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Dynamic Trajectory Planning Algorithm for Automated Driving for Unmanned Ground Vehicles

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Abstract: In this modern world, the need of automation is in every possible field of human interference. Instead of wasting time on trivial less productive jobs people can invest in more productive work while automating the petty jobs, driving being one such job. Further, human error while driving is a major issue. Unmanned Ground Vehicle was introduced to solve such a problem. UGV has been an area of research since its introduction as a concept. Obstacle detection and decision making are major areas of research in UGVs. Trajectory planning algorithm is implemented for this purpose. In our proposed algorithm, Dynamic trajectory planning algorithm, we have extended the scope of TPA. It can now be used for multiple detections thus enhancing decision making. Simulation results confirm the results of our modification.

Keywords: Unmanned ground vehicle, Trajectory Planning algorithm, Dynamic trajectory Planning algorithm, image segmentation and obstacle.

I. INTRODUCTION

Over the past few years, UGV has been used in different applications like military and civilian operations i.e. border patrol, surveillance, law enforcement, hostage situation, police for some specific mission i.e. detecting and diffusing bombs etc. The ability to detect obstacle autonomously is very crucial to the safety of mobile robots and robot navigation [1, 2].

UGV is a smart autonomous vehicle that is capable to do tasks in structured or unstructured environment without the help of human operator.UGV can be one of modified version of modern era robots; In fact it is advance robotics. In simple words, UGV is autonomous vehicle that detects no. of obstacle and calculate distance from them and correspondingly accelerate or de-accelerate or continue with same acceleration. Here threshold setting is criteria of Image partition. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze and work. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics.

Unmanned ground vehicle (UGV) are being deployed for many mission critical applications to operate primarily in hazardous environments. Small UGVs are already widely used for tasks like explosive ordnance disposal and scouting. UGVs are now being used in rescue and recovery missions. As the military adopts larger UGVs for tasks like convoying, more personnel will be working around potentially hazardous systems. By reliably limiting the UGV's behaviour, the Safety Monitor reduces the need for physical barriers and large stand-off distances.

A. UGV are mainly classified into two classes:

a. ***Remote operated***: It is a vehicle that operates with the help of human operator via a communication link. All the activities which are performed by it are observed by the operator either through direct visual observation or remote use of sensor such as a digital video camera. For examples a toy remote control car, explosives and bomb disabling vehicles [2].This communication link is generally radio waves based .this has to be fast and responsive enough to provide results accurately and in time.

b. ***Autonomous operated***: It is an autonomous vehicle that mainly operates without the help of a human operator. This type of vehicle use sensors to sense the environment which is then used by control algorithm to take a next action to achieve a goal. It has the ability to learn autonomously. These are based on self learning and can easily adapt to multi environment. For example: a Vislab's autonomous car etc. [2].

In this paper, we are identifying the obstacle using threshold based image segmentation and calculating distance using distance of obstacle from bottom of image results in approximation of obstacle and decision to be taken accordingly.

II. IMAGE SEGMENTATION

Images are considered as one of the most important medium of conveying information, in the field of computer vision, by understanding images the information extracted from them can be used for other tasks. A digital image is defined as set of two coordinates depicting the basic element of the image called pixel. All the operations are performing on pixels in the fundamental process of image processing. Now there is a need of a method, with the help of which, we can understand images and extract information or objects, image segmentation fulfill above requirements. Thus, image segmentation is the first step in image analysis. The image denoising like image binarization is done before the segmentation to avoid from the false contour selection for segmentation to segment the image without loss of information. UGV identify obstacles using image segmentation. Image segmentation is the process of dividing a digital image into multiple segments.

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UGV uses image segmentation technique to divide an image into parts that have a strong correlation with objects or areas of the interest contained in the image including terrain shape and formation. In image processing, useful pixels in the image are separated from the unrequited pixel or pixel of no interest.

