DESIGNING AUTOMATED GUIDED VEHICLE USING IMAGE SENSOR

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CERTIFICATE

This is to certify that the Project Report entitled, "**Designing automated Guided Vehicle using image sensor**" submitted by **Shashi Kant** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering Session 2009-2010, at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

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An assemblage of this nature could never have been attempted without reference to and inspiration from the works of others whose details are mentioned in reference section. I acknowledge my indebtedness to all of them. Last but not the least to Project Coordinator Prof. K.P. Maity and also Prof. S. Murugan and Prof. P.K. Ray for spending their valuable time to do the evaluations, and who were patient in extending all sorts of help for accomplishing this undertaking.

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ABSTRACT

Automated guided vehicles (AGV) are one of the greatest achievements in the field of mobile robotics. Without continuous guidance from a human they navigate on desired path thus completing various tasks, e.g. fork lifting objects, towing, and product transportation inside manufacturing firm. Their development can revolutionize the world in the sense of fool proof navigation and accurate maneuvering. Though most of the presently the AGV work in a retrofitted environment, work space as they require some identification for tracing their guide path, works are going on developing such AGVs which are dynamic in sense of navigation and whose locomotion is not limited to just a retrofitted workspace. The aim of this work was developing such a natural feature AGV which takes visual input in the form images and gains detailed object, obstacle, landmark, identification to decide its guide path. The AGV set up developed, used a commercial electric motor based car 'Reva i', as chassis which was fitted with camera to take real time input and resolve it using segmentation and image processing techniques to reach a decision of driving controls. These controls were communicated, or better imparted to vehicle using parallel port of computer to servo motors, which in turn controlled the motion of vehicle. The work was focused more on dynamically controlling the vehicle using refinement of driving mechanism (hardware), however it could be assisted using better segmentation and obstacle detection algorithm. All the retro-fitting and codes were developed in such a way that they could be improved at any stage of time. The results could be enhanced if a better stereoscopic camera were used with a dedicated cpu with better graphics capability. This vision based AGV can revolutionize the mobile robotics world, including systems where a human driver is required to take decisions on the basis of visualized condition.

Chapter 1

Introduction

1. INTRODUCTION

The project involves the designing of Automated Guided Vehicle (AGV) using image sensor as guiding mechanism. Precisely the vehicle will move by taking image as an input criterion for the judgment of guide path. Presently in commercial sector use of AGV is limited to the task of ware house management, however their use drastically reduces the manufacturing cost.AGV (automated guided vehicle) can revolutionize the mobile robotics, especially the automated navigation to perform specific tasks

AGV can have a variety of functions but are presently being utilized for the following functions commercially

a.)To tow objects behind them

b.)To move raw materials, to get them ready for manufacturing

c.)In lifting the objects

d.)For transporting materials e.g. medicines in hospitals

Known by different names e.g. Laser Guided Vehicles(LGV) ,or Self Guided Vehicles (SGV) or Fahrelose Transport System(FTS) in German Technology, is known back to the time of early 1950's, when it was a tow truck which followed a path created by a wire on floor , rather than using any guiding rail setup. However in the present date AGV have grown to the level of communicating with each other to ensure smooth movement of product or raw material in workspace.

In present date the technology has developed many times past 1950 and today the AGV's are mainly sensitive sensor based for example laser guided vehicles (LGV).They play a key role in designing of new factory, warehouse etc. to move goods to their destination, and even that safely.

1.1TYPES OF AGV (Automated Guided Vehicles)

Based on requirement and the working condition, optimal accuracy in movement, initial investment and scope of path change in future, one can go for different types of AGV .Each of them have their own advantages and limitations

1.1.1 WIRED TYPE

- A wire sensor is placed on the bottom of AGV such that it is facing ground, so as to detect the signals emitted by the wire .In fact the wire lies buried in ground approximately one inch below the genuine floor surface. This wire continuously emits radio signals which are sensed by the sensors on AGV and AGV follows the path exactly as the wire is lay buried.
- It has the advantage that excess of dust and traffic doesn't affect this system. It is generally used when

a.) Scope of change in path of AGV is not anticipated in future

b.) More accurate movement is required

Drawbacks

a.)Any change in path, if desired in future requires re-digging and placing of wire.

b.)Even initialization requires digging of floor which is really tedious for laying out wire

c.)The wire needs to be continuously energized.

1.1.2 GUIDE TAPE BASED

- Either magnetic or guide tape can be used as guide path for many light and as well heavy duty AGV .It is a passive guiding technique as the guiding device is not energized for working(the guide tape need not energized).

- It also has its own advantages and disadvantages.

Advantages

a.)It is passive and energy need not be dissipated as in case of wire guiding mechanism.

b.)Initialization doesn't require any slot cutting or floor remake as incase of wired.

c.)Flexibility of changing guide path in future simply by relocating the tape, without any digging of floor

But on the same time it has the disadvantage that it can't be applied on places of heavy traffic or in places where it can get damaged or covered by dirt.

1.1.3 GYROSCOPIC NAVIGATION TYPE

This navigation system utilizes an inertial guidance mechanism. Transponders are embedded in floor and the slightest change in orientation of the vehicle is traced and corrected accordingly by the gyroscope. The transponders in the floor are connected to the computer system, controlling the direction rectified. Deviation from ideal track is hardly 1 inch.

ADVANTAGES

a.)It can operate nearly in all conditions; environment and can withstand high temperature conditions.

b.)It has a longer life span

The major trouble associated with it is that the floor needs to be embedded with the transponders

1.1.4 LASER BASED NAVIGATION

The latest AGV are all laser based. More comprehensive, accurate and versatile type of navigation is provided by laser based AGV. The walls, poles, or other machines are to be fitted with retro-reflecting tapes. This AGV carries an onboard laser transmitter and receiver on a rotating turrent. The LGV has a stored reflector map by which it can locate its position and also makes necessary corrections by estimating the difference in expected and current position .Thus the position is continually updated by LGV.

1.1.5 NATURAL FEATURE NAVIGATION

At times it may occur that any pre-specified path can get choked or may have some kind of disturbance in any sense , or any how an urgent but temporary change may be required .In all such case re specifying the guide path and retro fitting in work space for creating a new the guide path is too tough. Thus the production is hampered bringing down the manufacture.

This problem leads to the requirement of designing of such an AGV which dynamically (taking various conditions and parameters into consideration) plans the best fit optimal path which is shortest between the current location and target without any retrofitting in work space. It may utilize gyroscope, laser based equipments and Monte-Carlo and/or Markov localization technique to locate itself and plan further its shortest path dynamically.

Chapter 2

Literature Review

2. LITERATURE REVIEW

As we proceed further in our project, the research and development round the globe also progresses and necessarily, not at all leaving an important topic like that of designing an AGV. So it becomes important to have a study of all those works, literature, and ideas already carried out and being carried to develop a better concept, avoid mistakes, and utilize the best of existing pathway. The papers discussed below are some of all those works, which helped us a lot understanding what has been done and what has to be done and how it needs to be done.

2.1 Literature review in Mobile robotics

The paper by Lim et al. [1], suggests a Q-learning technique, for AGV to have their guide path get designed. According to this study total time of travel is used as the decision criterion for the construction of the guide path layout. A unique learning technique is applied where the total time of travel of vehicle on each segment of guide path is calculated, rather estimated. Here computational experiments are performed for the evaluation of the performance of proposed algorithm. The simulated results show the efficiency of it.

Also the paper by Cao et al. [2], emphasizes and explains the use of fuzzy logic control for the development of comprehensive control system of mobile robots. The advantage of fuzzy logic system is that the multiple type of inputs ,including those from real time environment(visual sensors ,sonars etc.) ,and those from pre stored information e.g. stored map, land marks etc. can be simultaneously utilized to reach a decision as rich as that of a human. The vision guidance can be accomplished by CCD with the facility of a zooming. Sonar detection system can be used to get information and avoid any banging. Here program Galil motion control system is used to control the motor. Just with minor adaptation, and this design creates a moveable autonomous set up for vehicle control.

The paper by Le Anh et al. [3], presents a review on design and control of Automated Guided Vehicles. Many important issues including steer path designing, assessment of number of vehicles, arrangement, idle vehicle positioning, vehicle routing, inconsistency resolution, battery and its management etc. are also discussed. Very often the neglected areas such as inoperative vehicle positioning and power management are discussed and so the models are categorized. In addition to above a decision framework for design and accomplishment of AGV is also proposed.

The core work in thesis by Davision[4] focuses on simultaneous localization and map construction for a robot which is operating rather working in an unknown or say a more generalized workspace, and using markable key features (rather than comprehensive one) as visual landmarks. Importance has been given to produce maps which are useful for longer period of time for navigation and which have the flexibility of getting modified in future as per requirement, as changes with time are inevitable.

Failure is observed for many map preparation methods on prolonged use, as they don't have the capability to recognize previously visited location, as such and are simply unable to adjust their previous map in view of that. However using active cameras and advanced image processing methods, it's really possible to recall all those features in the areas visited previously, even though the area has not passed through original course. Maintaining such a large reliable map requires comprehensive information to be stored about their features and association. Storing this data information is computationally expensive to create (suppose through a survey initially) and even to maintain, however a small map of landmark features can be stored as well as tackled successfully .A method which can drastically increase the efficiency of updates, incase measurements are made for a single but unique feature, permitting continuous real time tracking of features, irrespective of total map size has also been presented. Active sensing requires decisions to be made where possessions can be applied best. Useful map can be automatically maintained by adding and deleting features to and from the map whenever and wherever necessary. In most of the applications, even if the explicit path gradient in the work space may not be known in advance, but at least there will be some prior information or commands governing the required motion and it will be looked upon that how this information can be harnessed and utilized with map building methods for unknown environments. Thus a totally automatic, real time implementation of the ideas developed is presented, and a variety of detailed extended experiments in realistic environment are used to evaluate the proposed algorithm, and make ground truth comparison.

For any manufacturing system /activity, material handling has always been an integral part of it. Also high costs are involved in equipments and safety issues. So it is really imperative to design a sound material handling system. The design concerns issues regarding the course path design and the number of other vehicles in convoy. The objective of thesis by Agarkar [5] is to review the literature dealing with Automated Guided Vehicles and various other issues involved in designing its flow path, and reliability of AGV system. Incorporating the reliability aspects in the design of Automated Guided Vehicles is very important, though a bit complex .There is a need to identify critical components which account for catastrophic failure of system. Failure modes and effect analysis are useful techniques in identifying the critical components. Once these critical components are identified the individual reliability can be calculated and the setup block diagram can be used to calculate the total reliability of any proposed system.

A guidance system based on machine vision, for agricultural combines was developed at the University of Illinois .Improved safety; increased efficiency etc. can be achieved using automated agricultural equipments and systems. Three machine vision guidance algorithm were developed of which the most successful algorithm was analyzed to utilize just a single camera, at a level approximately on the level of operator's eye. The algorithm was called CAB MOUNTED CAMERA ALGORITHM (CMCA), which closely copies the discernment process used by an operator in reality. This algorithm was used to harvest a 4.6 ha corn field during both day and night. The indicated accuracy for it was analyzed the same as that of GPS system used to record the position.

The paper by N'u~nezfi et al. [6] proposes the use of a geometrical feature detection and navigation system which is to be worked with two dimensional Laser depth sensors. It consisted chiefly of three modules, namely the data acquisition system and pre-processing, the segmentation, and Land mark extraction and the characterization. The specialty of this system can be addressed as the approach for laser data segmentation based on adaptive curvature estimation. Thus for every landmark, characterization not just gives the parametric vector but also completes the statistical information. These items are used directly to extract various types of landmark features integrated with the desired and even additional features of the environment such as edges corners line segments crosses and trees etc.

