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Design and Development of Integrated Semi - Autonomous Fire Fighting Mobile Robot

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Abstract: ***The Design and Implementation of this project is mainly based on control of Semi - Autonomous mobile robot (SA-BOT). The system controls four DC Geared motors which is powered by the Atmega2560 and controlled autonomously by Navigation system which comprises of integrated ultrasonic and infra red sensors. The bot is outfitted with wireless camera which captures the video and transmits it to the base station. The fire detection system comprises of LDR and temperature sensor, if there is a fire, the sensors detects it and the bot will be moved to the source and starts extinguishing it. The Extinguishing System comprises of a BLDC motor with water container. The SABOT can also be operated manually for extreme conditions. We have provided a GUI support through which the bot can controlled from the base station.***

***Index Terms*— Atmega 2560, Camera, Fire fighting Robot, Low cost, SA-BOT.**

I. INTRODUCTION

Now a day's machines have become essential parts of human life and robots are designed in order to minimize the discomforts thereby making life easy. Robots are used in variety of fields in order to minimize the difficulties like medical, space exploration, underwater exploration, defense and humanoid robots[1] [4] [6] [7]. Here in our proposed system we are designing this SA-BOT for fire extinguishing operations. Fire fighting is an important but dangerous operation for the people who are involved so here these SA-BOT are developed to replace humans from this kind of hazardous environment. Numerous methods and algorithm are proposed for the Navigation of robots [9] [10]. Swarm behaviors in firefighting robots are also proposed [2] [5]. Thermal imaging camera based humanoid robot (SAFFiR) also proposed [8]. Computer vision based robots are uses high resolution camera to capture the images and controlled remotely by humans [3]. Here we are proposing a low cost SA-BOT for extinguishing fire and also help the soldiers for reconnaissance process. The movement of SA-BOT is controlled autonomously by the Navigation system but in the extreme condition like if there is dense condition, it can be operated manually through GUI interface.

When the robot enters the environment it starts navigating, locates the fire and starts extinguishing it and in parallel it transmits the video feed to the remote station from where we can monitor the whole process. It is designed in a way that it adapts its Navigation to all kinds of layout dynamically so its suitable for all kinds of buildings and environments. In this project, SABOT performs signal conversion from the integrated 4 infrared sensors and fed it to the controller based on these signals controller controls the four DC motors for Navigation purpose. This paper presented as follows, section 2 defines the system model and block diagram section 3 defines Hardware modules used in SA-BOT and section 4 defines the algorithm used for Navigation purpose and section 5 shows the experimental results of SA-BOT.

II. SYSTEM ARCHITECTURE

The system architecture of SA-BOT is shown in figure 1. SA-BOT contain three different kind of system unit 1. Navigation system 2. Fire detection system 3. Extinguishing system. The four integrated ultrasonic sensor and infra red sensor forms the navigation system, LDR and temperature sensor forms the detection system, water container and sprinkler forms the extinguishing system

