Design and Implementation of Smart Transportation System

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ABSTRACT

The purpose of this thesis is to detect and analyze the drivable path and obstacles ahead of the autonomous vehicles by implementing obstacle and path detection algorithms for the navigation of autonomous vehicles on MATLAB. This report presents basic introduction to image processing, its applications. The use of image processing in autonomous vehicles in place of sensors and other hardware equipments is discussed in detail and it presents why image processing is chosen as the procedure to make the autonomous navigation possible. For the complete autonomous navigation, the task is divided into two major parts: obstacle detection and path detection. For obstacle detection and pitch detection, a single frame stereo system is used and for detection of drivable path, decision network approach uses monocular vision system. The methods that I have described about in this report and will be implementing those methods using, stereo images captured from the cameras set up on the vehicle to give the image showing path and obstacle ahead, for the successful execution of my purpose, are defined in this report.

INTRODUCTION

1.1 Image

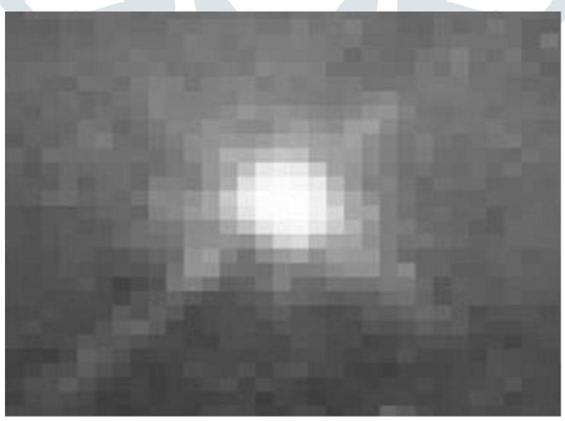

Fig. 1.1 Matrix of square pixels rows and columns

Image consists of matrix of square pixels arranged in rows and columns. Any image is called as digital, if it represents two dimensions containing a finite number of digital values called pixels or picture elements. Digital data do not change even when it is reproduced a number of times and also it retains the originality of data. Values of pixel represent gray levels, colors heights, opacities etc.

1.1.1 the most common formats of image includes

1. 1 sample per point (B&W or Grayscale)

2. 3 samples per point (Red, Green, and Blue)

3. 4 samples per point (Red, Green, Blue, and "Alpha", also known as Opacity)

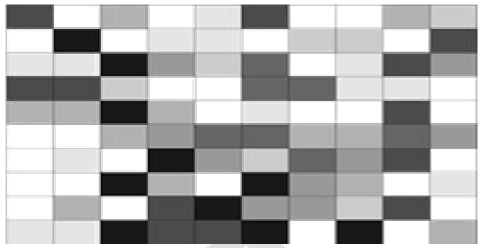

Fig 1.2 Pixels having value 0(black) to 255(white)

Any image is called a true color image if it has:

color depth of 24 bits (8*8*8 bits) = (256 * 256 * 256) colors = 16 million colors (approx).

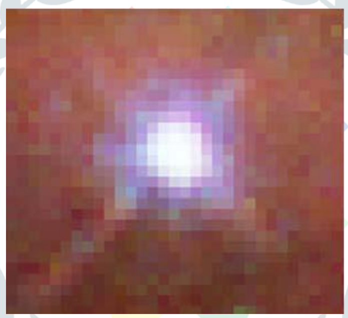

Fig 1.3 True color image

1.1.2 Common formats of image file

1. GIF: it is 8-bit (256 color) compressed lossless bitmap image format. Web resources generally use this format. Animated GIF is one of the sub-standards of GIF image format.

2. JPEG: The JPEG format is most efficient format of image as it contains maximum information per byte. It is lossy compression, 24 bit bitmap format representing the complete million colors. It is widely used specially for web and internet.

3. TIFF: it is also lossless compressed, 24 bit publication bitmap format. It uses Lempel-Ziv-Welch (LZW) compression.

4. PSD: This is typically a photo shop format that keeps all the information layers conserved in an image.

5. PS (Postscript): This is a vector format. It also has sub standards and is difficult to transfer theses images across other platforms and for operating.

1.2 Image processing

The image processing performs conversion an image into digital form and perform some operation whether it be enhancing or extracting out features or some sort of information from an image. Examples of computerized methods for information extraction is pattern recognition, classification etc. from remotely sensed image to obtain categories of information about a particular feature. In this the input signal is image and output may be image or the attributes of input image. In general, image processing treats images as two dimensional signals or data. Now a days it has become the most rapidly growing technology with its applications in almost every field such as Biology, Astronomy, Medicine, Security, Biometrics, Satellite imagery and many more.

