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Object Follower and Barrier Escaping Robot Using Image Processing

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ABSTRACT: In the recent work, the difference in axes level of moving object helps in getting control signal using Lab VIEW image processing code which is sent to the Arduino board using wireless communication. The snap images of the object are processed using LabVIEW-VDM software. Depending on the shift in position of object, proper commands (coordinate details) are given to the robot to follow moving color object. This project aim is to design and develop a miniature mobile robot which can follow a moving object. Here, we use the mobile camera/webcam to capture image of the colored moving object and these snaps are processed to get coordinate of both the moving object and robot. The features of the moving object such as the color, shape, size can be monitored for tracking the article. In this project color and shape information of the target is used to track the moving object. The robot is made using specially made control circuits such as IR for barrier escaping for shorter distance, Ultrasonic sensor for barrier escaping in wider range. The movement of the robot is controlled by an Arduino based on the control signals received directly from image processing, IR and Ultrasonic sensor outputs.

KEYWORDS: Robot, Object Follower, Barrier Escaping, Image Processing, Lab VIEW-VDM, Arduino

I. INTRODUCTION

The emerging research field on miniaturized automatic target tracking and obstacle avoidance robot is given importance in defense and hazardous industry for navigation, surveillance, security and target recognition by image processing [1-9]. The target tracking and obstacle avoidance made using image processing techniques is introduced in this paper was motivated by a course project work in Sensors and Actuators at Mechanical Department, SOLVE LAB, NITK. The goal of this project was to develop a prototype robot capable of tracking an object and reaching it while avoiding obstacles along its path using image processing. The problem statement of the course project restricted the robot size to be at most 12" by 12". However, the method used here can be used with minor changes to make scale up robots for article in larger size. The changes being number of sensors being used and minor changes to the Arduino code to incorporate the data from the extra sensors.

Dynamic obstacle avoidance is one of the key issues for most real world mobile robots. Generally, the path of a mobile robot is determined by using a CAD model or pre-detected information about objects in the environment. The robot follows this path to the desired destination. The problem with such an approach is that when unexpected or unmodelled objects, either static or moving appear the robot may fail in avoiding them. The method used in our prototype is based on diverting the robot away from the obstacle and then returning to the path after the obstacle has been passed. In contrast to static or global path planning, dynamic obstacle avoidance approach uses only the local information of the surrounding environment. The path chosen may not always be the optimal path, but it provides faster response to



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unexpected obstacles. This mobile robotic system can simultaneously track a moving object and avoid obstacles in realtime. In this paper first introduce the system construction, then present the object follower approach, obstacle finding and avoidance mechanism/algorithm, and robot control via remote control laptop [1].

II. RELATED WORK

A robotic that follows a moving object by utilizing a path algorithm with multiple sensors. The robotic platform uses a visual camera to sense the movement of the preferred object and a range sensor to help the robot to notice and then avoid barriers in real time while continuing to track and follow the desired object. In terms of real-time barrier avoidance capacity, this uses potential field algorithm called DGPF for this robotic application specifically. Experimental results show that the robotic and intelligent system can fulfil the requirements of tracking an object and avoiding barriers simultaneously when the object is moving [1, 2].

The variation in horizontal and vertical axis of tracked object generate control signal which is send to the controller wirelessly. The captured images of the object are processed using software MATLAB. Depending on the change in position of object, proper commands are given to the robot to track moving ball [10].

III. CONSTRUCTION OF BARRIER ESCAPING ROBOT

Robot Body : The mechanical structure was made of 1/4" plywood of dimensions 9.5" by 3.5". Four 12V 100RPM Permanent Magnet DC (PMDC) motors were fixed to the chassis using U-clamps. The body consists of eight 1/4" plywood pieces in-order to construct rugged system. The body was assembled using nails and SH grade Fevicol. The body was built over the chassis. One-eighth inch plywood was used to make the top cover. Holes were drilled in the body to allow for installation of indicator lights, servo motors and RF receiver with antenna. The NITK sensor and actuator team indigenously made object follower and barrier escaping robot is shown in Fig. 1.