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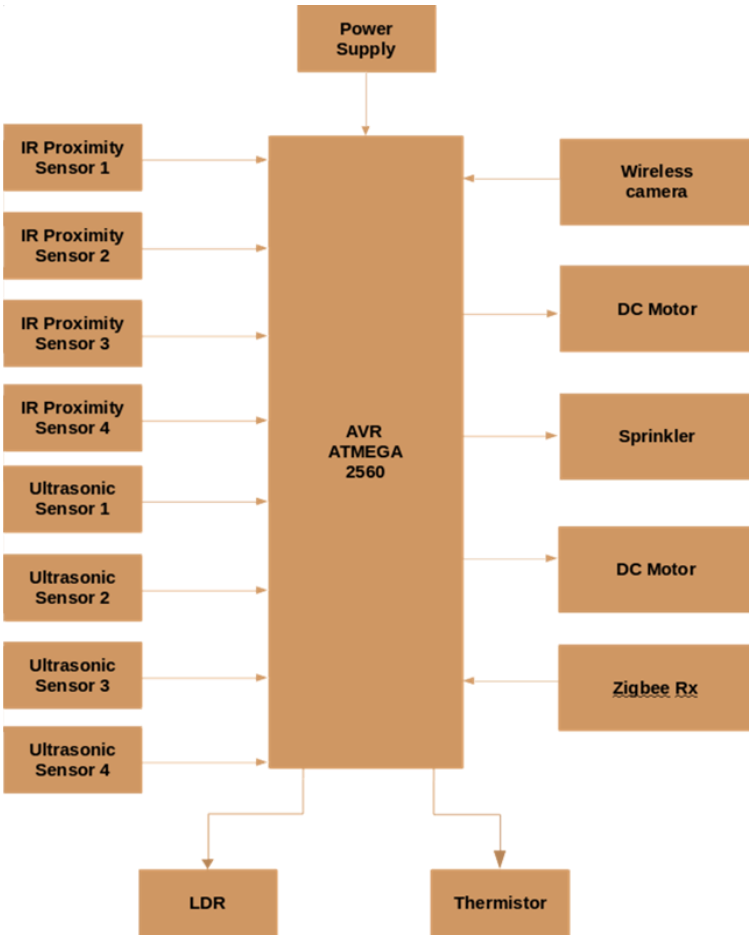

Fig 1. The system architecture of SA-BOT

A. Navigation Unit

SA-BOT uses four IR sensor to detect the obstacle and four ultrasonic range finder to find the distance between the bot and obstacle. We have integrated the IR and ultrasonic range finder to get the layout of the whole environment. The ultrasonic range finder reads two different types of objects

- deterrent
- Non deterrent

The distance between the obstacle and SA-BOT(A) is given by S_A, risk-free distance between a SABOT and obstacle is given by S_F, S_D is a threshold value which ensures that SA-BOT is not closer to obstacles.

The relation function of Infra red sensor S_R is given by

$$S_R = \begin{cases} 1 \text{ If Si has deterrent} \\ 0 \text{ If Si has no deterrent} \end{cases}$$

The relation function of Ultrasonic sensor S_U is given by

$$S_U = \begin{cases} 1 \text{ If } S_D \leq S_F \\ S_F/S_D \text{ If } S_D \geq S_F \end{cases}$$

Another important part of Navigation unit is two +12v DC motors which are connected through H bridge LD239D , the inputs from the IR sensors are fed into micro-controller based on the deterrent and non deterrent conditions. From these inputs a layout is generated with this layout control of DC motors will be defined

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III. FIRE DETECTION UNIT

SA-BOT's fire detection unit comprises of LDR and Temperature sensor if there is a fire, there will be a potential difference in LDR which is proportional to intensity of light and its fed to the micro-controller as an input. In-order to prevent false triggering from ambient we are integrating LDR with temperature sensor

IV. EXTINGUISHING UNIT

Here the water container and BLDC motor forms an extinguishing unit, inputs from the fire detection unit is fed to the micro-controller, and the Navigation unit helps the bot to reach the correct location where the fire is, if bot reaches the correct position and detection unit is activated sequentially it activates the extinguishing unit (i.e) water is sprayed by the sprinkler and the fire will be extinguished.

In parallel video is captured through wireless camera and video feed is sent to the base station. SA-BOT is also provided with a manual remote control which was made possible by zigbee unit in it, these zigbee units acts as a receiver which receives commands from the base station where the transmitter is located, thereby making the bot semi-autonomous.

V. HARDWARE MODULES

We are using two +12v DC motors for bot Navigation purpose these two motors are connected with micro-controller through LD293D which operates the motors in bidirectional conditions, IR sharp sensor module GP2D120X is used in Navigation unit detects the deterrent conditions which cover the range of 20 to 30cms in distance and blind-spot is about 0 to 4cms it contains transmitter LED with CCD Array and it gives out the analog voltage corresponding to angle of reflection. Ultrasonic range finder HC-S04 provides 2cms-400cms non contact measurement function, the module generates eight 40kHz signals and detects whether its bounced back. If its bounced back, through high-level the distance of the deterrent from the bot is measured by Test distance = (high level time X velocity of sound (340M/S) / 2.