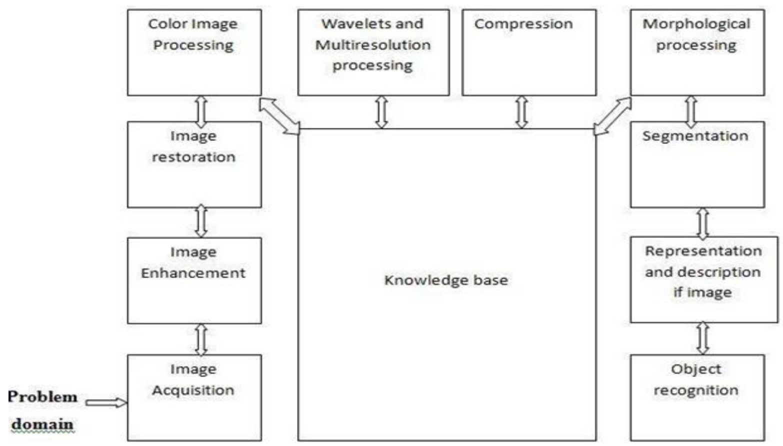

Fig1.4 Fundamental steps of image processing

1.3 Image processing system for autonomous navigation

Computer Vision is emulating the human visual system and interpreting 3D information (data) from 2D images or video by the other applications such as Object detection, Motion tracking, 3D information from 2D images etc. to calculate distance of points in an acquired image with respect to camera position is one of the important tasks of a computer vision system.

1.3.1 Stereo Vision

Stereo vision method is used to calculate depth information from the pair of stereo images. It is used widely in place of other algorithms because it requires less computational load. It is a process that provides 3D perception with the help of two different images of the same scene. It is very important in computer vision to calculate the distance from the cameras mounted on something to the target object. This technique can be implemented by the use of active as well as passive methods. Active methods include approaches that are based on monocular vision in which only the internal structures of the image are used. Active methods also use techniques based on laser, ultrasound, pattern projection etc. More complex hardware requirement is the main disadvantage of active methods and more energy is also needed to calculate depth map of image. Passive techniques reduce the amount of energy required to calculate the same perimeter that enables it to use more on the hardware. The performance and approaches used in passive methods depend on the number of cameras used and the distance between the two cameras.

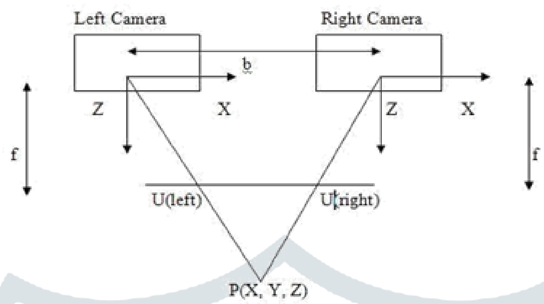

Fig. 1.2 set up for stereo vision

Where, f = focal length of camera

P = position of object defined by coordinates X, Y, Z

X = camera‟s X axis

Z = camera‟s Optical axis

U (left) = left camera projection on point P

U (right) = right camera projection on point P

b = baseline (distance between two cameras)

1.4.2 V- Disparity approach

It is performed for the image analysis and segmentation. As the vehicle oscillates due to terrain bumps while moving in off-road environments. Thus image needs to be stabilized by „v disparity‟. These images are the three dimensional view of similarities in left rows and right rows of image, depending on disparity values that are used for the comparison of those images. In cases, when the scene is having a plane(leveled) road and vertical obstacles, then finding the projection that can estimate the planes then the v disparity image is very powerful for such estimations. Mathematically, disparity can be calculated as:

Disparity = Xleft–Xright

Where, Xleft = horizontal coordinates of pixels of left image

Xright = horizontal coordinates of pixels of right image

Xleft – Xright = f * b/Z

Where, b= baseline, Z= depth, f=focal length of camera

The most common method for calculating depth is by using stereo camera setup consisting of two cameras separated by a known distance (baseline) with coplanar optical axes.

