Navigation Architecture for Autonomous Surveillance Rover

Saurav Kumar and Pallavi Awasthi

Abstract—**The paper proposes Navigation Architecture for Autonomous mobile robot navigating, exploring and avoiding obstacles in both outdoor and indoor environment. Mobile robot systems have recently been used in fields as diverse as rescue, surveillance and medicine. We bring into consideration the need of having navigation architecture for safe path planning with an emphasis on exploration. In this article by Exploration we specially mean surveillance. While the autonomous robot explores an either indoor or an outdoor environment it come across many human being present. Our unique architecture not only avoids them while navigating but also detect faces and stores the various faces that it comes across.Our algorithm is described in two steps. Motion model gives emphasis to obstacle avoidance at different speeds while exploration model gives emphasis to detection of human faces while moving at a safe speed following a safe trajectory. The algorithm has been successfully tested on "Lakshya"- an UGV‡ platform in both outdoor and indoor condition.**

Index Terms—**Autonomous System, Navigation Architecture, Obstacle Avoidance, Surveillance**

I. INTRODUCTION

A number of challenging problems are required to be solved for Autonomous navigation. The problems can vary in various domains like perception, localization, environment modeling, reasoning, and decision-making, control etc. Hence the navigation architecture becomes fundamentally important in any unmanned system. While designing an autonomous mobile system various aspects hold a great importance. The main goal is to reach the final point from the actual position with intelligent path-planning, obstacle-collision avoidance and a well-designed trajectory. Hence the entire burden is thrust upon the architecture which needs to be reflexive, reactive, robust and achieving correct motion and result in the unstructured environment too.

In this paper we propose the navigation architecture which has been successfully tested by us. Sensors under consideration for our research work include a stereo vision camera, a laser, a GPS and a heading sensor. A laser was able to solve the task of obstacle detection. But it had some limitations too so we fused the data of laser and stereo vision camera so as to get the efficient result. The system was also made to run in environment based on stereo vision camera only using the Binocular Stereo Vision Based Obstacle Avoidance problems encountered with it were that it takes high Algorithm for Autonomous Mobile Robots [1]. Some acquisition times and increases the computation burden a lot. Hence use of laser and stereo vision together was thought to be the most efficient. Sensor fusion has been subject to a lot

of research [2], most of the proposed methods use Kalman Filtering and Bayesian reasoning [3]. However, in recent years, there has been a tendency to make more and more use of soft computing techniques such as artificial neural networks [4] and fuzzy logic for dealing with sensor fusion [5] [6].

Multilevel architecture for navigation, based on a stereo vision system has been worked upon [7]. Modular control architecture for semiautonomous navigation has been proposed which aims to develop a humanitarian demining mobile robot which is able to scan semi-automatically a minefield [8]. Navigation architecture for automated car-like vehicles in urban environments has been discussed in [2]. Our Approach toward Navigation Architecture is drawn from above sources but for a different reason, Surveillance.

In this paper in Section II we discuss the Stereo Vision Camera and LRF and discuss their positives and negatives.In section III we discuss the obstacle avoidance algorithm and the two architectures used for navigation in Normal mode and in Surveillance Mode. Results and experiments are shown in Section IV. We conclude the paper with future work in Section V.

II. PROCEDURE FOR PAPER SUBMISSION

A. Laser Range Finder & 2D Point Cloud

Lasers are widely used for the navigation purpose majorly because of its accuracy and high acquisition rate making it more reliable for real time operation. But the reliability is limited to a particular range and is incapable in extraction of proper features of objects like a table or chair. This leads to some errors and discrepancy in path planning. Snapshot of front view of indoor environment and result from the Laser Scanner is shown in Figure 1 (a) and 1 (b).

B. Stereo Vision Camera & 3D Point Cloud Generation

We have used a Bumblebee Stereo Vision Camera for stereo data processing. Stereo Vision Camera has in housed two monocular SONY CMOS camera. Stereo Image processing can be groped majorly into three points as firstly establishing correspondence in the two views viz. left view and right view (Figure1).

