Sensor Guided Docking of Autonomous Mobile Robot for Battery Recharging

M V Sreenivas Rao, M Shivakumar

Abstract: For uninterrupted working of autonomous mobile robot, battery level needs to be continuously monitored. Normally, few hours of peak usage may be provided by rechargeable batteries. The batteries need to be recharged when its voltage reaches threshold value. The autonomous mobile robot docking for recharging is implemented in this paper. The robot employs sensors, microcontroller ATMEGA16 and voltage divider circuit. The robot has two sensors, IR sensor and Ultrasonic sensor which finds the obstacle (docking station) and orient the robot in the proper position for docking and recharging. The discharging voltage of the battery is detected using voltage divider circuit. The robot's ultrasonic and IR sensors perform the detection of docking station for battery recharging. Ultrasonic sensor helps to detect the obstacle and range from robot. IR sensor is used for the orientation of the robot at the exact position for docking purpose. These two sensors in the robot provide the data about the distance from the docking station to the microcontroller. The algorithm called as Random search algorithm (RAS) is developed to assist the robot to get docked for recharging. This algorithm randomly moves the robot to search the docking station, if found will move towards it and starts for docking and charging or else it rotates to the right. Atmel studio 6 is the software development environment used to write code in Embedded C language.

Keywords: Mobile robot, Ultrasonic sensor, IR sensor, docking station.

I. INTRODUCTION

Mobile robots depend on battery power for their operation. Batteries used in mobile robot require constant monitoring to ensure uninterrupted power supply for continuous operation. When the battery voltage reaches threshold value, the robot searches for docking station with the help of ultrasonic sensor. The ultrasonic sensor is largely accepted for addressing the difficulties in guiding and localization. The robot will detect the distance between docking station to the robot current position. If the charging station is not within the ultrasonic range then the robot rotates itself right by 360 degrees.

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In the proposed work, the docking station is considered to be the obstacle for the robot. During the search, if the docking station is found, the robot will move forward towards it. As the robot approaches near docking station, the infrared sensor will assist the robot to dock at docking station for recharging.

A. Problem statement/objective

In the real social environment, the mobile robot should operate with greater autonomy without human intervention Autonomous mobile robots consume energy from batteries which have reduced power life. It causes a bigger challenge for autonomous mobile robot. The status condition of battery power monitoring in robotic system plays significant role to check its power requirements while performing operations. If the battery voltage gets depleted and reaches threshold level the robot needs to locate charging station to get recharged. This paper describes the specially developed autonomous mobile robot and docking station for battery recharging. The problem mentioned can be dealt when the battery level reaches the threshold level. The robot searches for a docking station with the help of ultrasonic and IR sensors.

II. RELATED WORK

In recent years, different methods for docking and recharging of the autonomous mobile robot have been proposed. Guangming Song et al have designed a smaller sized surveillance robot with three numbers of wheels. The robot can communicate with docking station using zigbee to act as wireless mobile gateway for sensor network. In the proposed system, docking technique based on self localization and infrared detectors have been implemented. When the battery level becomes low the robot moves back to recharging operation at docking station [1]. M. Meena et al have buildup a docking station along with battery charging and replacement system for surveillance robot. When the battery level of the robot becomes low goes back to docking station. In the docking station the fully charged lithium ion battery will be exchanged within 30 seconds. The main advantage in this system is it saves the battery recharging time for which robot need not have to wait for it. After which the robot can resume its assigned task [2]. Kuo-Lan Su et al have demonstrated that automatic system for charging and docking for the autonomous mobile robots. The system can also monitor the status of the charging current at mobile robot and the docking station. In the auto recharging process it involves use of more number of sensors and on the robot the laser range finder is mounted. The mobile robot is guided towards docking station by searching land mark using laser range finder for docking and recharging [3].

