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An Improved Low Cost Automated Mobile Robot

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ABSTRACT

Background: In recent years, there has been increasing interest in developing new models of low cost mobile robots. As the number of sensors required considerably influences the cost of the robot, reduction in number of sensors used has become one of the targets. Objective: In this paper, the design and development of a fully automated low cost mobile robot for navigation in a given complex scenario, is discussed. Two differentially driven DC servo motors controlled by a PIC18f452 microcontroller and navigation algorithm based on Vector Field Histogram, have been used. One ultrasonic sensor for path scanning and three IR sensors for obstacle avoidance have been used. Color detection feature has been incorporated using Light Dependent Resistors (LDR) and super bright white LED. Results: A prototype has been designed, developed at low cost and tested. Conclusion: The performance of the robot in navigating in a given complex scenario while avoiding obstacles has been found to be very impressive and competitive.

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INTRODUCTION

In recent years, the application of mobile robots have phenomenally increased in many areas, ranging from mission in environments hostile to human beings such as space exploration to home services robots such as autonomous vacuum cleaners. Adept Pioneer [2014] robots and K-Team Kheperas [2014] are some of the most popular commercialized research robots. However, more often, these robots do not provide characteristics required and are difficult to adopt, since they use proprietary software and hardware. Moreover, a big drawback is their high cost: the basic Pioneer 3-DX costs around $4,500, the basic Khepera III costs around $3,000 and the basic Koala II around $9,000. Mobile robots controlled by vision are being used in office environment with specially colored and shaped objects [K-team corporation, 2014]. In the recent past, some researchers have developed mobile robots which are slow, bigger in size and costly [Lamiraux.L et.al, 1999], [Sakagami.Y, 2002], [Sebastian.T, 2006], [Balaram.T.O, Robert.I, 1996].

In our work, an attempt has been made to reduce number of sensors, size and cost without compromising on the performance. We have been able to design and develop a low cost automated mobile robot with one ultrasonic sensor and three IR sensors. This provides all navigational features offered by the mobile robots mentioned above. In addition to lower cost, it also provides color detection feature. A prototype has been designed, developed and tested. The performance of the robot in navigating in a given complex scenario while avoiding obstacles, has been found to be very impressive competitive.

The rest of the paper is organized as follows: section 2 presents the design and construction of proposed mobile robot; in section 3 presents the robot components with LDR, LED and ultrasonic sensors as sub sections; robot functionality and algorithm have been discussed in section 4 and 5 respectively, In section 6, results obtained using the prototype are presented and discussed; also, a comparison of the features of the proposed and existing mobile robots is presented and finally conclusions and future direction of the work is outlined in section 7

2.Design and construction:

The aim of this study is to design a fully autonomous low cost mobile robot and the study is real-time operating system that is implemented by executing three main stages as follows.

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The first stage is mechanical design where the structure of the robot is made of stainless steel to ensure robot reliability and stability. The developed hardware is compact in size and symmetrically shaped. In addition to that, all the components are fit efficiently in their places. As a result, the total dimensions of the robot are *15cm X 15cm* and the height is *11cm*.

The second stage, PIC18f452 microcontroller is chosen to build low cost mobile robot navigation system. The Circuit is powered by Rechargeable Nickel-metal hydride battery which supplies the voltage of *9.6V* and *700mAh*. As many loaded elements are to be connected in the circuit, much current is consumed and this causes the voltage regulator to heat up to a degree that is dangerous and might burn the regulator chip. The damage might allow the input voltage form the *9.6V* to pass to the microcontroller and other components; this in turn may damage the L298N motor driver. Current consumption and generated heat are to be reduced to solve this problem. Current consumption was reduced by having three different regulators which also helps to reduce heat generated. Temperature reduction was implemented by fixing a heat sink made of aluminum to the regulator. So when it heats up, the temperature transfers from it to the environment and prevent the chip form burning.