A mobile robot can be understood as unmanned self propelled vehicle having an aboard computer which can store path and machine function/instructions and controls the drive and steering system so as to cause the machine to follow the desired path. A number of, (usually many) reflecting back targets are mounted along the desired path. They do not have to be mounted at a specific height or distance apart necessarily. An improved guidance system for keeping the vehicle on the prescribed path includes a laterally scanning, laser transmitter-receiver mounted on the vehicle. An electro-mechanical following device controls the angle of elevation of the device emitting laser beam so as to keep it targeted at each target successively as the vehicle moves. The laser produces signals which generate decision control signals to steer the vehicle. It works such that the laser transmitters and the target are kept aligned in a proposed vertical plane. A positioning device can move the laser transmitter transversely on the vehicle so that the vehicle centerline may travel in vertical plane of laser or may travel in an offset line parallel to vertical laser plane. According to the filed patent certain targets can be even bar-coded and a target counter can sense and counts them as the machine moves along them to keep track of where the vehicle is located as per its desired path [US Patent 4790402 by Field [7]]

An automated guided vehicle (AGV) includes a body, and minimum one driver wheel for thrusting the body, at least one steered wheel for directing the vehicle with respect to the surface it is being propelled, and one inertial navigation system. The inertial navigation set up senses the actual progress of the body in at least three degrees of freedom .Such sensing is accomplished even though there is some side slippage of the vehicle. This can be embodied in an Automated Guided Vehicle having a ground track sensor which continuously senses the relative movement of the vehicle with respect to the surface being traversed, in order to determine the actual parameters of the vehicle locomotion. The ground track sensor may or may not physically contact the surface in order to sense the relative movement, and then called a non contact type. (United States Patent 5764014 by Jakeway et al.[8])

An autonomous wheeled mobile robot comprises of at least one wheel driving motor and for the purpose of steering even one more wheel. An intelligence system say a computer, a means for navigation, orientation and maneuvering in an environment with moving obstacles; Also sensor system is used to sense various parameters and hence the location; And even a wireless communication system for transreceiving. (United States Patent 70802350 by Skoog, Hans Västerås, SE) [9])

A system guides self propelled equipment through passageways, such as underground mine corridors. The vehicle contains a signal generator for generating signals which after bouncing off the walls of the passageways can be collected with some properties of walls obstacles and hence location. Actually a receiver collects the signals bounced off the passageways to determine the distance to sidewalls of the passageways. A storage device contains a set of interlinking nodes that represent at least one path through the passageways. Each of the nodes contains some steering information. A processor calculates and thus finds the distance to the sidewalls of the passage ways in order to determine how to steer the vehicle through the passageways. The system's operational state and method of steering may be change depending upon the location of the equipment setup in the interlinking nodes. (United States Patent 5999865 by Bloomquist et al.[10])

2.2 Literature review in image analysis

The image given out from the digital camera may be taken as input by the Image Analysis (set up) section which analyses the image to:-

1. Detect the edges in frames, and hence
2. Detect static obstacle
3. Detect moving obstacle; thus finding the guide path segment

The input Images can be analyzed using digital image processing to get all necessary information ,such as DEPTH IMAGING can be utilized to get the distance information, clarity vision can be obtained for both non focused objects and blur obtained due to

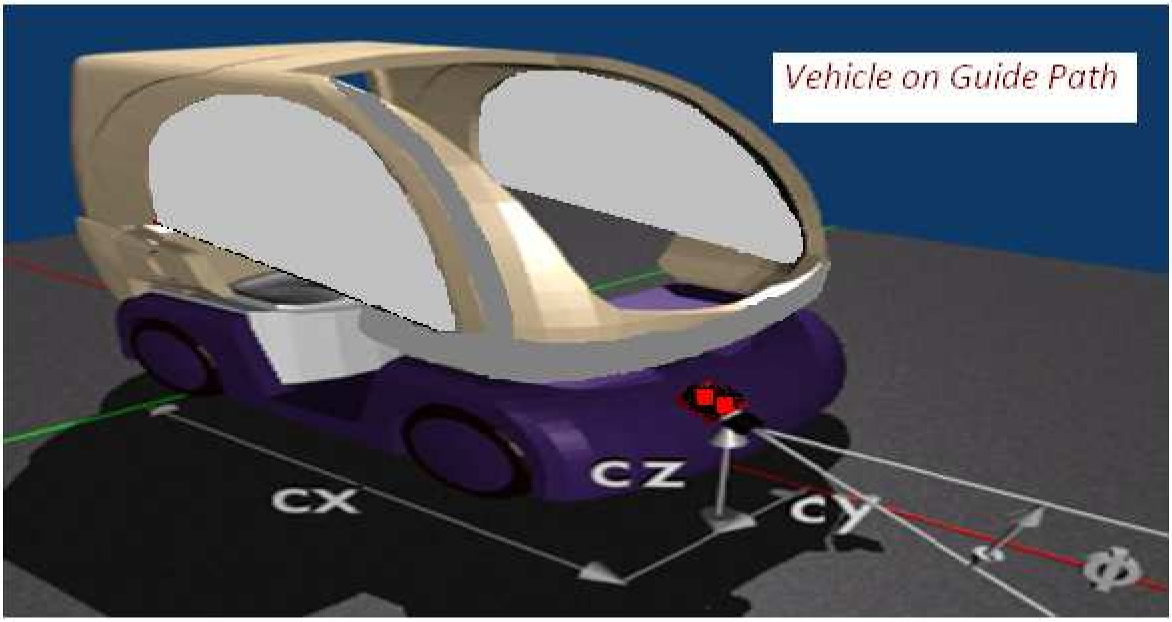


Figure 2.1

movement, thus identifying both static and dynamic obstacles and their respective position and orientations in pathway.[Obstacle Detection using Optical Flow et al.] [11] Vision is a very prominent sensor providing abundant types of information that can be explored in many contexts for obstacle detection. Several recognition for example say colour and consistency have been used to segment out the ground plane in images thus identifying free space for safe motion in the forward area [Cheng and Zelinsky, 1998] [12] Edge obstacle detection methods have been applied in many corridor type environments due to the existing straight line components and static lighting conditions [Ohya et al.,1997] [13]. Moreover edges over backgroung in the image have been considered as obstacles using the edge free ground plane assumption [14][Lorigo et al., 1997] [15][Chao et al., 1999]. So there are a large no of techniques each having their own assumption, and hence they have been seen to work successfully in their own assumed test environments. And its only when they are conducted in more general environments, failure occurs due to the various assumptions made in each case which usually do not hold true in a more generalized case. For example, texture recognition assumes that ground texture remains constant; even the colour recognition for simplicity assumes that objects are necessarily not of the same colour as that of the ground, and the edge detection method used in corridors requires strict model memory components and also a good simultaneous localization and mapping called sometimes as SLAM system. It has been shown that these spatial visual systems cannot function successfully all alone.

Instead it is suggested that these systems should operate in concurrence with one another for completing the visual motion system. Visual sensors are able to sample the combination of environmental motion and self-motion information of a scene through two or more successive snapshots. Usually these snapshots or rather frames in a video stream, encode motion at a very fundamental feature level which is used to estimate optical flow. Optical flow can be defined using a set of vectors with each vector describing the motion of some solitary features in the captured image space. These simple vectors can provide a two dimensional representation of the motion and even environment's three dimensional structure and motion under the rectified conditions. As such, optical flow has been utilized in many different ways for navigation and obstacle avoidance while moving on guide path. The common ground plane segmentation using optical flow patterns has been shown to be successful in identifying flat traversable surfaces [Illic and Masciangelo, 1992][16]. Furthermore, the use of variance maps from optical flow fields have shown promising results with robots, and has been seen to navigate between obstacles successfully using divergence plots [17] [Camus et al.,1999] [18][NelsonandAloimonos,1989]. Divergence calculations of time to contact for a central area have also been implemented suitably for frontal collision detection sub system [19] [Coombs et al., 1995].

The vision sensed as per image exploration using picture element exploitation utilizes discrete differentiation forms [farid et al.][20], and they even form the foundation for numerous other applications in machine vision. One such critical use is edge detection. Edge detection is critically important for many other applications including recognition of obstacles, thus bifurcating them from background. This topic is quite vast; however it can be briefly encapsulated mathematically, as given below. An edge is loosely defined as an extended region in the image that undergoes a rapid directional change in intensity. Differential techniques are the obvious choice for measuring such changes. A basic edge detector begins by computing first-order spatial derivatives of an image f[x, y]:

$$f_x[x, y] = (f[x, y] \star h'[x]) \star h[y] \quad \text{----------------} \quad (1)$$

$$f_y[x, y] = (f[x, y] \star h[x]) \star h'[y], \quad \text{-------------------------------} \quad (2)$$

Where h′[•] and h[•] are the derivative and prefilter defined as

$$f'[x] = f[x] \star h'[x]$$

$$\& \; h'(x) = \frac{\pi^2 x/T^2 \cos(\pi x/T) - \pi/T \sin(\pi x/T)}{(\pi x/T)^2},$$

The “strength” of an edge at each spatial location is defined as the magnitude of the gradient vector □[x, y] =(fx[x, y] fy[x, y]), defined as:| □[x, y]| = qf^2x[x, y] + f^2y [x, y].

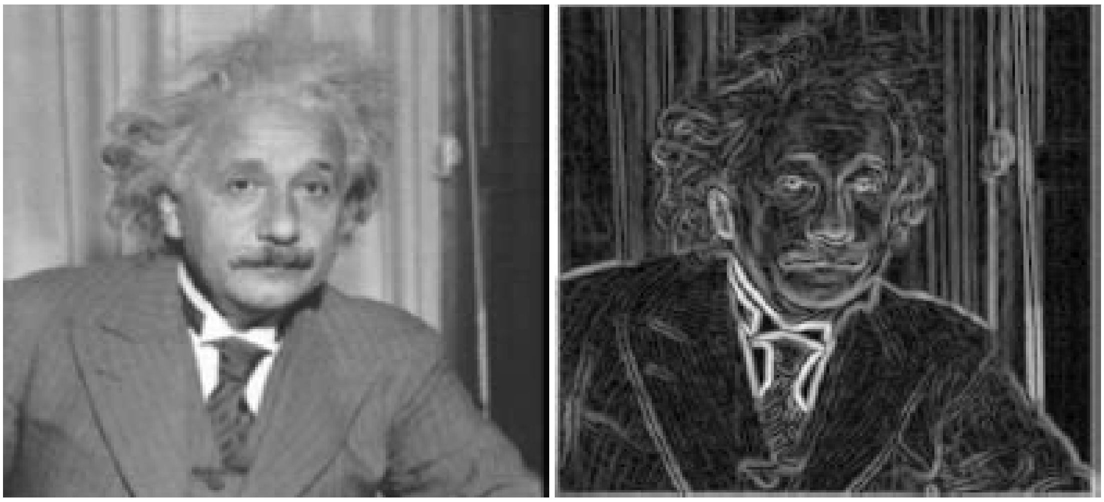
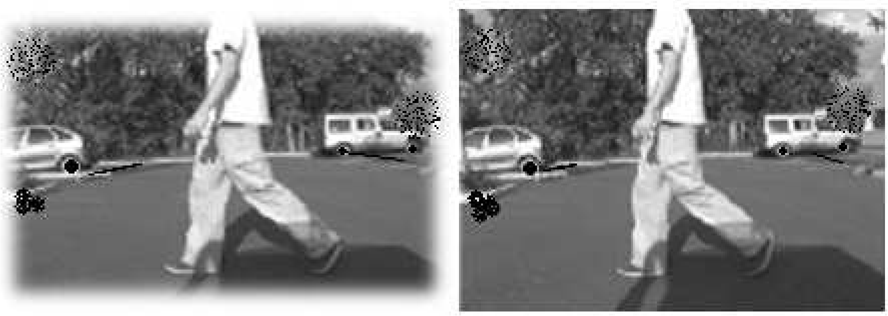


Figure 2.2

As shown in Figure above, the gradient magnitude is only the beginning of a more involved process of extracting and localizing the salient and relevant edges. [farid et al.][20]

First step is to extract a form of the existing environment and then comes separating the obstacles from the background by trying to compute the theoretical optical flow model to the observed video stream. A computation time of not less than 25 to 30 milliseconds is estimated, which corresponds to a frame rate between 30 and 40 Hz, on a standard 2.0 GHz laptop PC [Real-time moving obstacle detection using optical flow model Braillon et al., 2006] [21].

Taking frames from the input video stream, visual sensors are able to sample the amalgamation of surrounding motion and its own motion information of a scene through the different frames taken from input video stream. These snapshots are used to encode the motion at an elemental level and used to estimate optical flow.



Frames from input video stream

Figure 2.3

Thus consecutive frames can be analyzed with a focus on the edge/part/cluster of picture elements (pixels) which have a tendency in changing after the self motion correction is given to all observed frames. Thus comparing the number of frames taken per second taken, the speed of changing edge, and its depth change ,both its orientation and magnitude of speed can be analyzed. Hence the time to contact (TTC) can be calculated.

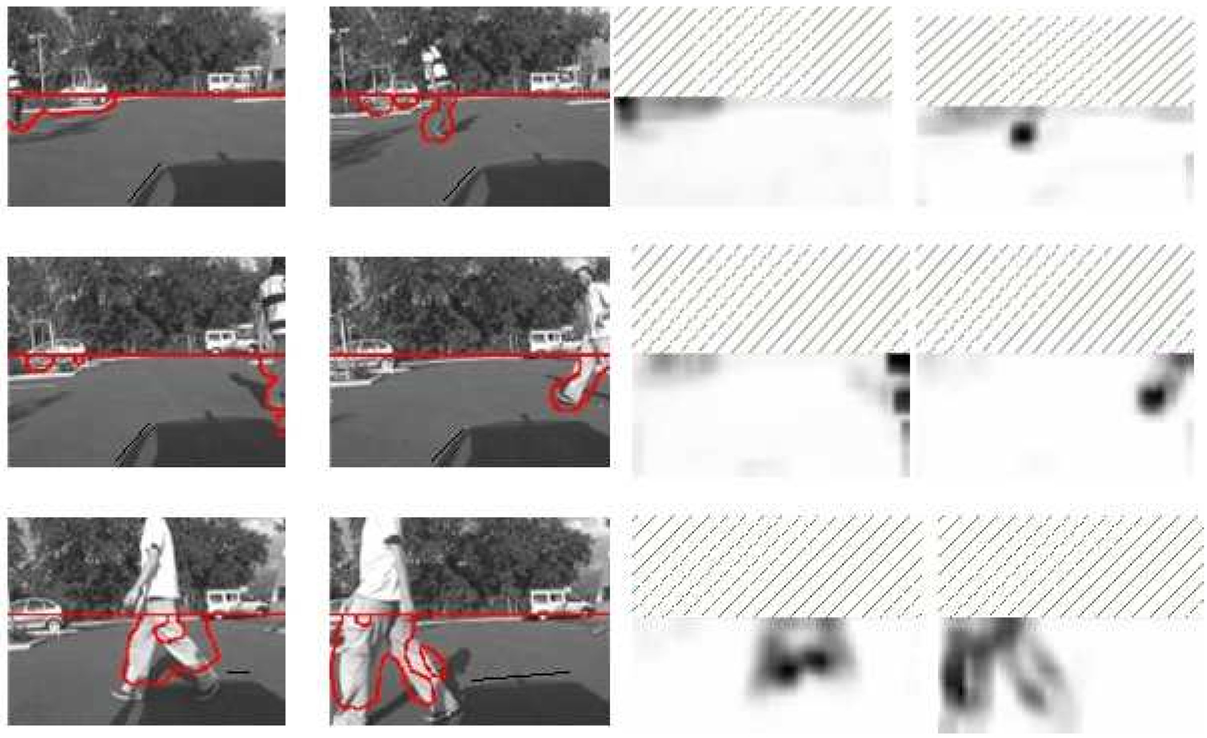


Figure 2.4

SSD images corresponding to the figure .The grey scale corresponds to the SSD value. White means that the SSD is low and black that it is high. The hatched part corresponds to an area of the image which cannot be the ground (the algorithm mark these pixel as unusable)The red curve marks the edge of detected obstacles.