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Syed Muhammad Umer et al have designed a method which uses infrared generated two spots on the celling which is invisible to the eyes of human but which can be captured by the IR camera. The image from IR camera used to find the robot position and the robot can be controlled for the movement towards docking station for recharging [4]. Ren C. Luo et al have presented a method for docking control and device for automatic recharging of security robot. To determine exactly when robot needs to move towards docking station for recharging a power prediction algorithm is developed. Image processing system assist the robot in detecting and recognizing the land mark created artificially. The robot and docking station whose depth and orientation of geometrical relationship is calculated. Based on the proposed spring model the robot approaches the docking station [5]. Roberto Quilez et al have proposed docking approach for mobile robots in passive charging technique. In this method, the system uses QR code which act as landmark with Infrared distance sensors to assist robot to reach docking station. To position the robot with respect to dock visual patterns with its relative size of the lateral edges are employed. IR sensors helps to locate and position the robot for docking. Different approaching techniques are adopted by infrared sensors based on the distance [6]. Yanan Renet al have proposed a method for docking control depending on feedback from vision assistance in narrow space. The wheel chair with intelligence can be aligned to get docked automatically in U-shaped bed. Based on some features of definite symbol set on the bed the wheel chair can identify it to get oriented towards it. The docking algorithm assists in making wheel chair to get dock into bed.by the feedback from vision. Wheel chair without collision moves to the entrance of bed by the control of line trajectory algorithm to dock into the bed [7]. T.Narendran et al have proposed a wireless power transmission from docking station to defense surveillance robot. The power transmission used to charge the battery of the robot through wireless charging and also more efficient due to shorter distance. The wireless charging is done to the robot from the docking station with more accuracy and also a successful monitoring of battery level and location of robot using GPS detector from the control room is done. The simulation result gives measured voltage and the current of the battery unit and it is displayed in the front panel of labview software [8]. Peter Won et al have built a system which is capable to dock autonomously using algorithms for mobile robot which can self-configure by the help of sensors. The infrared sensors are used to calculate the distance depending on transmitting and receiving angles are equal to zero. Extended Kalam Filter and Particle filter employed for estimating distance measurement and orientation. The results have shown that the proposed system precisely calculate distance making robot to dock exactly without calculating initial distance [9]. Fernando de Lucca et al have proposed a technique not based on battery threshold voltage value for recharging robot, by using fuzzy method. In this method, the robot can be recharged autonomously by employing three set of fuzzy conditions. The conditions are, present level of energy remaining, the target distance to reach to perfoand distance to be travelled to reach energy station. The results have shown improvement in the overall performance of the robot recharging mechanism without wasting much of the time and energy [10].

III. PROPOSED METHODOLOGY

In the proposed sensor guided docking for battery recharging of autonomous mobile robot, the hardware consists of mobile robot and docking system for battery recharging. The programs are written using embedded C on Atmel studio6 the integrated development platform environment for robot operation.

A. Working of mobile robot

In the current work, robot is made using ATMEGA16 microcontroller, ultrasonic sensor, IR sensor, voltage divider circuit, L293D interface circuit, geared servo DC Motors, 12V lead acid battery and LCD display.
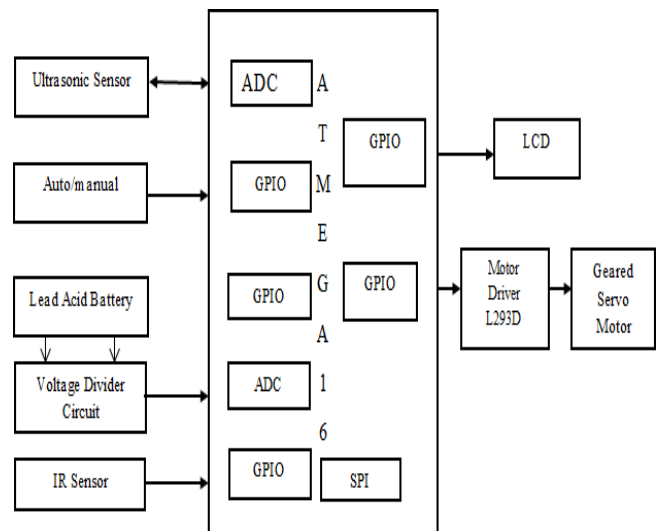

Fig. 1. Block diagram of mobile robot

Fig.1. shows the block diagram of autonomous mobile robot. It consists of input section, microcontroller and output section. Input section has two sensors Ultrasonic and IR sensor, auto/manual switch and manual on/off switch. The output section consists of motor driver L293D, geared servo motor and seven segment display interface. The voltage divider circuit continuously detects the discharging battery voltage and inputted to microcontroller. When the battery voltage level reaches threshold level (set to 40% of its maximum level of 12.5V), robot starts searching for docking station with the help of ultrasonic sensor. The high frequency sound wave of about 40 Khz is emitted by one of the piezoelectric transducer which converts it to voltage. The piezoelectric transducer gets trigger pules from microcontroller and sends the detected pulses back to microcontroller. The shape of the beam from sensor is conical in shape and the beam width is function of the surface area, frequency and kind of transducer used. The maximum sensitivity of beam spread is 200 cms across upto 8 ft range away from sensor. The infrared sensor consists of an IR LED and an IR photo diode together called as optocoupler. When the IR transmitter emits the radiation, it reaches the object and some amount of radiations gets reflected back to IR receiver. Based on the intensity of the reflected light, the output of the sensor will change.

