A development of map building sensor system for mobile robot using low cost photo sensor

Woong-Keun Hyun, *Member, KIMICS*

Abstract— Mobile robot has various sensors for describing the external world. The ultrasonic sensor widely applied to the most mobile robot to detect the obstacle and environment owing to low cost, its easy to use. However, ultrasonic sensor has major problems: the uncertainty information of sensor, false readings caused by specular reflection, multi path effect, low angular resolution and sensitivity to changes in temperature and humidity. This paper describes a sensor system for map building of mobile robot. It was made of low cost PSD (Position Sensitive Detector) sensor array and high speed RISC MPU. PSD sensor is cost effective and light weighting but its output signal has many noises. We propose heuristic S/W filter to effectively remove these noises. The developed map building sensor system was equipped on a mobile robot and was compared with ultrasonic sensor through field test.

Index Terms— *Map building, mobile robot, PSD sensor.*

I. INTRODUCTION

Many different sensor technologies have been used to develop 2-D environmental models including ultrasonic, laser and infrared range-finders[1,2,3,5]. Ultrasonic sensors are popular due to their low cost, small size, low power consumption[3,5]. However, ultrasonic range finders have several drawbacks including low angular resolution, show data collection rate about the azimuth, specular reflection, sensitivity to changes in temperature and humidity, and relatively low accuracy in distance measurements compared to their laser counterparts. In addition, their annoying clicking sound when operation makes them less attractive for practical applications that involves a human user. In addition to the uncertainty in distance measurement, the ultrasonic transducer's wide beam angle results in greater uncertainty in the width of detected obstacle[4]. 2-D laser scanners, on the other hand, have been widely used and studied for applications including object following and obstacle avoidance feature extraction, map building, and self-localization. Laser range-finders provide more accurate range data over a longer detection range with higher angular resolution but are more expensive, bulkier, and heavier than ultrasonic[2]. There is a need for a cost-effective sensor that can be used in 2-D mapping for mobile robotics. In this paper, a range finder sensor module for indoor 2-D mapping has been developed by using low cost infra red sensors such as PSD (Position Sensitive Detector). The developed PSD sensor system transmits a narrow beam width (4mm) and makes no disturbance among sensors unlike ultra sonic sensors. More over the system requires smaller power than laser scanners. The rest of this paper is as the following. Chapter 2 presents the problem of ultrasonic sensors. Our development system will be presented in chapter 3. Chapter 4 illustrates the proposed noise reduction algorithm. Experimental verifications are presented in chapter 5 and concluding remarks are given in chapter 6.

II. THE PROBLEM OF MAP BUILDING BY PREVIOUS SENSORS

Many sensor measurements are uncertain, e.g. an ultrasonic sensor, which measures a distance, is uncertain about the angle from the sensor at which this distance is measured, as sketched in Fig.1. The sonar emits a sound-pulse, which is reflected by an obstacle somewhere within the cone. When the reflected pulse is received by the sonar, it can accurately estimate the distance to this object using the "time-of-flight" of the pulse. However, it cannot determine at what angle within the cone the pulse was reflected. Thus, there is uncertainty about the angle at which the obstacle was measured which is about as large as the opening angle of the sonar[4].

Ultrasonic sensors measure the range to the obstacle point that first reflects their signal. Because of the

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Woong keun Hyun, Dept. of Electrinics Engr., Honam University, Gwangju, 506-714, Korea (Tel: +82-62-940-5482, Fax:+82-62-940-5484, Email: wkhyun@honam.ac.kr)

large beam width of these sensors there is uncertainty about the real direction of the obstacle. Fig.1 shows an example of map built by 12 sonar sensors equipped in a mobile robot. Because of specular reflection and multi path effect the built map is shown to be very different to the real object.

