Autonomous Ground Vehicle

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***Abstract*—In today's world, science and technology is breaking the limits and proceeding towards the autonomous mechanism, in which the Artificial Intelligence is fueling the scenario and stretching its legs in almost every field of life. After looking into this phenomenon, a system is needed which can help us on roads too, for going to the sensitive areas where sending a human is a life threatening risk. So, some autonomous vehicle would be needed which can serve in those conditions by working for mankind and taking the decisions at its own to get the job done which was specified to it earlier.**

This paper is based on making such kind of ground vehicle which can serve us by going to the remote places at its own avoiding the obstacles in the route, and making it decisions according to the conditions with the help of the Artificial Intelligence provided to it. The major applications for AGV are in defense related areas or cargo controlling system.

***Index Terms*— Autonomous Vehicles, Bipolar Transistor switches, DC Motor drives, PWM, Image Object detection, Microcontrollers.**

I. Introduction

Implementation of an Autonomous Ground Vehicle (AGV) is a step towards making a ground vehicle that can work at its own, which can make decisions and do the tasks which we require from it to be done. It would be a vehicle which can process the data in real time and take the respective decisions on the basis of that processed data. The paper is based on integration of different hardware and software modules and their interaction to produce an efficient outcome.

The concept of autonomous vehicles begins in 1977 with the Tsukuba Mechanical Engineering Lab in Japan. The vehicle, at that time achieved the speed of up to 30 km/h by following white markers on a clearly marked course.

In the decade of 80s, a vision guided robot was made by Mercedes-Benz, headed by the team of Ernst Dickmanns at the Universität der Bundeswehr in Germany [1], which achieved the speed of 100 km/h.

In 1994, the robot vehicles, named Vita-2 and VaMP of Ernst Dickmanns [2] and Daimler-Benz of UniBwM drove the vehicles more than one thousand kilometers on a highway in standard heavy traffic at speeds up to 130 km/h, although it was partially autonomous, with human involvement.

The three US Government funded military efforts are currently in progress, known as Demo I, Demo II, and Demo III. Demo III [3, 4] showed the capability of unmanned ground vehicles to steer a long distance of difficult off-road path, avoiding obstructions such as rocks and trees.

In 2008, General Motors stated that they will begin testing driverless cars by 2015, and they could be on the road by 2018 [5, 6]. There are also some mathematical calculations done in this regard in 2012. MATLAB/SIMULINK is used for an autonomous vehicle for obstacle avoidance [7]. Previously another work for lane detection in autonomous ground vehicle is done using Hough Transform and RANSAC Algorithm [8-10]. But the method presented in this paper is different to that and works in real time. The information from AGV can be transferred on low and reliable power transfer with data hiding and encryption techniques using UWB [9-13]. Interference cancellation can also be utilized using STBC algorithms [14]. Vehicles having two wheels can be balanced using the techniques as provided in the literature [15].

The basic idea of AGV is to design a vehicle that would be autonomous. Meaning that, it can go to the places where sending a human would be a life threatening process and do the tasks which we specify it to do. It can take decisions at its own using the camera as an input device to acquire the video of the road, then this video is sent to the onboard computer system which processes the desired frame (image) of the video in real time and takes the decisions on the basis of that processed image that whether the space in front of the vehicle is a clear way or is it a hurdle. If the system finds it as a hurdle, then it changes the route of the vehicle and switch to a way where the track is clear for the vehicle to move forward and so on.

The vehicle is designed on a simple toy car of approximately 2x3 feet, having a computer system onboard with a camera, a pair of batteries, microcontroller circuitry, motor driver circuitry, and motors to drive the car.

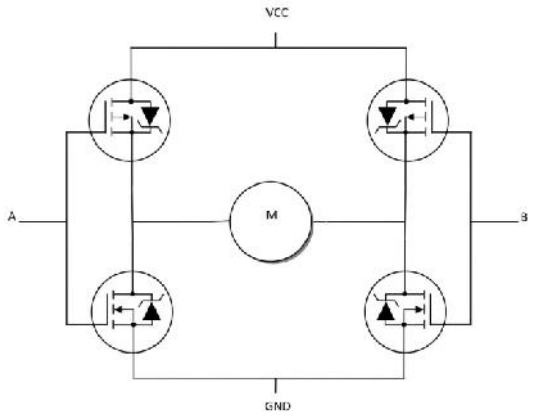
The AGV required the programming skills to be utilized in the processing of the image and as well as for the micro controller. The programs for Digital Image Processing (DIP) are written in MATLAB. The C language and VMLAB software is used for the programming of the microcontroller. The AGV also required the skills of circuit designing using electronic components; to design a biasing circuit of a microcontroller, the motor driver circuitry, and circuitry for interfacing of the modules.