IR sensor is used to detect the obstacle in the distance range less than 6 cms to align the robot at the exact position for docking and charging purpose. LCD is used to display battery voltage and measured distance from robot to docking station by the sensors. The algorithm called Right Search Algorithm which works on the information from these two sensors. This algorithm randomly searches the obstacle, the robot will take a right rotation until the obstacle is detected and if the obstacle is found it will move towards it and gets docked. In Fig. 2(a) docking and recharging station is shown. It consists of a hollow cylinder with two metallic rings fitted to it. These metallic rings are connected to the charger terminals for purpose of battery charging. Fig 2(b) shows the autonomous robot with two inverted L shaped metallic plates to make contact during battery recharging.
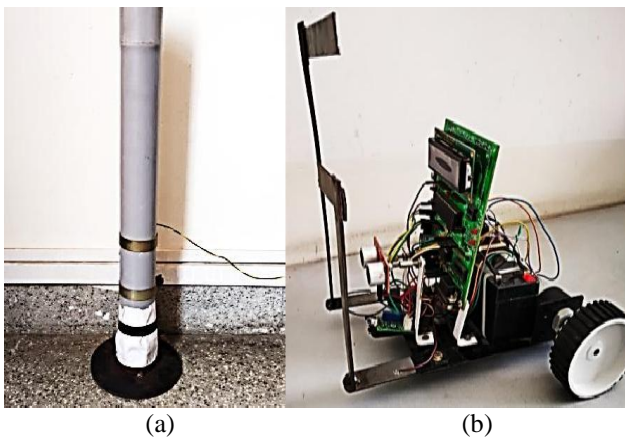

(a)   (b)

Fig. 2. (a) Docking station for recharging.
(b) Robot with metal plates

IV. SOFTWARE DETAILS

The programming is done in Embedded C language and Atmel Studio6 software. Atmel studio6 is the platform for developing and debugging Atmel AVR microcontroller (MCU) based applications. The Atmel Studio6 IDP environment facilitates the applications written in embedded C.

A. Flowchart for robot docking algorithm

The method involved in the docking algorithm is represented in the flowchart shown in the Fig.3. In the proposed work, the robot has on board control switch to set either in auto or manual mode of operation. Initially it will check the selected mode of operation. In the auto mode, the algorithm will check whether the battery threshold level has reached 40%, if this condition fails then the robot starts its process from the beginning. Once the battery of the robot reaches threshold value it will check for the obstacle (charging station). If the obstacle is present within the ultrasonic range, the robot will move towards the charging station, if not robot will take right rotation about 360 degrees until it detects the charging station. If the robot is set in the manual mode, the algorithm assumes the battery voltage has reached the threshold level and it will start checking for the obstacle. If obstacle is detected within the range of 200 cms by ultrasonic sensor, robot is directed to move forward. When the robot reaches closer to docking station in the range of 6 cms, the IR sensor helps robot move closer to docking station. In this range sensor provides the better environment perception for the smooth navigation of the robot. The robot will moves slowly to avoid the collision with docking station. The algorithm will also check for the data from ultrasound range is less than 2cm, it means the robot will stop its movement 2cm away from the docking station. At this stage, robot will connect to the connector with the help of metal plate placed in front of the robot for charging.

until it detects the charging station. If the robot is set in the manual mode, the algorithm assumes the battery voltage has reached the threshold level and it will start checking for the obstacle. If obstacle is detected within the range of 200 cms by ultrasonic sensor, robot is directed to move forward. When the robot reaches closer to V