Temperature sensor LM35 used in the fire detection unit produces the output voltage linearly in proportional to the centigrade temperature. It can measure a range of -55ºC to 150ºC and output voltage is about -550mV to1500mV which is fed to the analog pin of micro-controller for signal conversion process. Light dependent resistors are photo-conductive cells with spectral responses same as human eye. The cell resistance falls with increasing in light intensity so when integrated with LM35 it's used to detect fire conditions. Zig-bee transmitter and receivers (XBEE S1) used for remote control of SA-BOT. This module yields the 802.15.4 stack and wraps it into a simple serial command. It can be easily interfaced with the serial port of micro-controller AT-Command sets are used to configure the module for the baud and frame rate. It operates with the ISM 2.4 GHz frequency band.

Micro-controllers plays a vital role here in controlling the different units of SA-BOT. We have chosen **At-mega2560** as a controller which is low powered 8 bit AVR RISC based controller combines 8KB of SRAM, 4KB of EEPROM, 86 GPIO's , Six flexible timers /counters with compare mode, 10 bit A/D converters for signal conversion and 4 USART's which supports serial Communication between controller and peripheral. Throughput of controller is defines by the instructions executed per clock, powerful single cycle execution provides a high code density and device achieve a throughput of 16 MIPS at 16 MHz operates between 4.5-5.5 volts.

VI. ALGORITHM FOR NAVIGATION

SA-BOTS performance is totally based on the Navigation unit, this unit steers the bot to the point where the fire is, for this it has to identify each and every obstacle in the path and have to tackle it dynamically in-order to reach the destination. So we define an algorithm which defines the path for navigation of SABOT.

Numerous algorithms are made for robot navigation the fundamental concepts for navigation are self localization, path planning and layout making & interpreting. Our SA-BOT is going to operate in indoors so the navigation unit comprises of IR and Ultrasonic range sensor which helps in avoiding obstacle. Here we are using one of the maze solving algorithm for navigation purposes, the algorithm is as follows in figure 2. Figure 4 shows the possible criteria’s during robot navigation.

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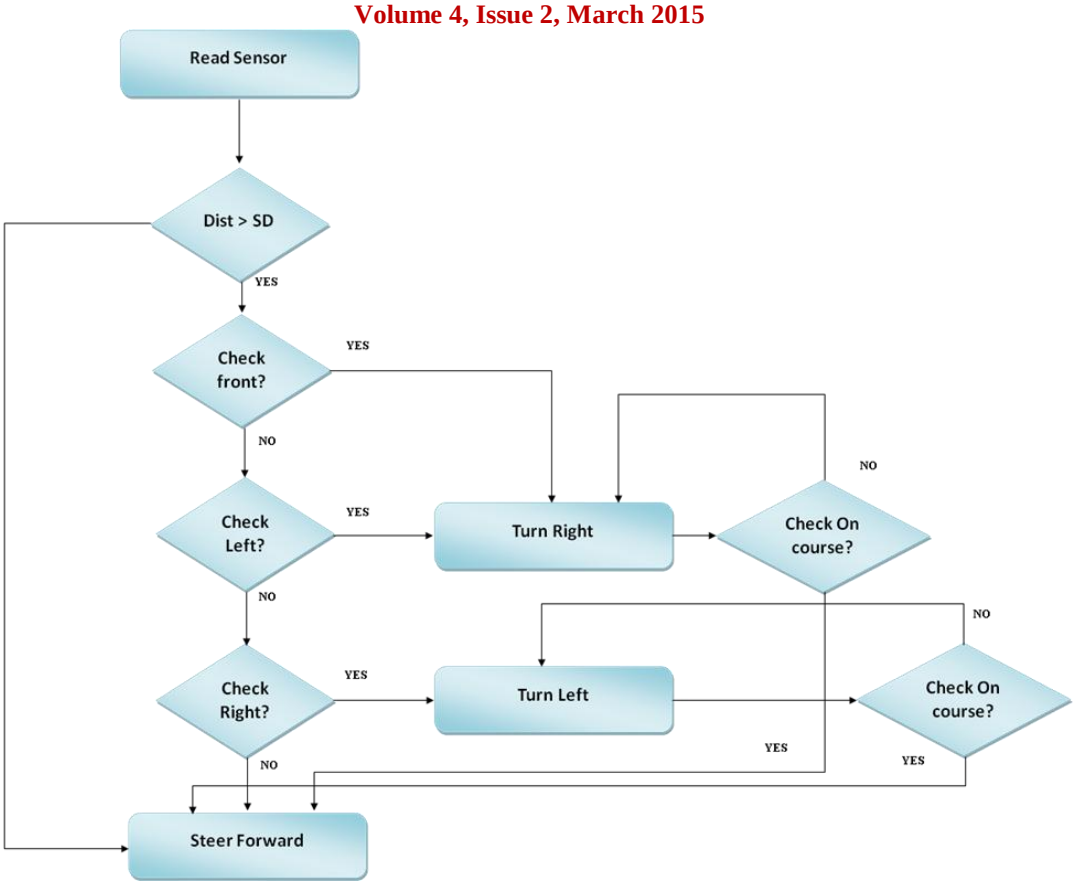

