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Obstacle Detection Based on LAB-HSV Color space Morphological Image Segmentation for Navigation of Micro Aerial Vehicle

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Abstract

The present work proposes an obstacle detection, collision detection and collision avoidance algorithm using image segmentation for navigation of quadrotor in outdoor environment. Obstacle detection method is developed based on the LAB-HSV color space information extracted from the images of outdoor with obstacle. New single channel outdoor images with color and luminance information are obtained by normalizing the LAB-HSV information from the images. Binary image is obtained by thresholding the single channel outdoor image. Median Filter is employed to remove the noise from the binary image. Filtered binary image is eroded using the arbitrary shaped structuring element. Furthermore, Morphological closing and opening operations are performed on the eroded images to detect the obstacle. Proposed image segmentation algorithm is used to segment the obstacle and collision detection area to find the obstacles in the flight path of quadrotor. Finally, Collision detection area is used to determine the Obstacles which are threatened to the MAV flight in the outdoor environment. Experimental results show that the proposed obstacle detection approach based on LAB-HSV Color space Morphological Image Segmentation method is suitable for real time obstacle detection and collision avoidance operations.

Keywords: *Micro Aerial Vehicle; Obstacle detection; Collision detection; Collision avoidance; Navigation.*

1. Introduction

The problem of flying a Micro Aerial Vehicle (MAV) around obstacles to perform surveillance, rescue, and search operations in outdoor environments is still a challenging task. In indoor and outdoor environments, the MAV has to detect and avoid static and dynamic obstacles. Image segmentation method is proposed for obstacle detection based on the computation of optical flow using Lucas–Kanade optical flow method. Desired heading is obtained from the segmented imaged to avoid collision with the obstacles [1]. Optical flow of Harris corner features is computed for segmenting the obstacles from the images and collision cone control and guidance law is proposed for the navigation of UAV through urban environment [2]. Obstacles are detected by comparing and matching the database of obstacles from the images acquired using a monocular camera based on the detection of SURF feature points in the image frames [3]. It was found that proportional controller performs better and optimal than human and a bang-bang controller for the control of UAV between the start point and goal point. Collision-free waypoints are generated and dense depth maps are estimated for navigation and obstacle avoidance of quadrotor using a set of image frames acquired from a monocular camera mounted on the MAV [4]. For dynamic collision avoidance, distance between the MAV and the obstacle was controlled based on the range measurements obtained from the ultrasonic sensor and infrared range finder [5]. In a GPS-denied environment, Waypoints are generated based on the obstacle avoidance strategy and Hector Simultaneous Localization and Mapping (HSLAM) approach to navigate the MAV autonomously and avoid collision with the obstacles [6]. Real time path planning and obstacle avoidance algorithm was implemented for the position and attitude control of multirotors in the presence of obstacles [7]. Multimodal sensors such as stereo cameras, 3D Laser scanner and ultrasonic sensors are used for the perception of obstacles by fusing the laser range, dense stereo and ultrasound measurements and a collision free flight trajectory are planned for the navigation of the MAV in restricted environments [8,9]. Hierarchical path planning approach and reactive collision avoidance algorithm was implemented using multiple sensor setup such as 3D laser range finder, ultrasonic range sensors and optical flow camera. GPS

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and optical flow camera are used for the estimation of position and velocities of the MAV [10]. HSV color space and connected component analysis is used to segment the obstacles for obstacle and collision detection in the flight path of UAV [11]. Real time vision based obstacle detection algorithm is developed for the collision avoidance of frontal obstacles in the flight path of UAV through GPS denied unstructured environment [12]. Additional benefits namely, reduced power consumption and computational processing has been achieved by the use of on-board camera compared to other multiple sensors employed for obstacle detection and collision avoidance. A mathematical model is proposed to compute the position of the surrounding obstacle in 3D space and the distance between the Unmanned Aerial Vehicle (UAV) and the obstacle. Speeded Up Robust Features (SURF) based image matching algorithm is used for the detection of obstacles. Obstacles cannot be detected using SURF based obstacle detection algorithm due to blurred images obtained in poor illumination conditions.

2. LAB-HSV color space morphological image segmentation based obstacle detection

Image segmentation is to partition an input image frame into image sub-regions to segment the obstacles using a connected set of pixels that has similar attributes namely, gray level values, image histograms, object contours, texture features etc. In this paper, LAB-HSV color space morphological image segmentation-based obstacle and collision detection method are presented as illustrated in Figure.1. Foreground pixels (Obstacles in the image) and background pixels (Non-target in the image) are segmented for the detection of obstacles. MAV has to avoid collision with the static and dynamic obstacles within the forward field of view.