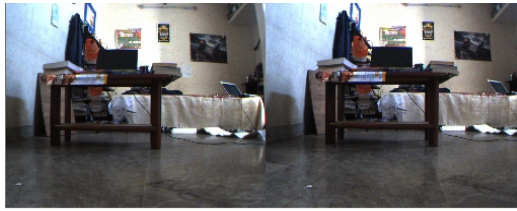Figure 1(a) Indoor Environment (b) Laser Scanner Output
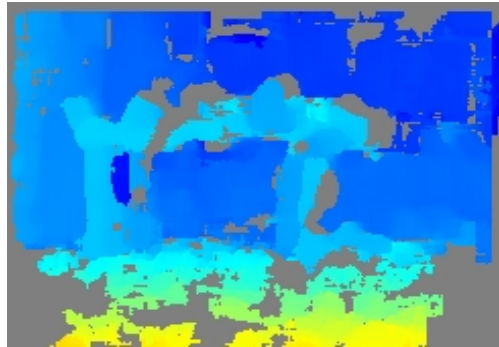
Figure 2 Pair of Left and Right Images
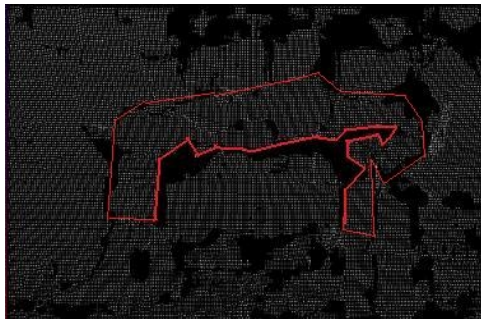

Figure 3 Disparity Image

Figure 4 3D Point Cloud

Disparity is calculated as the relative displacement between features and has shown in (Figure 3). Finally camera geometry is used to extract the 3D information about the environment (Figure 4). These steps have been discussed in detail [1].

Stereo Vision Camera is capable of extraction of proper features of objects like a table or chair as you can see in the figure 4.

The major drawback while working with the stereo vision system is that it takes comparatively quite high acquisition time. This leads to difficulties in working in the real time environment while dependent upon this system. Still the system is used quite often especially for its feature extraction properties which enables us to detect the objects like a chair or table which otherwise is misinterpreted by other sensors like lasers.

The figure shown above clearly shows the relative data of Stereo Vision System and the Laser mounted together on the system. Both of them are present in the same environment hence capturing the same data but in their respective manners. As per the information given by Laser there are two obstacles separately present (can be seen in figure) and there is enough space between them which may allow the autonomous system to pass through. Whereas the information given by the Stereo Vision System says that there is some object (table in this case) present which is continuous and no space is

available for the Autonomous mobile to go in that direction. Hence, the path planning in processed differently. Hence of the data from both the sources prevents our robot from hitting the obstacle.

III. ALGORITHM DESCRIPTION

Before we move on to describe the various models and what navigation architecture we have proposed in two different scenarios viz. Motion and Exploration we will first discuss the obstacle avoidance algorithm that is used to predict same trajectory in real time situation and the basic data fusion model for fusing Stereo and Laser Data.

A. Obstacle Avoidance Algorithm

Our obstacle avoidance algorithm is an improved version of VFH + as described in [9]. We draw our inference from the biological based obstacle avoidance used by human being to avoid obstacle in real time. Instead of creating the polar histogram of environment from Laser Reading 0o to Θo (Where Θ is Laser's Range of View) in either clockwise or anticlockwise direction we are start to make polar histogram from angle β (where β is the angle in which robot has to move to reach its waypoint) and in both direction clockwise and anti clockwise simultaneously. We calculate angle between the finding an occupied cell in the clockwise direction and in anti clockwise direction and compare it with the angle required by the rover to move. If it is greater than required angle then the rest of calculation for path generation is dropped else we start to find new candidates in clockwise and anti clockwise alternatively and finding the best fit. In this way we decrease the computation time required to calculate the whole of Laser Data and plan a trajectory in lesser time.
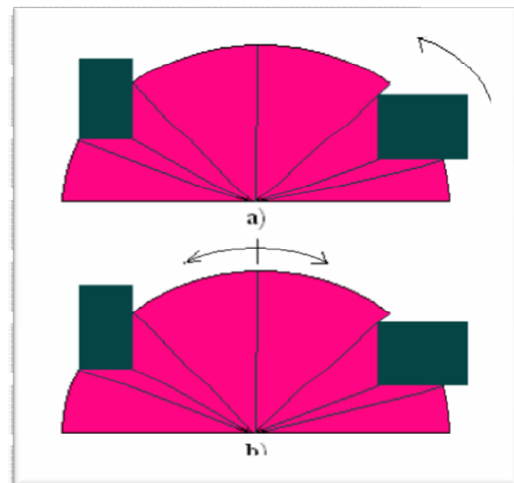

Figure 5: Visualization of New Improved Obstacle Avoidance Behavior

Now we discuss the architecture for the Motion model and Exploration model.