The in-stream frames must be filtered out for noise, inactive background, or any other irrelevant inclusion thus to find out the active edges. Several measures for analyzing similarity such as

1. SAD (Sum of Absolute Differences) 2. SSD (Sum of Squares Differences) 3. ZSAD (Zero mean Sum of Absolute Differences), 4.ZSSD (Zero mean Sum of Squared Differences), and 5.ZNCC (Zero mean Normalized Cross Correlation) are used. The best result is given by the SAD and SSD measures, this is as because in all continuous cases of the incoming video streams, especially observed with higher number of frame rates the lighting condition between any two snapshots will vary very slowly and is almost same. Actually ZSAD, ZSSD and ZNCC are zero-mean and ZNCC is normalized, this leads in general to incorrect associations, because they can associate a dark region and a bright one. In our case, the lighting conditions between any two successive taken images are the same, which is why the best results were given by SAD and SSD. Figure above shows some of the analysis.

2.2.1 Time to Contact

The theory of time to contact (TTC) was first introduced by Lee [Lee and Young, 1985] [22]. Lee conducted many studies upon humans and birds showing confirmation that TTC is a critical component which is utilized in showing the reactions for timing of motion and actions. As we fundamentally wish to develop the robot for obstacle avoidance and control over desired path, we choose to use the TTC information and some how believe that it will help the task of obstacle avoidance. One can also simply convert these time measurements to range estimates by discretely multiplying it by the speed of the robot to have the instantaneous TTC (this will change every instant depending on motion parameters and orientation).

There are chiefly three problems associated with using optical flow images to obtain 3D environmental information and also self-motion information. Firstly, to fulfill the assumption of all smooth movements, the robot has to move quite slowly and this as a result produces poor and coarse optical flow data. This causes large errors in range of calculations especially when neglecting sub-pixel corner finding algorithms (which makes it lengthy and tedious). The second problem is a well-known issue in computer vision, whereby any rotation or rotational disturbances will add a constant optical flow vector to each point of interest. As examined, rotations do not encode at all any range information and hence must be removed in order to obtain the correct range information from translational movements.

Lastly comes the problem of lens distortion and even that has an affect on the optical flow information. Sensitivity of optical flow is quite high and hence its vulnerability, thus even minor lens distortion can play havoc on the optical flow vectors. It complicates the situation by altering the optical flow vectors depending on the position in the image. We can employ the tracking Corners process to help solve the problem of coarse optical flow data, and this is done by tracking over a number of successive images. Tracking was conducted in all directions so as to produce satisfactory results with each match chosen to be tracked from either of 1 to 5 images. However if tracking over five successive images, it slows down the process of obtaining range information but the reason it is performed over five images is due to the slow robot motion. If the robot were to move at a fast pace, the number of tracking images can be successfully reduced. This would produce the same resolution of optical flow at a faster rate (needed at higher speeds for control) but with the forfeit of outlier reduction.

Although tracking helps improve optical flow data input, the problem of coarse optical flow data at very slow speeds still exists. Thus we chose to ignore any information obtained from vision motion below a certain forward speed. The problem is that, many of these techniques require numerous assumptions, and are computationally very expensive and still produce results containing errors. [23][Giachetti et al.,1998] [24][Gebert et al., 2003].

When the camera is aligned with the robot's turning axis, rotation removal becomes an easier task in finding the reading difference in image space and subtracting it from the optical flow data. For indoor environments, large disturbances either from computers, electrical equipment or from the Pioneers power and motor units, affects the magnetometers greatly. Thus the magnetometers were abandoned and the gyroscopes rate information fused with the Pioneer wheel odometry was brought in use. The original sensor fusion method which utilizes a complementary filter with an additional integral gain was kept, as it is simple. A complementary filter (CF) can be designed where kp and ki are the specified proportional and integral gains. The filter results are from which we can analyze the combination of the gyroscope's fine resolution and the odometry's values helping to remove gyroscopic drift.

For the exact and accurate TTC (Time To Contact) calculation we use a few image analysis technique which includes a few calculative and a few rectification methods, some of them are

1. Motion blur rectification(Purely correction procedure)
2. Lens distortion removal
3. Rotational error rectification
4. Edge Recognition(a bit reconstruction based analysis)
5. Depth Image Analysis (depth of edges recognized in frames)

2.2.2 Depth image

Depth Images are practical representations that can be computed from the real world using cameras and/or other scanning devices. The depth image/map gives a visibility-limited model of the scene and they can be rendered easily using available graphics techniques. A set of Depth Images can provide complete fool proof rendering of the scenario. Multiple views are needed to blend information obtained to provide a smooth make. However such a depiction of the scene is exhaustive and needs developed algorithms for competent representation. The image representation of the depth map may not by itself comply with standard image compression techniques. [Verlani et al., 2006][25] [penta et al., 2005][26] [Narayan et al., 2004][27] The scene representation using multiple Depth Images contains a lot of redundant descriptions of common parts and hence can be compressed without hampering vital informations. Compressing these depth maps using several standard image techniques such as JPEG(Joint Photographic Experts Group) and comparing the quality of rendered novel views by varying the quality factors of JPEG can give us a good idea to preserve quality and optimum compression ratio. Multiple views of compression of texture images can be performed by exploiting the restraints between views such as discrepancy, epipolar constraint, multi-linear tensors, etc.

Figure 2.5

Normal snaps in first row above and their corresponding depth image shown below them.

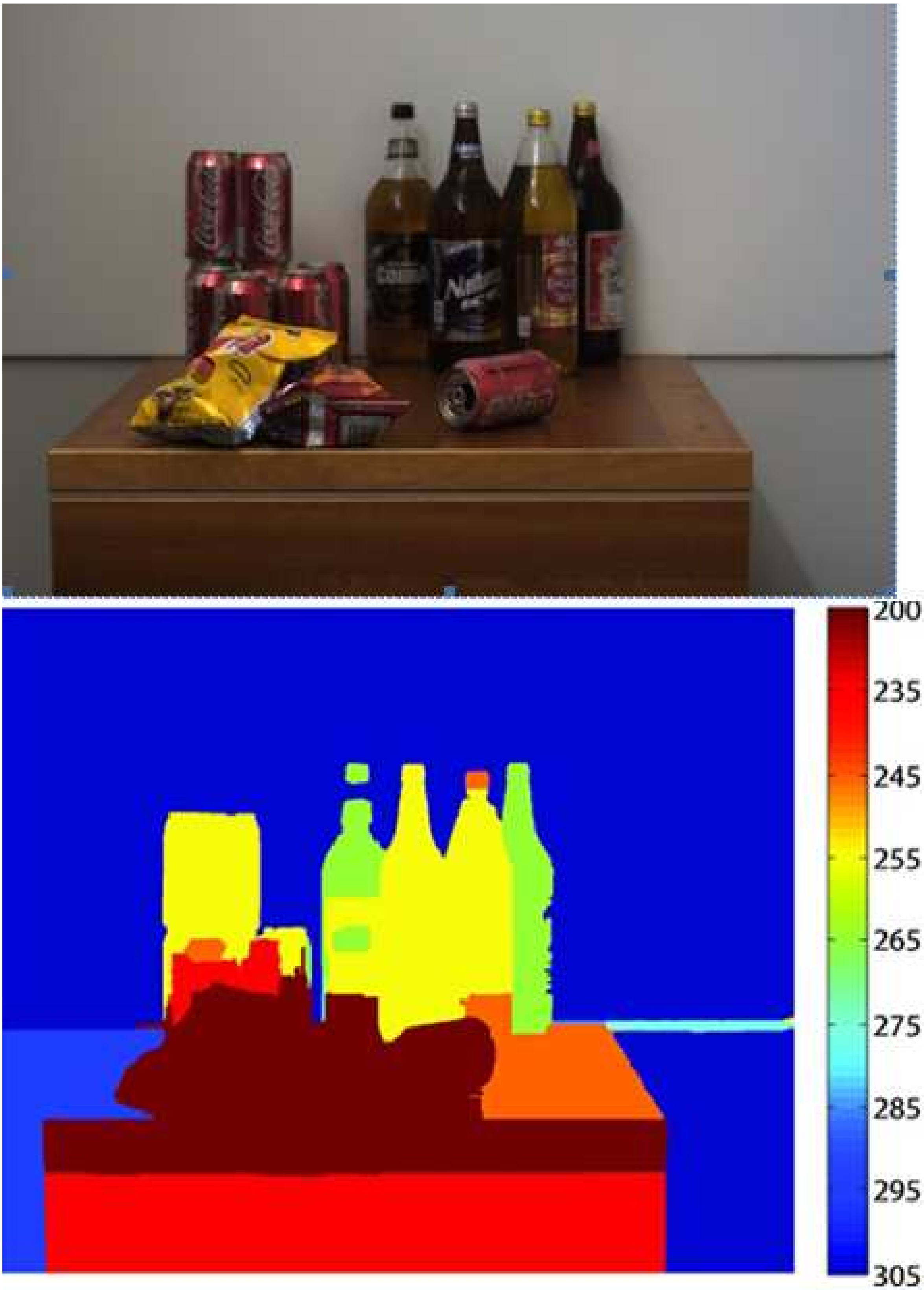


Image and its corresponding depth details in colour coding form.Image and depth from conventional camera with coded aperture, [Levin et al.] [28]

Figure 2.6

2.2.3 Motion Blur

It is all possible that we can identify the static obstacle(s) clearly, but the moving obstacle(s) especially the fast moving one, don't give their clear orientation, as because of motion blur, which gives a hazy image of them. Rather than going for an improvement in camera focus and construction we can go for rectifying the image itself. This can be done by reconstructing the image by using some nonnegativity constraint, or by using Boolean boundary method.

[Displaying confidence images, Nagy et al.] [29] Using motion Cameras we can capture the image of the license plates of cars that fail to obey speed limits or other traffic regulations and are thus they are employed to enforce law. The images acquired are usually contaminated with motion blur, so we can examine the uncertainties involved in the processing of such images. Supposing a moving object say a bus, were it is moving directly away from the camera, then the motion blur encountered would be in the vertical direction of the captured image. Such a blur can be practically simulated as spreading each pixel to the adjoining 19 pixels, and then adding a noise image, cropping such an image and resizing it to size say 36 x 36, which gives each column of pixels an independent reconstruction matrix problem of rank 36. The original and blurred images are shown in the top row of figure below. However the second row shows the reconstructed images, using the assumptions of nonnegativity of pixel values and using the bounds of [0, 1] respectively.

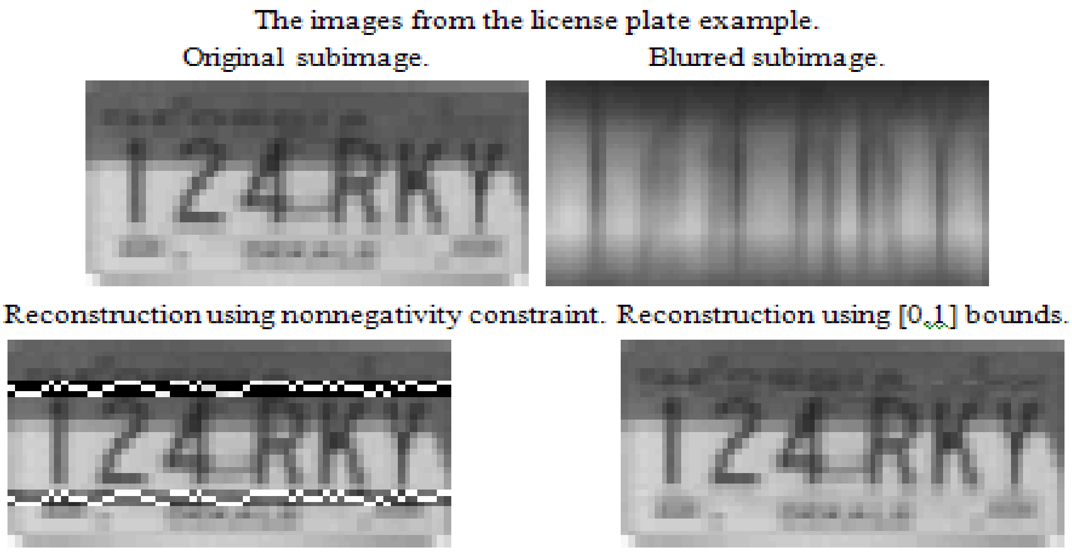
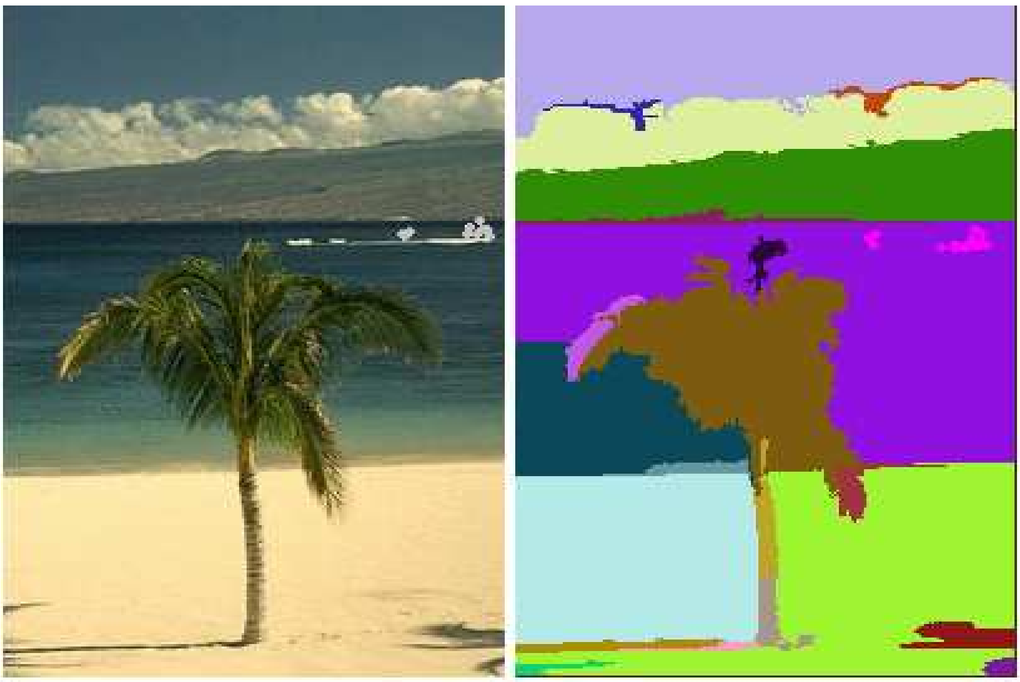


Image deblurring or rather reconstruction

Figure 2.7

Even a total video of rectified image by de-blurring technique can be obtained but there are some limitations to it. In such a case, if the pixels surrounding the sub images are not known exactly, the errors in these border values contribute to the error distribution and even propagation. Although this additional error can been neglected in the computation of confidence intervals but may play havoc in cases.

