detection module applying in Chung Cheng I security robot using microprocessor (MCS51), and the experimental results are very successful [1]. The power detection module (measure current and voltage) can only measure current values using four current sensors. We design the power detection module applying in the mobile robot using HOLTEK microchip. The goal of the module is to enhance the accuracy, and extend the interface function to transmit the data to IPC using series interface, and extend the function of the power detection modular. The user can select detection range of current and voltage.

In the past literature, many researches have been proposed current detection methods. A. J. Melia and G.F. Nelson postulate that monitoring of the power supply current could aid in the testing of digital integrated circuits [2,3]. Malaiy and Su use I_{DD} testing and estimating the effects of increased integration on measurement resolution [4,5]. Frenzel proposed the likelihood ration test method applying on power-supply current diagnosis of VLSI circuits [6]. Hawkins et al reported on numerous experiments where current measurements have forecast reliability problems in devices which had previously passed conventional test procedures [7,8].Then, researches dedicated to improving the accuracy of measuring current [9,10]. Maly et al proposed a build-in current sensor which provides a pass/fail signal when the current exceeds a set threshold [11].

The paper is organized as follows: Section II describes the system structure of the power detection and faulty isolation system for the mobile robot, and presents the hardware structure of power detection module for the power system of the mobile robot. The two level detection and diagnosis algorithm is explained in the section III. Section IV presents the four experimental results for power detection and isolation scenario of mobile robot. Section V presents brief concluding remarks.

II. SYSTEM ARCHITECTURE

The mobile robot has the shape of cylinder and its diameter, height, and weight are 50 cm, 130 cm, and 100 kg, respectively. The robot is equipped with an IPC (Industry Personal Computer) as the main controller, some microprocessors, a touch screen, several sensor circuits, GSM modern, batteries, NI motion control card, wireless LAN, fire fighting device and sensory circuits, touch screen, distributed control module, power detection and diagnosis module, driver system and some hardware devices, two DC servomotors and a color CCD. Meanwhile, it has four wheels to provide the capability of autonomous mobility. We embed the module on the top of the mobile robot. Fig. 1 shows the hardware configuration of the mobile robot [12].

We proposed a power detection and diagnosis system using four current sensors for the mobile robot, and use multilevel multisensor fusion method to decision the exact residual current of mobile robot. The detection system contains five parts (see Fig. 2). They are main computer, auto-switch, A/D and I/O card, power detection and diagnosis module, and batteries. The current detection sensor is LEM55-P. The sensor is current sensor transducer for electronic measurement of currents, and contains galvanic relation between the primary (high power) and secondary (electronic circuits). The module can transmit measured value and decision output to main controller (PC) using series interface (RS232).

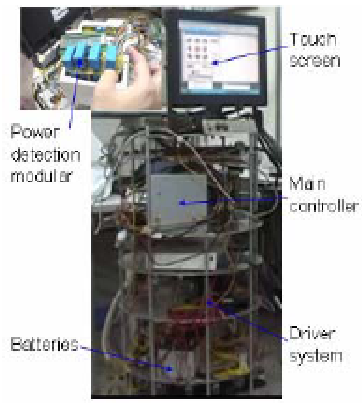

Fig.1. The contour and structure of the mobile robot

The power detection system of mobile robot contains four DC type current sensors and series interface. The hardware block diagram of the power detection and diagnosis module is shown in Fig. 3. The controller is HOLTEK microchip, and detects the current variety using four DC type current sensors. And the input signal has scale selection switch and mode selection switch, too. The output signal contains safety switch, series interface, I2C interface, display and alarm. The safety switch may be to cut off or turn on the power of the mobile robot according to the real status of mobile robot. The power detection module can measure maximum current to be about 50A.

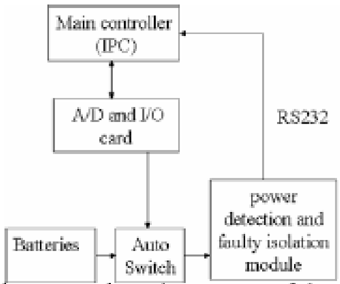

Fig.2. The power detection system of the mobile robot

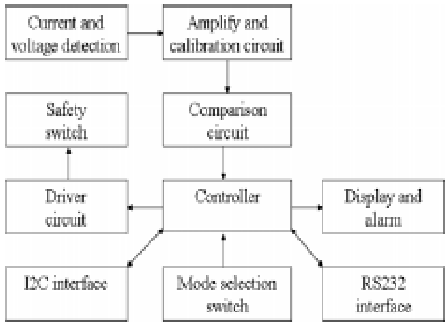

Fig.3. The hardware block diagram of the power module

The main controller of the mobile robot is industry personal computer (IPC). The IPC must receive power status of the mobile robot. Then the power detection and diagnosis module can transmits four current measured values, maximum current value, minimum current value, detection status, average value and estimate value to the IPC through series interface (RS232). The display status of the mobile robot is shown in Fig. 4.

