Design of an IoT Based Autonomous Vehicle with Fuzzy Logic Controller

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Abstract;- **The paper presents a design of partially autonomous vehicle with fuzzy based control . The paper highlights the idea of an autonomous vehicle which has Fuzzy logic based controller and object detection applications . The car will have ultra sonic sensors whose input will be considered as fuzzy variables , it will also a GPS module which will enable the car to navigate from one location to another . The system consists of raspberry pi module which is used for live video streaming over the network which is subject for object recognition using tensor flow . The motive behind the design is to reduce traffic accidents during driving and thus ensuring safety to human life in long term and this supports the automation requirement for semi-large prototype for autonomous vehicle . The car system mainly consists of arduino micro-controller and ultrasonic sensors for collision avoidance and fuzzy based control , Raspberry PI mini computer along with camera is used for object detection and live video streaming over the internet and a Neo 6m GPS module for GPS navigation . The proposed model is gives effective methods for sensor placements and improving efficiency and accuracy. The autonomous vehicle is based on rocker-bogie suspension system with six wheel drive and the work details the responses of motors in form rpm values with respect to various situations .**

I. INTRODUCTION

More than 150,000 people are killed in India as per reports by the government. That is about more than 400 fatalities a day ,which is very higher than countries US who have developed auto markets . Traffic congestion and reduced road infrastructure capabilities are the other challenges that we are facing currently . Driver assistance systems and fully autonomous vehicles can play significant role in reducing these problems. Automation has huge demand due to its purpose of eliminating human effort in day to day tasks . Automated cars are the ones capable of moving around and reaching target destinations with very less amount of human interventions . These vehicles will use a group of sensors to collect data about the environment and analyze it to make necessary changes .The software involved in autonomous vehicles takes data from the sensors and use this data to take real-time decisions . The sensors in autonomous vehicles are required to have high degree of accuracy which is major challenge . This paper deals with autonomous vehicle control with applications of fuzzy logic concepts .Using a micro-controller and a computer which is raspberry pi a real-time feedback control system can be created [1] . The work focuses on developing an autonomous vehicle which can coordinate itself through multiple number of way points while avoiding obstacles on the path .Since object detection is a vital part in autonomous vehicle the paper discuss about object detection methods using deep learning implemented in raspberry pi and Anaconda environment . The paper also discuss on challenges in implementing object detection in raspberry pi mini computer and efficient method of placing sensors to acquire high efficiency .

II. FEATURES

A. Collision Avoidance

The collision avoidance and obstacle detection is achieved by using a multiple ultra sonic sensors (HC -SR04) . The HC-SR04 uses SONAR to detect and determine the distance and object ahead of it . In a HC-SR04 there is two transducers which are , a transmitter and a receiver . The transmitter send out a pulse train signal which may hit on any object and returns the echo which in turn is received by the receiver .The distance of the object is calculated by

$$D=v*(t / 2)$$

Where d is distance ,v is the velocity of sound in room temperature 340 m/s , t is total time . The locations for sensor installations are crucial point when it comes to autonomous vehicle . The sensors should be placed in such a way that it should be able to cover most of the regions surrounding the vehicle . Earlier many of the works done in this platform uses sensors attached to servo motors such that the sensors can rotate 180 degrees on servo and cover most of the area , but the problem with this design is that the servo motor rotations and ultrasound sensors distance calculation on matching up takes lot of time .This affects the efficiency and speed of the vehicle , so it is easy to effective to place multiple ultrasound sensors on various locations such that there angles covers most of the area , this reduces time required for calculating distance to an object compared to servomotor attached ultrasound sensors .

B. Live video streaming and remote access via web server

The car is equipped with raspberry pi with has inbuilt Wi-Fi shield . Raspberry which works on Raspbian operating system can host both simple HTML web pages and other web apps through Apache web server .Using an MJPG streamer the raspberry pi can be used to stream video to the web pages . This can be accessed over the network by typing raspberry pi's IP address and port number .The same page can be used for controlling the car over the page ,using a python script the control commands can be send to the raspberry pi over the internet which in turn control the the actuators which we will implement in future work.