The vehicle is having a camera in the front which acquires the video stream and sends it to the onboard computer system which then provides that to the Image Acquisition Toolbox (MATLAB). The video stream is 15 frames per second. We don't fetch all of the frames; rather we select alternate frames to get processed. This image is in RGB format which is then converted to grayscale, then this image is converted to pure black or/and white colors only by using specified threshold level. Then the processing is done on this image with defined algorithm. On the basis of this processing, the decision is made that whether the image contains an obstacle or a clear track in front of the vehicle. Then the signal is sent to microcontroller that whether to turn right or left or proceed moving straight. Then the microcontroller take the action against the given signal from the computer system which eventually drives the different motors and keep the vehicle running on road.

II. H-BRIDGE

H-bridge is the circuit usually used for rotating the DC motor in both directions. In this case; it is used for the operation of PWM (Pulse Width Modulation) to control the DC motor in both directions. By adding PWM, we can synthesize more sinusoidal waveform and drive the motor accordingly [16].PWM is implemented in software or it is burned on the microcontroller, but for actual operation on hardware, some physical components or the circuitry is required for driving the motor on different speeds and on different directions (Clockwise or Anticlockwise). Normally it is a circuit comprising of four switching transistors (i.e. usually BJTs or FETs) and load is connected in Centre of the circuit elements

Normally H-bridge circuitry is made on buffer based technique, but this technique is not efficient in most of the cases. As PMOS passes a strong Logic1 and N-MOS passes a strong Logic 0 [17]. For that reason we replaced this buffer based technique with inverter based technique which gives better result. In this technique if logic high (Logic 1) is needed then it drives from P-MOS and logic low (Logic 0) drives from N-MOS. Its circuitry is shown in Fig. 1.



Inverter based H-Bridge

MODES OF INVERTER BASED H-BRIDGE

A	B	Motor State
0	0	Stop (But Ignored)
0	1	Clockwise Direction (Assuming Clockwise)
1	0	Anticlockwise Direction (Opposite to assumed)
1	1	Stop

III. WORKING

The idea to make this AGV was to develop an unmanned vehicle which can take decisions at its own but perform the tasks which we tell it to do for us. Before this, the Autonomous Ground Vehicles were developed but their scope was limited. i.e. some were designed using line following technique and for this, they were using different types of sensors such as Infrared or Ultrasonic sensors. In AGV a new method is introduced i.e. by using image processing. No such sensors are required in this case which are less efficient. Image processing helps in different ways. Our vehicle works on images and takes decisions in real time; by using and processing these captured images.

A design is essential for implementing any technique. 1st of all a design was developed that what will be the parts of AGV. For this purpose a small car structure is taken so that a design can be made on small scale, this structure will have following major items mounted on it.

- A camera
- An image processor
- Motors
- Batteries
- Decision implementation device

In AGV, the field of image processing is involved so for this purpose an imaging device is necessary which provide the images on the basis of which the decision will be taken. A camera is mounted on front side of the car which captures the images of the path. All of the system is partially rely on this camera and its output i.e. the images produced by it.

An image processor (a system which performs processing on an image) is also necessary for the processing of images and taking measures against any of the happening. For image processor a laptop system is used. An onboard laptop is the most feasible and easily implementable solution for the basic goals of the AGV. A laptop system does not put any extra heavy weight on the structure and it can work quite efficiently for basic tasks so it is preferred.

For driving the structure some machinery was required. For this purpose simple DC motors (12V, 6A) are used. Two motors are used in AGV, one is for rotating the steering wheel

(either left or right) and the other one is used for moving in forward or backward direction. Acrman's drive technique is implemented in this structure for the AGV.

The design will require power for the motors to drive the vehicle, and to operate the circuitry of the system. For this purpose two batteries are used, each of 12V/7A; so that it can drive the load easily. One battery is used for motors and the second one is for circuitry.

