Prototype Implementation of IoT based Autonomous Vehicle on Raspberry Pi

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Abstract--- *The autonomous vehicle concept all started with the advancement of driver assistance and has extended to a new level that now it is semi-autonomous and autonomous vehicle. The main objective of this work is to inculcate a new feature to Advanced Driver Assistance System (ADAS) which in turn lead to development of semi-autonomous/autonomous vehicle.*

In this connection an attempt is made to integrate obstacle detection, vehicle to vehicle communication and voice control module to provide the necessary control to the vehicles using Raspberry Pi processing unit.

A unique and novel approach in the above work is controlling the vehicle through intranet/internet by using concept of Internet of Things (IoT). However, concept of IoT is used to connect various devices with help of protocols for communication.

Keywords--- ADAS, Raspberry Pi, obstacle detection, vehicle to vehicle communication, IoT (Internet of Things).

1. INTRODUCTION

Many industries follow Software Development Life Cycle, or SDLC to design the system. SDLC is a process used to develop software. There are different stages or phases within the Software Development Life Cycle and in each phase, different activities take place.

The V-model is a graphical representation of the System Development Life Cycle (SDLC)¹. The V represents the sequence of steps in a project life cycle development and also produced the product development as shown in figure 1. In the "V-model", left side of figure shows decomposition of requirements and right side of figure shows integration of parts.

Requirements need to be validated first against the higher level of user needs². The easiest way is to say that verification of "V" is always against the real world².

Need of Autonomous Vehicle

In the past few years, as a result of the number of traffic accidents plaguing the country and the devastating injuries and fatalities that resulted from them, a greater push has been made in the sphere of technology to make vehicles safer, drivers more aware, and accidents less likely. Alongside other technology that has emerged during this time is the idea of self-driving vehicles, an advancement that seems like it belongs in a futuristic movie. The reality is that self-driving vehicles aren't that far off, actually, but the debate over whether they increase or decrease safety ranges on.

The automotive industry all started with the invention for the improvement of the technology in the vehicles and its safety. But this led to the concept of autonomous vehicles soon.

The autonomous vehicle technology offers social welfare- reducing crashes. The crash is due to both human and machine error, but most of the cases it is due to human (driver) error. So by making the vehicle semi-autonomous or autonomous the potential threats caused by the driver error are reduced. Another advantage of it is that it increases mobility for disabled people. Autonomous navigation broadly refers to any technique, approach or method which can be utilized to navigate a vehicle safely on its own in a static or dynamic environment without any intervention by a human controller. Advanced Driver Assistance System (ADAS) technology exists at different levels of active assistance and is being introduced in overlapping stages. ADAS containing different subsystems helps the vehicle to drive without intervention of human.

This paper is structured as follows: Section 2 describes the silent features of the Raspberry Pi model B+ and its hardware software interactions. Section 3 describes the implementation steps for building the prototype. Section 4 describes the silent features of Voice control module which helps in navigation of the vehicle. Section 5 reviews the theory of sensors and actuators and different types of sensors and actuators used for building this prototype. Section 6 describes the concept of vehicle to vehicle communication using ZigBee module. Section 7 deals with the results and Section 8 concludes the paper with a brief summary.

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2. RASPBERRY Pi - THE ADVANCED

CONTROLLER

Raspberry Pi

The Raspberry Pi, shown in figure 3, is a credit-card sized computer that plugs into Television (TV) and a keyboard, which can be used for many of the things that our average desktop does. Figure 2 shows the software and Hardware interaction with Raspberry Pi.

The Raspberry Pi gets the first half of its name from a long-standing tradition of using fruit to name new computing systems from classic microcomputers like the Acorn, Apricot and Tangerine to more recognizably modern brands including Apple and BlackBerry but the second half comes courtesy of the Python programming language.

