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Development of the Residual Power Prediction System of Mobile Robots

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Abstract: The article presents a multiple residual power prediction system to be applied in mobile robots or automation fields. The system contains multiple power detection units to measure multiple on-line power values. Each power detection unit uses four current sensors to measure the current variety, and uses weighted average method and redundant management method to calculate the exact current value, and isolates faulty measurement values. We use the proposed algorithms to be applied in voltage detection of each power detection unit, too. Then we can calculate the real-time power values according to the current and voltage measurement values. The control core of the power detection unit is HOLTEK microchip, and communicates with the data integration unit via wire I2C interface. The power detection units transmit the measurement values of current and voltage to the controller of the system. The main controller of the power detection system is PC based system, and communicates with the data integration unit via wire RS232 interface. The main controller of the system can controls each power output ratio of the power sources, and predicts the power loading and the residual power for each power detection unit using auto-regression algorithm, and computes the residual time of mobile robots to work in the free-space, and arrange the residual power of the enough power source to the weakness power sources using sequential single-item auction algorithm. In experiment result, the residual power prediction system can adjusts the working time of the power sources to be the maximum value.

Keywords: multiple residual power prediction system, weighted average method, redundant management method, HOLTEK microchip, I2C interface, RS232 interface, auto-regression algorithm, sequential single-item auction algorithm.

I. INTRODUCTION

Intelligent power management system can provides convenience and high efficiency for human living in the 21st century, and allows effective management of power source with minimum life-time costs at the same time. In the recently, Intelligent system has been widely applied in many fields. The residual power of the intelligent system is under the critical power. The system can't work and shutdown. The power supply of the system must be stability. The power management system may knows the residual using time, and adjust the power output to improve the working time of the intelligent system to be maximum. We must detect power variety of the intelligent system all the time very carefully, and program each power output to supply all devices of the intelligent system in the limited total power condition.

We have been designed a power detection module applying in Chung Cheng I security robot using microprocessor (MCS51), and the on-line experimental results are very successful [1,2]. We are implemented the new power detection module applying in the fire fighting robot using HOLTEK microchip, too. The goals of the paper integrates many new power detection modules to extend the interface function, and transmits the measurement values to the controller of the intelligent power management system using series interface, and extends the function of the power detection module to isolate the faulty measurement values, and reduce detection error, and predict the residual time using multi-level multisensor fusion algorithms [3].

In the past literature, many researches have been proposed power detection and prediction algorithms. Levi was one of the first persons to comment upon the characteristics of CMOS technology which make it special amenable to I_{DD} Testing [4]. Malaiya and Su use I_{DD} testing to estimate the effects of increased integration on measurement resolution [5,6].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 [11,12].

II. SYSTEM ARCHITECTURE

We develop the residual prediction system in the paper, and measure the exact power values to isolate the error measurement values, and calculate the residual time under the critical values to adjust working time to be maximum value. The system architecture of the residual power prediction system is shown in Fig. 1. There are many power detection units, many power sources, one data integration unit and a controller. The system measures the variety power outputs of the power sources respectively. These power detection units can detects multiple DC power sources.

Each detection unit assigns identification (ID) code to be classified the data sequence.

The data integration unit connects with many power detection units via I2C interface, and deals with the received measurement values according to ID code of each power detection unit, and transmits the measurement values to the controller of the residual power prediction system via RS232 interface. The prototype of the power detection unit is shown in Fig. 2. The controller unit of the power detection unit is HOLTEK microchip, and monitors each power variances of the power sources. The controller of the residual power prediction system is PC-based structure, and adjusts each power output of the power sources via wire series interface.

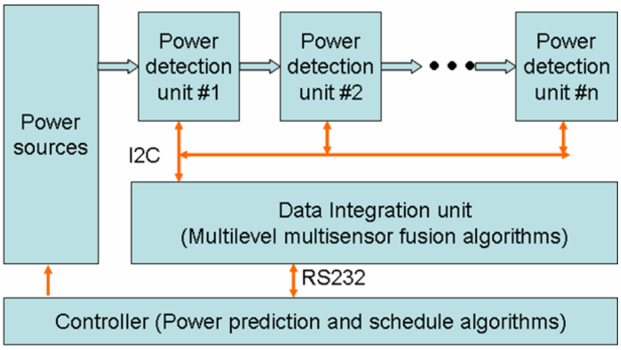

Fig. 1 The system architecture

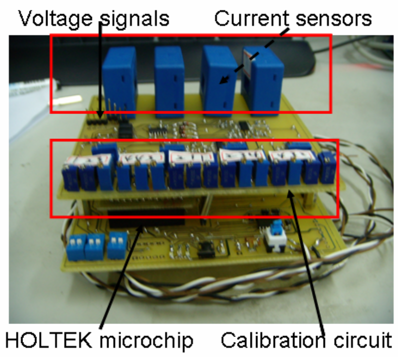

Fig. 2 The prototype of the power detection unit.