C. GPS navigation

The car can be made to movie from point A to point B by feeding in the longitude and latitude coordinates of the points or locations.This made possible by using a neo 6M GPS module and a magnetometer . The GPS module tracks the current position of the car while magnetometer gives the current heading . When the car encounter with any obstacle it changes the path to avoid collision , it again then reroutes back to original path by comparing and making a matching between target heading and current heading The following logic is applied.

1.Update the course and distance to the target upon

receiving new GPS information

2.If the current destination is reached move to next way

point.

3.Turn the vehicle to desired direction by reading target

heading from the compass

4.Move the vehicle to desired direction and check for any

obstacles

5.Update the current heading , target heading

D. Object Detection using Deep Learning

Object detection is a technique to detect and identify the object from the specific scenes by a certain measure or method .Deep learning based object detection method had region selection done according to some strategy ,feature extraction through convolutional neural network and the classification can be realized by traditional SVM .The object detection models can be divided into (1) Models based on region proposals such as R-CNN, Fast R-CNN, etc (2) Model based on regression such as YOLO ..The deep learning object detection based on region proposal includes two main works: one is the extraction of region candidates; the other is the building of deep neural networks. But these region proposal models where not able to satisfy application requirements due poor real time object detection .Thus model based regression models where

introduced . Since deep learning object detection methods required great network parameters and huge computational algorithms most object detection methods are poor real time in terms of computational power .

In this work object detection was implemented in raspberry pi to check working of object detection in limited computational power . The object detection model was based on tensorflow and opencv . The raspberry model 3 works on raspbian OS which is based on debian , the dependies for tensorflow was installed using python. The raspberry pi was not able to handle the computational requirement of the program and it was crashing instantly , reducing the frame rates per second also did not make much changes hield . Raspberry which works on Raspbian operating system can host both simple HTML web pages and other web apps through Apache web server .Using an MJPG streamer the raspberry pi can be used to stream video to the web pages . This can be accessed over the network by typing raspberry pi's IP address and port number .The same page can be used for controlling the car over the page ,using a python script the control commands can be send to the raspberry pi over the internet which in turn control the the actuators which we will implement in future work

III. PROPOSED MODEL

A. Control loop formulation

The proposed model consists of computer vision algorithms which is used for object detection and video transmission with internet . Raspberry PI and arduino are the devices to implement the prototype. The video streamed by raspberry pi can be accessed by user over the internet via a browser.The raspberry pi which can be used stream the video to the user over the internet can be used for object detection and classification in further stages . With the upcoming of deep learning technology object detection has seen significant growth from traditional methodologies . Tensor flow library which is a machine learning library developed by Google to implement deep learning methodologies . The raspberry pi can be equipped with object detection in real time from raspberry pi camera by incorporating tensor flow library into the same .

Once an object is detected by any of the sensors the ,the distance and further calculations are done by arduino controller . Based on the position of the object the arduino will give command to respective motors for rpm change thus the vehicle will have change in direction or speed .The vehicle consists of four different motors which control the respective four tires, thus by controlling one or more motors at the same time the arduno will be able to control the direction and speed of the car at the same time . The gps module will be used to give target heading for the car. (Figure 1).

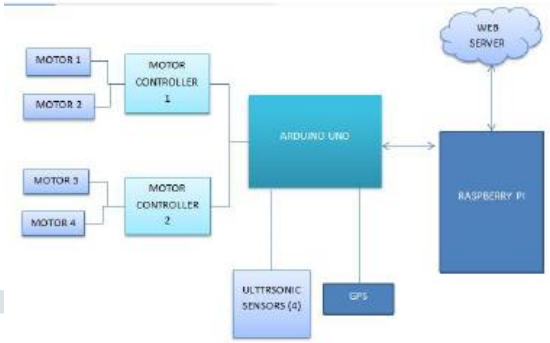

Fig. 1. Architecture

B. .Fuzzy Logic Controller

The autonomous car has sensors which continuously read values from the environment and the environment is dynamic environment objects wont be in the same position as the car is moving Since the autonomous car has a very dynamic environment it is required to have very quick to react algorithm .A fuzzy logic based system was seemed to be suitable for this as the general control rules is sufficient to run the car in those environments .