III. TECHNIQUE OF SEGMENTATION

Image segmentation refers to the process of partitioning a digital image into multiple segments i.e. set of pixels, pixels in a region are similar according to some homogeneity criteria such as color, intensity or texture, so as to locate and identify objects and boundaries in an image. This is challenging problem in image processing and computer vision. Based on different technologies, image segmentation approaches are currently divided into following categories, based on two properties of image.

a. ***Detecting Discontinuities:*** It means to partition an image based on abrupt changes in intensity [6], this includes image segmentation algorithms like edge detection.

b. ***Detecting Similarities:*** It means to partition an image into regions that are similar according to a set of predefined criterion [6]; this includes image segmentation algorithms like thresholding, region growing, region splitting and merging.Image segmentation can be on different basis most popular ones are local and global thresholding. The difference is of the different threshold which can be global as well as local in its nature or validation of existence.

In local thresholding division is on basis of local variation of pixel intensity in the region of the image where as in Global thresholding. A global variation of pixel intensity is parameter of partitioning the image into no. of segments.

UGV detects and identify the obstacles on the basis of local thresholding i.e. local similarities in the variation in the energy level of pixel decide the image partition. Image segmentation by thresholding is a simple but powerful approach for segmenting images having light objects on dark background [6]. Thresholding technique is based on image space regions

i.e. on characteristics of image [5]. Thresholding operation convert a multilevel image into a binary image i.e., it choose a proper threshold T, to divide image pixels into several regions and separate objects from background.

Any pixel (x, y) is considered as a part of object if its intensity is greater than or equal to threshold value i.e. $f(x, y) \geq T$,

Else pixel belongs to background. As per the selection of thresholding value, two types of thresholding methods are in existence [4], global and local thresholding. When T is constant, the approach is called global thresholding otherwise it is called local thresholding. Global thresholding methods can fail when the background illumination is uneven. In local thresholding, multiple thresholds are used to compensate for uneven illumination [3]. Threshold selection is typically done interactively. However, it is possible to derive automatic threshold selection algorithms.

IV. DYNAMIC TRAJECTORY PLANNING ALGORITHM

In TPA algorithm just distance is calculated from the obstacle but in DTPA not only number of obstacles are identified but distance calculated is further used as a input to decision making algorithm .The decision making algorithm identifies distance as per criteria of threshold distance and monitor the velocity of the UGV according to decision taken for particular frame in the video. Frame per frame decision and distance are calculated and acceleration or deceleration or continuing with same velocity is being performed .This makes the existing TPA dynamic with different situation handle smoothly.

When generates trajectories, the proposed approach DTPA need some useful information as following:

a. The travelable region of the front road. The region can been decided by the geometrical characters of the front road. They are including the width, the curvature of the front road and the obstacles information, etc.

b. Human factors, such as driver physical burden, driver driving skill and the knowledge and handling degree of the vehicle dynamics, etc.

c. Vehicle state, such as position, velocity, time and the heading distance of the vehicle at present.

V. PROPOSED ALGORITHM

A. Description of the proposed algorithm:

Trajectory planning algorithm implements obstacle detection and decision making in a UGV. We propose to modify TRP to suit dynamic situations and real-world environment. Objects are detected and based on the distance of object from the vehicle speed and direction of motion of the vehicle is thus adjusted.

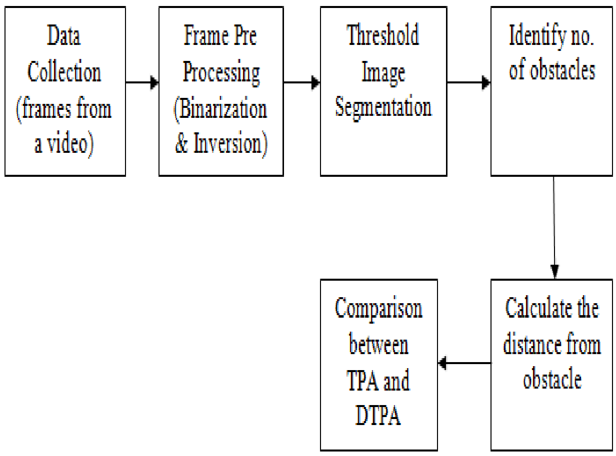

Figure 1: Block Diagram of UGV

Step I: Data Collection:

We get the frame from the video. Images are collected from the environment and are fed to the system.