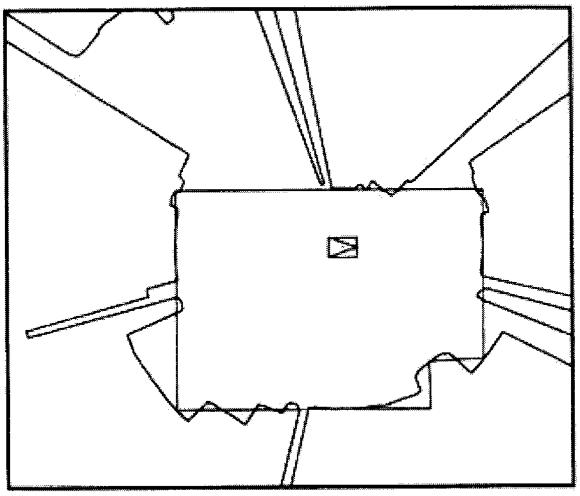


Fig.1. An example of scanned map by sonar sensors

III. THE DEVELOPED PHOTO-DISTANCE SENSOR MODULE FOR INDOOR MAP BUILDING

The developed system is shown in Fig.2. The PSD sensor module consists of 16 bit RISC MPU, 6 analog MUX for input of 24 PSD sensors.

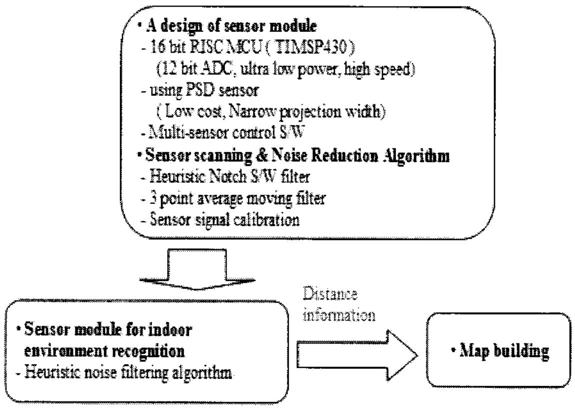


Fig.2. The block diagram of the developed system.

After 24 PSD sensors scans environments for map building, the measured data are filtered by our proposed heuristic notch filter. These filtered data will be used for removing the switching noise. MPU in sensor module has 8 A/D converter channel. To expand the A/D channel to 24. Analog multiplexer with 6 switched analog channels are used. For noise reduction, RC filter and average moving S/W filter and heuristic notch filter algorithm is proposed. The sensor controller transfers the filtered data to robot controller with RS-232 communication. The sensor controller has 2K byte ring buffer to avoid the data loss problem owing to transmission speed.

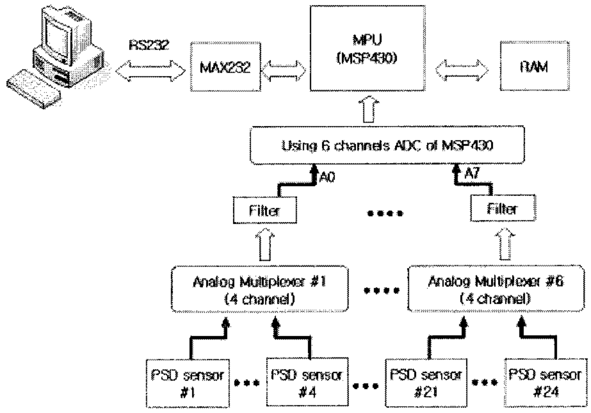


Fig.3. A structure of the sensor module

The moving velocity of robot for map building was be decided by 20cm/sec. Considering the power consuming control as shown in Fig.4, a cycle time of 24 sensors scanning is decided as 250 msec. Therefore, PSD sensor system can scan the environment at every 5cm moving.