Salient Features of Raspberry Pi B+

- Broadcom BCM2835 System on Chip (SoC) processor with 700MHz ARM1176JZF-S core. 512MB RAM.
- Video core 4 GPU (Graphic Processing Unit) supports up to 1920x1200 resolution.
- 5 MP Camera module capable of full HD video at 30fps.
- Micro SD card slot, 10/100Mbps Ethernet port, 4 x USB2.0 ports, HDMI, audio/video jack, General Purpose Input output (GPIO) header, micro USB power port, DSI and CSI ports.
- Dual step-down (buck) power supply for 3.3V and 1.8V.
- It is designed to run an operating system called GNU/Linux.
- Any language which will compile for ARM can be used with the Raspberry Pi, here Python is used.
- The General Purpose Input Output (GPIO) header has grown to 40 pins, while retaining the same pinout for the first 26 pins as the Model A and B.

3. IMPLEMENTATION

The system will be designed using object orientated methods. The hardware and software requirements are determined, and their interactions are understood to fulfill these objectives.

The methodology will employ the following tools and technologies are as follows

- Raspberry Pi Model B+.
- Ultrasonic sensor.
- Speech recognition chip HM2007.
- Motor Driver.
- Python 2.7 32 bit.
- ZigBee module

Block Diagram Description

The block diagram shown in figure 3 the different part of the autonomous vehicle as individual subsystem working, which finally get together to form an efficient autonomous vehicle.

The input in the form of voice is taken from the user and then fed into the voice recognition system which compares

the given input value with the already stored value and gives the respected output to the controller, which then computes the required data. Any obstacle which comes in the way is detected by the ultrasonic sensor and depending on the distance, decision is taken.

Interfacing of Sensors and Actuators

The Ultrasonic Sensor, IR sensor and voice recognition module acts as sensors. DC motors and buzzer used as the output devices i.e actuators. The presence of obstacle is detected by the ultrasonic and IR sensor, accordingly the functions of dc motor and buzzer takes place.

Figure 5 represents the interfacing of sensors and actuators to the raspberry pi processing unit.

Flow Chart

The algorithmic approach is followed in order to achieve the objective of this work. i.e, the flowchart shown in figure 6 gives the clear scenario of the implementation process. Any obstacle which comes in the way is detected by the ultrasonic sensor and depending on the distance, decision is made. And depending upon on this decision the motor wheels are turned accordingly.

4. VOICE CONTROL MODULE

Microphone takes the analog voice commands and sends it to voice recognition Chip (HM 2007) shown in figure 7, in the form of electrical signal. The chip contains an analog front end, voice analysis, recognition, and system control functions. The chip may be used in a stand-alone or connected CPU. The advantage of this stand-alone Speech-Recognition Circuit (SRC) is its programmability. We can program and train the SRC to recognize the unique words that to be recognized.

Salient Features of HM 2007

Some of the silent features of HM2007 are as follows:

- 12 V single power supply.
- A microphone can be connected directly.
- Multiple –chip configuration is possible.
- Maximum 1.92sec of word can be recognized.
- Maximum 40 words can be recognized for one chip.
- Response time is less than 300ms.
- Easily interfaced to control external circuits.

5. SENSORS AND ACTUATORS

Sensors and actuators play a critical role in determining automotive control system performance.

Sensor is a device that receives a signal or stimulus and responds to it in a distinctive manner. Sensor acts as a transducer which converts received signals to that form which can be interpreted by the processor.

In the present work, mainly two sensors are used,

- Ultrasonic sensor
- Infrared ray sensor

An actuator is a mechanical device that converts the controller output signal into some form of action. This action may be a change in velocity, position, direction.

Usually actuators are fitted with amplifiers, to convert low level control signals into strong signals sufficient enough to drive the actuator. Two actuators used are as follows,

- DC motor and Buzzer

Ultrasonic Sensor

The HC-SR04 ultrasonic sensor shown in figure 9 is used to measure distance of an object. It provides good accuracy in an easier way.

Specifications:

- Working Voltage : 5V(DC) .
- Static current: Less than 2mA.
- Output signal: Electric frequency signal, high level 5V, low level 0V.
- Sensor angle: Not more than 15 degrees.
- Detection distance: 2cm-450cm.
- High precision: Up to 0.3 cm.
- Input trigger signal: 10us TTL impulse.

The major goal of obstacle detection is to ensure that the path ahead of the vehicle is free from the obstacles.

Specifically there are two goals:

- Obstacle detection at the right time.
- Correctly identify obstacles.