In fuzzy logic a single output is determined by a set of rule . Fuzzy logic is different from traditional logic like where digital 1 or 0 is produced. Fuzzy can analyse more detail on a certain condition and make the final decision on the output. . Various Smart home scenarios are identified and implemented.

Here the input is the taken as reading from the ultra sound sensor,which ranges from 0 to 100 cm. We convert the reading from the sensor in cm unit by D=v*(t / 2) So based on the distance reading from the sensor we can determine if it is CLOSE and COLLISION or FAR . On a single sensor which is placed in front of the vehicle will be used to detect distance of object in front ,with following logic such that if distance < 50 cm then slow down and if distance < 10 cm then stop . If the distance is above 50 cm then we have a clear path ahead .Based on this feed the controller will give command to the motor driver to reduce the rpm of the motor and thus reduce speed.Since using only one sensor was not efficient so there is two more sensor placed on sides such a way that one is facing north-east and other is facing north-west

IV. PROPOSED METHEDOLOGY

After the arduino micro-controller is the decision making system . Based on the sensor values from different sensors the controller takes specific actions . The arduino sets direction of the car on specific situations by controlling motors on both sides via motor drivers .Meanwhile the raspberry pi camera will stream the video to a web server through raspberry pi .Object detection techniques can be implemented in the raspberry pi .GPS module attached will give the current location and along with magnetometer it will give the current heading and error in degrees from the target heading .

Based on the distance values from the sensor the system decides how to react for specific situations . A set of rules is given for the system on which can take the specific actions .

The crucial rules includes
Rule 1 => If A is Collision and (B is collision or B is Close or B is far)
Then take a hard right
Also,
Rule 2 => If B is collision and (A is Close or A is far)
Then take a hard left
Also,
Rule 3 => If A is close and (B is close or B is Far)
Then take a right
Also
Rule 4=> If A is far and (B is close)
Then take a left
Also,
Rule 5=> If A is far and (B is far)
Then go Straight
Here, A = fuzzy value of the left sensor ,
B = fuzzy value of the right sensor.

V. LIST OF COMPONENTS

Raspberry PI

Raspberry PI which is basically a mini computer that runs on Linux OS . Raspberry PI model B+ has 1 GB DDR2 SDRAM and 2.4 GHz .It is equipped with wireless LAN, Bluetooth ,HDMI and USb ports . The raspberry pi has has a CSI camera port for connecting raspberry pi camera .Raspberry pi being a mini size computer equipped with wireless capabilities can be used for wireless video streaming and object detection using deep learning .

Motor Driver/ Motor Shield

The Adafruit Motor Shield is a quick way to control DC motors and step up motors .A single motor driver can run up to 4 bi-directional DC motors with various speed selection .It has L293D chip set that provides 0.6A per bridge with thermal shutdown protection and can run motors on 4.5VDC to 25VDC .In the model it is required to use at least two motor drivers such that we can control four different motors at four tires respectively .

Neo 6m GPS Module

The Neo 6M GPS module is arduino and raspberry pi compatible global positioning system module which can give the position,time and speed . This is used to identify the location of the car with longitude and latitude coordinates

TABLE I. GPS MODULE CONNECTIONS

No	NEO-6M GPS Module	Wiring to Arduino UNO
1.	VCC	5V
2.	RX	TX pin (as defined in the software serial)
3.	TX	RX pin (as defined in the software serial)
4.	GND	GND