The problems of image segmentation and grouping remain great challenges for computer vision till date. [Pedro & Daniel et al.][30] Since the time of the Gestalt movement in psychology, it has been known that perceptual grouping plays a powerful role in human visual perception. A wide range of computational vision problems could in principle make good use of segmented images. When such segmentations are reliably and efficiently computable, they can form the method of image analysis. For instance intermediate-level vision problems such as stereo and motion estimation require an appropriate region of support for correspondence operations. They bear the advantage that even spatially non-uniform section of support can be identified using segmentation techniques.



Segmentation parameters: sigma = 0.5, K = 500, min = 50.

Figure 2.8

Even higher-level problems such as recognition and image indexing can also make use of segmentation results in matching, for example to address problems such as that of figure-ground separation and recognition by parts. While the past few years have seen considerable progress in eigenvector-based methods of image segmentation, these methods are too slow to be practically employed for diverse applications. While there are other approaches to image segmentation that are highly efficient, these methods generally fail to capture perceptually important properties say non-local properties of an image. The segmentation technique developed here both captures certain perceptually important non-local image characteristics and is computationally efficient running in time for image pixels and with low constant factors, and can run faster in practice at standard video rates. As with certain classical clustering methods based on selecting edges from a graph, where each pixel corresponds to a node in the graph, and certain neighboring pixels are connected by undirected edges.

In a total (summary), analysis and results have shown that optical flow information method is capable of providing useful obstacle information that can add to the strengths of other visual methods such as colour, texture and edges recognition. Motion is the first and critical component for navigation, to which our obstacle detection system highlights the usefulness of optical flow and its promising abilities to fill the visual motion gap for our AGV. After few corrections and a few reconstructions we are able to get complete information regarding the orientation of both, static and moving obstacle and hence the free path in forward zone, with the anticipated time of contact (TTC). This completes the automated vision based anti colliding navigation system's analysis for real time input.

A flowchart analysis of image input right from input video stream till release of required control signal can be encapsulated in the form of flowchart as follows:

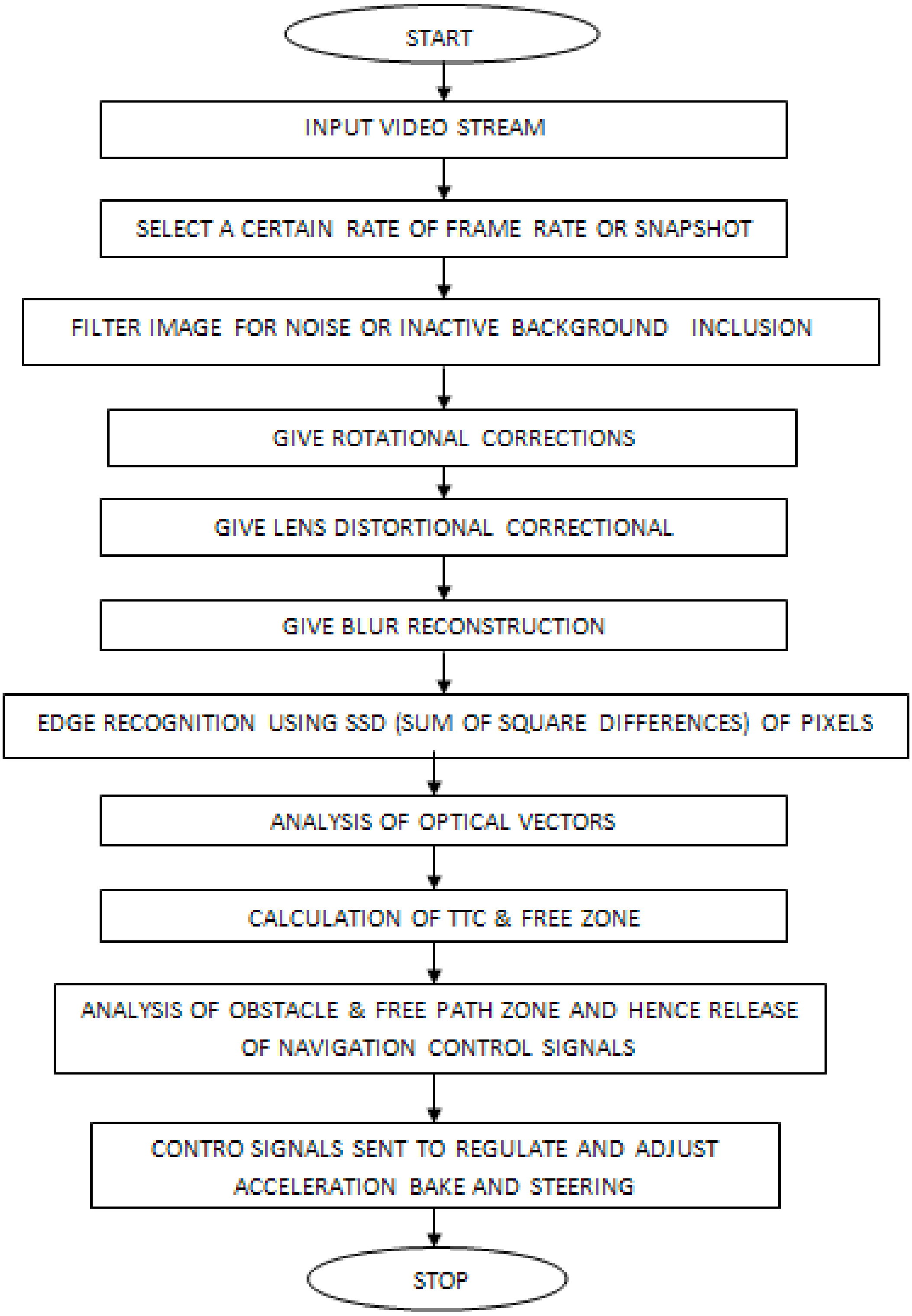


Figure 2.9

Chapter 3

Strategy

3. STRATEGY

Developing an AGV using image sensor makes it a natural feature navigation system, As such because it works without any retrofitting in the test/work space, and we have desired navigation. Now a proper strategy needs to be developed that how the AGV will plan its shortest path to the target. In the most simple words, it can be done by simultaneously utilizing, engaging comparing both ,the real time information such as interpreting the image sensed, identification of land mark etc. and the pre stored information such as map ,area plan etc and then making decisions on pre fed logic and criterion after identification of moving and stagnant obstacles. Thus as similar a human thinks, and has senses to take real time inputs and simultaneously analyzing them with pre stored information's and then observing them in the light of earlier activities, the proposed system should also have the same mechanism of making decisions. The memory may/should be utilize to have the maps etc. which should have the flexibility of getting updated either through some source or through the own analysis of AGV and there must exist a logic system which can be harnessed to have such comparison analysis to reach the decisive action.

The total progress of the project can be made in steps as below

a.)Designing an AGV (preferably with hub wheel motor to ease speed regulation electronically), which works in the practical condition with optimum weight, or selecting such a setup where the speed regulation can be suitably altered.

b.)The design should be such that it does not cause any harm to environment or to itself

c.)The vehicle should be made in an optimum cost, as per properties. But still with improvised raw materials and not compromising with any required function.

d.)The AGV should be designed to take the weight of the battery and other electronic accessories including the computer system and if possible the weight of a person.

e.)The vehicle should be able to implement normal manual control and also automatic control and semiautomatic type if possible.

f.)The design must support the installation of a camera in a suitable position to ensure proper visualization (at least covering frontal zone), and the same will be utilized for navigation

Referring to point 'e' in the above explanation, the AGV should be capable of implementing normal manual control whenever required and also electronic control.

Also there exists a bridge in between total manual control and total automated control. The AGV which may be developed at later stage which will have all its decision without any

Guidance at all, must utilize a complicated neural network to have fuzzy based decision making, to reach a decision. We can have a block diagram base scheme for manual and fully automated type AGV working through Image sensor