The third stage is the software design; C language programming is used to write the algorithm of the system. The navigation is done by using Vector Field Histogram algorithm [Borenstein.J, Koren.Y, 1991]. Infrared sensor is one way to help mobile robots differentiate between black and white or detect objects. For obstacle avoidance, two normal infrared sensors are used for this mobile robot. Each one of them has two main parts: transmitter and receiver. As the sensor output voltage is analog, the microcontroller is used as comparator to measure the voltage across IR to detect objects surface. Sharp Analog Distance Sensor is a more advanced infrared sensor using the same concept of the normal IR sensor but with accurate measurement and better resolution. The output is analog signal connected to an analog-to-digital pin in PIC microcontroller to converter for reading distance measurements. The output can also be connected to a comparator for threshold detection. Specification, working range is from 4cm to *30cm* which is represented by *2.45V - 0.45V* output voltage. The distance is found by $r_o = v_s \times t_o / 2$ where v_s is the speed of sound *343m/s* at standard pressure and temperature [Sharp, 2014].

3. *Robot Components:*

3.1.1 Light Dependent Resistors (LDR) and LED:

HC-SR04 ultrasonic sensor uses sonar signals to determine distance to an object. Ultrasonic sensor sound waves signal above *20,000 Hz* which is beyond the range of human hearing, Accuracy range is excellent and readings are stable. Ultrasonic sensor requires digital input and output. The operation is not affected by the color on the object or sunlight like IR sensors. Knowing that, acoustically soft materials like cloth could be difficult to detect.

3.1.2 Ultrasonic Sensor:

HC-SR04 ultrasonic sensor uses sonar signals to determine distance to an object. Ultrasonic sensor sound waves signal above *20,000 Hz* which is beyond the range of human hearing, Accuracy range is excellent and readings are stable. Ultrasonic sensor requires digital input and output. The operation is not affected by the color on the object or sunlight like IR sensors. Knowing that, acoustically soft materials like cloth could be difficult to detect.

4. *Robot Functionality:*

Sensor board is attached on top of servo motor at the front part of the robot. Working range distance is *2cm to 400 cm* which gives resolution up to *0.3 cm*. The time taken to finish scanning all positions is high. At the first run of the robot, it did not detect the obstacles because the sensors take long time to feedback the signals whether for detect obstacles or color on the ground. The solution was to lower the speed DC motors for the wheels at mobile robot. Low speed DC motors with high torque were used. Taking fewer readings from the total data before calculating the average is to speed up sensors feedback. Another solution was speeding up servo motor which is used to scan the environment. ADC conversion is used to get the analog readings from sensors, to have higher efficacy and more precise results this function will take the measurement *200* times then take the average by dividing the result by *2* only so the decimal point is shifted two number [Huang, 2005]. ADC_Read is a build-in function in PIC18f452 that will convert analog signals to digital. If the analog input is *5V* then the digital output will be *1024* using the formula for $V_{out} = (adc\_value \times 50000)/1024$ [Reese.R.B, 2005].

Problem encountered was IR and LDR light sensitivity. The method that is used for detection is basically by measuring the reflected light intensity form the object. Since the environment of the mobile robot is not always fixed. The solution was by implementing LDR_set & IR_set. Those functions are to set the parameters according to the real run environment. Otherwise, user has to manually set those parameters by writing the number in the code then reprogram the system every time the light of the environment changes. For example, LDR_set function basically ask the user if the color under the robot is the same as the one displayed on the screen, if yes, the robot will save the readings from the LDR as the color. Similarly, IR_set will ask the user if the mobile robot is not facing any obstacles, if yes, the system will record the readings as there are no obstacles.

LDR_CHECK & IR_CHECK are two separated function used to check the colors and obstacles. The method here is to compere the sensors current readings with the saved parameters from the previous LDR_set & IR_set functions. The comparison is done after ± tolerance to the parameters. After that those functions will return the results to the main function. Scan_left is the function that combines both servo_angle and get_ultra. It is called scan left because it will start by zero angle and finish on *180* degree. The function will calculate the required number of stops or positions which the desirable angles and it is pre-assigned by the user. If it is *5* positions then the servo will start at *0, 45, 90, 135, 180* degrees by following the given formulas [Huang, 2005].

$$Angles = Angles - 1$$

$$Step = 180 / Angles$$

Scan right is the opposite of the function scan left. The main reason for this function is after scan left the robot should decision based on the reading and position itself before taking the second readings. Another reason for scan right function is to not waste time by sending the servo form *180 to 0* without getting any readings since scan left function will start from zero position.

5. Algorithm (Flowchart):

The programming techniques for color detection and obstacles avoidance tasks are shown along with the navigation algorithm at the flowing flowchart in Figure 1.