Fig 2 Flowchart for Navigation Algorithm

Now our algorithm steers the bot to its destination once the destination is reached, the conditions for fire were checked if the conditions are satisfied extinguishing unit gets activated.

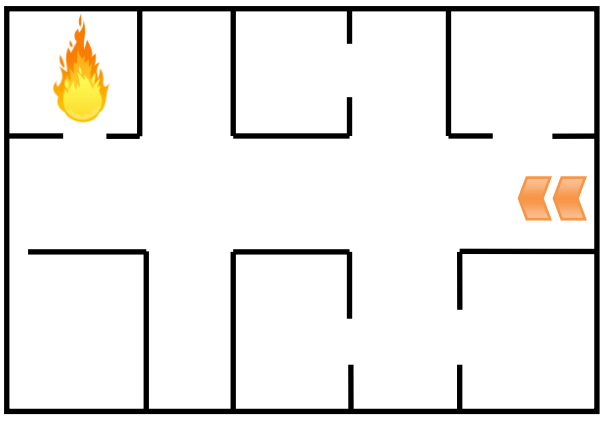

Fig 3 Experimentation Layout

VII. EXPERIMENTAL RESULTS

SA-BOT is supposed to operate in all kinds of indoor environment so it has to navigate dynamically by creating a layout. We have used the following layout for experimentation as shown in fig 3. Whenever a flame is detected, our SA-BOT stops its movement and the extinguishing unit gets activated. For different types of fire different methods has to be carried out but here we have tested water as an extinguishing agent. Depending on the type of environment the extinguishing agent has to be changed for effective results.

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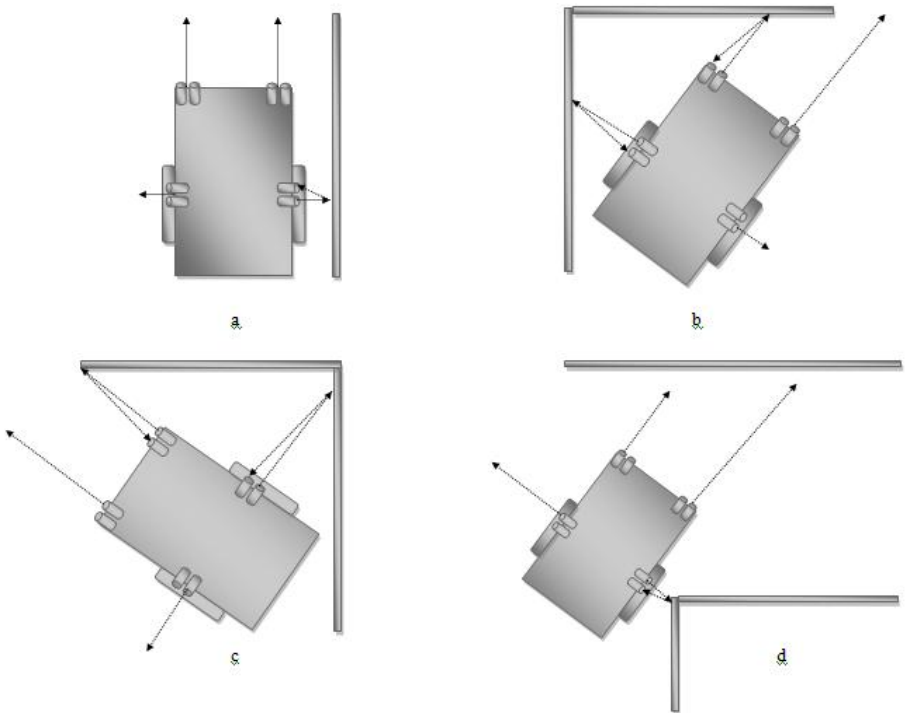