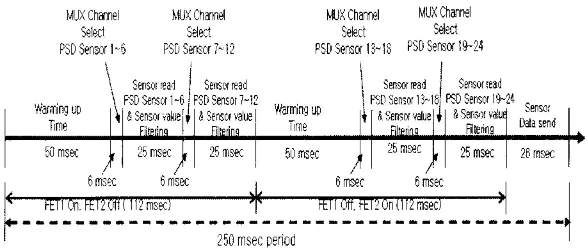


Fig.4. Timing chart of sensor system

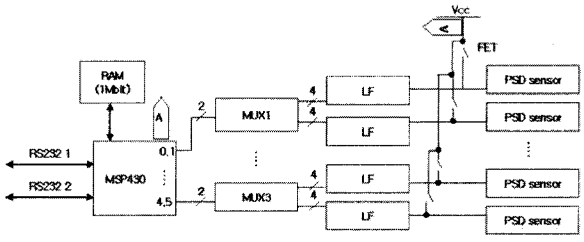
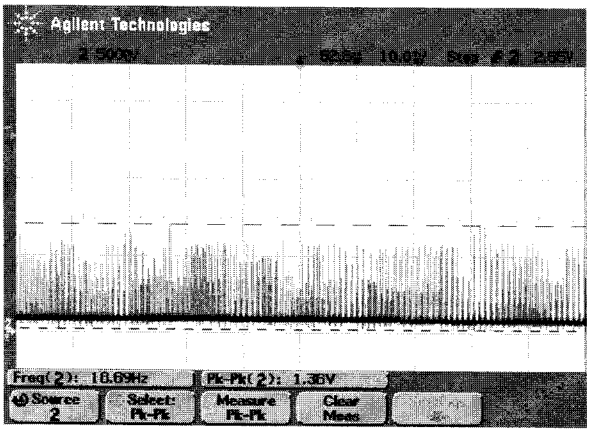


Fig.5. The sensor controller block diagram.

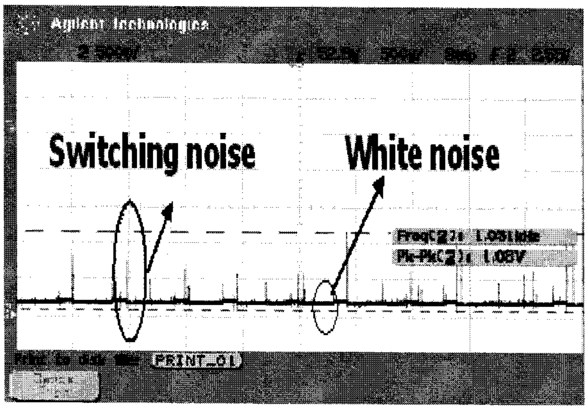
Fig.5 shows the block diagram of the developed sensor controller. A PSD sensor consumed a current about 50mA. Therefore the whole PSD sensor module consumed about 1.2A when all PSD sensors scan at the same time. To save the current consuming, we proposed power control method by switching the supply voltage to the PSD. The supply voltage switching control circuit with FET is shown in Fig.5, 24 PSD sensors are clustered as 4 groups by 4 analog multiplexers. MPU makes a switching motion by sequential on and off control of the FET. So, the one multiplexer will be activated at one time, which make 6 PSD sensors are read an many as 10 times at one scaning time.

IV. THE ALGORITHM FOR NOISE REMOVING

While PSD sensors are cost effective and easy to use, their signal output has many switching noise as shown in Fig.6(a) and (b).



(a)



(b)

Fig.6. Switching noise signal before filtering

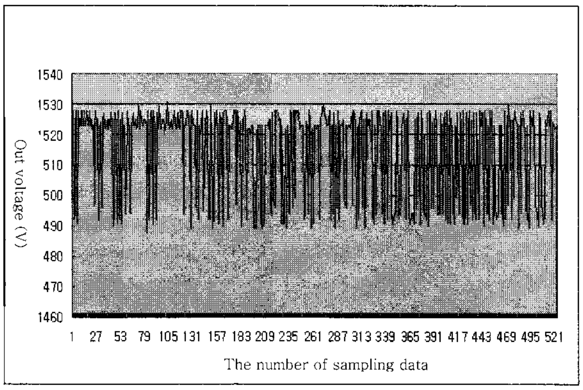


Fig.7. Raw data before filtering

The frequency of switching noise is about 1 kHz and its magnitude is as many as 20 times than white noise. From these observations, we can recover the switching noise by following heuristic filtering algorithm. Fig. 7 shows the raw digitized data form PSD sensor. For smoothing and noise canceling, we propose the notch filtering algorithm. The sensing time of 24 sensors are about 1 msec. So the difference of magnitude between the n-th data and (n-1)-th data is small. From this idea, we propose a noise reduction equation as Eq. (1) to prevent the abrupt change between sequentially sensed data.

$$
\begin{aligned}
& x^*[n]=\alpha(x[n]-x[n-1])+x[n-1] \\
& \quad if(|x[n]-x[n-1]|<\delta) \\
& \qquad x^*[n]=x[n]; \\
& \quad else \\
& \qquad x^*[n]=\alpha(x[n]-x[n-1])+x[n-1];
\end{aligned}
\tag{1}
$$

Where x[n] is a n-th sensed signal and α is multiplier constant, δ is tolerance for the |x[n]-x[n-1]|. α and δ were defined as 0.3 and 15 by trial and error method.