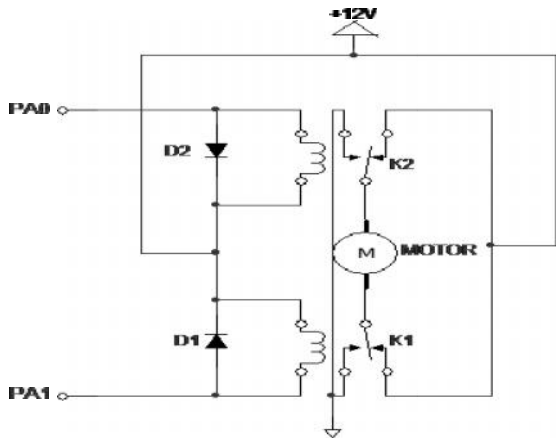
A decision implementation device or module is also required to implement the decisions that image processing system asks it to implement on the design. Microcontroller is used for this operation. It takes input from laptop that is on board and then implements that decision accordingly.

Driving motors was an initial and central task for the driving of the AGV. Both of the motors were controlled using different technique. The methods used were:

- Using relay
- Using H-bridge

A relay is a component operated as electrical switch. Relay normally use electromagnet to operate its functionality as switch It has a SPDT switch; when signal comes on coil of the relay it on the switch otherwise the common connection is connected with NC pin of SPDT switch.

In AGV, relays are used to control the front motor (which is used for rotating the steering wheel). Relay based circuitry is made for motor to rotate in both directions. Circuit for that purpose is very simple and is shown in Fig. 2. Relay coil is connected to the pins of microcontroller and on the other hand, it is connected to the front motor which is used for rotation.



Circuit for relay based controlling

For controlling the rear motor, PWM was implemented on it because it has to be driven on different speeds. The issue in controlling the motor was that, implementation of PWM needs extra hardware which in this case is H-bridge. So H-bridge is used for the control of speed and forward/backward movement. At one side, H-bridge is connected to the motor and on the other hand it is connected to the pins of microcontroller.

Normally available H-bridge circuitry is made on buffer based technique which is not very efficient. It does not provide good result where low voltages and high currents are required. If we have used this kind of H-bridge in our circuit then the high current flow in the MOSFET used in H-bridge will burn the whole circuitry. For this issue, an inverter based H-bridge is used that solves this issue and it can also work on the scenario where high current and low voltages are required. It also does not affect the speed of AGV. A circuit of inverter based H-bridge is shown in Figure-2 previously.

Camera is the key element for AGV whose decision based on Image Processing. It is used to capture the images of the path and send to the image processing device and then decision can be taken according to that data.

Digital cameras have built in hardware which deals with its mode of operation. It can work in outdoor or sunny environment easily and gives fine result. Although a digital camera have a frame rate less than the frame rate of web camera but its images are more stable and provides better results than web camera. However, there are some digital cameras available in market which gives better frame rate than the current camera attached to our AGV. So in our case, digital camera is used to provide a video stream to the laptop that is attached to AGV and rest of the processing would be done by the laptop and software installed in it.

A computer system is used for the processing on the images and taking measures against each image that whether the AGV should continue moving on the same track or change the track. A laptop is on board which receives the images from the camera and then uses MATLAB, which does processing on the image and then on the basis of that image it takes any decision. According to decision then the system delivers signals to microcontroller which then takes any further action.

A microcontroller is used for the implementation of decisions that were made by the computer system. Atmel ATMEGA 16 microcontroller is used for this purpose. Microcontroller takes the signal from the laptop's parallel port; this signal tells the microcontroller that what to do and how to drive the motors of AGV. One port of microcontroller is connected to the laptop's parallel port for taking the signal. Among the rest of the three ports, one port is connected to relays for controlling the rotation of AGV, one is connected to one pin of parallel port for synchronization purpose and the last port is connected to H-bridge and the H-bridge is connected to the motor which drives forward or backwards. Diagram of Parallel port and microcontroller interfacing is shown in Fig. 3.