Step II: Frame Pre-Processing:

Frame obtained is converted into grey scale image using grey scale operation and then visually compressing it.

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Then binarization of a visually compressed image is done by converting it into black white image setting a particular threshold of the white. Then, it followed by inversion operation.

Step III: Thresholding based Image Segmentation and Identify no. of obstacles:

Here we divide the image into different part on basis of local thresholding .This local thresholding help in identify no. of obstacles in the given frame. The moving objects present in a video frame are segmented out by using background subtraction method. The background subtraction can be done by using the simple frame differencing method. In this method, the intensity difference of every two consecutive frame is calculated and thresholded to obtain foreground pixels as shown in Eq. (1).

$$Intensity_n(x,y) = \begin{cases} 255, & \text{if } \left| Intensity_n(x,y) - Intensity_{n-1}(x,y) \right| > T_s \\ 0 & Otherwise \end{cases} \qquad (1)$$

Where n is the number of frames in the video sequence and T is the threshold value.

In case of fast moving objects like a ball, the two-frame differencing techniques gives erroneous results as it generates many “ball-like” objects. To incorporate with this, we use a three-frame differencing technique [10] where we use three consecutive frames instead of two. Morphological opening, closing and dilation operations are performed to fill the gap between the segmented images. To detect the significant discontinuities in the intensity values in the segmented images, an edge detection method is used.

Step IV: Calculate Distance:

Distance of the object from the foot of the frame is calculated. This gives the distance of the obstacle from the vehicle. Taking the distance and position of the object as input, the velocity and direction of motion are adjusted. The distance of the object is continuously scanned and the velocity and direction are accordingly moderated. For monitoring speed , we have three threshold distance d1
If (D <d1)
Then UGV accelerate.
Else if (D==d1)
Then UGV continues with same velocity
Else if (D>d1)
Then UGV slows down
End if

Step V: Comparison between TPA and DTPA:

TPA is then implemented on the binarized image. Object in front is detected. The TPA is implemented on multi-vehicle environment. Parametric analysis of UGV is carried out.

The DTPA algorithm scans the environment for multiple objects and then calculates its manoeuvring directions accordingly. The Dynamic Trajectory Planning Algorithm takes the surrounding environment; surrounding obstacles and a decision making process that assess the road situations.

VI. SIMULATION RESULTS

During our implementation, we worked on distance and velocity features of the UGV. Simulations were done on frames in MATLAB.