B. Algorithm Description for the Motion Model

The laser incorporated scans the scene and gives accurate data in 2D slices of the environment. Since the laser data takes very less time so a trajectory is first planned using this data only without waiting for the stereo depth data. The Laser data is processed by the proposed obstacle avoidance algorithm and a safe trajectory is calculated and passed on to

the Motors. Meanwhile, the Stereo vision camera is involved in acquisition of the stereo images of the environment. Its broad visual field allows the extraction of accurate scene information. The data from camera is used to generate the 3D Depth map of the environment. This 3D depth map is first processed to prune out unnecessary data so that the system can be more

Efficient according [1]. Data fusion of camera and laser is achieved through the algorithm discussed in [4]. resulting in fused depth map of the environment.

Thus we have the tradeoffs, feature and accuracy. This fused data is passed on to the obstacle avoidance algorithm which predicts the new trajectory and speed. This updated trajectory is passed on to motors when changes its motion accordingly. Difference in the path planning can be easily observed by the fact that initially from the Laser data of the environment mentioned in Figure 1, Path Planner decides to move in between the two front legs of the table (if the angles between the detection of legs > angles required by robot to move) but when Stereo combines it makes the whole area between the legs as obstacle. Therefore it can be seen that architecture for motion model emphasizes more on accuracy of obstacle avoidance.
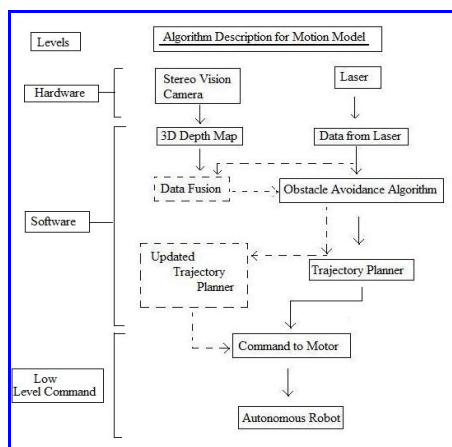

Figure 6: Block Diagram Motion Model

C. Algorithm Description for the Exploration Model:

Detect Human Faces in real time environment is complex due to different lighting condition and occlusion. Best thing that works in this situation is implement the face detection algorithm with emphasis on Machine Learning Techniques. We used method described in [10].

In order to proceed with the Face detection, the foremost thing to be done is to train the classifier. Hence various sample views of face are taken (Faces with different lighting Condition and occlusion were too taken) and scaled to same size and are referred to as "Positive samples". Along with it some arbitrary images are also taken and fed to the classifier which are taken of same size and referred to as "Negative samples". The cascade of boosted classifier is used which works with the "haar-like" features. After the training of the classifier its application is done on the region of interest in an input image. Now the output decides if the object of our interest (face in our case) is detected or not. The output "1" tells its detection else "0" is obtained. The object can be searched upon in the entire image using the classifier by

allowing the user to move the search window across the image and check every location. At times the desired object can vary in size in the image given as input, hence the classifier is designed keeping it in mind such that it can easily be "resized", it gives more efficiency and ease than resizing the input image itself. Hence the scan procedure should be done several times in order to find the object or our interest of unknown size in the image. Multiple face detection is shown in Figure 7.

Meanwhile the camera captures the images of the environment and the laser is involved too in the extraction

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Figure 7: Multiple Face Detection
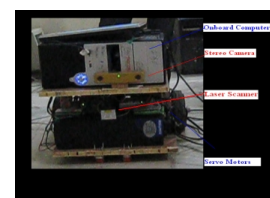

Figure 8   (a)   (b)

Figure 8: a) Outdoor b) Indoor Mobile Robot

of the features of the same. The planar depth is calculated and an obstacle avoidance algorithm is proposed. The trajectory is then planned considering the 2d laser input. The acquisition of the images by the camera and the training of the cascade of boosted classifier then does the

classification of the faces and the non-faces. Now some processing takes place and the decision is to be taken if it's a face or not. If 'Yes' then it is recorded into the database, the system time is noted and the surrounding image with the face is captured. If 'No' then the command is directly passed on to the motors.

As the face is encountered the command is given to move towards it without hitting it and to pause as soon as it is approached. The path is planned safely so that the obstacles are avoided too. In brief, the software level is divided into two parts: one for the face detection and other for the safe path planning. In case more than two paths are wide enough for the robot to get through then the one which is closest to its way point is selected. The exploration model is shown in figure 9.