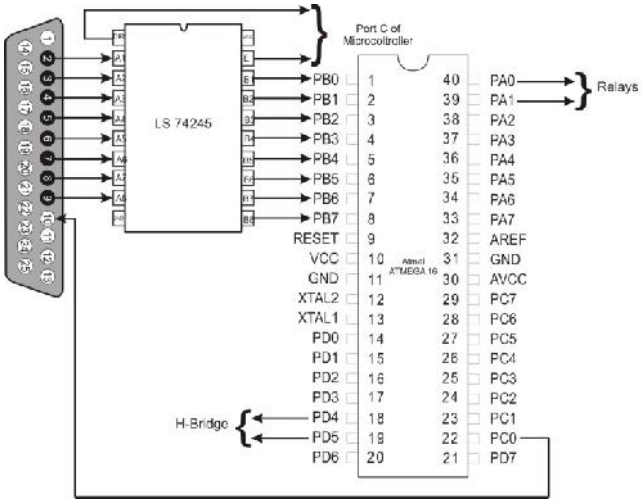
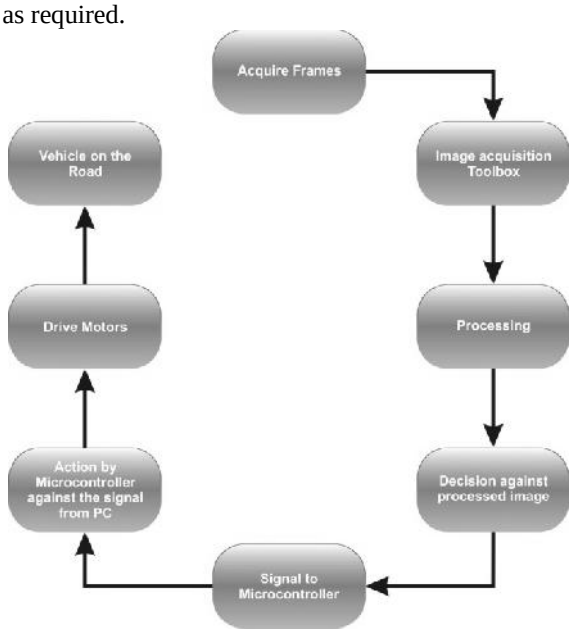


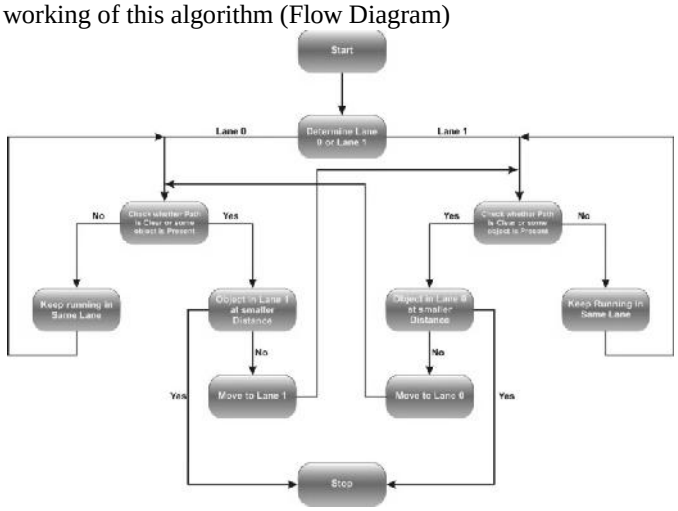
Diagram for parallel port and microcontroller interfacing

Working of hardware can be understood from Fig. 4. It shows that generally how this system works. First of all, the camera acquires frames, or in simpler words the video stream of the path or anything on its path. Then it sends that video stream to the laptop with which the camera is attached. In laptop, MATLAB's image acquisition toolbox processes on that image and on the basis of that, takes decision that what should AGV do? It sends signal to microcontroller through the parallel port and then microcontroller takes action against that signal and drive motors accordingly. And as a result AGV works as required.