1.4 SCOPE OF THE STUDY

The information about the drivable path and the obstacles present at the road surface ahead of the moving vehicle is useful for autonomous driving. Using stereo vision technique to detect the road has many benefits in comparison to sensors such as more features, low cost or low consumption of power, easy to integrate. Other vision based approaches for detection use low level features (color or texture) as visual output that helps in grouping the pixels that exhibit same properties. Since, the roads are being imaged from a mobile platform; it is difficult to achieve a perfect clustering algorithm in outdoor as well as unstructured environments. New challenges are presented for autonomous navigation in cross-country environments. The complexity of the problem increases that is even the simple object detection becomes complex when the vehicles are to move in highly unstructured environments. In addition to the obstacle detection knowledge about type of terrain is also important for the system. This whole criterion helps the path planner to follow the correct path chosen having higher efficiency toward the goal. Robots that can drive autonomously in unstructured environments have gained a huge success in the past few years and they will in the future also. The US Department of Defense has been the major sponsor of research in this field including its various agencies that also organize various autonomous driving championships. One of the basic information a vehicles needs, is about the road the it is driving on further, information about the meaning of each lane of the road if it is structured one in order to decide which lane should be taken. Type of region (road) can be predicated based on the assumption that the regions that look similar will be of similar type.

1.5 OBJECTIVES OF THE STUDY

Based on the literature review, the objective of the research can be divided into two major parts:

1. Identification of different type of roads by the autonomous vehicles through image processing

2. Finding the clear path by avoiding the rough terrain and other obstacles.

These two objectives can be achieved by using single frame stereo system for obstacle detection and pitch detection, and monocular vision system followed by decision network approach for detection of drivable path

2. LITERATURE REVIEW

R. Manduchi and L. Matthies presented different types of terrain geometrically for enabling the autonomous vehicle to plan the path by recognizing the type of terrain and finding obstacles coming on the way and choosing the most efficient path toward the goal. The algorithm used is based on the two sensor systems that complement each other (a color stereo camera, and a single axis ladar). For obstacle detection, stereo range based measurements are done in which there is not much visible plane ground hence color based classification is used to label the obstacles on the basis of terrain classes and analysis of sensor data to differentiate between surface and obstacles (such as grass, rocks etc.) also when these obstacles are hidden partially. The algorithms which were developed in this paper were used in Jet Propulsion Laboratory (JPL) that enabled safe autonomous navigation in highly unstructured paths [1].

Parag H. Batavia and Sanjiv Singh described two methods for obstacle detection one is adaptive color segmentation and other is stereo based color homography. Both of these methods are complementary to each other. But this algorithm is well suited for the terrain which is relatively flat and roughly of the same color i.e. with lesser variations. Also these two complementary methods are more prone to false detections as objects. Color segmentation classifies an image as obstacle or free space based on the color. And the stereo based homography is used to find whether an image feature rises above the ground but this method does not provide the information about depth of the obstacle as pure stereovision techniques do [2].

Alberto Broggi, Giancarlo Alessandretti took the data from radar system and vision system is fused for vehicle detection. The radar data helps in locating the region of interest in an image, and then vertical symmetry is used to search the vehicle in that region. The vehicles so found in these image areas are mixed together and the data is processed onto series of filters to remove the false detections of objects. To improve the performance of the system, guard rail detection method is used to manage the overlapping areas. In the end, efficiency of both the methods is computed based on frames and events in vehicle detection system and based on time saving and true detection in case of guard rail detection[3].

Alberto Broggi , Massimo Bertozzi, used Generic Obstacle and Lane Detection system also known as GOLD, is a hardware as well as software architecture based on stereo vision which is used on moving vehicles for increasing the safety measures on the road. Based on hardware, it detects both the obstacles and the position if lanes in a structured terrain where the lanes are already marked on the road. From the two stereo images, the left image is used to detect road markings with the help of morphological filters, then the stereo images are mapped again and used for free-space detection in front of the moving vehicle. This system was tested on the mobile laboratory (MOB- LAB) experimental land vehicle and its robustness is demonstrated with respect to shadows and varying illumination conditions, type of texture, and movement of the vehicle [4].

Paolo Lombardi , Alberto Broggi, processed digital image to detect the track left by the vehicles moving in front on ice covered roads. This paper used colony of ants approach to determine the shortest path and thus improving the initial coarse solution on each attempt. Artificial vision algorithms are made to drive these vehicles in snow regions [5].

Dan Frentiu , Sergiu Nedevschi , detected Obstacles on the basis of 3D information which is obtained by stereo reconstruction. This 3D information is different in features of road and obstacles. This method does not rely only on smooth and flat surface of the road, but the vertical road profile is estimated from the lateral projection of 3D points. These estimated points above the ground are chosen to be grouped as objects, by varying the density of points with varying distance. The resultant (detected) objects are used as measurement for tracking algorithm with higher accuracy, obstacle detection from far distance [6].