Fig 4. The various possibilities on SA-BOT Navigation a) Forward, b) steer right c) steer left d) steer at the corners since we are following right hand rule

VIII. OUTPUT RESULTS

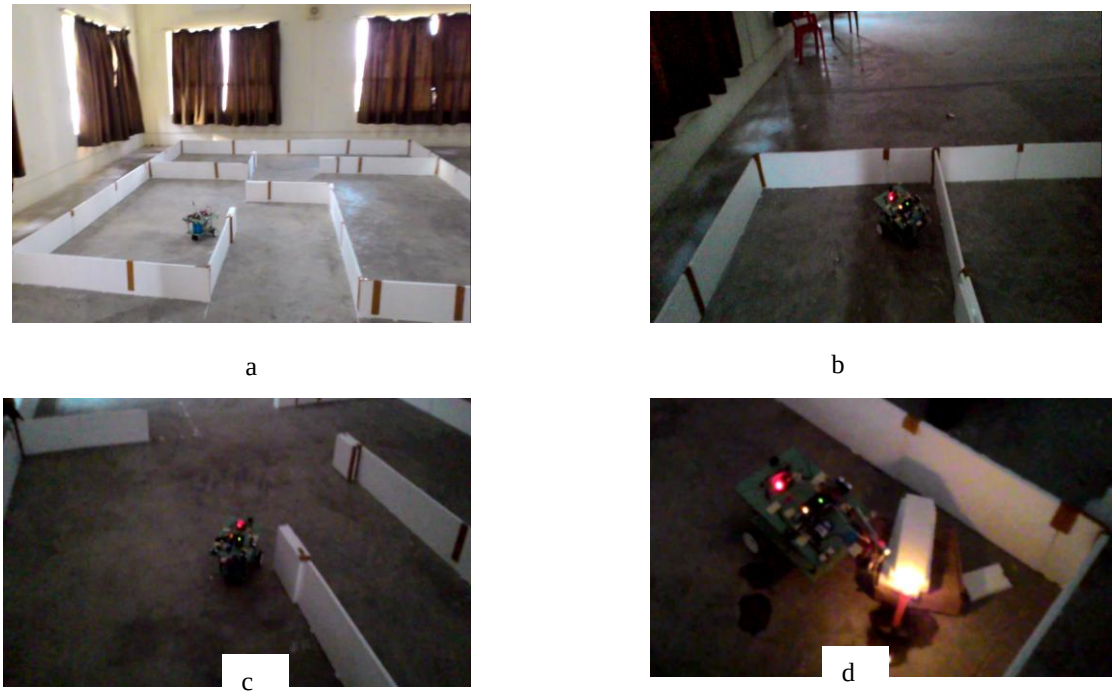

Fig 5 a) Experimental Layout b) bot navigation performing hard right c) bot navigation performing hard left d) fire detection inside the layout

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IX. CONCLUSION

Here in our paper we have explained in detail about the design and development of SA-BOT, it finds out the fire in different types of indoor environments. Experimental results are carried out for a two wheel mobile robot in order to illustrate the proposed system. SA-BOT accurately finds out the point of fire with in a small amount of time period.

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