General working of AGV

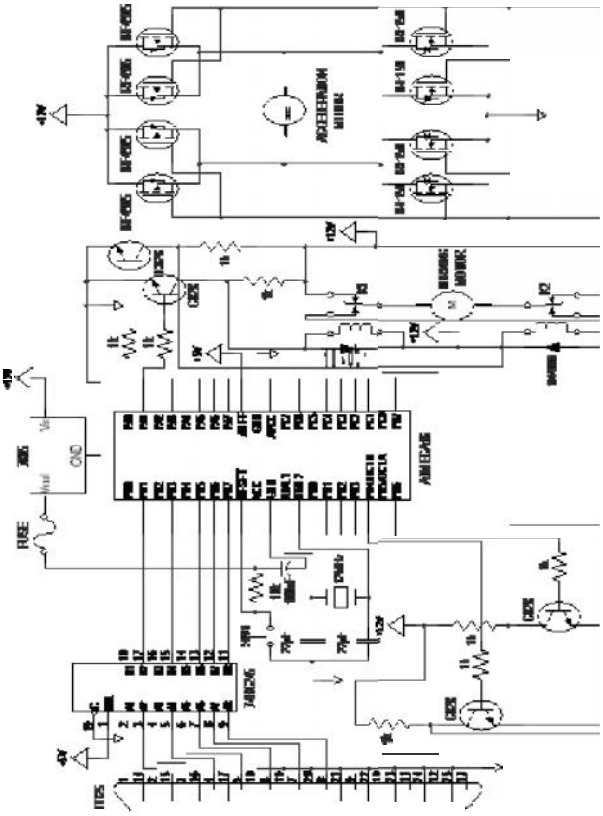
MATLAB is used for the purpose of processing on the acquired images. It takes video from the camera which is attached to laptop's Universal Serial Bus (USB) port. It then fetch some frames from that video and does processing on them using certain commands and then implements the algorithm for object detection. The AGV works on the decisions taken by the MATLAB. First of all, the AGV starts and detects the first image, after processing that image it decides that in which lane it is currently residing, whether its Lane 0 (the right lane) or Lane 1 (the left lane). Suppose it is in lane 0 currently. It will continuously check that whether the path in front of the vehicle is clear or some object is present there using the pre-defined algorithm. If the path is clear then it will keep on moving on the straight path but, if the path is not clear and some object is present in the path then it will move to the next lane i.e. lane 1 or left lane. If there is again some object at lesser distance so that it cannot turn then it will stop, else it will do the same job as done in lane 0. The only difference will be that when there is any other object in that lane then it will move to lane 0 from lane 1. Fig. 5 shows the working of this algorithm (Flow Diagram)



Flow Diagram of software algorithm

Object detection is also done by using the MATLAB software. For object detection a simpler algorithm is used which is enhanced for the advanced tasks. A small mask is made which will monitor at a particular place in image. This mask is set to a particular place on the image and will monitor the path. If any object gets into the path then the values in mask will change and hence the object will be detected.

For hardware designing a Printed Circuit Board (PCB) is made. A schematic of Microcontroller circuit is shown in Fig.6.



Schematic of Microcontroller circuit in AGV

IV. Applications

The scope of AGV is not limited to one perspective only. It got a vast field of applications in many areas of technology. It can be used in many fields of life and can help in various ways. Some of its applications are:

- E-car
- Defense applications
- Cargo handling applications
- Vehicle for disabled (special) persons

Autonomous Ground Vehicle is itself an E-car which can be driven with the help of an onboard computer system. Its scope as an E-car is very useful that it can be driven or controlled anywhere without the help of any external assistance.

Its scope in defense applications is very practical. It can be used to go to the places where a human being is incapable to reach or at that time it is not possible for a human being to go to some place. To solve this problem, an excellent solution is to use AGV. By using AGV there is no fear of losing a human life because everything will be done autonomously.

There are some cases in which the work is done throughout the day in a factory e.g. transferring goods from one place to another. So in this kind of environment, extra labor will be needed and some extra machinery too which can be so much costly for a factory. So this transfer can be done very easily by using AGV. With the help of AGV less manpower will be used and initially, may be it will cost more, but in long run, it would be a cheap deal to use AVG instead of manual machinery and labor.

Special persons always need some help. The AGV helps them in such a way that with the help of this vehicle, moving from one place to another place is not a big deal for them anymore. They can move without being dependent upon any person. All they need is to use AGV and their problem for transportation will be solved. Simply, they have to tell the AGV that where they want to go, the vehicle carries them to the desired place at its own.

V. Conclusion

Autonomous Ground Vehicle is a totally autonomous vehicle. It drives on a specified path and avoid obstacles present on it. If there is any obstacle on the road then it changes its lane or stop accordingly. All of this work is application in real time environment and it takes decision at its own. The camera is mounted on the vehicle to capture the images and so provides monocular vision to the car. The images are processed on the same time in Image Acquisition Toolbox. This Toolbox is responsible for taking decision against the images. Usage of this toolbox helps the microcontroller to derive the car in desired direction. This vehicle is useful where sending a human being is not feasible or a life threatening risk. The vehicle can be used mostly in defence applications and sensitive security environment. The vehicle is compatible for the advanced tasks like reading sign boards, Traffic signs/Signals and avoiding special kind of obstacles.

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