Additionally, for smoothing the signal, we applied 3-point moving average filter to the modified data.

V. THE EXPERIMENT RESULTS

Fig.8 shows the digitalized white noise signals converted with 8 bit binary resolution. For getting rid of this white noise, we adopted a 3-points moving average filtering algorithm to the averaged signals from heuristic filter. Fig.9 shows the resultant signal after the 3- points moving average filtering. As shown in Fig.8 and Fig.9, the magnitude of the noise reduced as many as 4 times.

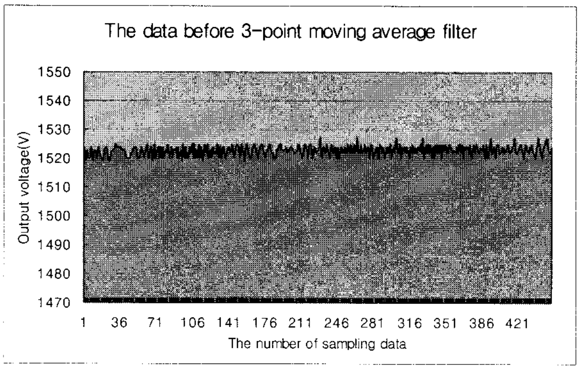


Fig.8. The data before 3-points moving average filter.

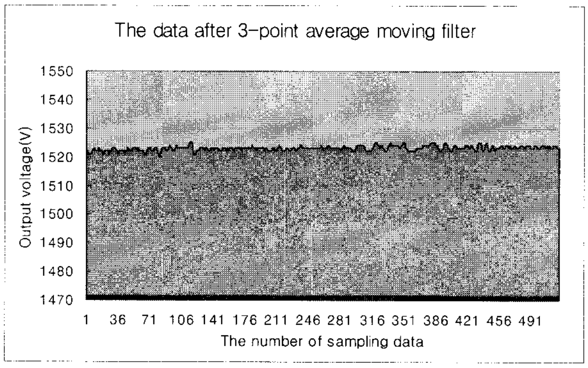


Fig.9. The data after 3- points moving average filter.

Fig.10 shows the developed ring type sensor controller for map building. The 24 PSD sensors are allocated on the ring plate at every 15 degree position.

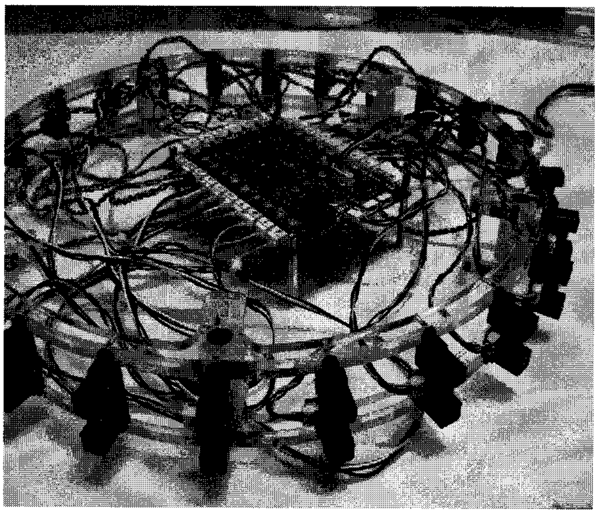
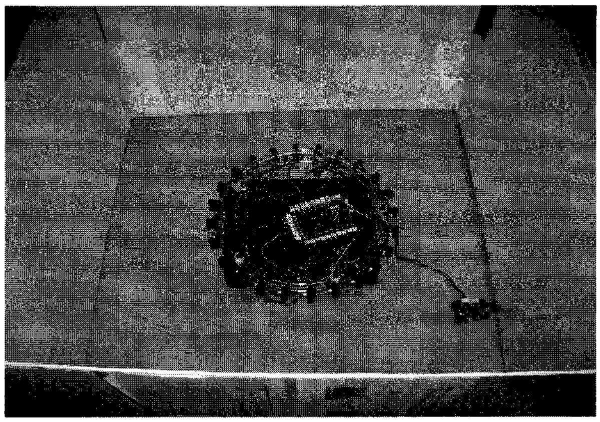
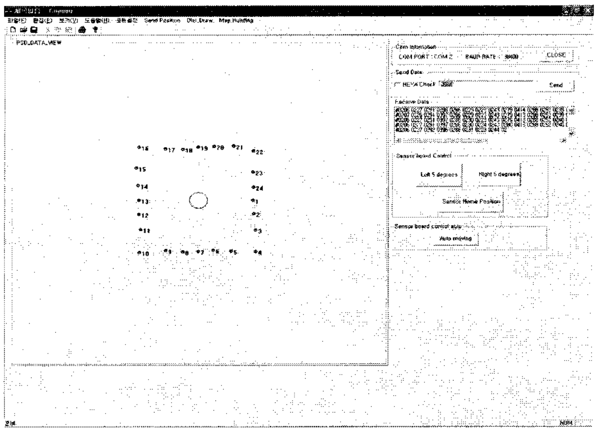