3.1 MANUAL

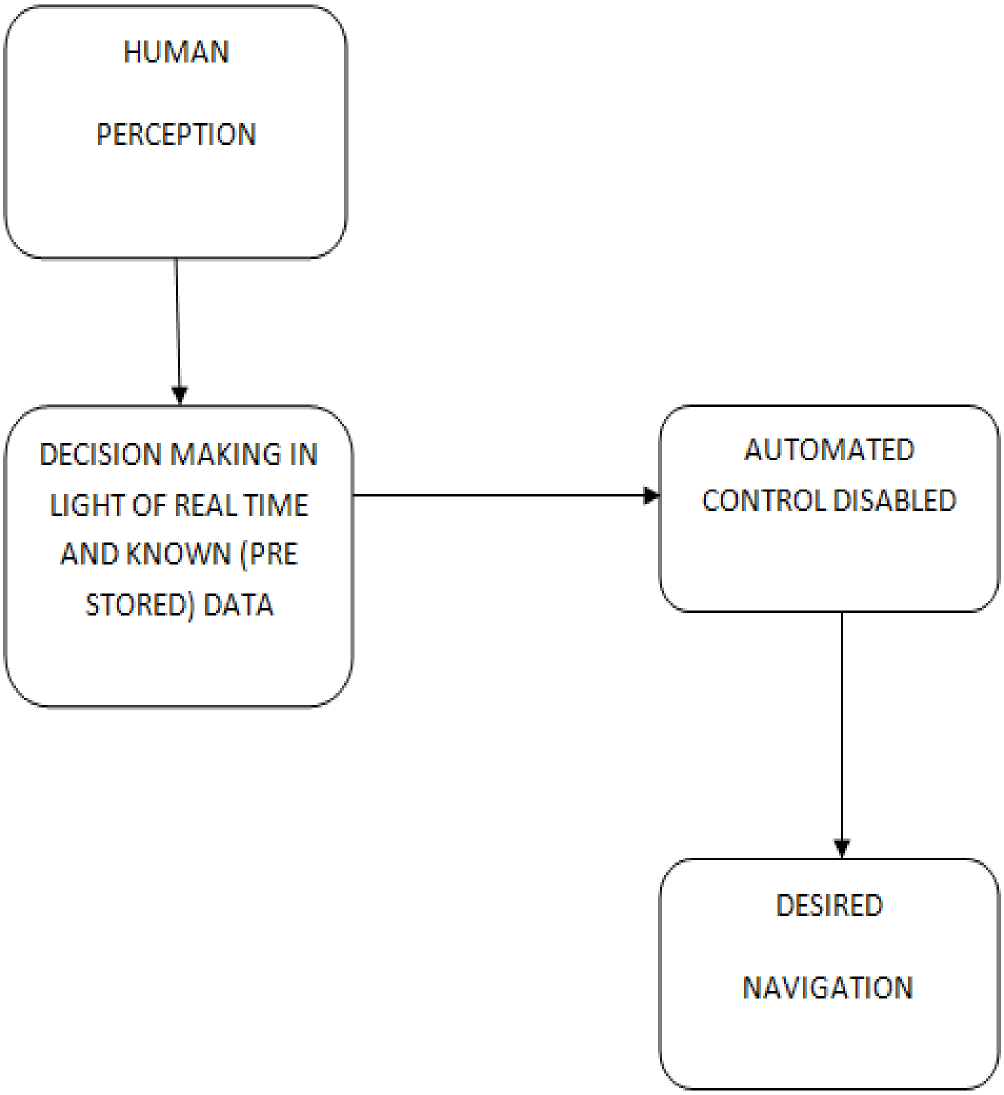


Figure 3.1

3.2 AUTOMATED USING IMAGE SENSOR

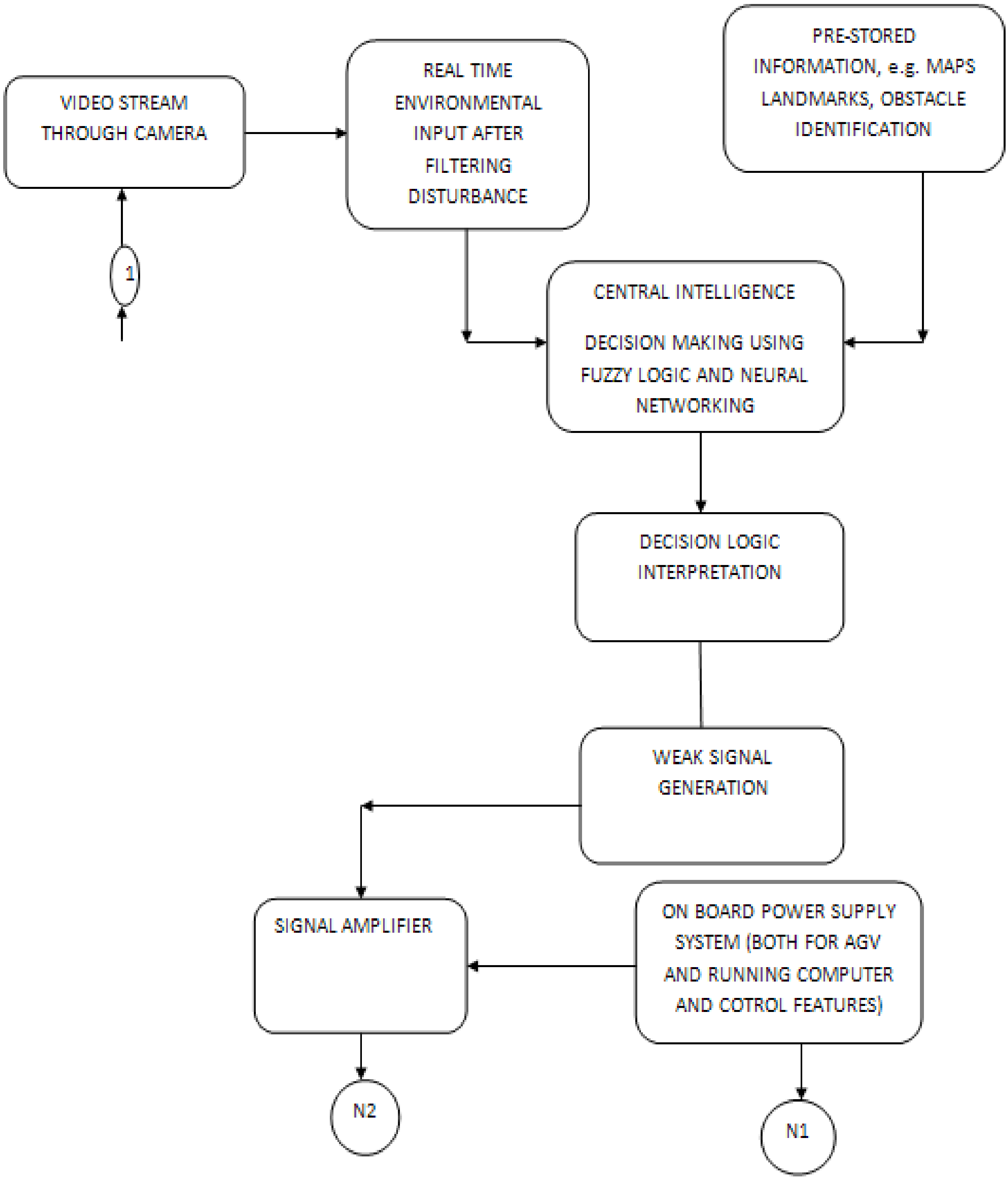


Figure 3.2

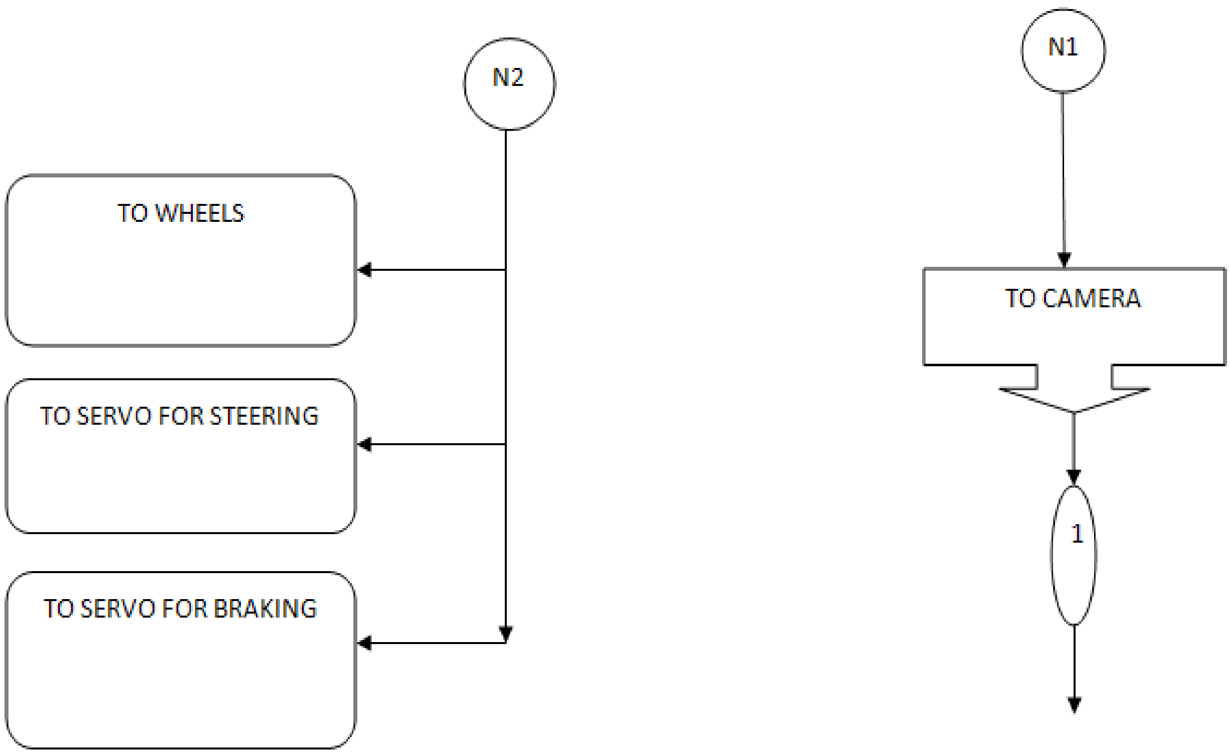


Figure 3.3

Now we are able to visualize the difference between manual and automated control fully using visual sensor (rather a video stream).There exist a huge gap between designing of the two vehicles. Also providing full topographical map details of a locality is possible only if it is small and even doing such survey is a tedious task. Thus for time being this non availability of map information may be solved by remote human guidance.

Thus our aim is to design and develop an AGV which can process an image or send it to remote location so that the real condition variables are identified and then can be controlled as per image signals received either by artificial intelligence, or in absence of detailed map a program/software /human to guide to a distant location without directly driving the vehicle.

3.3 FOR THE SEMI-AUTOMATIC TYPE SCHEMATIC LAYOUT USING BLOCK DIAGRAM

Schematic layout of set up on the AGV (Automated guided Vehicle)

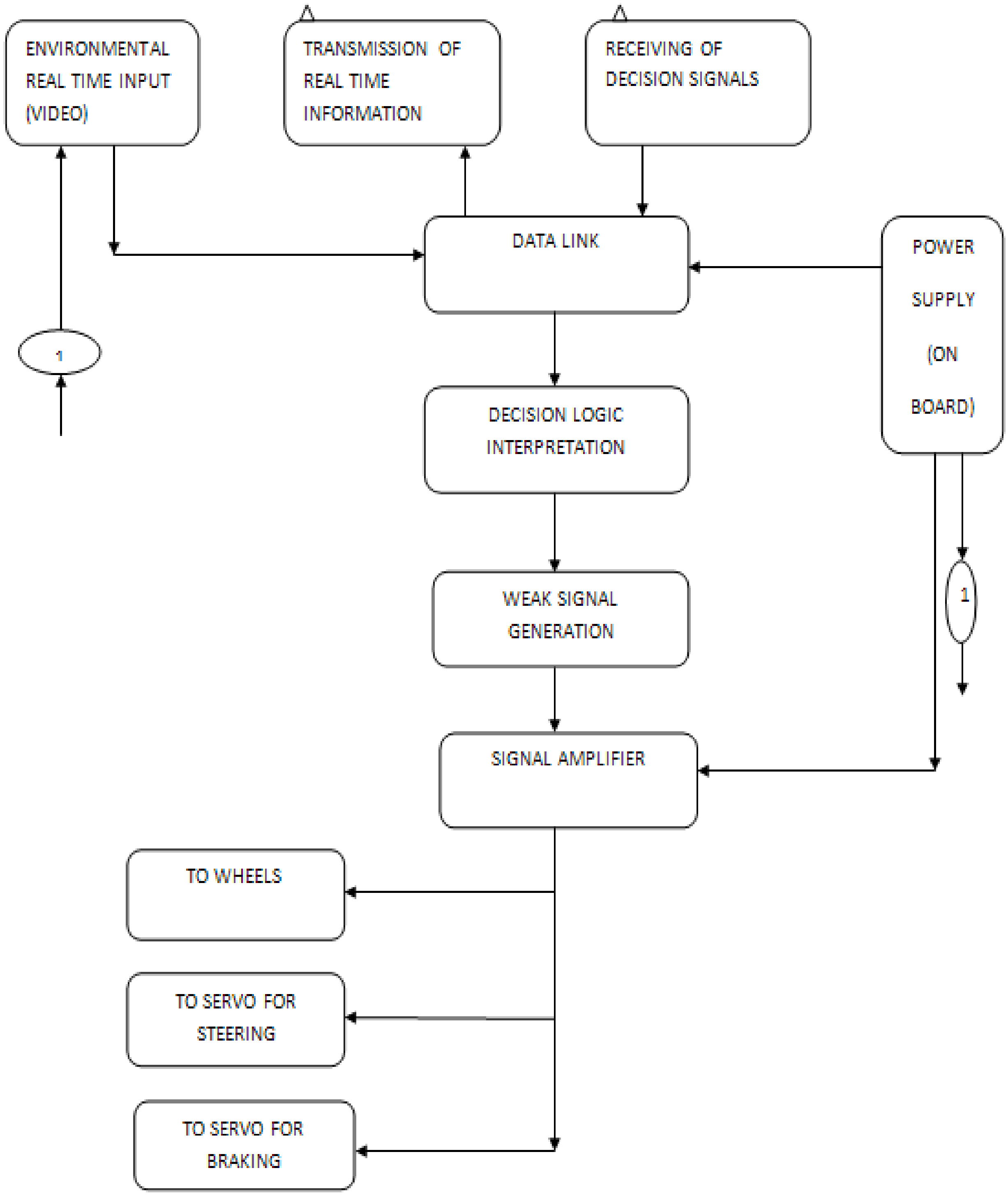


Figure 3.4

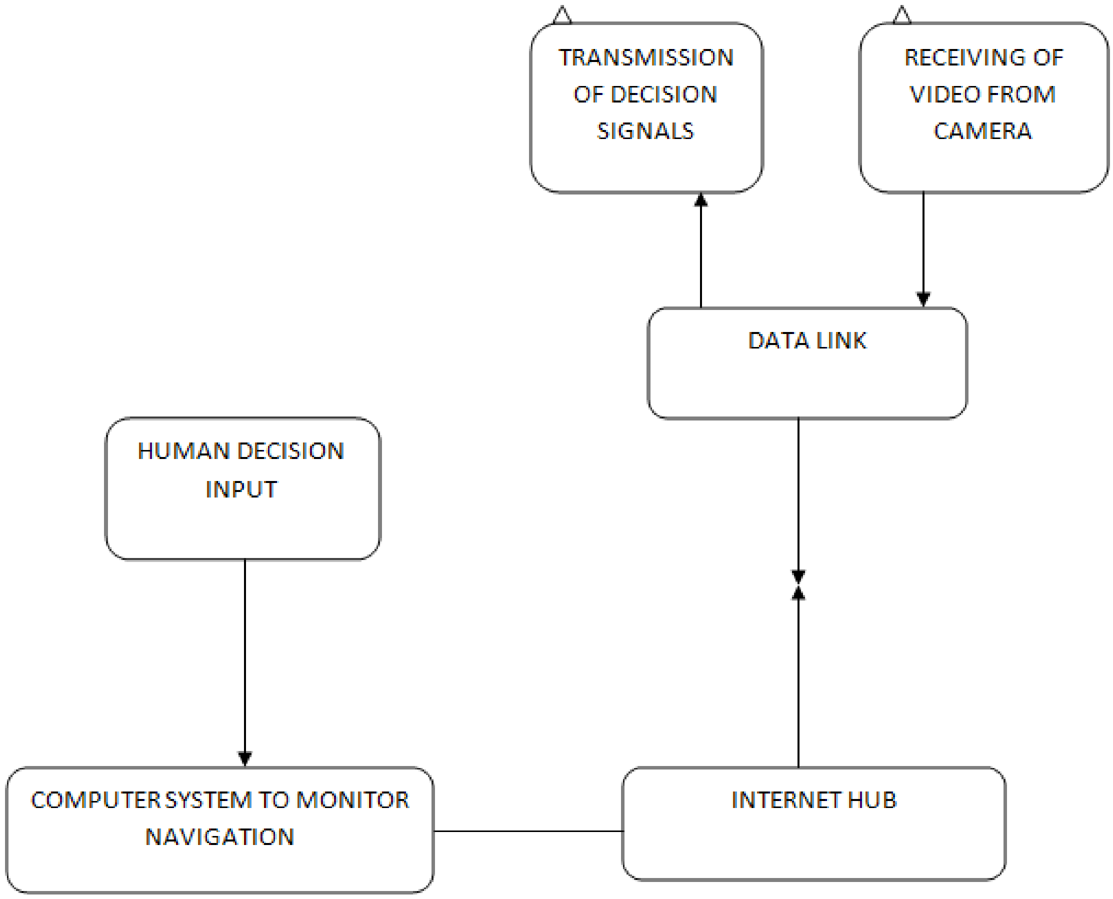

TRANSMISSION OF DECISION SIGNALS
RECEIVING OF VIDEO FROM CAMERA
DATA LINK
HUMAN DECISION INPUT
COMPUTER SYSTEM TO MONITOR NAVIGATION
INTERNET HUB

Figure 3.5

Chapter 4

Design and Analysis

4. DESIGN AND ANALYSIS

The designing phase includes the hardware designing, hardware set up (including mechanical design or retrofitting) and then software design and then finally synchronizing software and hardware together.