V. EXPERIMENTAL RESULTS

The docking of autonomous mobile robot for battery recharging is implemented in this work. We have employed IR and ultrasonic sensors for detecting the docking station. The random search algorithm works on
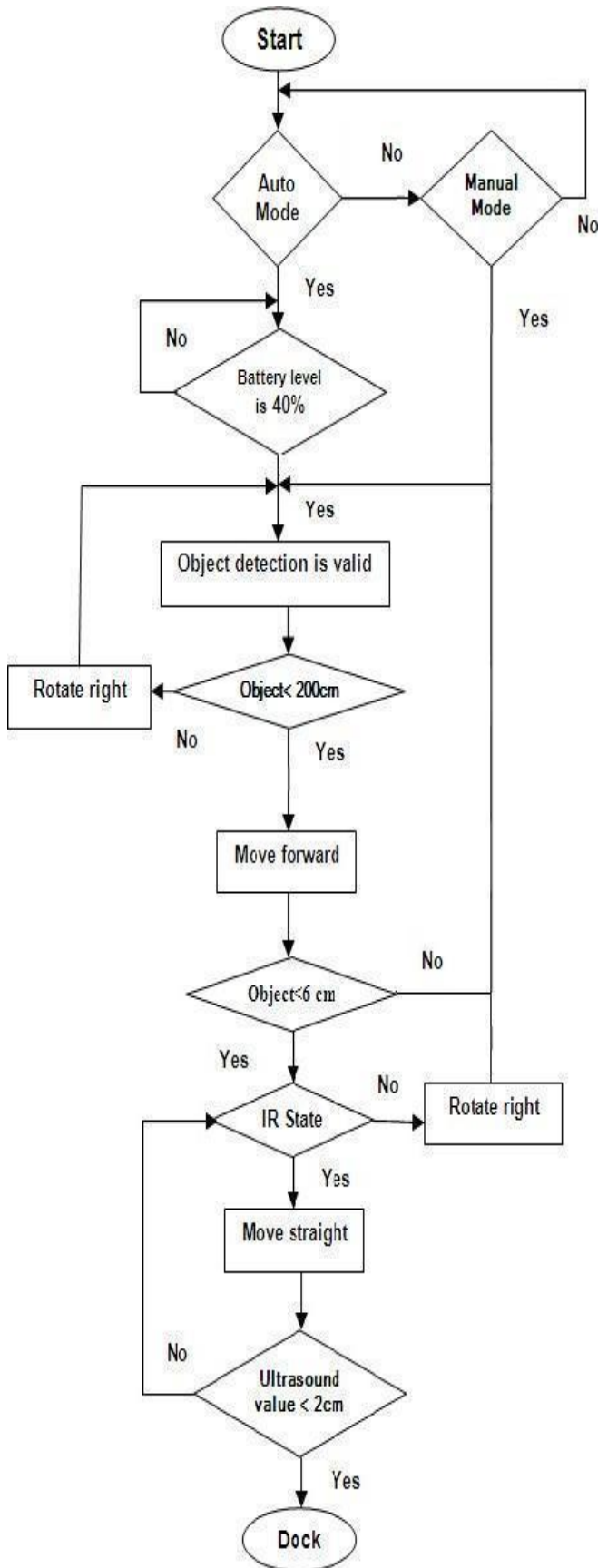
Fig. 3. Flow chart of the robot docking algorithm.

the acquired data from sensors to control the robot to move towards the docking station for recharging the battery. Fig.4 (a) shows the robot movement in ultrasonic range, the ranges covers distance of less than 200 cms from the target.

Fig.4 (b) shows IR state, when the docking station is located at a distance of less than 6 cms range. The robot has approached close to docking station and moves slowly forward. Fig.4 (c) shows the robot in contact with the metal rings in the docking post for recharging. At this point the robot on its seven segment display indicates that Target Reached and the percentage of remaining battery voltage.
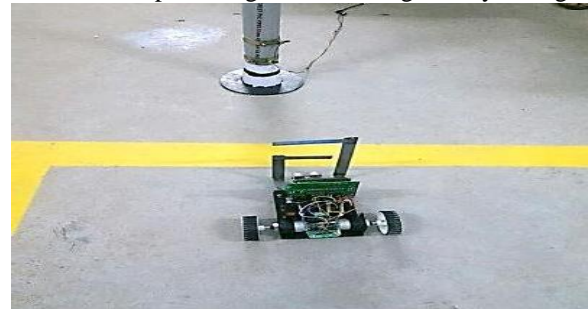

Fig.4(a). Robot movement in ultrasonic range

Fig.4(b). Robot in IR state

VI.   CONCLUSION

Sensor guided docking of autonomous mobile robot for battery recharging is developed and tested. The robot is assembled using ATMEGA16 controller for processing the data and its software program helped robot for guiding movement. The robot equipped with the distance measurement sensors, uses IR and ultrasonic range sensors which helps in acquiring the real time data. For detection of docking station ultrasonic distance sensor provided a wider field of detection.

(c)
Fig.4(c). Robot docking for recharging

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The IR sensor provided short range detection with considerable accuracy for the robot to move forward slowly for docking. The robot with metal plates mounted in its front connects for recharging in the docking station. In order to enhance the robot movement, there are many considerations for improvement.

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