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Stereo Vision for Obstacle Avoidance and Distance Measurement in UAVs

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ABSTRACT: An unmanned aerial vehicle (UAV), commonly known as a drone, unmanned aircraft system (UAS), is an aircraft without a human pilot aboard. Compared to manned aircraft, UAVs are often preferred for missions that are too dull, dirty or dangerous for humans. The military role of UAV is growing at unprecedented rates making significant contributions to the war fighting capability of operational forces. UAVs are used for low altitude surveillance where they come across unknown obstacles. They're not capable of detecting the obstacles as they require sensors for detection and avoidance which makes the flight heavy, energy consuming and expensive.

Our project focuses on detection of obstacle and avoid it by means of calculating the distance between the UAV and the identified obstacle. It also gives an exact distance of the obstacle which helps in taking immediate decisions to avoid the obstacle and change the direction of flight. This can be achieved by means of Stereo Vision. Using this technique, we produce a 3D image from a disparity matrix obtained by merging 2D images. Using further Matlab operations we calculate the distance and thus an obstacle is detected and processed for avoidance.

KEYWORDS:UAVs, Stereo Vision, Disparity Computation, Depth map generation.

I. INTRODUCTION

Digital image processing is the use of computer algorithms to perform image processing on digital images. The 2D continuous image *is* divided into N rows and M columns. The intersection of a row and a column is called a pixel. The image can also bea function other variables including depth, color, and time. An image given in the form of a transparency, slide, photograph or an X-ray is first digitized and stored as a matrix of binary digits in computer memory. This digitized image can then be processed and/or displayed on a high-resolution television monitor. For display, the image is stored in a rapid-access buffer memory, which refreshes the monitor at a rate of 25 frames per second to produce a visually continuous display.

II. EXISTING SYSTEM

Previous works into this field has made use of digital cameras, laser scanners, sonar, odometer etc.

One of the methods used in previous work is using color segmentation then disparity computation and finally disparity clustering by fuzzy c-means or k-means algorithms. Next method is edge feature extraction for object identification and then disparity computation. The other method is graph cut; i.e. composition of segmentation and graph theory.

III. DISADVANTAGES OF EXISTING SYSTEM

- Poor segmentation of the objects could cause problems while detecting obstacles.
- Low image quality.
- High time consuming.
- Low accuracy.

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IV. PROPOSED METHOD

In our proposed work we are detecting obstacle. This method is easy to implement and fast enough for obstacle avoidance in highly textured environments. Calibration is the first step to rectify images captured from two cameras with different focal lengths. The camera off-line calibration procedure requires the Euclidean distance of the various points on the object. Then the adaptive thresholding, resizing and noise removal are performed. The adaptive thresholding is based on the average intensity of whole image. For obstacle detection, the thresholding is used which removes the texture and the lower pixel regions. After these pre-processing the disparity map and depth are computed. SAD cost function is used to calculate disparity of a given pixel and after computation of depth, the calculation of distance of an object/ obstacle from camera was measured by using the Euclidean distance and SHD (Sum of Hamming Distance).

We also propose a design to generate the disparity map of the left image of a rectified stereo image pair by giving Left and Right image as the input. We can also compute pixel disparity by comparing shifted versions of images. This method works well in highly textured environments and ideal for real applications.

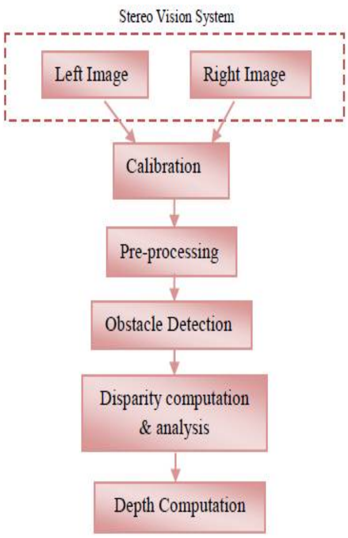

Fig 1: Overall procedure of the proposed view

V. PROPOSED SYSTEM ADVANTAGES

- Dense disparity map.
- Ideal for highly textured environments and easy to implement.
- The noise content will be removed and the visual quality is high.
- High accuracy.
- The calculated values corresponded to the measured values within a less than 10% tolerance, which was close enough to plan the objectives of the obstacle detection process.

VI. METHODOLOGY

MODULES:

- Stereoscopic view generation
- Calibration
- Preprocessing
- Obstacle detection
- Disparity computation and analysis

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- Depth computation
- Distance measurement

MODULE DESCRIPTION

STEREOSCOPIC VIEW GENERATION

This accepts the left and the right color image in the RGB format and converts it to thestereoscopic views, known as Left and Right image which are in grayscale format.

CALIBRATION

Calibration is the first step to rectify images captured from two cameras with different focal lengths. This helps to have parallel and exact horizontal epipolar line.

Camera Calibration is the process of finding the internal parameters of the camera. The camera off-line calibrationprocedure requires the Euclidean distance of the various points on the object.