IV. EXPERIMENTAL SETUP AND RESULTS

A. *Mobile Robot Platform: Hardware Setup*

"Lakshya"- is an outdoor unmanned ground vehicle (Figure 8 a) platform developed at the Innovation Lab, Delhi College of Engineering India. The vehicle is driven using two Quicksilver Servo Motor. Bumblebee Stereo Vision Camera and Hokuyo Laser Scanner are installed for obstacle avoidance.
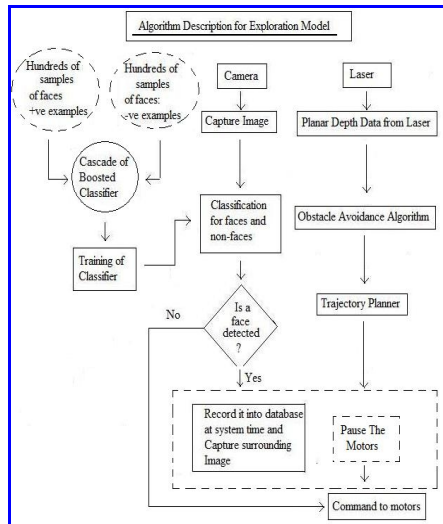

Figure 9: Block Diagram Exploration Model

Indoor Platform (Figure 8 b) is again having the same electronics and sensor onboard as that of the Outdoor ground vehicle. An Ocean Server Heading sensor is also installed onboard which gives the vehicles heading direction w.r.t to North Pole. An extra Monocular camera is installed onboard when the vehicle moves in the surveillance mode to detect human faces and record them into database.

B. *Software*

Obstacle avoidance program and Path Planning is written in Microsoft Visual Studio 9.0 in VC++ environment. It uses PGR library and Intel Open CV's Machine Learning Library for Stereo Processing, 3D Point Cloud Generation and Face Detection. When a face is detected it captures the image and records it into the data base which we can see later as log file with reference to images and time.

C. *Result*

1) *C.1 Motion Model*

Different frames of the video showing the autonomous robot both moving in indoor and outdoor environment is shown. Algorithm proved to very efficient and worked in real time. It was able to detect and avoid obstacles like table, chair. It was shown in Figure 10 (a, b, c, d) and Figure 11(a, b).
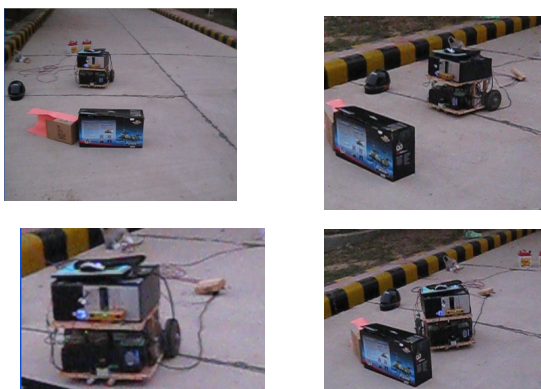

Figure 10 (a, b, c, d)

2) *C.2 Exploration Model*

Sample for data base of multiple faces detected by the Robot in the exploration mode was built and can be seen in figure 11.

Figure 11 (a, b, c, d)

V. CONCLUSION

In this paper we presented navigation architecture for a surveillance robot which was built at Innovation Lab located at Delhi College of Engineering was supported by DSIR, Govt. of India and Sulabh International Social Service Organization. The work can be extended to detect faces using different more advanced machine learning based algorithm.

Further work could be done in the field of the navigation architecture where we can in house a better data fusion algorithm rather than using a convention approach to first convert a 2D occupancy map to a 3D information and then finally fusing with 3D Map from Stereo Vision Camera as then the computation time and complexity increases which makes it difficult to use in real time. Work can carried out as the inverse of the above process wherein we can reduce the 3D information captured from camera to 2D information and fuse with laser data.

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Saurav Kumar is an undergraduate student at CS Deptt., Completing his BE from Delhi College of Engineering India in the year 2009.He worked at Artificial Intelligence Lab, IISc Bangalore as summer intern and was also a visiting student scholar at Robotics Institute, CMU USA during Summers 2008.He worked in the field of Unmanned Systems related technologies for 2/3 years and has lead a research project to develop a Prototype of Unmanned Ground Vehicle at Innovation Lab, DCE India.

Pallavi Awasthi is a 2nd Year Undergraduate student at the Bio Technology Deptt., Delhi College of Engineering India. She is working in the field of Bio Inspired Robotics where she wants to develop algorithm for Obstacle Avoidance, Localization and Mapping of Mobile Robots and Image Processing. Her interest also lies in the field Biomedical Imaging, Bio Informatics and Computational Biology