Didier Aubert , Raphael Labayrade, managed uphill and downhill gradients as well as dynamic pitching of the vehicle, V-disparity approach can be used which provides better representation of the geometric contents of the road scene. The main advantage of this method is that it can detect obstacle even in case of partial occlusion or when there are errors during the matching process. This method does not explicitly extract features like road boundaries or lane markings from the two stereo images provided. Hence firstly the v-disparity image is constructed and on the basis of this obstacles are detected in context of flat and non flat road surface including pitch distance and height of the stereo sensor with respect to road surface. Then the vertical profile of road is estimated and the objects lying above the ground are extracted as potential obstacles thus leading to correct obstacle detection [7].

Richard Szeliski , Daniel Scharstein, used computer vision(stereo matching) and designed taxonomy to design decisions made in each stereo algorithm. Then these algorithms are compared with already existing stereo methods and performed experiments for evaluating the performance of different variants. In this paper, flexible implementation is designed that enables the evaluation of individual components so that new algorithms can be derived [8].

Jan C.M. Kleijweg , Johan C. van den Heuvel, presented a new class in public transport with new and promising capabilities as people movers (autonomous road vehicles). In this paper a roadmap is presented that describes about the development of new technologies for these autonomous vehicles and the most important technology is Obstacle detection. Stereo vision and radar systems are used for obstacle detection. To reduce the false obstacles detections and to detect the situations which need an instant action to be taken, tracking is used with sensor fusion system. The system developed for obstacle detection is tested on autonomous test vehicles that showed promising results [9].

Keiichi Uchimura , Zhencheng Hu, used stereo vision technique when driving in traffic environment as confusion occurs because of various factors such as guard rails, poles, parked vehicles and bikes etc. in this type of condition, stereo vision technique proves to be effective in place of radar based system as stereovision system has more wide field of viewing to categorize the scene into planes and different road surfaces, structures on the road side as well as obstacles [10].

Michel Devy , Diana Mateus, retrieved semantic information from the vision information after its processing to provide better reliability to the system by various fusion and filtering techniques used. Robots require complete integration of planning and control functions including path planning, environment changes and control on its motion, on board to remove the sensor data uncertainty. Type of environment highly controls the navigation problems. This problem is negligible in indoor environments, in which the geometrical features are known and it can be modeled accordingly but the conditions are opposite in case of unstructured environments. Therefore more complex strategies are opted for unstructured outdoor environments [11].

Christopher Rasmussen used the combined information obtained from laser sources color and texture data to detect and distinguish gravel, dirt, small rocks, grass etc. in the unstructured environments. Laser features such as three dimensional heights and the smoothness of the road are combined with features of image like color histograms and response of the filters. Individual pixels of the image are segmented and are then combined with laser sensor information to construct three dimensional maps that are required for path planning. Autonomous vehicles are required to make instant decisions to increase the speed and safety so that they can move on any type of road. For this, the system should be able to discriminate well between the drivable road and the non smooth environments [12].

Hoffmann ,Thao Dang, used various sensors can be used such as lidar, radar and stereo cameras etc. among all these techniques stereo cameras are proved to be potentially more strong. Object hypotheses is made from movement of the image due to vehicle oscillations and the stereo obstacle detection, as it uses various cues such as displacement, disparity, color, shape and texture. Whole process is divided into two algorithms: obstacles detection using stereo vision and segmentation of obstacles into clusters in three dimensional space[13].

Paolo Grisleri, Claudio Caraffi, Stefano Cattani, divided the task into two major parts: obstacle detection and path detection. For obstacle detection and pitch detection, a stereo scopic system of single frame is used and for detection of drivable path, decision network approach is used by a monocular vision system. Before the obstacle detection algorithm pitch is evaluated as the vehicle is moving and thus the vehicle pitch varies by the oscillations produced by the autonomous vehicle when moving on an unstructured path. Stereo vision and V disparity is used for detection of obstacles. These vision systems are developed to detect the obstacles and evaluate their location, avoiding wrong detections, also reducing the risk caused by wrong detections. The partial results of obstacle detection algorithm are exploited by the path detection algorithm [14].

5. RESEARCH METHODOLOGY

5.1 Problem Statement:

Path identification and finding the obstacles is the most important task of autonomous vehicles. For the complete autonomous navigation, the task can be dividing into two major parts: obstacle detection and path detection. For obstacle detection and pitch detection, a single frame stereo system is used and for detection of drivable path, decision network approach is used by a monocular vision system. The implementation of all these algorithms is to be done in MATLAB.