Fig. 1 Indigenously made object follower and barrier escaping robot

IV. ROBOT INTELLIGENT ELECTRONIC CIRCUITS

The circuits used in the robot are grouped into following major intelligent circuits to control wire free automated mini robot system activities as



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IR Proximity Sensor Circuit : Consists of an IR LED, Photo diode pair. The IR LED produces electromagnetic radiations in the IR region as shown in Fig. 2. This reflects off obstacles and is received by the photodiode. The voltage output across the photodiode is compared with a potentiometer output. The potentiometer output is calibrated such that it matches the voltage across the photodiode for a given obstacle distance. This point is henceforth referred to as set point. The set point potentiometer output depends on the distance chosen as threshold for the IR sensor. The potentiometer must be calibrated to the set point for the surrounding light conditions. The comparison of voltage is done by a LM741 Op-Amp used as a comparator. The output of the Op-Amp is either a high or low (8V logic).

The circuit can be made to work at 5V, this however reduces the intensity of the IR led and drastically reduces the maximum range of the IR sensor. The circuit shown works at 8V, hence the output must be stepped down to 5V to make it compatible for the Arduino to read them without destroying it by excessive voltage to the input pins. The conversion from 8V to 5V was achieved using 1W 4.7V zener diode (IN4732) in reverse bias with a 1K Ohm series resistor. The circuit ensures that voltage greater than 4.7V is dissipated across the resistor. Since the output of the Opamp is High or Low (8V or 0V), the circuit generates output of 4.7V or 0V. This can be detected on the Arduino without any harm to it.

The basic prototype had four of these circuits, to detect the presence of obstacles in four directions. The number of sensors used decides the complexity of the obstacle avoidance code. The addition of each additional IR sensor creates additional cases. The total number of outputs combinations possible with 'N' IR sensors is 2^{N} . The addition of one extra IR sensor results in doubling the number of output combinations to be accounted for in the program and an additional input pin on the Arduino. Hence an optimum number of IR sensors must be selected or the outputs must be multiplexed to save pins on the Arduino.



Fig. 2 IR Proximity Sensor Circuit



Fig. 3 Pulse Generator Circuit for PWM

Pulse Generator Circuit for Producing PWM : The pulse generator circuit was used to produce PWM output as shown in Fig. 3. This output was then connected to the base of an NPN transistor which switched the buzzer on/off. The principle used was to make a 555 timer re-trigger itself on every cycle to allow it to operate as a free running oscillator. This is also called as a stable mode operation of 555 timer. In this mode, the 555 timer will indefinitely continue charging and discharging between $\frac{2}{3}$ Vcc and $\frac{1}{3}$ Vcc until the power supply is removed (In our case this was an Arduino output). The charge, discharge times and frequency are independent of the supply voltage. They only depend on the values of the capacitor and resistors.

Charging and discharging times are given by	
$T_c = 0.693(R_1 + R_2)C$	(1)
$T_d = 0.693(R_2)C$	(2)
Total cycle time is given by	
$T = T_c + T_d = 0.693(R_1 + 2R_2)C$	(3)
Frequency of pulses is given by	
$f = \frac{1}{T} = \frac{1.44}{(R_1 + 2R_2)C}$	(4)
Duty cycle of the PWM is	



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Duty Cycle = $\left(\frac{R_1+R_2}{R_1+2R_2}\right) \times 100\%$

(5)

Components used in PWM circuit is $C = 10\mu F$, $R_1 = 1k\Omega$, $R_2 = 100k\Omega$ by using these components the total cycle time T = 0.7s, frequency f = 1.429 Hz and duty cycle = 49.75%

LED circuit : The led circuit consists of five sets; direction indication (Forward/ Reverse), Turn Indication (Left/ Right), Brake indicator. Each Indicator set is connected to a pin on the Arduino. Hence, each of the 5 pins controls the state of one indicator set. These pins are programmatically set high/low depending on the motion being performed and the required indication to be provided.

RF Receiver Circuit : The RF receiver chip WS-RX-02 consists of 8 pins (4 distinct functions: Power, Ground, Data and Antenna). The chip has maximum voltage input limits of 5V and hence was powered using the Arduino and not the 12V rechargeable battery. The Data pin was connected to one of the Arduino digital pins. The antenna pin was connected to a bare wire; the end of the wire was attached to a bolt to increase RF wave reception.

V. MOTION CONTROL OF ROBOT

Four of the Arduino digital pins are connected to the H-bridge as shown in Fig. 4. The pins are used to control the speed of the robot using PWM signals. The Arduino is capable of delivering a maximum current of 40mA. If the motors are driven using the Arduino, they will draw currents greater than 40mA which will damage the Arduino. Hence, H bridges are used. Once the motion command is read, the Arduino determines the pins to be made high to perform the required motion.