We use area-based algorithm for stereo matching by SHD (Sum of Hamming Distance) function matching with 11*11 window. The area-based algorithm has the advantages of having dense disparity map, ideal for highly textured environments and easy to implement. The SHD function is new function matching with demanded accuracy which is calculated as:

$$SHD = \sum_{(i,j)\in W} I1(i,j) \, bitwiseXOR \; I2(x+i, y+j)$$

Sum of Hamming Distances is normally employed for matching census-transformed images (can be used on images that have not been census transformed) by computing bitwise-XOR of the values in left and right images, within a square window.

The first step is the determination of the optical centrecoordinates of the camera system, ideally in the centre of theimage. A simple method is to rotate the camera around the lens axis.

. The horizontal tiltis adjusted till the crossing line appears horizontal on theimage. At this point, the camera position can be locked.Two measurements are needed: the height of the opticalcentre and its horizontal distance to the crossing point. The optical centre can usually be considered ascorresponding to the centre of the external element of the lens.

The tilt angle can be computed using

$$\frac{h}{OP} = \tan\delta$$

Where, h is the height of the optical centre and $\delta$is the angle of tilt.

A different method can be used to get this vertical tilt: allpoints at the same height as the lens optical centre are locatedon the image on a straight line, positioned horizontally if thereis no lateral tilt of the camera. With just two of these points,the lateral tilt of the camera can be measured and accounted foror simply used to find the camera position with no lateral tilt.

The distance of the optical image centre to this same height point is measured in terms of image coordinates. Using the lensfocal distance, the tilt angle can be computed using

$$\delta = \arctan\left(\frac{dy}{f}\right) \qquad f = dy \cdot \frac{h}{OP}$$

This equal angle condition, for both object and image, is thecore of this work: from the image side, the angles can be easilycomputed and its value used to compute the distances for theobject side.

PREPROCESSING

Preprocessing includes the implementation of the adaptive thresholding technique which separates the foreground portions from the background with non-uniform illumination in the given image in which noise removal was also done by using mean and median filter. The adaptive thresholding is based on the averageintensity of wholeimage. The binary image was obtained as the output with the local threshold mean or median ranges from 0 to 1 for the given input image.

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Another requirement for the implementation of this adaptive thresholding is the local window size which ranges from 3 to 16 or more. After these pre-processing the disparity map anddepth are computed.

OBSTACLE DETECTION

Obstacle detection is defined as “the determination ofwhether a given space is free of obstacles for safe travel by an autonomous vehicle”. Obstacle detection is one of themost renowned problems within the subfield of computervision in terms of the amount of research ithas attracted andthe number of uses it has.

A good obstacle detection system must be capable of the following:

- To detect obstacle on a given space in good time.
- To detect and identify correct obstacles.
- To identify and ignore ground features that may appear obstacles.

Althoughthere are several methods to achieve obstacle detection here thresholding is used which removes the texture and the lower pixel regions.

DISPARITY COMPUTATION AND ANALYSIS

A novel algorithm is used to obtain disparity map of the left and right image of a rectified stereo image pair. The algorithm is a hybrid approach (mixture of block and region based. In a nutshell, it first converts the stereo image pair from RGB to Lab color space. Next, It perform intensity(L)-based segmentation of only left image pixels using a fast histogram-based K-Means implementation, then refine the segment boundaries using morphological filtering and connected components analysis. Then It determine the disparities of pixels that make up the refined boundaries using a block-based SAD approach, and lastly, fill in the (missing) disparities of pixels lying inside refined segment boundaries based on boundary disparities, using my reconstruction method.

DEPTH COMPUTATION

Finally, depth of obstacle is computed as follows:

$$Z(x,y) = \frac{f.B}{d(x,y)}$$

Where f is focal length, B is base line (distance of cameras center), d(x,y) is disparity value in x row and y column.

The procedure to find the Depth map of the is to generate the linearly spaced vectors and then the histogram counts which counts the number of values in the matrix (given input image) that fall between the elements in the edges vector (which must contain monotonically non-decreasing values), where the output n is a length vector containing these counts.

DISTANCE MEASUREMENT

The distance of an object from camera will be varied for the different types of images. Here we are using only the images captured by the camera and not directly using the camera, it'squite difficult to analyze the distance of an object from camera. But the distance between the objects present in the left and the right images can be measured.

After obtaining the pixel coordinates (x, y) from the image processing algorithm of the point of interest, and with the location coordinates of the optical centre of the image (x0, y0) the relative coordinates (dx, dy) are computed.

dx=x-x0;

dy=y-y0;

Inverting the signal of the vertical coordinate, to put it in the normal Cartesian reference, where positive dy values correspond to points above the xx' axis.The angle α is calculated by

$$\alpha = \arctan\left(\frac{dy}{f}\right)$$

And the horizontal distance OY

$$OY = \frac{h}{\tan(\delta - \alpha)}$$

where $\delta$is the constant calculated by

$$\delta = \arctan\left(\frac{dy}{f}\right)$$

$$\tan\beta = \frac{dx}{f}$$

Considering d the angle on a plane that contains the optical axis and whose projection on the horizontal plane isβ_H, bothprojections coincide, although $\beta_H$is greater than β.
To calculate the distance TX we need to project O 'Y on theoptical axis O'P to have d, the distance to the target measuredon the optical axis:

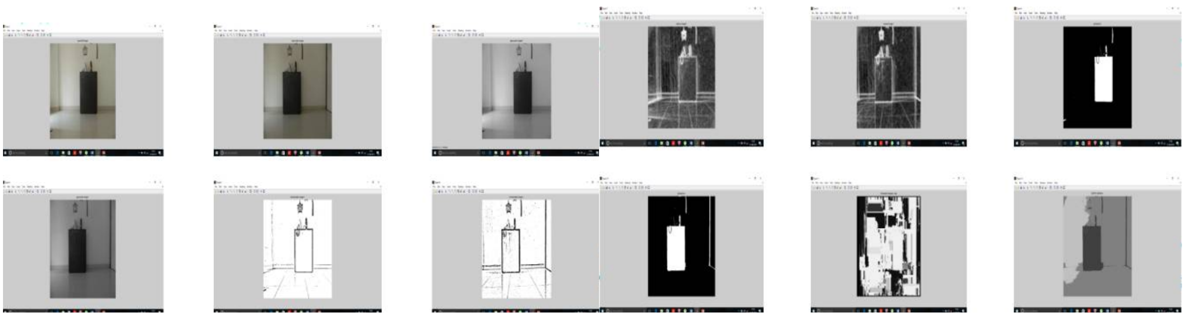
$$d = O'Y \cdot \cos\alpha = \frac{OY \cdot \cos(\alpha)}{\cos(\delta - \alpha)}$$

With OY and With distance d and angle β, YT can be obtained by:

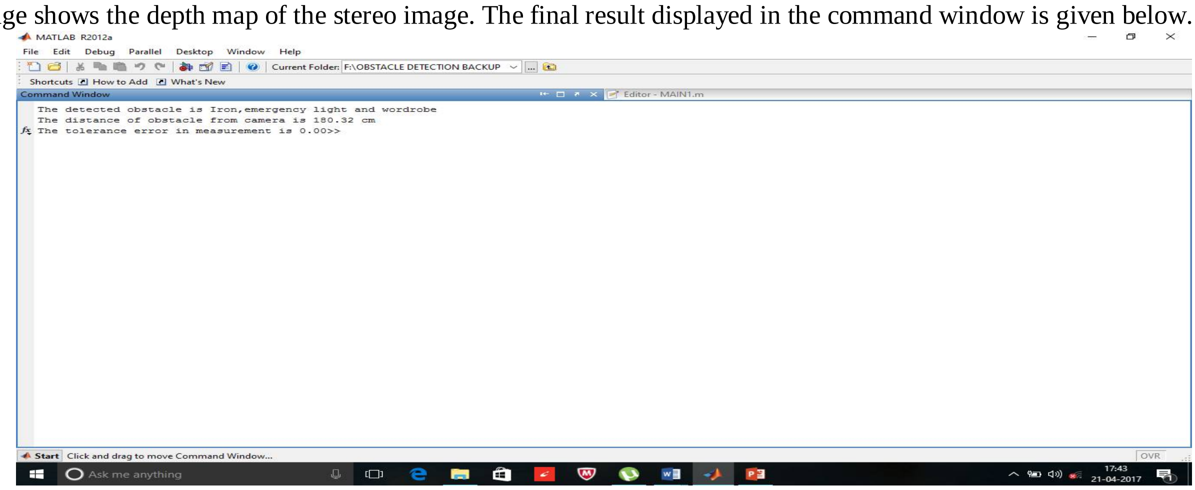
$$YT = \frac{dx}{f} \cdot d$$

, Where YT is the distance of the target.
And in this way it is possible to calculate distance andorientation for different targets just from a single image if thetargets are located on the floor. For targets whose height isknown, the procedure is the same, but substituting theheight of the optical centre for its difference to the targetheight.

VII. RESULT ANALYSIS



Figures show the different stages of processing of captured images described in the methodology module. The last image shows the depth map of the stereo image. The final result displayed in the command window is given below.



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VIII. APPLICATIONS

- For Visually impaired
- In Medical fields

a. Endoscopy

b. Stereoscopic Microscope

- Mobile Robotics Navigation
- Random bin picking
- Volume Measurement, Object Location

IX. CONCLUSION

In this paper, we proposed the Stereo vision based obstacle detection which is an algorithm that can help to detection and computation of obstacle depth. It is performed using stereo matching and disparity map.

We also proposed a robust method to detect positive obstacle in highly textured environments. After calibrating the left and right images, parallel and exact horizontal epipolar line is achieved. This method is fast enough for obstacle avoidance. For obstacles, the thresholding removes the texture and the obtrusive details. We use area-based algorithm for stereo matching by SHD (Sum of Hamming Distance) function matching with 11*11 window. It depends on knowing the height of target point above the floor. It just needs to be subtracted from the camera height h to use the described procedure to locate the target.

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