4.1 HARDWARE/MECHANICAL DESIGN

The hardware or mechanical design basically includes the followings

a.)Chassis designing for AGV.

b.) Designing of body to accommodate equipments and desired load.

c.)Maintaining the symmetric property of vehicle, if possible.

d.)Focus on the driving energy source and its sitting on vehicle.

4.1.1 DRIVING ENERGY

The AGV should be capable of self propulsion and hence a suitable battery powered AGV was proposed in the possibility of our case which can deliver the required power for considerable period of time.

4.1.2 SELECTION OF REVA i (With a bit of retrofitting)

The chassis designing part was tackled by selecting Reva i , a Lead Acid Battery powered Car(2.6m by 1.3m by 1.5m) in dimension and a 200 Ah battery capacity. It has an AC drive mechanism which makes it capable of having peak speed at 80 Km/Hr . It weighs 665 Kg, out of which the total battery weight is 270 kg . There are eight 6v, 200 Ah sealed Lead Acid battery under front seat. Power flows through a 350 amp motor controller to a three phase AC motor rated at 17 hp(peak).

Figure 4.1

4.1.3 ADVANTAGES OF OPTING REVA i

a.)Tests for accurate navigation can be conducted at a higher speed due to its specially designed 3 phase AC motor hub wheel.

b.)Compact Design

c.)A typical real vehicle which is driven on road, (traffic compatible), and hence will provide a real test of control and accuracy, using proposed mechanism.

d.)More pay load capacity (upto 270 kg)

e.)Light and strong Body construction

f.)Easy charging at 230v, 13A outlet

g.)Better suspension and shock absorption

4.1.4 RETROFITTING

The car is a rear wheel driven, and right located steering controlled .The seat is adjustable back and forth in the steps of 25mm.The driver seat provides ample space for fixing servo mechanism which can steer the car. The acceleration pedal has a total deflection of about

40mm (full throttle to idle condition).A servo was fitted in vicinity of acceleration pedal which will regulate the acceleration and hence speed as per requirement. Instant braking can be done or the vehicle can be decelerated, subject to the deflection of brake pedal (total deflection is 35mm, taken about a mark mean point about the pedal).

4.2 ELECTRICAL AND ELECTRONIC DESIGN

The wheels are already connected to the battery via a speed regulator and accelerator pedal in between, and hence no necessity to disturb these connections .We can have the speed regulation by using servo mechanism to deflect the accelerator pedal servo is a three wired motor which can have a static deflection corresponding to duty cycle of the input square wave signal. The two of three wires are for providing driving voltage, and the third one for taking input signal as interpreted and generated by microcontroller on receiving control signal through data link. Elaborately the control signals received by a distant decision unit is received by data link they are fed to computer and then equipment control commands are released by computer's parallel port to the micro controller which along the amplifiers then give signals to the servo motors for desired control action. The control of vehicle was given using four ports from computer's parallel port. Each port signal is utilized for a specific function.

Signal from each port is used for a particular function

PORT NUMBER	FUNCTION
1	Turn Left
2	Turn Right
3	Move Straight
4	Brake

Table 4.1

Function of each port

The control executed by each of the port can be given by corresponding circuit diagrams as given below