Each power detection unit contains four current sensors, a HOLTECK microchip, a calibration circuit and a series interface, and measures four current and four voltage signals. The control core is a HOLTEK microchip (HT46R25) to detect the power variance using four DC type current sensors, and measures four voltage values simultaneously. Users can adjust the sensitiveness of the measurement signal, and delete offset value, and select all measurement values are the same sensitiveness. The output signal contains safety switch, I2C interface, display and alarm. The safety switch may be used to turn on or off the supply power to the target devices. The current range tuning can be assigned the maximum measurement current up to about 50A.

The user interface of the residual power prediction system is shown in Fig. 3. Users can select any time point of these curves, and display these current and voltage measurement values on the upper side of the monitor to be shown in the part "1" and "2". Uses can select each power detection unit to display current measurement values and voltage measurement values, power estimated value, and plot the curves for these measurement values to be shown in the part "3". The part "4" of the user interface presents the color curve to display the variety detection power sources for each power detection unit. The part "5" can displays the real-time power, critical power, residual power, assigned power and residual time of each power detection unit. The part "6" displays the set residual time of the system to be 60 second, and calculates the power efficiency.

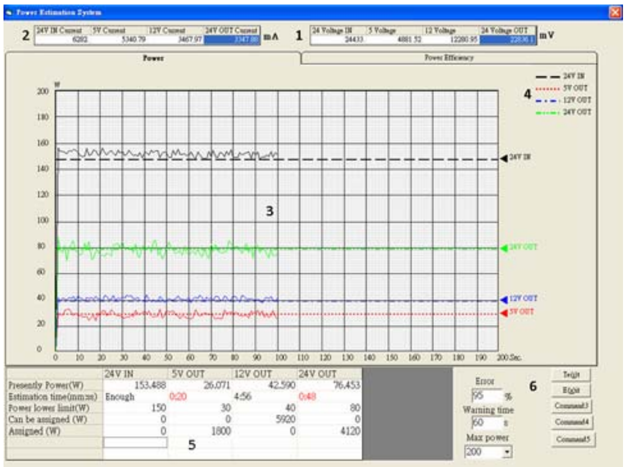

Fig. 3 The user interface

III. ALGORITHM ANALYSIS

In the power detection unit, we use weighted average method and redundant management method to compute power measurement values. The proposed methods are implemented in the HOLTEK microchip. The weighted value of the nth sensor measurements x_i is w_i with $0 \le w_i \le 1$. We can compute the weighted value according to the precious of the measurement value relation to the others; thus

$$I_i = \sum_{j=1}^{n} u_i, \quad i = 1,2,......,n \tag{1}$$

$$u_i = \begin{cases} 1, & \text{if } |m_i - m_j| \le b_i \\ 0, & \text{if } |m_i - m_j| > b_i \end{cases} \tag{2}$$

$$w_i = \frac{I_i}{\sum_{j=1}^{n} I_j}, \quad i = 1,2,......,n \tag{3}$$

The b_i is a threshold value for each measurement value m_i, and m_j is another measurement value. The maximum value of w_i is n, and the minimum value is zero. Then we can compute the estimated value $\overline{m}$ according to each weighted value to be

$$\overline{m} = \sum_{i=1}^{n} w_i m_i \tag{4}$$

Where $\sum_i w_i = 1$ and $w_i = 1$ if m_i is not within some specified thresholds. The weights can be used to account for the differences in accuracy between sensors, and a moving average can be used to fuse together a sequence of measurement values from a single sensor so that the more recent measurement values are given a greater weight.