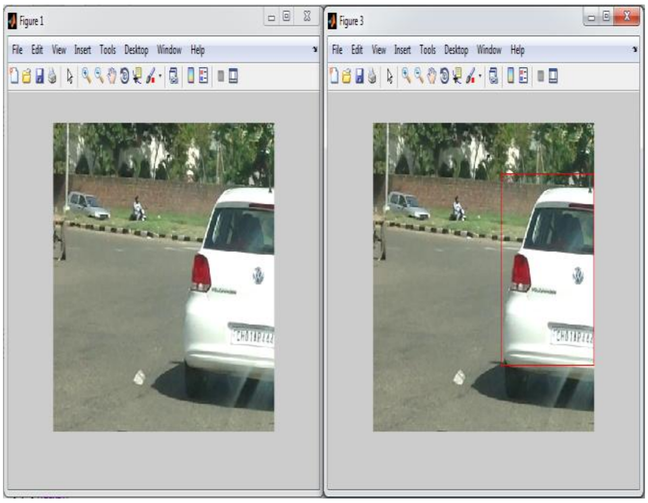

Figure 1: (a) Original image1 (b) Segmented Image1

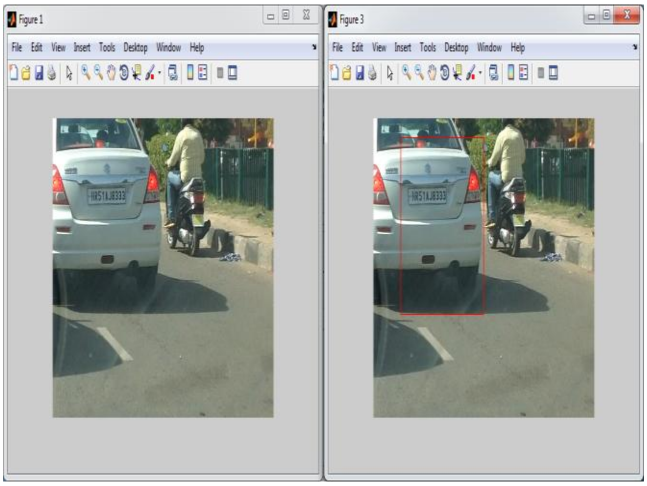

Figure 2: (a) Original image2 (b) Segmented Image2

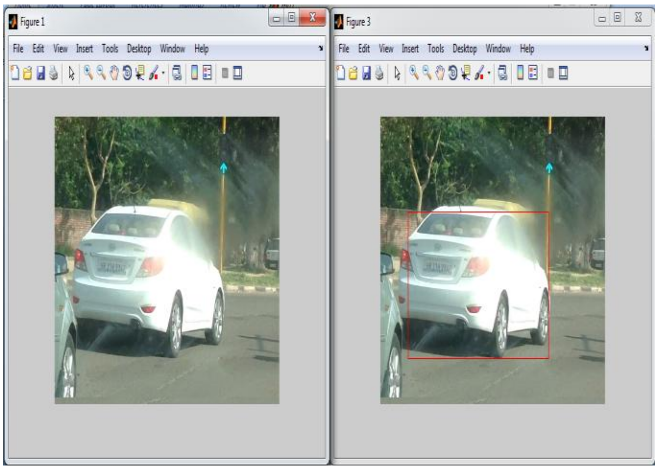

Figure 3: (a) Original image 3 (b) Segmented Image 3

In this above figure 1, 2 and 3, frames are shown on which proposed algorithm is being tested upon. Object has been identified and track with red color box. The distance is approximated by calculating distance of pixel of obstacle from the bottom of the image. We take distance as input to decide the monitoring the velocity of UGV.As distance calculated has crossover thresholds so, UGV is slow down. On other hand if calculated distance is larger than threshold then UGV is accelerated. Otherwise it moves on wit same velocity.

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In figure 1, calculated distance is less than threshold so it's give message to slow down. In Figure 2, calculated distance comes out to be in range of threshold distance .so, UGV is goes on at same speed. In figure 3, 1calculated distance is less than threshold so it gives message to slow down.

Table 1: No of object identified and distances from UGV using DTPA

TPA				DTPA		
S.No.	No. of contours	No. of objects	Distance from object(units)	No. of contours	No. of objects	Distance from object(units)
1	23	1	35	38	1	70
2	47	1	104	78	1	55
3	13	1	35	20	1	35

In this table 1, all values of experimental set are recorded .The first column contain the no of contours i.e. the function which is used to detect an object. The second column contains number of object identified. The third column contains the distance of UGV from object detected. Now comparison of both the algorithm whether proposed one and existing one is easy to judge.