2.1 Video Acquisition

Outdoor videos are captured with a forward looking camera with a resolution of 1280×720 pixels mounted on the Parrort AR Drone version2 Quadrotor (See Figure 2). After converting the videos into image frames in the preprocessing stage each image frame from the outdoor input video is resized into 256×256 pixels.

2.2 RGB into LAB-HSV Color Space

RGB image frames obtained from the outdoor videos are converted into HSV color space. HSV color model is based on the human visual characteristics and has three components namely, Hue (H), Saturation (S) and brightness (V). Humans can perceive the color information based on the HSV color space. The transformation from RGB color space into HSV color space can be obtained by the following equations:

$$H = \begin{cases} \frac{60(G-B)}{V}, V = R \\ 120 + \frac{60(G-B)}{S}, V = G \\ 240 + \frac{60(G-B)}{S}, V = B \end{cases} \quad (1)$$

$$S = \frac{V - \min(R,G,B)}{V}, (V = 0, S = 0) \quad (2)$$

$$V = \max(R,G,B) \quad (3)$$

Where H, S, V and R, G, B denotes the hue, saturation, brightness value and normalized red, green and blue color components respectively. LAB color space can be computed as follows:

$$L = 116\left(\frac{Y}{Y_0}\right)^{1/3} - 16 \quad (4)$$

$$a = 500\left[\left(\frac{X}{X_0}\right)^{1/3} - \left(\frac{Y}{Y_0}\right)^{1/3}\right] \quad (5)$$

$$b = 200\left[\left(\frac{Y}{Y_0}\right)^{1/3} - \left(\frac{Z}{Z_0}\right)^{1/3}\right] \quad (6)$$

Where X, Y and Z denotes the reflectance values of red, green and blue components of the images.

2.3 Single Channel Grayscale Image

Single channel grayscale image is obtained from the LAB-HSV color components of the outdoor images. The color and luminance information were extracted from the outdoor images. LAB-HSV color components are integrated to obtain a single channel grayscale image. The Equations used to compute the single channel grayscale intensity image is expressed as follows:

$$G_{HSV} = \min(H_{norm}, S_{norm}) \times 255 + \min(S, \delta) \times V_{norm} \quad (7)$$

$$G_{LAB} = \min(\mathrm{L}_{norm}, \mathrm{A}_{norm}) \times 15 + \min(\mathrm{B}_{norm}, \mathrm{A}_{norm}) \times 15 \quad (8)$$

$$G_{LAB-HSV} = G_{LAB} + G_{HSV} \quad (9)$$

Where G_{LAB} , G_{HSV} and $G_{LAB-HSV}$ denotes the image with Lab and HSV and single channel intensity image with integrated LAB-HSV color space components respectively.

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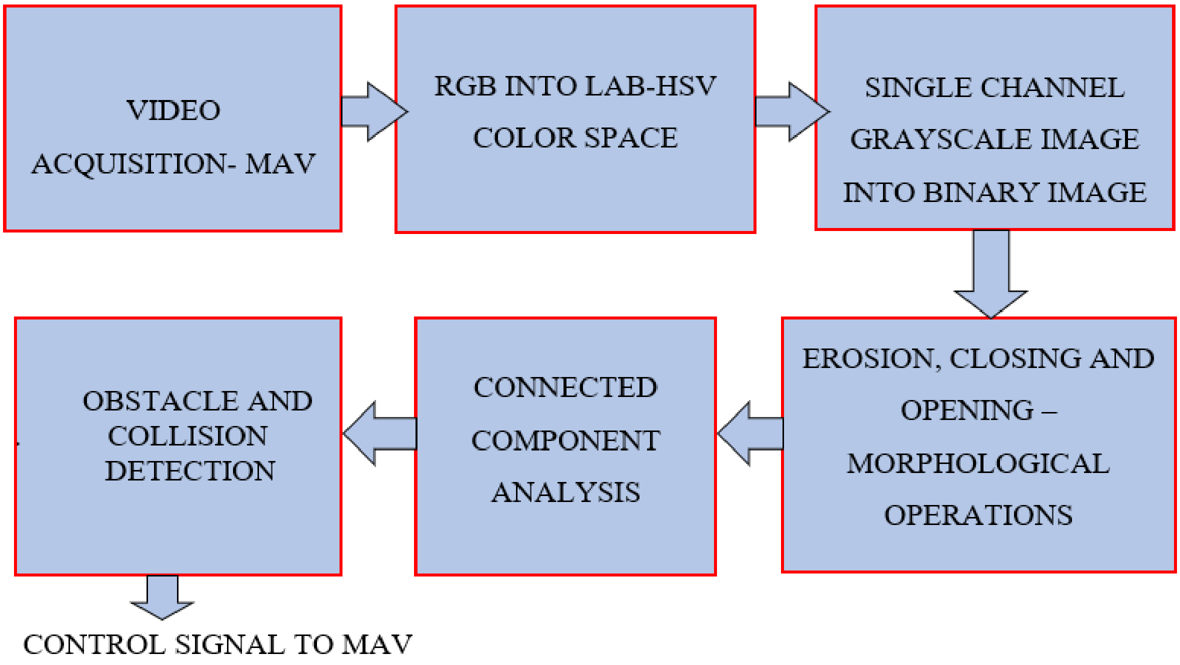