Then we want to calculate the residual time under the critical power using power prediction algorithm for each power detection unit. The algorithm is based on ARIMA (p,d,0) model structure and least square method. It general form of model is as following.

$$\varphi(B)w(t) = a(t) \quad (5)$$

Where $a(t)$ is zero mean value white noise, B is backward operator, and

$$\varphi(B) = 1 - \varphi_1 B - \varphi_2 B^2 - \cdots - \varphi_p B^p \quad (7)$$

Then equation can be expressed in the vector form can be rewritten as

$$w(t) = u^T(t)\lambda + a(t) \quad (8)$$

$$\lambda = [\varphi_1, \varphi_2, \cdots, \varphi_p]^T \quad (9)$$

$$u^T(t) = [w(t-1), w(t-2), \cdots, w(t-p)] \quad (10)$$

Take the place of λ and u^T into recursive least square formula with forgetting factor. Given the original value, regressive parameters estimation can be found out on line.

Next we can compute each residual time of each power detection unit on the assigned critical power. If the power detection units measure the average powers of the n power sources to be $\overline{P_1}, \overline{P_2}, ..., \overline{P_n}$. We use sequential single-item auction algorithm in the paper. The weakness power source bides the enough power source. The goal of the proposed method wants to increase the working time in the fixed power condition. A formal definition of the auction algorithm is given a number of enough power sources $p_1, p_2, ..., p_m$, and a number of weakness power sources $s_1, s_2, ..., s_l$. The total power sources $n = m + l$, and subtasks are, $P = \{P_1, P_2, ..., P_n\}$. A subtask $P(s_i)$ is a set that contains some enough power sources that are bided by the weakness power sources s_i. A function $F(s_i, p_j)$ specifies the cost of using the enough power source p_j to provide to the weakness power sources s_i.

$F(s_i, P(s_i))$ specifies the cost of using power sources $P(s_i)$ by the weakness power source s_i. We have two performance function to compare the efficiently for the multiple target devices executing power sources' allocation. The residual time of the ith power detection unit is T_{pi} $i = 1,2,...m$, T_{si} $i = 1,2,...,l$. The kth power is under the critical power, and the residual time is smaller than the threshold time (60 second). The lth power source is enough to provide the lth target device. The part of the lth power source is assigned to provide the power to the ith target device using single-item auction algorithm. We define the maximum average working time to be T_M, and fine the balance relation s following:

$$\underset{T_M}{MAX}\left[\sum_{i=1}^{m} p_i(T_{pi} - T_M) = \sum_{j=1}^{l} s_j(T_M - T_{sj})\right] \quad (11)$$

IV. EXPERIMENTAL RESULTS

The residual power prediction system measures multiple power sources to display on the user interface. Users select the measurement range value of each power detection unit on the user interface to be shown in the upper side of Fig. 4. The user interface can plots four power curves and four prediction curves that are selected by users (5V, 12V 24V input and 24V output). The sample time is 1 second for the PC-based controller of the residual power prediction system.

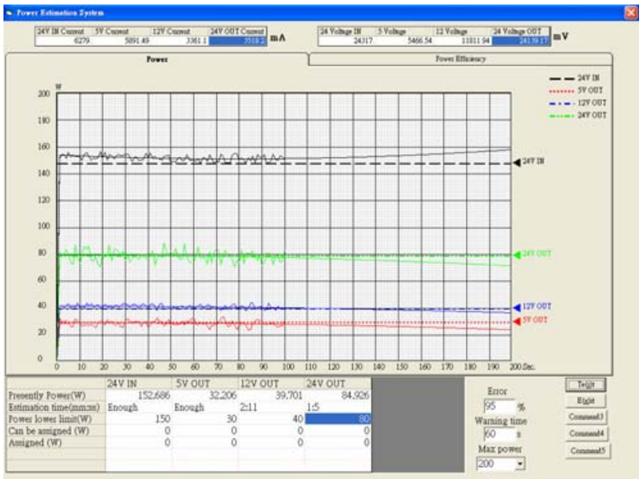

Fig. 4 The residual power prediction experimental result (I).

In the residual power prediction experiment, users can set the four critical powers and four residual times on the user interface of the system. We can select the critical power for 5V to be 30W, 24V (IN) to be 150W, 12V to be 40W and 24V (OUT) to be 80W, and the same critical time to be 60 second. The controller plots curve lines on the monitor of the interface according the real-time measurement value. First, the system can fits four second-order curves using polynomial regression algorithm for each assigned power sources. Then it computes the cross points of the critical power lines and the second-order curves. The cross points are the residual times (unit is second) for each detection power sources, Otherwise, the cross point is not exist, and the power source is enough. These cross point times displayed on the bottom of the interface. The user interface computes the residual times under the critical power to be 2 minute 11 second for 24V (output), and enough time for 12V and 24V (input) (no cross point). All residual times are bigger than the threshold time (60 seconds). The system can't execute the power assigned in the case.