Fig. 4 Motion control by H-Bridge

VI. BARRIER ESCAPING

Barrier escaping comprises of two sensor outputs, namely the IR proximity sensor and the ultrasonic sensor.

IR Sensor : Sensing direction is shown in Fig. 5. Each execution of the Arduino loop checks all the four IR sensors to check which of them are HIGH. It then checks if any of the conditions stated below is true, it begins another loop to avoid the barrier. It takes the correction motion until it reaches a state where none of the sensors is HIGH. This part of



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the algorithm over-rides the inputs received by RF transmission from LabVIEW. This is because barrier escaping is given higher priority over minimising distance travelled to reach the objective.



K-MAP OF	-MAP OF OUTPUTS FOR GIVEN INPUT COMBINATIONS OF IR					
		A'B'	A'B	AB	AB'	
	C'D'	x	Forward	Right	Right	
	C'D	Right	Right	Right	Right	
	CD	Reverse	Stop	Stop	Reverse	
	CD'	Left	Left	Left	Left	

TABLE 1

Fig. 5 IR sensors direction of sensing for barrier escaping

From the Table 1 the following relationships between IR sensor output and robot response can be obtained as $BCD \rightarrow Stop$, $A'BC'D' \rightarrow Forward$, $B'CD \rightarrow Reverse$, $AC' + DC' \rightarrow Right$, $CD' \rightarrow Left$ If any of the left hand side expression results as TRUE, then, the command on the right is to be executed to divert the robot away from the obstacle.

Servo Ultrasonic Sensors : Two ultrasonic sensors HC-SR04 were used to scan the region around the bots for obstacles. The ultrasonic sensors were mounted on servo motors. The servo motors turn to precise angular positions based on the input PWM duty-cycle. The ultrasonic sensors trigger after the servo reaches the angular position and waits to receive the echo. Once the echo is received the Arduino calculates the distance of the obstacle and then again rotates to the next angular position. This cycle occurs in every loop of the Arduino execution and consequently an obstacle map around the robot is generated using the proximities and distances of the obstacles sensed.

Ultrasonic Sensor : The ultrasonic sensor mounted on top of the servo motors, sweeps the region around the robot, scanning for barriers. Both their position and direction are stored in a matrix as given in Table 2. A spatial map of obstacles is created consisting of barrier distances and directions. The region around the robot has been divided into four regions around it as shown Fig. 6



Fig. 6 Ultrasonic sensor barrier escaping region

TABLE 2 K-MAP OF OUTPUTS FOR GIVEN INPUT COMBINATIONS OF ULTROSONIC

	A'B'	A'B	AB	AB'
C'D'	x	Reverse	Reverse	Reverse
C'D	Forward	Left	Stop	Right
CD	Forward	Stop	Stop	Stop
CD (Family	16	Char	Diela
CD'	Forward	Left	stop	Right



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From the Table 2 the following relationships between ultrasonic sensor barrier maps and robot response can be obtained as

VII. WIRELESS COMMUNICATION

RF Communication : The RF communication between the laptop and robot occurs over the RF transmitter-receiver module. The modules used were WS-TX-01 and WS-RX-02. Five distinct movement codes were to be transmitted for motion commands namely, forward, reverse, left, right and stop as shown in Fig. 7. The codes were transmitted as a sequence of 1's and 0's or HIGH and LOW. The percentage of HIGH in the signal determines the code. The LabVIEW code determines the direction that the robot must travel. This is communicated to the Arduino connected to the laptop using serial communication. The Arduino then determines the percentage of 1's to be transmitted. Each command is sent twice from the receiver side, in order to avoid data loss during communication [8, 9].

In the receiver side (Robot), the percentage of 1's are checked. If the new command matches with the previous command, then the robot continues with the previous command. If however, a new command is detected, the command is read again. If the new command matches with the previous one, then the new command is implemented. Otherwise, the old command is executed. This was done because it was observed that there are some erroneous bits being read at the receiver side. To guard against such erroneous bits, this method of double checking new command was implemented. The system was tested by transmitting commands from one laptop and reading them using the robot transmitter and Arduino connected to another port on the laptop. The system showed 100% accuracy in data transmission. No errors were observed in the communication during the test.



Fig. 7 Five distinct movement codes

The above said mechanical structure, IR & Ultrasonic sensors, actuators, LED, Buzzer actuates during object recognition, intelligent circuits, 12v battery and RF module for wireless communication has been used to built rugged miniaturised robot as shown in Fig.1. The position of robot and object recognition by color and shape using virtual software is discussed in detail in upcoming session.