Ultrasonic sensor works on the principle of SONAR (Sound Navigation And Ranging) which evaluates the object by using radio waves. It generates high frequency sound waves and evaluates the echo which is received back by the sensor.

To start measurement, Trigger of sensor must receive a high pulse of 5V for at least 10us, this intern initiates the sensor to transmit out 8 cycle of 40kHz ultrasonic burst and wait for the reflections as in figure 10. After detection of ultrasonic frequency from the receiver, the Echo pin will be set to high, 5V. To obtain the distance, measure the width (Ton) of Echo pin.

$$\text{Distance} = \text{speed in air} * \text{time taken for echo to return} / 2$$

$$= (3.4 * 10^8) * (\text{time} / 2)$$

Infrared Ray Sensor

An infrared sensor is an electronic device that emits in order to sense some aspects of the surroundings. An IR sensor as in figure 11 can measure the heat of an object as well as detects the motion. This type of sensors measures only infrared radiation, rather than emitting it that is called as a passive IR sensor.

DC Motor and Buzzer as Actuators

Input from the various sensors is taken and processed by the Raspberry Pi as illustrated in figure 5. If any obstacle is detected by the Ultrasonic and IR sensor then the corresponding movement of the motors is actuated and at the same time buzzer starts to make sound. In normal conditions the movement of the motors takes place according to the instruction given through the voice recognition module.

6. VEHICLE TO VEHICLE

COMMUNICATION

ZigBee module is used for vehicle to vehicle communication and the two ZigBee must be paired with the same baudrate (for Ex: 9600) with X-CTU Software. Attach the two ZigBee's to the two dongle's and connect one pair on the USB port of the Raspberry Pi as shown in figure 12. Connect the other pair to the USB port of a computer or a Laptop. Wireless data transfer from Raspberry Pi to Laptop using ZigBee, the system should have hyper terminal software to transmit the data.

ZigBee Module

ZigBee modules are used to build a Personal Area Networks (PAN). It is a data transferring communication device, which facilitates communication between the controllers, computer systems etc. with a serial port. Its transmission distance is limited to 10–100 meters line-of-sight. ZigBee device is used for long distance communication.

ZigBee is usually preferred for low data rate applications. Its main applications are in the field of wireless sensor network based on industries as it requires short-range low-rate wireless data transfer. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless networks.

Here we make use of an interface of ZigBee with Raspberry Pi for a proper wireless communication. Raspberry Pi has got four USB ports, so it is better to use a ZigBee Dongle for this interface.

7. RESULTS

The proposed aim of the project is to build a functional vehicle which can navigate on its own, which can be used in many applications. Figures 13, 14, 15, 16 and 17 shows the step wise building of the prototype with respect to raspberry pi, ultrasonic sensor, voice recognition module and DC motors.

8. CONCLUSION

A small attempt is made in developing prototype model for semi-autonomous/autonomous vehicle using Raspberry Pi which is more than a processor which is used in present work for integrating and controlling the different peripheral components such as display, sensors, cameras and wireless communication units.

The algorithms for obstacle detection, vehicle to vehicle communication and voice control module are successfully implemented to provide the necessary control to the vehicles using Raspberry Pi processing unit.

Further ZigBee module is being communicated with two different devices (laptop and raspberry Pi) to make a prototype of Autonomous Vehicle with the help of IoT.

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Figure 2: Software and Hardware interaction with Raspberry Pi

Figure 3: Raspberry Pi B+ Development Kit

Figure 1: Schematic of V- model

Figure 4: Prototype Block diagram

Figure 5: Interface of Sensors and actuators

Figure 6: Flow chart of the Obstacle Detection and Motor Control

Figure 10: Timing Chart of Ultrasonic Sensor

Figure 11: Working of IR Sensor4

Figure 7: Voice Recognition Module HM2007

Figure 12: ZigBee module With Raspberry Pi5

Figure 8: Block diagram of signal flow through sensor and actuator

Figure 9: Ultrasonic Sensor

Figure 13: Raspberry pi and H –Bridge (L293D)

Figure 14: Voice recognition module (HM2007) and Motor

Figure 17: Prototype of autonomous vehicle (side view)

Figure 15: Raspberry Pi and Sensors, actuators

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Figure 16: Prototype of autonomous vehicle (top view)

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