In the other case, the residual power prediction system can knows the residual time to be 35 seconds. The 5V power source shutdowns on weakness power, and programs the enough power source 12V to provide the power to the weakness power source (5V) using single-item auction algorithm. Then we can compute the residual power until the critical power for each power source. The residual power output is about 2480W for 12V power source, and the residual time of 24V is about 1 minute 13 second. We can know the arrangement percent on each power source of the residual power prediction system, and program the 12V power source to provide 1000W to the 5V power source using the proposed algorithm. The experimental result is shown in Fig. 5.

The residual power prediction system can knows the residual time to be 49 seconds for the power source 24V (output), and the others are enough. The system programs the enough powers 5V and 12V to provide the power to the weakness power source (24V output) using single-item auction algorithm. Then we can compute the residual power until the critical power for each power source. The residual power output is about 1800W for 5V power source, and the residual power output is about 2400W for 12V. We can know the arrangement percent on each power source of the residual power prediction system, and program 5V and 12V power source to provide power to the 24V power source output using the proposed algorithm. The experimental result is shown in Fig. 6.

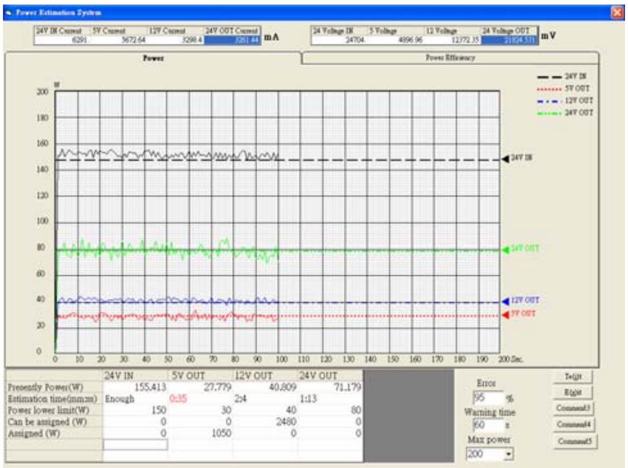

Fig. 5 The residual power prediction experimental result (II).

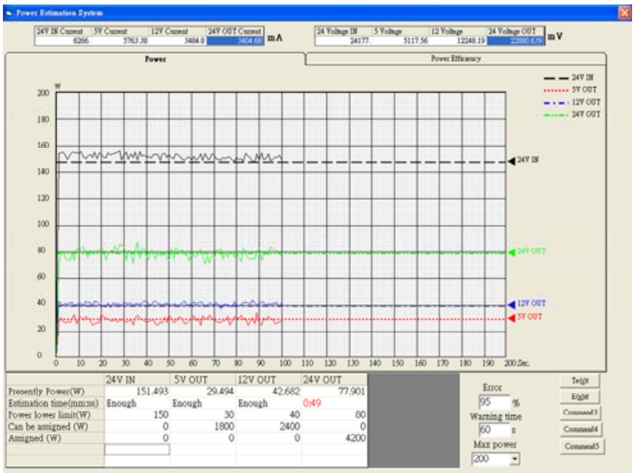

Fig. 6 The residual power prediction experimental result (III).

V. CONCLUSION

We have successful designed a residual power prediction system that has been applied in the multiple power source management. We developed the new power detection unit that used the HOLTEK microchip as controller to measure multiple power sources. The residual power prediction system used statistical signal detection algorithm and auto-regression algorithm to predict the residual times on the critical threshold power values for each power detection unit, and used single-item auction algorithm to adjust the power output ratio according the residual time. The system used the proposed algorithms to program the maximum working time of the target device before the weakness of the power source. We develop the user interface to integrate multiple power detection units to measure the power values. The power detection units can transmits the measurement values to the data integration unit via wire I2C interface. The PC based controller of the residual power prediction system communicates with the data integration unit via wire RS232 interface. In future, we want to adjust the more and more power sources of the system to increase the maximum working time of the target devices of the intelligent system, and implement the experimental results using the improved power detection unit.

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