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VIII. IMAGE PROCESSING

Real-time Robot Tracking and Object Recognition : The purpose of this work is to develop a real-time object tracking LabVIEW program which is robust against such disturbing situations like illumination variation, object shape deformation, and partial occlusion of target images. Object recognition and tracking is carried out in LabVIEW using Vision Assistant Module. Camera is calibrated to acquire image of the entire arena. The resolution is fixed as 644×320 with 14 frames per second. Android phone and Vision Acquisition modules are used to acquire image data. And video is wirelessly transferred to LabVIEW through IP Webcam android app [1, 5]. The particle analysis module is used to recognize and track the robot. On the top of the robot a circle is drawn which is filled with color. This is used to recognize the robot [4-9]. particle analysis algorithm gives the centroid of the particle, i.e here the position of the robot as shown in Fig. 8. The entire arena is mapped to camera resolution. The position of the robot is with respect to the origin of the image which is top left corner.



Fig. 8 Robot and object tracking by image processing

Steps involved in the implementation of the code:

- 1. Thresholding of input image frame to select only the object of interest.
- 2. After thresholding, the image contains some unwanted particles, which can be removed using morphological erosion operation.
- 3. Empty pixels of the object are filled using morphological dilation operation.
- 4. Particle analysis module outputs centroid of the object, which is then used to track the object of interest.
- 5. Above steps are applied for each frame. And subsequently object can be tracked.

The LabVIEW code is shown in Fig. 9. Once the current position of the robot is known, the co-ordinates of the robot are used in Manhatten Algorithm. This algorithm is used to find the path in which the bot move.

Manhatten Algorithm: Initially, the coordinates region of the arena on which the bot can move (white space) is obtained through grayscale morphology. The arena is then mapped as a matrix with the camera resolution acting as matrix dimensions. The coordinates of the white space are then compared to the corresponding matrix index and marked as 1. The regions besides white space are marked as 0.

The matrix is the considered to be a 6x6 matrix (after comparing the size of the bot, arena and camera resolution), with each node (107x70) being the equivalent of the bot size (26cmx24cm). This is implemented through a series of loops and not stored in another matrix. The node is a virtual matrix. As the bot would be traversing the arena, its coordinates would be marked as 0 in the mapped matrix. Therefore, it is necessary to mark the node occupied by the bot as 1 so as to use the algorithm to arrive at a solution. If there is an obstacle present in a particular node, and there is a 0 marked in that node matrix, the entire node must be marked 0 so as to avoid commanding the bot to traverse that area. The



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Manhattan algorithm is used to determine next best node to traverse from the current position of the bot towards the target. This algorithm essentially uses a cost analysis approach where it checks the cost to move to any one of its adjacent nodes (8 in total if all the adjacent nodes are marked as 1). The node having the lowest cost is selected. The midpoints of the bot (which is already obtained through image processing) and the midpoints of the adjacent nodes are stored. Comparing the coordinates of the bot and the midpoints, a horizontal or vertical movement yield 10units and a diagonal movement yield 14units. This forms the first half the cost value. The distance from the midpoint of the node and that of the target is then calculated and added to the node's cost value. The latter is a crude implementation of the actual heuristic used in the algorithm which determines the least number of nodes to reach the target. The reason the actual heuristic was not implemented because it would require massive coding time as this entire process is coded in the MathScript VI in LabVIEW which is the equivalent of a MatLab code. After extracting the midpoint of the least cost node, the bot is then commanded to move in that direction (Either front, back, left or right depending on the least distance to be traversed).



Fig. 9 LabVIEW code for image processing

IX. CONCLUSIONS

Thus we have made object tracking robot with barrier getaway using image processing for miniaturised robotic application which will detect the objects and avoid the obstacles by image recognition technique. This miniaturised model can be used in various applications like defense, hazardous industry for safety, navigation, surveillance and security purposes. The application we have developed with remote computer in that the user gives a command to capture image, access and control remotely .This captured image is stored as destination image. After that user gives command to start the robot which will capture the images of robot and moving object. This newly captured image will be compared with the destination image in LabVIEW-VDM. Comparison will give a conclusion whether the captured image matches with the destination image or not. This system compares the images using region wise comparison. The robot is implemented with wireless communication using LabVIEW-VDM image processing techniques to reach object destination. The future work may be continued to make scaled up robot to use in heavy load requirement. The components used in this unit need to be studied for high temperature application.



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