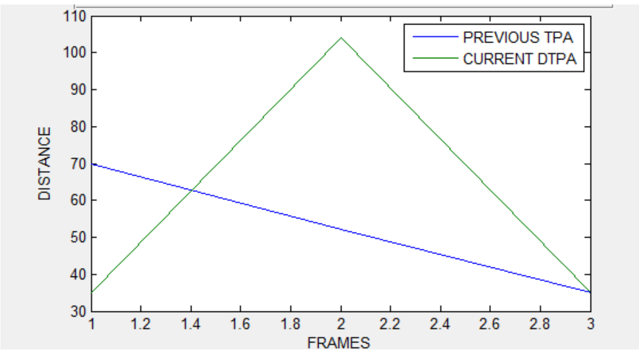

Figure 4: Comparison of distance vs. number of frames Using TPA and DTPA

In this graph, comparison of distance vs. number of fames is shown. The line drawn in blue represents the Trajectory planning algorithm while the line drawn in green shows Dynamic trajectory planning algorithm.

The graph for TPA shows a dip initially and then a sudden rise. Thus the evaluation of distance initially degrades and then improves abruptly. The DTPA on the other hand shows a constant graph with gradual increase on distance with number of frames. Thus the DTPA is smoother than TPA.

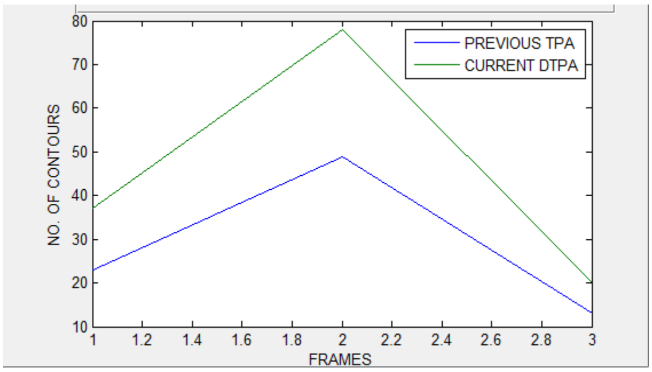

Figure 5: Comparision graph of Number of Contours in three different frames using TPA and DTPA

In this Figure, number of contours is compared. The blue line represents trajectory planning algorithm and the red line represents dynamic trajectory planning algorithm. The comparison of the DTPA with TPA shows that DTPA detects more number of obstacles than TPA. This proves the enhanced multiple detection ability of DTPA. From the resulting observations we can conclude that our DTPA performs better than normal TPA as evident from the above graphs of distance evaluation and measurements of no. of obstacles.

It is evident from the experimental results that the proposed Dynamic trajectory based algorithm not only detects and tracks the obstacle correctly, but it also helps to locate the occluded obstacle and the obstacle merged with other objects in the frame. The proposed 2D trajectory analysis is very much efficient in detecting the true obstacles and the same method can be applied to other Frames with similar Threshold image segmentation characteristics.

VII. CONCLUSIONS

The proposed algorithm, dynamic trajectory planning algorithm (DTPA), extends the scope of trajectory planning algorithm (TPA) from detecting a single object to detecting a whole range of objects at varying distance from the vehicle so that the vehicle may plan its path accordingly. TPA can detect simple geometrical patterns. However obstacles in real world are somewhat different. The figures are more complex than exact geometrical shapes. This can cause error in detection. Dynamic TPA on the other hand has been enhanced to detect complex geometrical figures, for example human that suddenly comes in front of the vehicle. TPA is implemented in a multi-vehicle environment which increases interaction. Simulation results confirm that distance evaluation is uniform and more number of obstacles is simultaneously detected in case of DTPA.

VIII. FUTURE WORK

The scope of TPA has been extended by our work. However, much needs to be done to make the UGV ready for real world deployment. Obstacle detection can be enhanced such that the UGV is also able to detect any obstacle that comes immediately in front of it in no. time and take action accordingly. Also the UGV may also be made to scan its environment so as to detect any obstacle that may come in course of its chosen path.

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