Fig. 1. Proposed method for Obstacle detection

Fig. 2. Parrot AR Drone 2.0 Quadrotor

2.4 Binary Image

LAB-HSV color space single channel intensity image is converted into a binary image. In the binary image, small objects (connected component pixels) with a threshold value of less than 225 pixels are removed to detect the larger objects in the outdoor image frames. Eight connectivity is used to determine the connected components of the object pixels. Two dimensional median filtering is applied to remove noise on the binary image. Each output pixel of the filtered binary image contains a median value in a 12×12 pixel neighborhood around the corresponding pixel in the input image.

2.5 Morphological Operations

Three different morphological operations such as erosion, closing and opening are employed for the detection of obstacles in the outdoor image frames.

2.5.1 Erosion

Shape and edges of the objects can be extracted from the filtered binary images based on the erosion morphological operations. In this work, binary image is eroded with the arbitrary square shaped Morphological structuring element with the neighborhood size of 20×20 pixels. Erosion of binary images removes all the pixels on the boundaries of objects. Let X is defined as the filtered binary image and A as the structuring element. Erosion of binary image X with the arbitrary shaped structuring element A can be computed as follows:

$$X \Theta A = \left\{ z \middle| (\mathrm{A})_Z \subseteq X \right\} \quad (10)$$

Eq. (10) indicates that erosion of binary image X by structuring element A is the set of all points z such that A, translated by z is contained in the binary image X. In

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the eroded image, narrow object regions are completely eliminated and wider object regions are thinned.

2.5.2 Closing and Opening Morphological Operations

In this work, two different morphological operations such as closing and opening operations are performed on the binary image. Binary closing and opening morphological operations are used to remove small holes in the objects and to separate all small connected objects in the outdoor scenes respectively. Closing morphological operation is dilation morphological operation followed by the erosion morphological operation.

Closing of eroded image by using a disk-shaped structuring element is denoted by

$$I \bullet B = (I \oplus B)\Theta B \tag{11}$$

Where I denotes the eroded image and B denotes the structuring element.

Opening morphological operation is erosion morphological operation followed by the dilation morphological operation. Opening of closed eroded image by using a disk-shaped structuring element is denoted by

$$I \circ B = (I \ominus B) \oplus B \tag{12}$$

Where I denotes the closed eroded image and B denotes the structuring element.

3. Obstacle and Collision Detection

Small obstacles detected by the proposed image segmentation method are not considered as a severe threat to the forward motion of the MAV. Connected components are labelled using 8 connectivity objects in the closed eroded image. Object regions in the outdoor image is highlighted using a colour for better visualization of the large obstacles, that pose a threat to the navigation of the MAV. Foreground objects detected in the outdoor image frame are labeled into RGB color image to visualize the detected obstacle and collision detection area. Once the obstacles are detected, a suitable Pulse Width Modulated (PWM) signal is transmitted from the ARDUINO UNO board to the pitch channel of the flight controller board to pitch the MAV backwards to avoid collision with the obstacles.