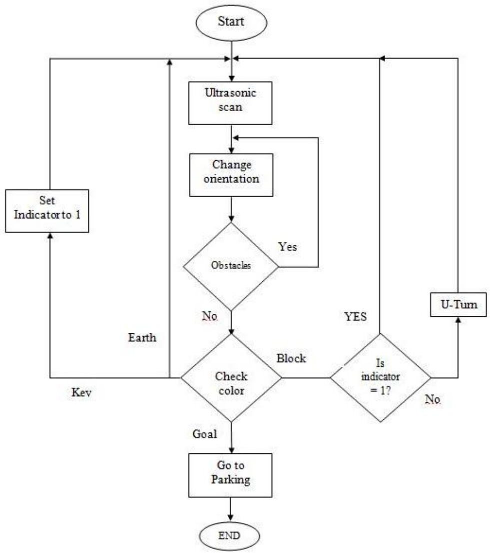

Fig. 1: Flowchart of Navigation Algorithm for Mobile Robot.

RESULT AND DISCUSSION

6.1 Prototype:

The overall behavior of the system is presented as well as the data obtained. Once the robot was completed mechanically, electronically and programmed, it was ready for testing. In Figure 2 shows a three dimensional view of the prototype developed.

The prototype allows real investigation and analysis for the results. These results and findings are obtained by conducting real world tests on the system and then monitoring robot reaction in real time.

6.2 Comparison with Existing Models:

The Table 1 given below illustrates a comparison of various features of the proposed models with those of three recently reported models of mobile robot. It can be seen that the proposed robot model uses lower number of sensors compared to corresponding references [Aziza.M.Z et.al, 2014], [ViVek.H et.al, 2013], [Siti.N, 2011]. Though the model of corresponding reference [Vivek.H et.al, 2013] uses lower numbers of sensor but the proposed model uses different microcontroller which are preferable in terms of availability in small quantities and cost. The proposed robot model provides all the navigational features of all the existing models bit at a lower cost and additional feature of color path detection.

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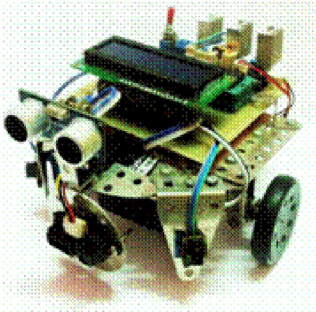

Fig. 2: Mobile Robot Prototype.

Table 1: Comparing data features with other mobile robots.

Components Title	Our Proposed Mobile Robot	Microcontroller-based Mobile Robot Positioning and Obstacle Avoidance [Aziza.M.Z et.al, 2014]	Low Cost Obstacle Avoidance Robot [Vivek.H et.al, 2013]	Intelligent Low Cost Mobile Robot and Environmental Classification [Siti.N, 2011]
Effectors	Wheels	Wheels	Wheels	Wheels
No. of Wheels	3	4	2	3
No. of Sensors	3 (IR), 1 (Ultrasonic)	24 (Ultrasonic)	2 (IR)	5 (IR)
No. of Motors	2 (DC)	4 (DC)	2 (DC)	2 (DC)
Navigation	Vector Field Histogram	Odometry	Binary Logic, Dynamic Steering	Fuzzy Kohonen Network
Microcontroller	PIC18F452	Atmel AVR90S8515	ATMEGA-8	ATMEGA-16
Power Source	9.6V, 700mAh Nickel-Metal Hydride	Battery assembly with a total of 48V	N/A	Two 3.7V, 1000mAh Lithium-Ion
Cost	$170	$1550	$200	$450

6.3. Robot Navigation Performance:

The slope is used as factor in the program to conclude the distance by knowing the output voltage which comes from the sensor. When the obstacle is detected by the center sensor within *18 cm to 20 cm*, if the left sensor detect the obstacle the mobile robot will move right forward with normal speed, else if right sensor detect the obstacle the mobile robot will move left forward with normal speed. When the obstacle within *6 cm to 18 cm*, the react as same as the operation in *18 cm to 20 cm*, but the speed is slow. However, when the center, left and right sensors at 6 cm, the mobile will stop and turn to left, if the right sensor detects, or turn to right, if the left sensor detects.

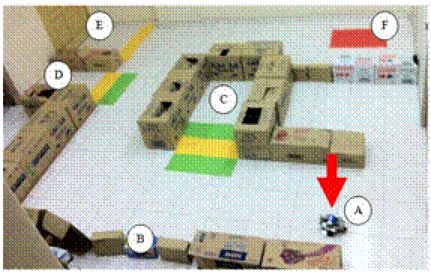

Fig. 3: Description of Complex Scenario.