Fig.10. The PSD sensor controller system.

Fig.11-(a) shows that the scanned data for the rectangle room type objects.



(a) Test bed example



(b) The PSD Sensors Output

Fig.11 The test bed example for rectangle type room

Fig.12(a) and Fig.(b) show the maps sensed by PSD and sonar, respectively. Since the beam angle of the sonar sensor ± 15 degree, the maximum number with which each sonar sensor can work without disturbance of the side sonar sensor is 12. The experiment space in Fig.12 has concave and convex type walls. Fig.13-(a) and Fig.13-(b) show the detected result by our developed system and sonar sensor system, respectively. Because of specular reflection, the sonar sensor can not describe for the convex wall well as shown in Fig.13-(b). From the result shown in Fig.13-(a) and Fig. 13-(b), we can see that the sensing ability for map building of our developed system is better than that of sonar sensor system.

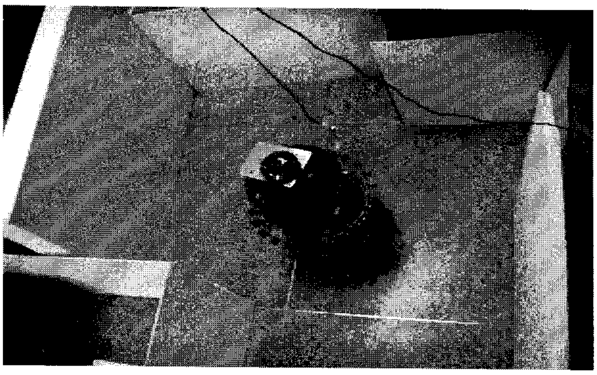
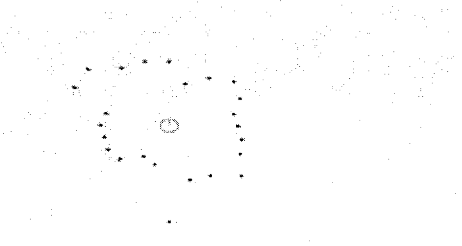
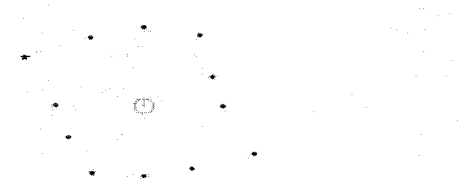


Fig. 12 The test bed example for more complex shape room



(a) The PSD Sensors Output



(b) The Sonar Sensors Output

Fig.13 Mapping result of concave and convex type walls.

VI. CONCLUSIONS

Owing to low cost and its easy to use, ultrasonic sensor widely applied to most mobile robot. However, because of the uncertainty information of sensor, false readings caused by specular reflection and wide beam width, it is not appropriate for map building sensor of mobile robot. We developed an effective and low cost sensor module for 2D map building using PSD sensor instead of ultrasonic sensors. The developed sensor system can describe unknown objects more accurately than commonly used sonar sensor. Though PSD sensor has a merit of low power consuming, it has shortcoming of noise problem. We proposed a heuristic filtering algorithm to remove the noise. To save the current consuming for operating 24 PSD sensors, we developed time varying power control switching circuit. Experimental results show that our developed system is useful in practical applications.

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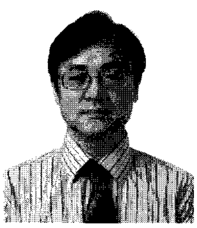

Woong keun Hyun

He received BS, MS and Phd degree from the Hanyang University, He has been a professor of department of electronics engi- neering of the Honam University since 1993. His current reaserch interests include localization and map building of the mobile robot.

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