4. Experimental Results and Discussions

Vision based obstacle detection algorithm were implemented in a MATLAB (R2017a) environment. Computational cost of the obstacle detection algorithm is 1.2 seconds. Input Outdoor image and transformed LAB-HSV images are shown in Figure 3. Color information, namely, L Component, A Component, B Component, H Component, S Component and V Component extracted from the outdoor images for obstacle detection are shown in Figure 3 (a) – (f) respectively. Obstacle area and collision area threatened to the MAV flight was detected to avoid collision with the obstacles. Input outdoor image frame acquired from the MAV was resized into resolution of 256×256 pixels. LAB component and HSV component was extracted and integrated to produce the LAB-HSV intensity image. Next, LAB-HSV intensity image is converted into a binary image. Logical NOT operation is employed to detect the foreground pixels from the outdoor images. Small obstacles in the outdoor image is removed using the connected component analysis based on the object pixels less than 225 pixels and pixel

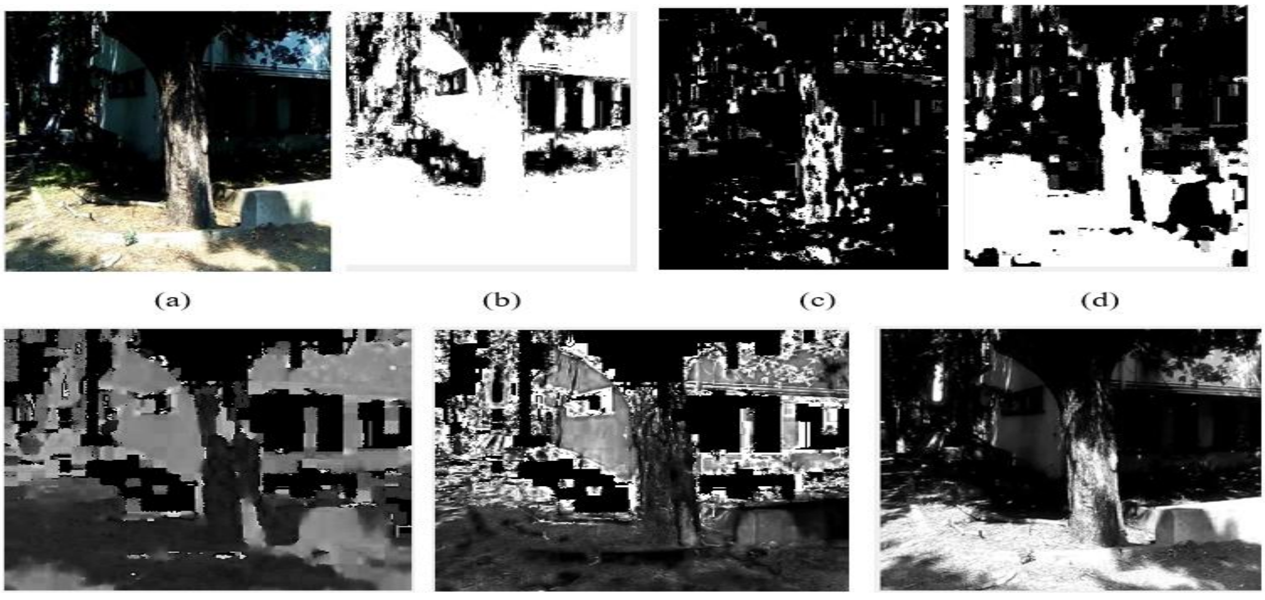

Fig. 3. Input Outdoor image and transformed LAB-HSV images (a). Outdoor image (b). L Component (c). A Component (d). B Component (d). H Component (e). S Component (f). V Component