As seen in Figure 3, the environment to mimic a warehouse with rooms or zones, where there are some rooms allows mobile robot to navigate in and some other restricted areas that the robot should not enter. Scenario description as follows: (A) The mobile robot (B) Wall or obstacles (C) A zone that robot is allowed to enter and exit from it (D) An area that robot is allowed to enter but not allowed to exit from it (E) Restricted zone and (F) The Goal.

First the robot is scanning the environment using ultrasonic sensor, then move toward the farther obstacle or the longest path. As shown in Figure 4.

In Figure 5, the robot is allowed to enter zone C since yellow color comes after green color.

In Figure 6, the robot is navigating in zone C and will exit soon since it is small.

In Figure 7, the robot is exit zone C since yellow color comes after green color.

In Figure 8, the robot is navigating and avoiding the obstacles.

In Figure 9, the robot is allowed to enter zone D since yellow color comes after green color.

In Figure 10, the robot is trying to exit from zone D, the robot should not exit since yellow color did not come after green color.

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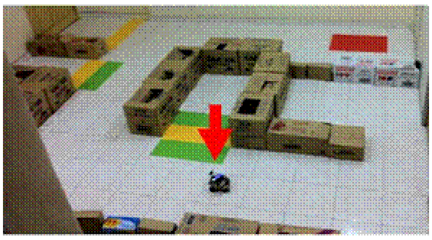

Fig. 4: Navigating of Mobile Robot prototype.

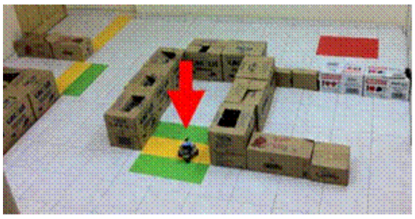

Fig. 5: Mobile Robot Entering into Zone C.

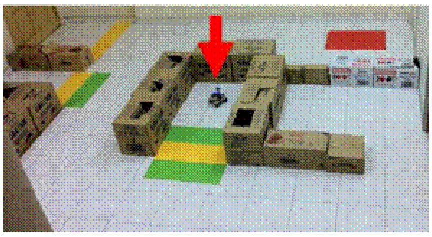

Fig. 6: Mobile Robot At Zone C.

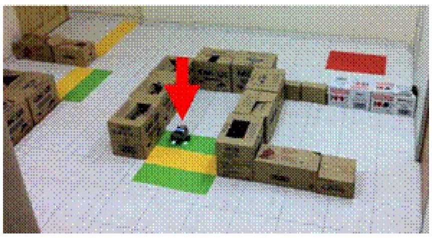

Fig. 7: Mobile Robot Exiting from Zone C.

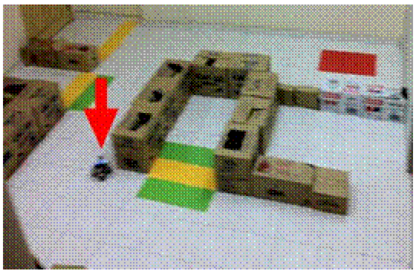

Fig. 8: Mobile Robot Navigating.

In Figure 11, the robot is trapped at zone D and will not come out. The reason for this step is prevent the mobile robot from navigating far away from the goal if it enter the goal zone for example.

In Figure 12, the robot is not allowed to enter zone E since yellow color did not come after green color.

In Figure 13, the robot is navigating and avoiding the obstacles.

In Figure 14, the robot detect red color which is the goal.

In Figure 15, after reaching the goal the robot will go to parking and stop there.

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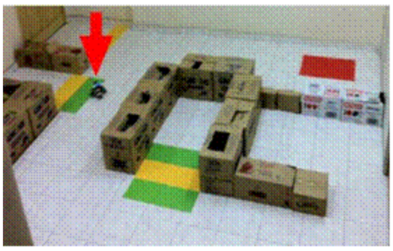

Fig. 9: Mobile Robot Entering into Zone D.

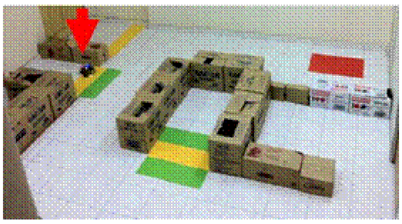

Fig. 10: Mobile Robot Trying to Exit from Zone D.