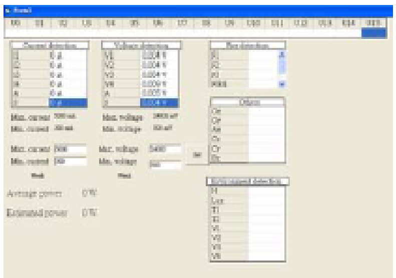

Fig.4. The display status of the mobile robot

III. DETECTION ALGORITHM

In the intelligent power detection module, we use redundant sensor management method to detect and diagnose sensory status. The redundant measurements of a process variable are defined as [13].

$$M = HX + E \tag{1}$$

$$|e_i| \le b_i \tag{2}$$

Where: M = the measure vector (l x 1) is generated from sensors. The ith measurement value is m_i . H = the measurement matrix (l x n). X = the n-dimensional measured true values. E = the measurement error. The ith measurement error is e_i . b_i = The specified error bound of the measurement m_i

The element ei of the vector must be $|ei| \le bi$, and we select the $b_i = 0.05m_i$. The magnitude of (m_i-m_j) is compared with the sum ($b_i + b_j$) of the respective error bounds for a consistency check. Any two scalar measurements m_i and m_j at the sample time k are defined to be consisted if

$$|m_i(k) - m_j(k)| \le (b_i(k) + b_j(k)) \quad (3)$$

In this condition, the inconsistency index of a measurement m_i is defined at a given sample time as

$$|m_i(k) - m_j(k)| > (b_i(k) + b_j(k)) \quad (4)$$

So we can define Ii and indicator function is

$$Ii = \sum_{j=1}^{l} f\left[\left|m_i - m_j\right| \le \left(b_i + b_j\right)\right] \quad i = 1,2,\cdots l \quad (5)$$

$$f[*] = \begin{cases} 0, & if \quad * \quad is \quad true \\ 1, & if \quad * \quad is \quad false \end{cases} \quad (6)$$

We can find $\hat{x}$ inconsistent at a given sample time, then the estimate of the measured parameter is obtained by the following equation at that sample time

$$\hat{x} = \frac{\sum_{i=1}^{l-j} m_i w_i (l - j - 1 - I_i)}{\sum_{i=1}^{l-j} w_i (l - j - 1 - I_i)} \quad (7)$$

In the intelligent power detection module, we use redundant sensor management method to detect and diagnose sensory status. When the method is faulty on the $N+1$ measurement value for the module, we can predict the measurement value using N estimation value as before.

In the level 2, the fusion method is statistical signal detection method. The fusion decision output of level 1 transmits to main controller (personal computer) using series interface (RS232). We modeled the observed system as the sum of three signal components, to be shown in equation (11).

$$M = X + E \quad (8)$$

If the signal is deterministic and the noise E is Gaussian with zero mean, then we can calculate the mean value from P estimated values. The mean value $\overline{x}$ and standard deviation S_i is:

$$\overline{x} = \frac{\sum_{k=N-P}^{N} \hat{x}_i(k)}{P} \quad (9)$$

$$S_i = \sqrt{\frac{1}{P-1} \sum_{k=1}^{P} \left(m_i(k) - \hat{x}(k)\right)^2} \quad i = 1,\ldots l \quad (10)$$

Then we use the same b_i as threshold value, and compute the error between the sensors measured value $m_i(N+1)$ and mean value $\overline{x}$. The error is over the threshold, and we can say the sensor measured value $m_i(N+1)$ to be faulty. Otherwise, we can say the sensor measured value is exact. That is

$$w_i(N+1) = \begin{cases} 0 \quad , & \left|\dfrac{m_i(N+1) - \overline{x}}{\overline{x}}\right| \ge 0.05 \\ 1 \quad , & \left|\dfrac{m_i(N+1) - \overline{x}}{\overline{x}}\right| < 0.05 \end{cases} \quad i = 1,2,\ldots l$$

(11)

$$\hat{x} = \frac{\sum_{i=1}^{l} w_i(N+1) m_i(N+1)}{\sum_{i=1}^{l} w_i(N+1)} \quad (12)$$

IV. EXPERIMENTAL RESULTS

In the power detection and faulty isolation module of the mobile robot, we use four DC type current sensors to detect the current variety of the recharging for the mobile robot. In this paper, we assume that a priori of all sensors are the same, and we use the proposed method to implement for four cases. Case I is all measurements are consistent, Case II is one current measurement faulty. Case III is one voltage measurement faulty. Case IV is two current measurements are faulty.