4.2.1 PORT NO 1 (Turn Left)

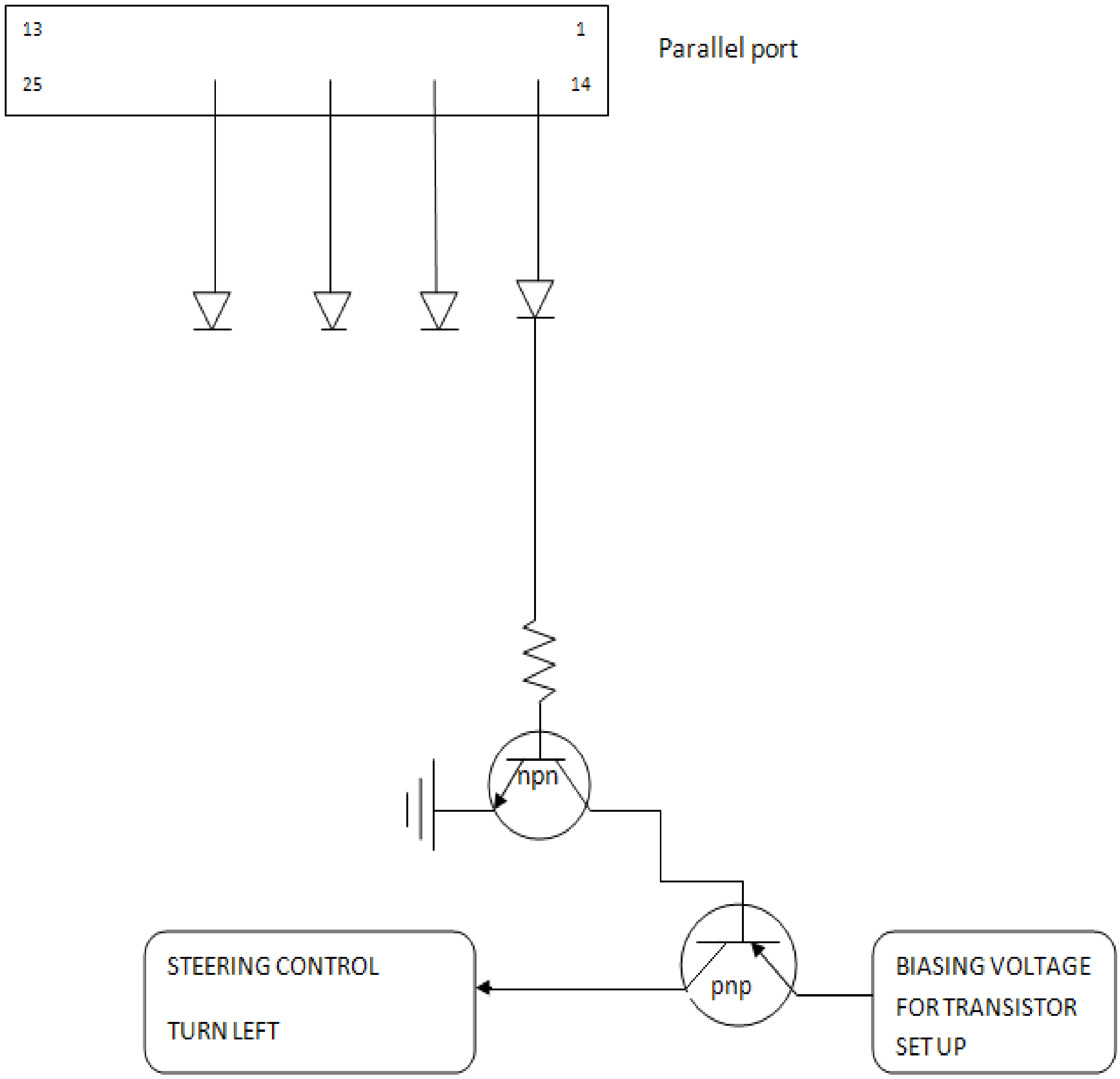


Figure 4.2

4.2.2 PORT NO 2 (Turn Right)

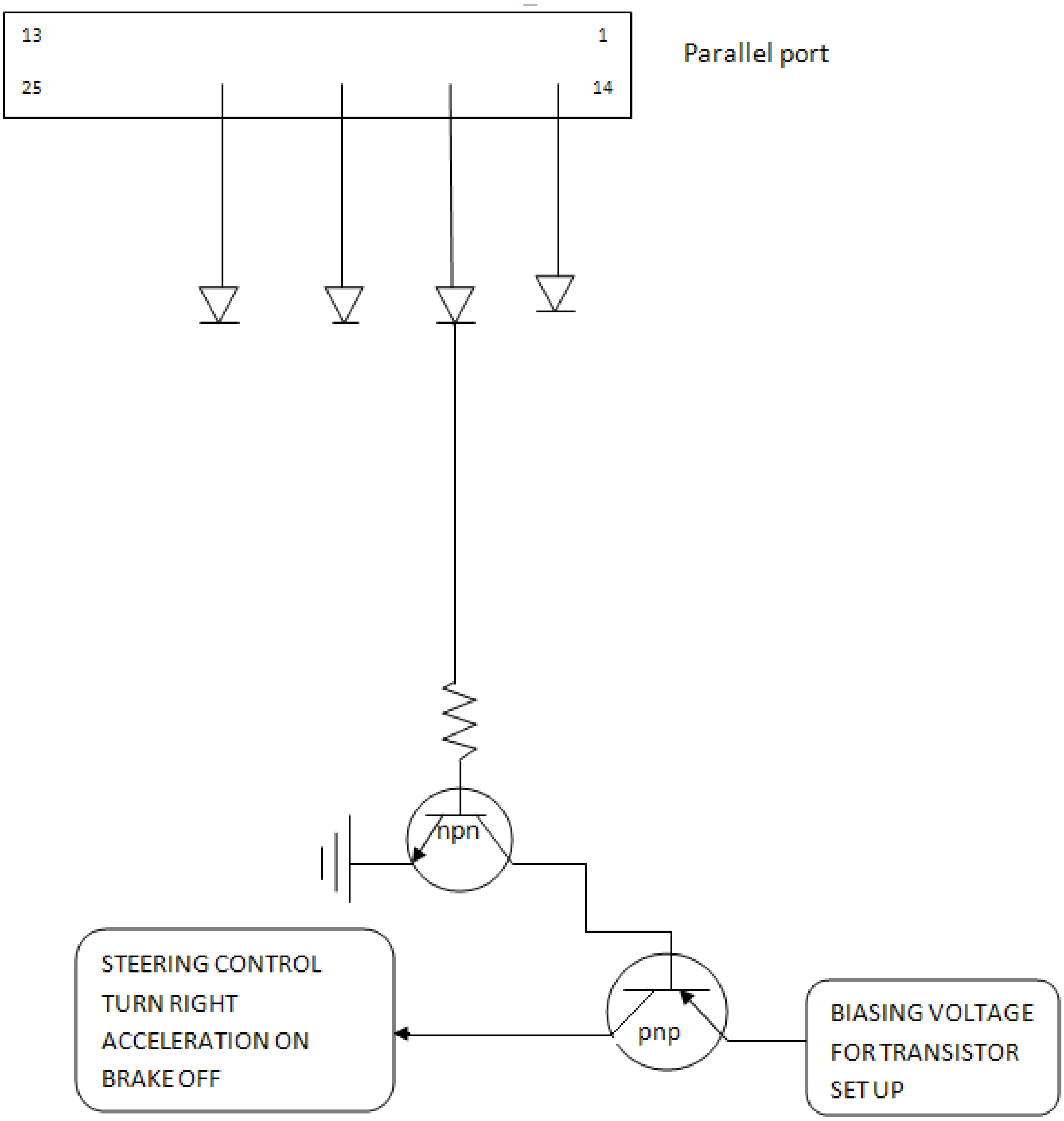


Figure 4.3

4.2.3 PORT NO 3 (STRAIGHT MOTION)

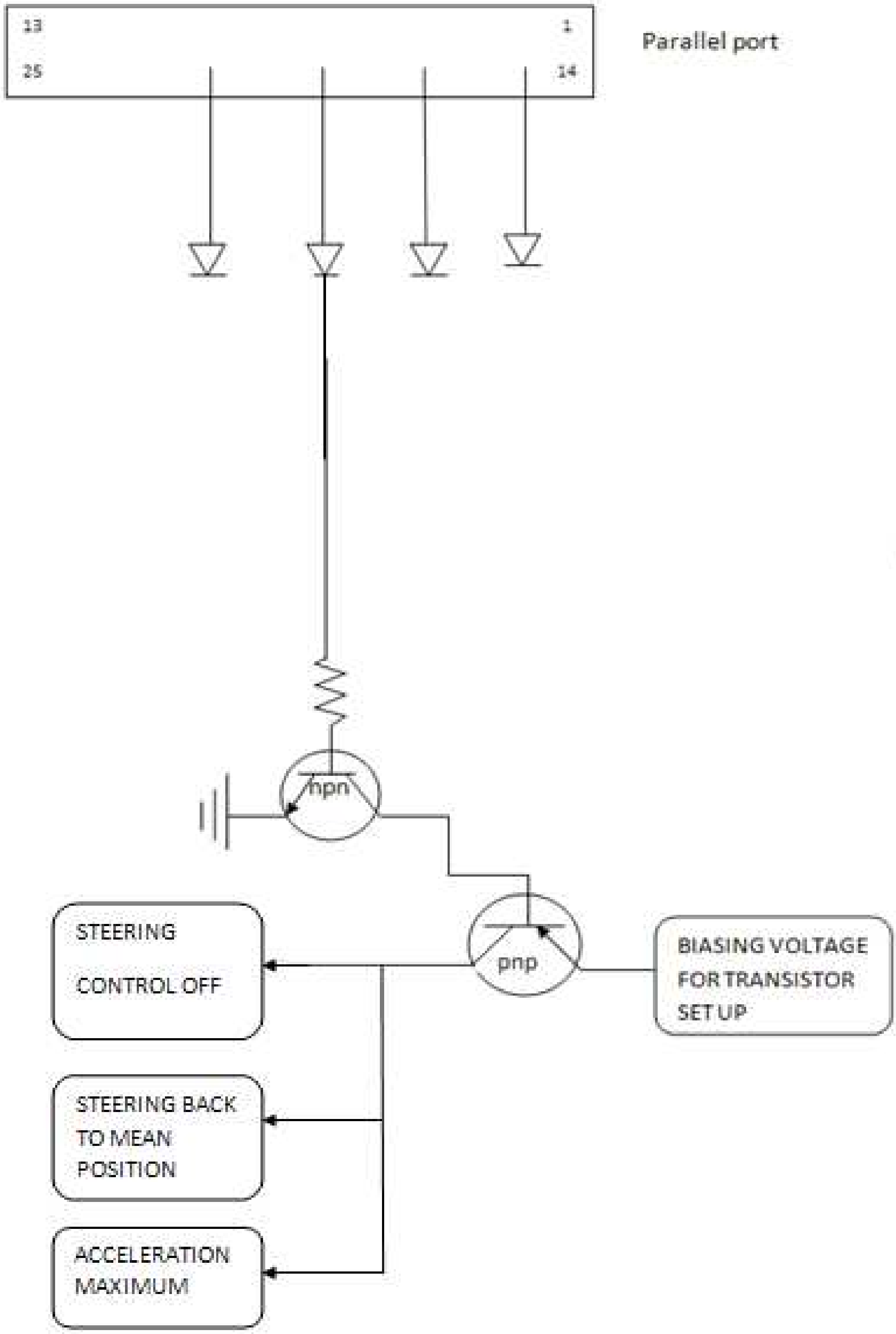


Figure 4.4

4.2.4 PORT NO 4 (Brake)

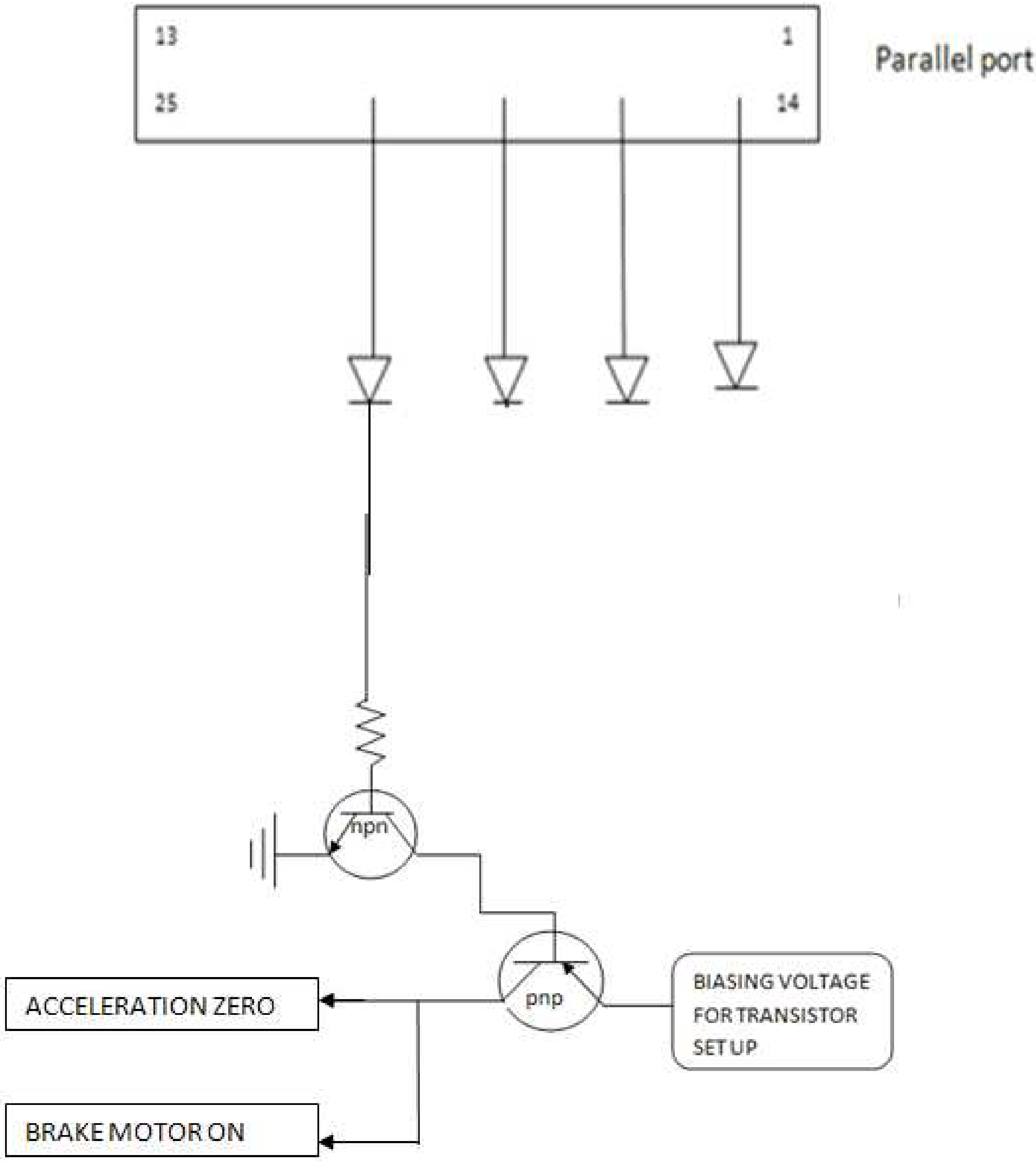


Figure 4.5

Servo motors used were of Hitech

Figure 4.6

The servo torque analysis has been encapsulated as below

Sl No	Servo Motor For	**Torque 4.8/6.0v (kgcm)**	No of Servo used
1	Brake (Hitec HS-805BB)	24	2
2	Acceleration	12	1
3	Steering (Hitec HS-805BB)	24	2

. **Table 4.2**

The microprocessor circuit & servo motors were all driven by a double battery UPS.

Figure 4.7

4.3 Software Design

In order to control the vehicle using onboard computer system, the designated and pre-decided pins from parallel port were connected to amplifier and central control circuit. To execute a certain task a signal current was generated in respective pin ,and this was done using a simple application built in c++ using devC++ as IDE.

4.3.1 The code used for navigation just using signals from parallel port was

```
#include <stdio.h>

#include<conio.h>

#include<windows.h>

#include<iostream.h>

Using namespace std;

/*Definitions in the build of inpout32.dll are as follows:   */

/*short_stdcall inp32(short port address);         */

/*void_stdcall out32(short port address,short data); */

/*prototype(function typedef) for DLL function Inp32: */

typedef short_stdcall (*inpfuncPtr)(short portaddr, short datum);

typedef void_stdcall(*inpfuncPtr)(short portaddr);

int main (void)

{

HINSTANCE hLib;

inpfuncPtr inp32;

outfuncPtr oup32;

short port_data;
```

```
int address;

char t;

/*load the default library*/

hLib = Load Library("inpout32.dll");

if (hLib==NULL)

{

printf("Could not Load the Library. Library loading rendered unsuccessful."\n);

return -1;

}

/*Acquire the function's  address */

inp32=(inpfuncPtr) GetProcAddress(hLib, "Inp32");

if(inp32==NULL)

{

printf("Address could not be procurement. GetProcAddress for inp32 Failed.\n);

return -1;

}

Oup32=(oupfuncPtr) GetProcAddress(hLib, "out32");

If(oup32==NULL)

{

printf("The GetProcAddress initiated for Oup32 unsuccessful .\n");

return -1;

}

/***************************************/
```

```
/*input and output32 addresses procured using library*/

/*To test the functions now*/

/*address initialization*/

address=0x378;

port_data=0x00;

/*Reading to verify back the addresses compatibility with that of loaded library*/

port_data=(inp32)(address);

cout<<”port read (%04X)=%04X \n”<<address<<port_data<<endl;

cout<<”enter the port data:”;

cin>>port_data;

cout<<endl;

(oup32)(address,port_data);

printf(“port write to 0x%X,datum=0x%2X \n”,address,port_data);

port_data=(inp32)(address);

printf(“port read(%04X)=%04X\n”,address,port_data);

cout<<”Enter any key for yes except N, which will be  for no”;

cin>>t;

cout<<endl;

while(y!=’n’||y!=’N’)

/*Testing once more with different data value*/

{

cout<<”enter the port data:”;

cin>>port_data;
```

```
cout<<endl;

(oup32)(address,port_data);

printf("port write to 0x%X,datum=0x%2X \n",address,port_data);

/*reading back for verification*/

port_data=(inp32)(address);

cout<<"port read (%04X)=%04X \n"<<address<<port_data<<endl;

cout<<"Enter any key for yes except N,which is for no";

cin>>t;

cout<<endl;

while(t!='n'||t!='N')

exit(1);

}

getche();

FreeLibrary(hLib);//getche();

return 0;

}
```

4.3.2 Segmentation Code

```
#include <cstdio>

#include <cstdlib>

#include <image.h>

#include <misc.h>

#include <pnmfile.h>

#include "segment-image.h"


int main(int argd, char **argt)

{

  if (argd != 6) {

    fprintf(stderr, "usage: %s sigma k min input(ppm) output(ppm)\n", argt[0]);

    return 1;

  }

  float sigma = atof(argt[1]);

  float k = atof(argt[2]);

  int min_size = atoi(argt[3]);


  printf("loading the input image.\n");

  image<rgb> *input = loadPPM(argt[4]);

  printf("processing under progress\n");
```

```
  int num_ccs;
  image<rgb> *seg = segment_image(input, sigma, k, min_size, &num_ccs);
  savePPM(seg, argt[5]);
  printf("got %d components\n", num_ccs);
  return 0;
}
#ifndef SEGMENT_GRAPH
#define SEGMENT_GRAPH
#include <algorithm>
#include <cmath>
#include "disjoint-set.h"
// threshold function
#define THRESHOLD(size, c) (c/size)

typedef struct
 {
  float w;
  int m, b;
}
edge;
bool operator<(const edge &m, const edge &b) {
  return m.w < b.w;
}
```

```
/* * Segmenting an obtained graph
  * num_vertices: The number of vertices in graph.
 * num_edges: The number of edges in graph
 * edges: The array of edges.
 * c: Stands for constant of treshold function.
 **/
universe *segment_graph(int num_vertices, int num_edges, edge *edges,   float c)
 {
  // sort edges by weight
  std::sort(edges, edges + num_edges);
  // make a disjoint-set forest
  universe *u = new universe(num_vertices);
  // init thresholds
  float *threshold = new float[num_vertices];
  for (int i = 0; i < num_vertices; i++)
   threshold[i] = THRESHOLD(1,c);
  // for each edge, in non-decreasing weight order...
 for (int i = 0; i < num_edges; i++) {
  edge *pedge = &edges[i];

  // components which are conected by this edge
```

```
int m = u->find(pedge->m);
int b = u->find(pedge->b);
 if (m != b) {
 if ((pedge->w <= threshold[m]) &&
 (pedge->w <= threshold[b])) {
  u->join(m, b);
  m = u->find(m);
 threshold[m] = pedge->w + THRESHOLD(u->size(m), c);
 } } }
 delete threshold;
 return u;
}
```

The above program/code may be triggered whenever we need to control the vehicle directly. However it may be linked through DATA LINKING to make it behave as per remotely controlled. Also, instead of operating for a defined no of times it may be, operated in an infinite loop and the image processed signals from the image processor can be taken to determine the position of stagnant and moving obstacles and path detection. Thus referring to the pre stored map, and making decisions for movement, and securing locomotion by obstacle and path detection the target can be reached.

Chapter 5

Installation

5. INSTALLATION

Installation refers to the final setting together and synchronization of all controls, electric and electronic setup, and the PC setup, battery source together on the vehicle, making it able to start and perform the desired task. The final integration and synchronization was done in several steps

1. Sensitivity check of response system of our automation setup.

2. Sensitivity analysis of original vehicle setup which is being automated

3. Brake ,steering ,acceleration with other navigation control features being adjusted according to above sensitivities(In fact they need to be enhanced and restricted in the sense to tackle the worst collision situation due to TTC being less than analysis time plus braking distance/deviating distance taken together)

As the vehicle is automated guided according to the analyzed video stream input, and hence it is the lag between the input signals and decision response on wheels, which poses a restriction on the navigation parameters.

The vehicle was thoroughly analyzed for its steering, brake and acceleration sensitivity.

5.1 Braking

The test vehicle (AGV) was thoroughly analyzed for its effectiveness in braking so as to limit its speed to avoid any collision till the image processing part releases the control signal for action. Thus the key factor that comes to picture is the braking distance to avoid any instant collision.

Table showing the results obtained from vehicle's test driving for limiting some or all parameters which may lead to get the vehicle out of control with our control and decision making setup.

Sl. No.	Level of braking	Speed of Vehicle	Braking Distance	Skidding/Slipping
	(Expressed as % of 'full unbraked braking lever deflection')	(km/hr)	More/less than 1meters	Yes/no
1	25 %	20	more	no
2	25 %	40	more	no
3	50 %	20	more	no
4	50 %	40	more	no
5	75 %	20	less	no
6	75 %	40	Less	Yes
7	100 %	20	instant	yes

Table 5.1

5.2 Steering

At any juncture during motion the vehicle can be stopped or just deviated to avoid any collision. However the term ‘deviated’ appears vague unless we have a figure of our control over steering. This raises a necessity of the steering mechanism.