Fig. 11: Mobile Robot Trapped At Zone D.

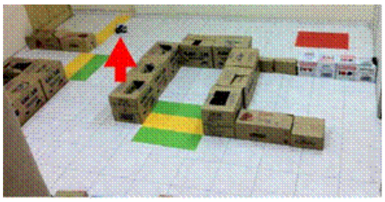

Fig. 12: Mobile Robot Trying to Enter into Zone E.

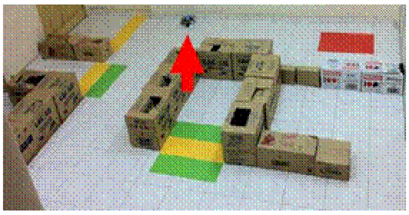

Fig. 13: Mobile Robot Navigating to Goal.

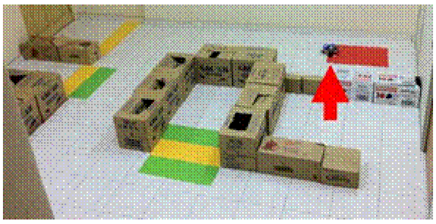

Fig. 14: Mobile Robot Reached in the Goal.

Fig. 15: Mobile Robot Parked in the Goal.

Conclusion:

In this paper, the design and development of a new low cost Automated Mobile Robot is presented. The robot is differentially driven by two compact *(15cmx15cmx11cm)* DC servo motors. The robot is interfaced with a PIC18f452 microcontroller and different peripherals such as LCD, IR, LDR, ultrasonic sensor and push buttons. Navigation is implemented by scanning 180 degrees in front of the mobile robot using one ultrasonic sensor that is mounted on top of servo motor and using Vector Field Histogram based algorithm. Obstacle avoidance is implemented by three IR sensors at front and sides of the robot. The programming language C is used. A prototype has been constructed and tested. Tests proved that the proposed model can successfully perform navigation in a complex scenario while avoiding obstacles without human intervention or assistance. The advantages of proposed model are: uses smaller number of sensors compared with many existing models to successfully perform navigation in a complex scenario with obstacle avoidance; lower cost and additional color detection feature. Future work is in progress to implement fuzzy algorithm with learning system.

REFERENCES

Adept Mobile Robotics, 2014, Pioneer 2-DX and 3-DX

Adept Technology, 2014, Inc. www.mobilerobots.com.

Aziza, M.Z., A. Osama, I.A. Sanaa, 2014. "Microcontroller-based Mobile Robot Positioning and Obstacle Avoidance," Journal of Electrical Systems and Information Technology, 58-57.

Balaram, T.O., I. Robert, 1996, "Rocky 7: a next generation Mars rover prototype", Advanced Robotics, 11: 4.

Borenstein, J., Y. Koren, 1991. "The vector field histogram-fast obstacle avoidance for mobile robots", IEEE Transactions on Robotics and Automation, 7(3): 278-288.

Huang, 2005. "PIC Microcontroller: An Introduction to Software & Hardware Interfacing", Thomson.

K-team corporation, 2014. Khepera, Khepera II and Khepera III.

Lamiraux, F., S. Sekhavat and Laumond, 1999, "Motion planning and control for hilare pulling a trailer", IEEE Transactions on Robotics and Automation, 15(4).

Reese, R.B., 2005, "Microprocessors From Assembly Language to C Using the PIC18Fxx2", Da Vinci Engineering Press.

Sakagami, Y., 2002, "The Intelligent ASIMO: system overview and integration", IEEE/RSJ International Conference on Intelligent Robots and Systems, (3).

Sebastian, T. and Team, S. Sven and Team, B. Gary and Team and M. Pamela, 2006, "Stanley: The Robot that Won the DARPA Grand Challenge", Journal of Field Robotics, 23: 9.

SHARP, 2014. "Analog Output Distance Measuring Sensor" (Read in SHARP Web site).

Siti, N., 2011. "Intelligent Low Cost Mobile Robot and Environmental Classification," International Journal of Computer Applications, (0975-8887), 35: 12.

Vivek, H., R. Sahadev, M. Santanu, 2013, "Low Cost Obstacle Avoidance Robot," International Journal of Soft Computing and Engineering (IJSCE), ISSN: 2231-2307, 3-4.