CASE I： If all measurements are consistent, i. e., the estimated value is the same as average value, and the current estimation value is 0.326A, and the voltage estimation value is 12.221V. The experimental results are shown in Fig 5.

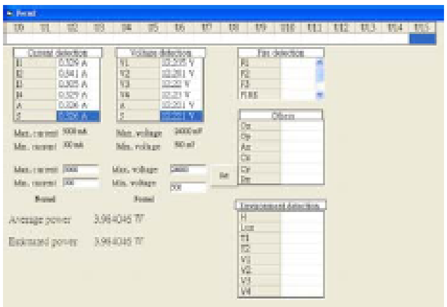

Fig.5. The display status for case I

CASE II: The module has one current sensor to be faulty. The current average value is (0.61A+0.329A+ 0.305A+0.317A)/4= 0.39A. The current value is wrong. The exact (estimate) current is (0.329A+0.305A+ 0.317A)/3=0.317A. The detection value of current sensor #1 is wrong. We must isolate the detection value, and the differential value (0.61A-0.329A) is bigger than threshold. The experimental result is shown in Fig. 6.

Case III: if one voltage measurement faulty. The experimental result is shown in Fig 8. The voltage average value is (0.009V+12.182V+12.201V+12.206V)/4=9.149V. The voltage value is wrong. The exact (estimate) voltage is (12.182V+12.201V+12.206V)/3=12.221V. The detection value of voltage measurement #1 is wrong. We must isolate the detection value. The experimental result is shown in Fig. 7.

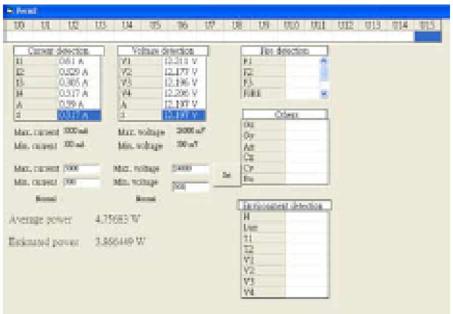

Fig.6. The display status for case II

Case IV: The module has two current sensor to be faulty. The current average value is (0A+0.439A+0.292A+0.292A)/4= 0.255A. The current value is wrong. The exact (estimate) current is (0.292A+0.292A)/2 =0.292A. The detection value of current sensor #1 is wrong. We must isolate the detection value. The experimental result is shown in Fig. 8.

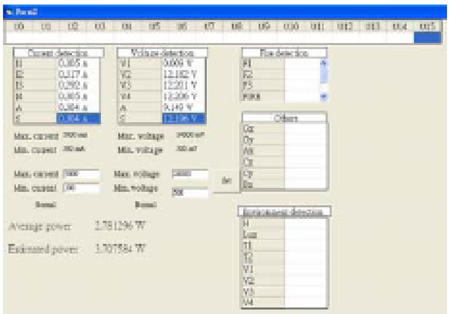

Fig.7. The display status for case III

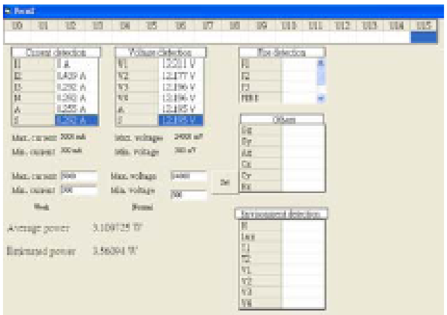

Fig.8. The display status for case IV

V. CONCLUSION

We successful designed a power detection and faulty isolation module that has been integrated in the ISLR-I mobile robot, and control the power status of the mobile robot. The controller of the power detection and diagnosis module is HOLTEK microchip. The detection, diagnosis and isolation algorithm use multilevel multisensor fusion method. There is redundant management method and statistical signal detection method. It can isolates faulty sensor, and estimates a exact power detection value for mobile robot. The module can measure maximum current is 50 A, and user can selects the current detection range and the detection mode. The maximum voltage detection value is 24V for the power system of the mobile robot. The module can transmits really current value and detection results to main controller (IPC) of the mobile robot using series interface (RS232). The module can control the current output using the safety switch (relay).

ACKNOWLEDGMENT

This work was supported by the project "The Development of Integrated Robotics System" under DOIT TDPA of Taiwan, R. O. C. 95-EC-17-A-04-SI-054.

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