It was analyzed that the steering can be turned about 280 degrees each side of normal forward wheel position. And we are using a servo mechanism for accurate driving/steering. The servo motor which we have been using gives a controlled output but its deflection is limited to a maximum of 90 degree on each side of normal position. Thus it poses a limitation on the sensitivity of position correction response and hence the vehicle cannot be navigated at a higher speed.

To tackle this problem i.e. to achieve more rotational deflection for some deflection by servo motor, many methods were proposed, however the most efficient as for high torque transmission appeared the spur gear train arrangement. As shown in the figure below initially two test spur gears of pitch circle diameter ‘2d’ were mounted on the servo motor output shaft, and another spur gear of diameter d was mounted on the center of steering.

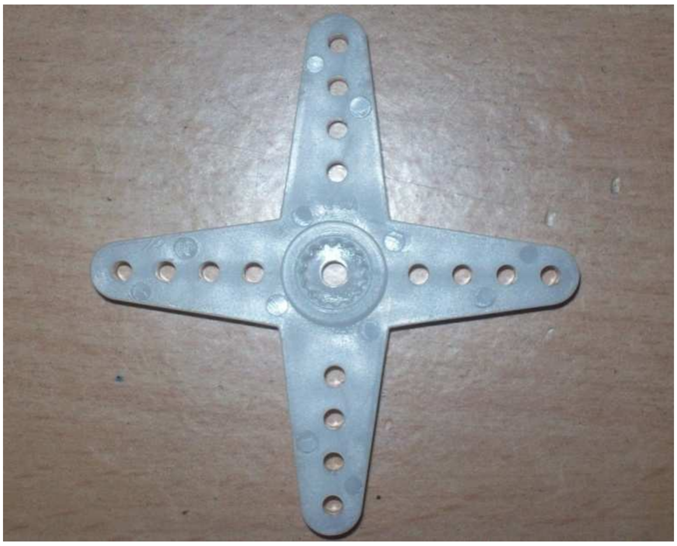
Pinion (spur Gear) that is attached to the servo motor for rotating the central pinion attached to the steering of vehicle. Diameter of pitch circle = 45mm

Figure 5.1

Central pinion (spur gear) attached to steering of AGV. Diameter of Pitch Circle=32mm

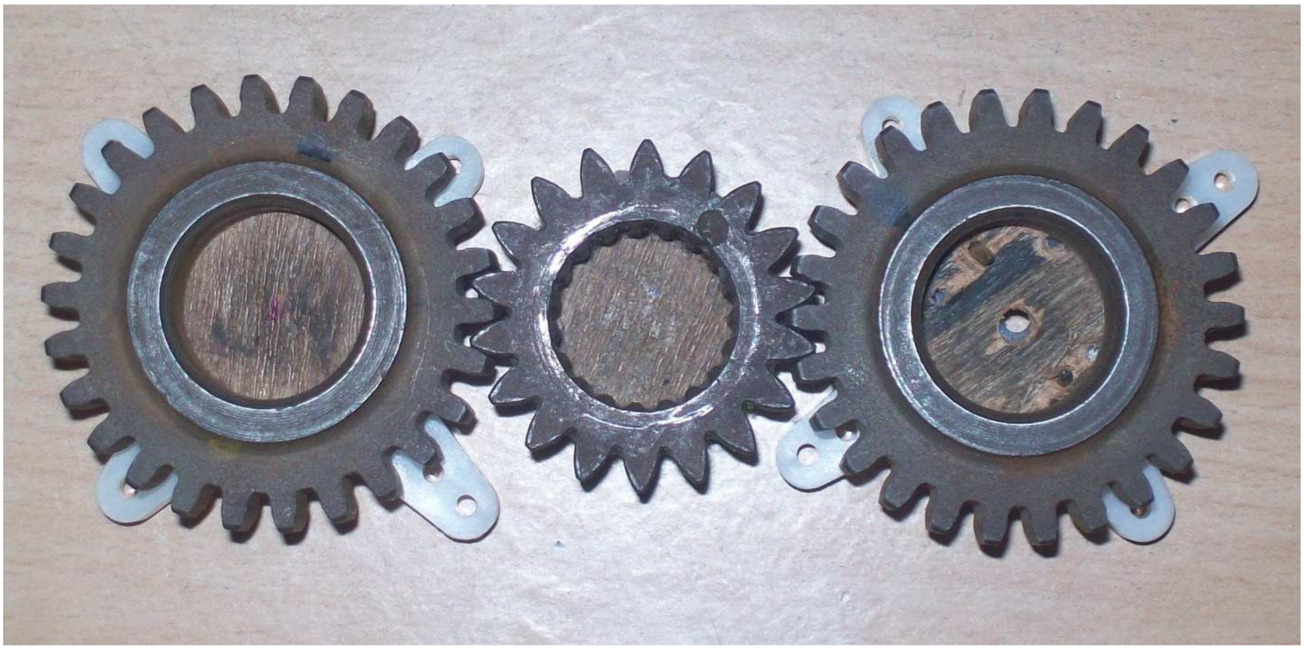
Figure 5.2

Thus for 90 degree deflection of servo motor the steering was turned by 180 degree, thus fulfilling our requirement. This could have been done using a greater ratio than 2:1 but in all those cases the net torque available at the steering would have been less, thus making it loath/slow or it could not have been turned even.



Arm Attached to servo shaft and permanently with the driving spur gears

Figure 5.3



Dummy setup (as not affixed to steering handle) showing driving gears mating with driven.

Figure 5.4

For achieving a greater angular deflection at the steering without net decrement in rotating torque we can surround more number of servo (D.C. Servo motors) surrounding the central gear fixed on steering handle. However the size of higher torque servos puts a limitation on maximum numbers of them that can be used all along, all at once.

5.3 Acceleration

The vehicle shows relatively low acceleration as compared to internal combustion engine based automobiles and is suitably controllable. Also the forward motion is well controlled using brakes (braking system), hence it appears that there is no necessity of accelerating the vehicles in steps defined between full and nil.

However if desired , the acceleration can be better controlled by deciding more steps between full and nil (complete and nil deflection of acceleration pedal using the servo motor).

5.4 Vehicle Analysis

The vehicle was tested for all the control responses in perfect position including the brake, steering and acceleration including their sense from pilot/driver point of view. The vehicle was not started until a complete check up of vehicle itself was done.

This completes the installation of vehicle by connecting synchronizing the setup and checking their controls suitably.

Chapter 6

Results

6. RESULTS

The result of the design setup and renovated mechanisms were successful to maximum extent. The results of the aimed objectives can be jotted down as

6.1 Hardware Design:-

1. The Automated guided vehicle(AGV) was successfully tested with a pay load of 270 kg which included the weight of batteries(additional to the battery used for powering the car), UPS, computer, circuits, servo motors and other accessories, for its controlled and safe movement

2. The Vehicle was successfully retrofitted, rather renovated with suitable driving gears to operate the steering, and even other control structures. The gear setup was directly attached to output shaft of servo to improve the steering output at servo, and was a complete success, providing better turn and torque.

3. The vehicle has inherent stability, and is of commercially ideal size with hardly any vibration during its maneuvering. Also its motion is smooth at turnings edges and cuttings with instant braking without skidding at desired places.

4. The design holds the capability of getting upgraded in almost all senses including option for applying solar panel to be used a s power source , thus making it totally autonomous.

The above stated results can be dis-ambiguously inferred from the setup and design photographs that have been put in project.

Some of the views of vehicle and its control setup are as shown.

Figure 6.1

Side view of the AGV with its content

Figure 6.2

Steering ring fitted with driven pinion

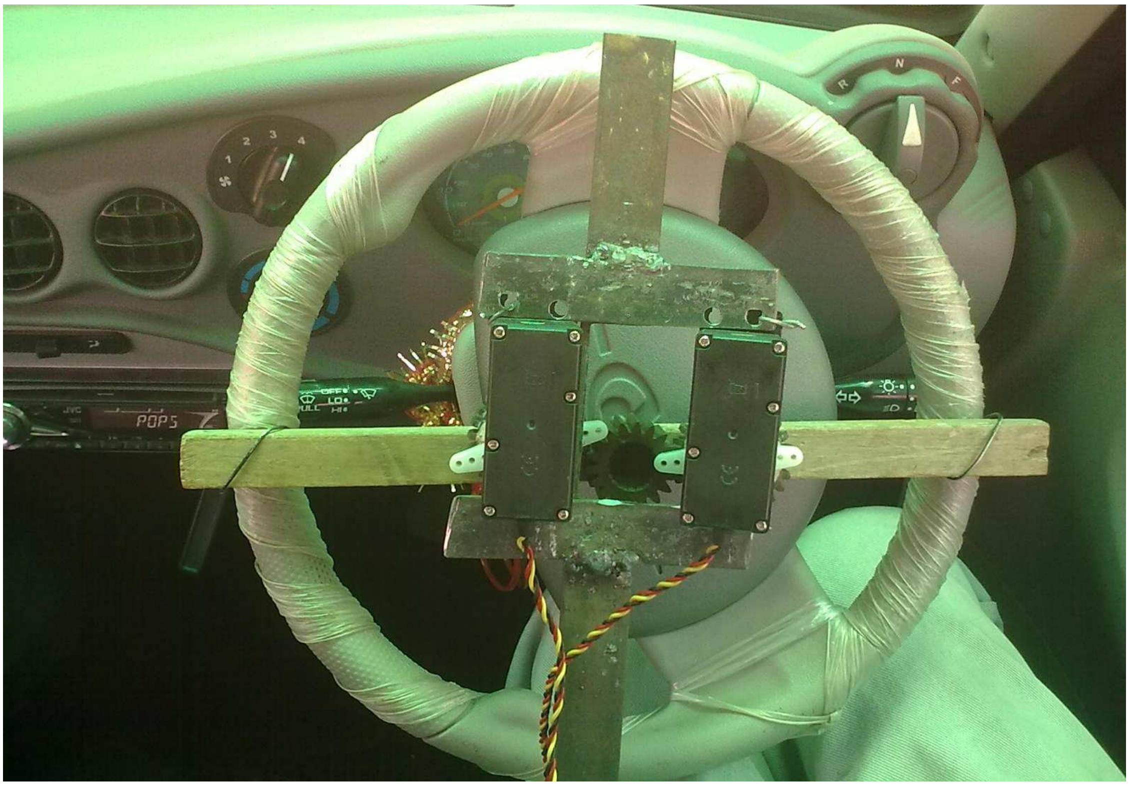


Figure 6.3

Steering with signal controlled D.C. servo Motor and driving Spur gear (one on each servomotor)

Figure 6.4

Rear view of the AGV

6.2 Software Design :-

1. The software applications built were perfectly functional for their intended use, and were even optimum in the usage of computer memory processing time and output generation, tested on a 1GB RAM and 2 GHz processor.

2. The AGV (automated guided vehicle) has been designed in such a way that any improved programming , code and application built at any instant in future can be easily incorporated in the existing setup, and this takes care of feeding ready to use maps with self updating capability with easily retrievable point landmarks.

3. However the console application needs to be given, a common interface so as to make its usage easily available.

4. The design is capable of getting linked to a ready to use e-map as well as optional remote assistance that generates control signals.

5. Though different image segmentation and their processing have been crudely implemented at present juncture, scope has been provided for its refinement or complete change of image segmentation part from algorithm.

Chapter 7

Discussion

7. DISCUSSION

7.1 Issues in hardware design :-

During the initial phase of designing much problems were faced to have an steering mechanism which could suitably perform the task, without causing much damage to original vehicle, however it were all sorted out with the implementation of spur gear setup, the servo motors were supported to the AGV frame using an iron angle which was bolted with the pilot seat.

Also the initial gear ratio used was 3:1 for achieving a better deflection of frontal tyres about the mean position for turning the vehicle, however lack of rotating torque was encountered especially at lower speeds and hence gear ratio was reduced to optimum existing condition.

Even the steering ring/wheel was at an angle to horizontal, and so was adjusted the plane of driving as well as driven gears.

As two driving pinions were used, hence proper symmetry was maintained about the steering ring and set up.

While trying to power the on-desk computer system using the batteries which used to power the car, the mileage of car subsequently decreased, and hence was powered using UPS system

7.2 Issues Software design :-

The software application development was quite smooth, and though it took time in developing and debugging, it never created problem in hang over or other signal generating problem using parallel port. The part that remained was development of much detailed segmentation program that was to be entangled with base code, which could then directly control the AGV.

Chapter 8

Conclusion

8. CONCLUSION

In spite of a lot of failure, despair and numerous changes, we were able to successfully design a fully operative Automated Guided Vehicle AGV, which can be controlled semi-automatically and as well can be autonomous in its maneuvering and navigation with the help of machine vision. However a lot has to be done to make it able to take on, in more generalized conditions, all types of terrains and other maps. Points where our AGV can be still improved are

1. The steering mechanism can be further enhanced using a better gear ratio to give more deflection at the driving wheel with better torque by employing more than two servo motor of the existing torque capacity, or replacing them with a higher torque servo motor. Also the setup can be made spring loaded to work better in sever jerk and jolt operating conditions.

2. A better quality stereoscopic camera may be employed with higher frame rate and feed back focusing capability to focus in at desired locations as per machine considers suitable.

3. The whole setup needs to be charged from mains after each operation, which can be suitably switched to solar photovoltaic cells and affixing solar panels around the body and making it a bit more autonomous.

4. On the software portion the algorithm and hence the codes might be more sophisticated for navigation. Fuzzy neural techniques could be harnessed to train the vehicle to detect the obstacles of various natures, static and mobile in various types of backgrounds and disturbances, to detect its guide path.

5. The common personal computer used in our case might be replaced by a custom made CPU which would have better graphics processor rather a dedicated processor, such that the response time of vehicle gets reduced and the response time of total setup decreases.

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