Arduino UNO :-

Arduino UNO is a micro controller board with fourteen digital input-output pins of which six of them can be used as PWM pins, also it had six analog pins ,a usb serial connection, power jack . The code which is based on C language written in arduino IDE can be uploaded/modified easily by the us

VI. RESULTS AND DISCUSSION

The model constitutes of an arduino and raspberry pi controllers which is used to implement a fuzzy logic based autonomous vehicle .The live video stream from the raspicam is accessed to laptop via raspberry pi web-server and subjected for object detection using tensorflow . Initially the plan was to implement the object detection in the raspberry pi but due to computational constraints of the raspberry pi the program was crashing . The multiple ultrasonic sensors placed in specific locations of the car is used to determine distance form the obstacles, based on the readings from the sensors the system will take decisions for specific situation. The sensors are placed in such way that the can cover maximum area surrounding the car also during the work it si noted that using a servo motor for rotating ultrasonic sensor is increasing time for detection . The controller uses a fuzzy logic modeled algorithm to take specific decisions according to various conditions . The raspberry pi enabled camera can be used for .Various deep learning methods has compared and studied for object detection Using tensor flow ,object detection can be implemented in raspberry pi computer which runs on Linux OS but this requires lot of computational power that at times raspberry pi cannot match with .

Module 1:

The live streaming from the raspberry pi requires the raspberry pi camera to be enabled in the raspberry pi configuration . The following commands can be used for ifconfig - can give the ip address of the raspberry pi . If the pi is connected to Wi-Fi network then ip can be obtained in the wlan0 section . Here our raspberry pi's ip address was

192.168.43.181.

Python3 Raspberry pi_live_stream.py command can be used in the command interface to enable the live streaming . This python file will start the live streaming .

This can be accessed via any device connected in the same network in which pi is also connected . The web server is can be accessed by typing raspberry pi's ip address along with port . Here the port used was 8000 , so the address is 192.168.43.181:8000 . The range of the stream is the max range of the Wi-Fi router in which the devices are connected

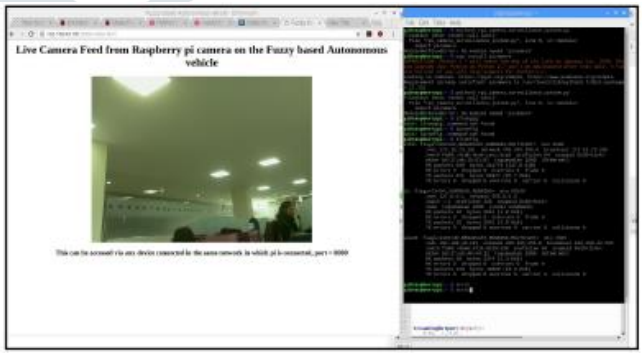

Fig. 2. Raspberry pi live camera feed & ip address of the pi

Module 2 -GPS

The GPS module which uses uses satellite up-link to determine the location of the device by tracking latitude and longitude . Since the Neo 6 M gps module connect with multiple satellites , this is able to give information on Altitude , Longitude ,Latitude, Speed and distance . The GPS module connected to arduino can give this formation to the laptop or mobile via bluetooth serial communication . A HC-05 Bluetooth module is used as communication device between the arduino and computer .

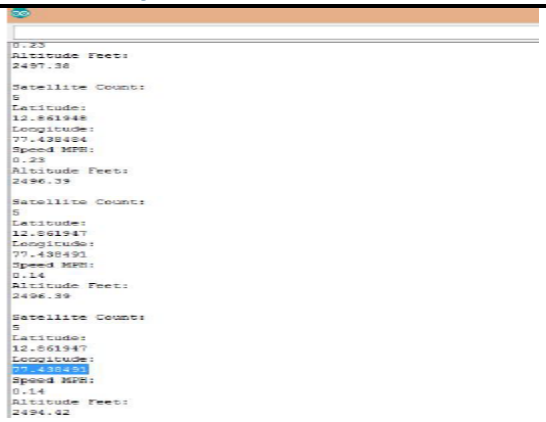

Fig. 3. GPS module output

Module 3 -collision avoidance

The primary objective is to make effective control response on the motors based situation awareness by reading sensor values