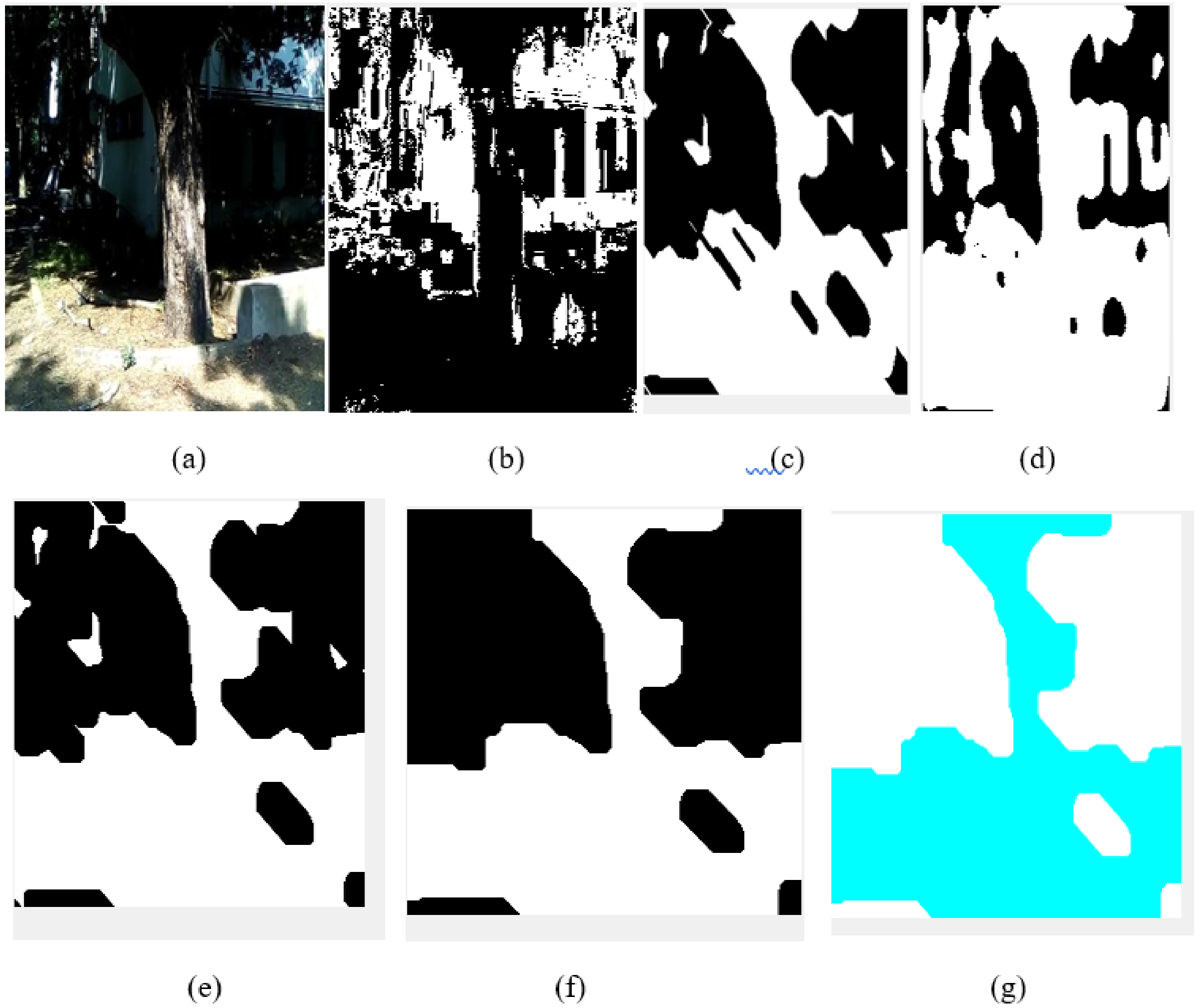

Fig. 4. Obstacle detection output (a). Outdoor input image (b). Binary image (c). Median Filtered image (d). Eroded image (d). Morphological closed image (e). Morphological opened image (f). Obstacle detected in the outdoor environment

connectivity of 8 pixels. Median filter is employed to remove the noise from the outdoor images. Arbitrary shaped structuring element is used to erode the filtered binary image. Dilation followed by an erosion; Morphological close operation is performed on the eroded image with a disk-shaped structuring element of size 8×8 pixels. In the morphological closed image, Morphological open operation is performed with a disk-shaped structuring element of size 10×8 pixels. Connected components are labeled for the obstacles in the morphological opened image. Finally, obstacle is detected in the outdoor image frame. LAB-HSV based obstacle detection output is shown in Figure 4. The proposed obstacle detection method based on the LAB-HSV color space can effectively detect the obstacle in the flight path of MAV. Experimental results show the detection obstacles in front of the MAV and the suitability of the vision based obstacle detection algorithm based on LAB-HSV Color space Morphological Image Segmentation for real time obstacle detection in outdoor environment. Eight neighborhood labeling rules are used to label the obstacle area. After detecting the obstacle area using the proposed LAB-HSV color space morphological image segmentation method, a suitable PWM signal is transmitted to the pitch channel of the flight controller to avoid collision with the obstacles.

5. Conclusions

Vision-based obstacle detection algorithm based on LAB-HSV Color space Morphological Image Segmentation was developed for obstacle detection and navigation of Micro Aerial Vehicle in outdoor environment. Obstacle area and collision area detected in the outdoor image frames are used to avoid collision with the obstacles in the flight path of MAV. The experimental results show that the proposed obstacle detection algorithm is suitable for real time obstacle detection and collision avoidance operations.

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