5.2 Proposed Solution:

Before the obstacle detection algorithm pitch is evaluated as the vehicle is moving and thus the vehicle pitch varies by the oscillations produced by the autonomous vehicle when moving on an unstructured path. For evaluating pitch following parameters need to be calculated:

1. Calibration of camera an selecting Baseline

   It is the distance between two cameras. Since, wider baselines enable distance estimation even for far obstacles more accurately, but at closer ranges, broader baselines give various angles thus making stereo matching task a bit complex. Thus shorter baselines are used for obstacle detection at closer distance. Similarities are measured by calculating sum of absolute difference for the stereo homologous point search.

2. V- Disparity approach

It is performed for the image analysis and segmentation. As the vehicle oscillates due to terrain bumps while moving in off-road environments. Thus image needs to be stabilized by v-disparity.

- The v-disparity image: The v-disparity image is calculated from the pixels of same disparity along the u-coordinate (normal axis). This V disparity image is used further to get information about both obstacles and path. For highlighting the ground components, ternarized image is obtained, by applying sobel mask(vertical) to the image in order to map the ternary domain (-1,0,+1) values.

- Pitch evaluation: pitch is estimated at the time of acquisition from the values in v-disparity image along the ground correlation lines choosing higher value. This estimated value of pitch is used in further steps of detecting obstacles and path.

5.2.1 Obstacle detection

Stereo vision and V disparity approach is used for detection of obstacles [14]. Pre requirement for the obstacle detection algorithm is to localize similar points on the vertical edges obtained by applying sobel filter.

a. DSI Computation: It is computed by using a narrow confrontation window of size 4x3 in order to detect thin and short obstacles. It is not measured in regions having no texture.

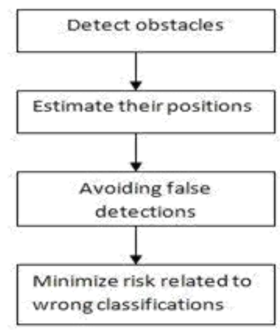

Fig 5.1 Obstacle detection algorithm

b. Obstacle search in DSI: one method to detect obstacles is to delete the matching regions from the DSI range image and group the remaining points as obstacles.

c. Filtering: to detect disparity values that can be the obstacles, a chain of fast filters are applied to the DSI image [14]. This also keeps the computational load under control.

5.2.2 Path detection

Path detection is basically a pattern recognition approach in which each part of the ground is to be classified as either road or off road surface. Since roads can be made up of either homogeneous or heterogeneous surfaces and the homogeneous part can be of any kind(structured or unstructured environment such as grass, gravel, sand, water, oil stains, rocks, shadows, lane markings etc).

Segmentation of image: it is also called clustering in which number of regions made up of same type of pixels is found, then those image pixels are grouped together and homogeneity calculated is applied according to set of local pixel properties. Functions which are further used to measure similarity in path detection algorithm are:

2. Decision: in the decision algorithm, each cluster is examined that whether it belongs to the road surface or not, using following information:

a. Cluster properties: a group of pixels are compared on the basis of cluster properties (, size, and similarity and shape factors).

b. Vehicle state: steering angle and speed

Higher the homogeneity and size, more better it is and the more closer the shape is to the road surface more better it is. The possible decisions are: classifying each cluster as road or off road, checking whether the classification is correct or not.

3. Cluster growing: First choosing a cluster at random, and if this cluster is considered as off road, another cluster is taken at random. And if the previously chosen cluster is classified as on road the maximum expected utility is kept equal to the utility of that cluster. Then this cluster is grown as its union with one of its neighbors and if the grown region is declared as off road part, and then next neighbor is taken. This process ends when it is not possible to increase the surface of road and addition of more clusters.

4. Decision network diagram: The figure above shows the decision network diagram of the system where the ovals represent the chance nodes. Chance nodes indicates the property of a cluster upon which decider has no control

6. SUMMARY AND CONCLUSIONS

The requirement is to minimize the number of incorrect classifications and minimizing their risks which is of great importance in autonomous navigation. If accurately calibrated, the obstacle detection system can provide robust response to wrong detections also in unstructured paths having slope etc and textures of road surface. To attain the required accuracy ant to make system reliable, algorithm for path detection is divided into smaller tasks first is clustering and then decision making. Similarly, if path detection algorithm is highly elaborated to some degree, risk of wrong path classifications is also minimized. The overall processing time for both the algorithms is not more than 60 ms using color images.

Chapter 8

7. REFERENCES

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