	SENSOR READINGS (Distance)		MOTOR 1 (RPM)	MOTOR 2 (RPM)	MOTOR 3 (RPM)	MOTOR 4 (RPM)
1.	Left Sensor -	5 cm	0	0	0	0
	Right Sensor -					
	Front Sensor -					
2.	Left Sensor -	Above 40 cm	90-100 rpm	90-100 rpm	90-100 rpm	90-100 rpm
	Right Sensor -					
	Front Sensor -					
3.	Left Sensor	20 cm	50-60 rpm	50-60 rpm	50-60 rpm	50-60 rpm
	Right Sensor					
	Front Sensor					
4.	Left Sensor	10 cm	10 -20rpm	10 -20 rpm	10-20rpm	10-20rpm
	Right Sensor					
	Front Sensor					
5.	Left Sensor	Above 10 cm	- 5 rpm (reverse direction)	10-20 rpm	- 5 rpm (reverse direction)	10-20 rpm
	Right Sensor	5 cm				
6.	Left Sensor	5 cm	10-20 rpm	-5 rpm (reverse direction)	10-20 rpm	-5 rpm (reverse direction)
	Right Sensor	Above 10 cm				
7.	Left Sensor	20 cm	50-60 rpm	90-100 rpm	50-60 rpm	90-100 rpm
	Right Sensor	Above 20 cm				
8.	Left Sensor	Above 20 cm	90-100 rpm	50-60 rpm		
	Right Sensor	20 cm				

Here motor 1 is back left wheel and motor 2 is back right wheel .
Also motor 3 is Front left wheel and motor 4 is Right front Wheel .
Note : The rpm values are highly depended on the voltage , here battery's used where of 9v and 12v specifications . As per the motor specification 12 v batteries gives best performance . From the table the following scenarios can be understood based on sensor readings
Case 1 : - Serial number 5 represents Hard left scenario where obstacle is very close in the right side
Case 2 : Serial number 6 represents Hard Right scenario where obstacle is very close in the left side
Case 3 : Serial number 3 represents Slight left scenario where obstacle is close to the right side
Case 4 : Serial number 4 represents Slight left scenario where obstacle is close to the right side (Table 2)
Serial number 1,2,3 and 4 gives various situations based on distance of obstacle/object from the vehicle and the response of motors with respect to it . The hard left and right can be achieved by rotating set of wheels on the sides in opposite directions . Other movements are achieved by making variations in the rpm.

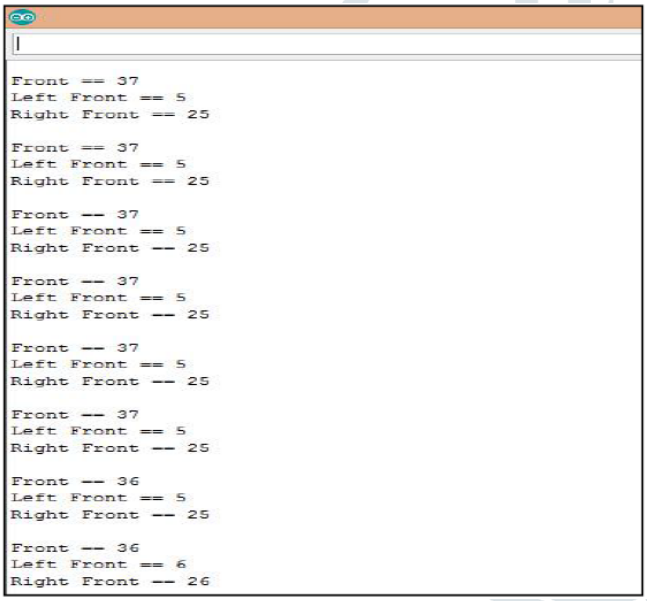

Fig. 4. Sensor readings

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