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Shape Detection and Classification in the Analysis of Images Taken from UAVs

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Abstract: Computer vision, a fast growing field, has vast applications, especially in ground observation and monitoring. It is widely being used to process images to extract more information from them for either better human interpretation or for the assistance of an autonomous system. An algorithm using Open CV library has been presented to detect shapes of objects/targets from images. The algorithm has been especially designed to work on images taken from a large altitude by a moving UAV. After denoising the image and K-means clustering to extract the region of interest (ROI), Canny operator and approxpolydp function are used to isolate the vertices of the shape. Geometrical characteristics are identified and analysed. These are then mapped to all shapes in the database. The closest map gives the largest confidence score (probability of the extracted feature being a particular shape). The algorithm can efficiently detect polygons (triangle, square, rectangle, pentagon, hexagon, heptagon and octagon), star, cross and circles.
***Keywords*: UAVs, Open CV, shape classification, Canny edge detector, approxpolydp, computer vision**

I. INTRODUCTION

Of the numerous technologies that have emerged over the last decade, the development and deployment of the Unmanned Aerial Vehicles (UAVs) has drastically increased. Even though the main application of UAVs is in the field of defence [1], this technology is now of high interest in non-military contexts like field monitoring, disease identification in crops to pesticide spraying in the field of agriculture, disaster management, rescue operations, logistics, environmental studies and different areas of civil protection, for example firefighting, police duties as well [2].

In most of these applications, the UAV has an onboard camera which continuously captures the land underneath. These pictures might then be transmitted wirelessly to the ground station or be stored in a storage device from which it can be retrieved after the UAV lands. The camera can be fixed parallel to the ground to take pictures at an angle of 0˚ but since this leads to less coverage, the camera is usually fixed at an angle. It might also be supported by a gimbal to help it rotate and take pictures in all directions. Since a UAV can be made to fly at high altitudes, there is no guarantee that the pictures would be clear. Hence the standard image processing algorithm that are used to process images taken at smaller distances on ground are ineffective when it comes extracting useful information from the pictures taken by a drone. Thus, effective image processing algorithms are required for feature extraction.

A picture can contain many useful pieces of information. We might want to know the colour, shape or location of objects in images, detect movement on the ground through analysis of consecutive frames, or recognize and interpret characters. All these various algorithms will have to first start with denoising the image, feature extraction and then application of intelligence to characterize the feature.

This paper explains a statistical approach to classification of shapes of the elements in a picture taken by the camera onboard a drone. It assigns a weight to the different characteristics used to classify different shapes and then calculates the probability of the contour under question being a square, a circle, a hexagon etc. These probabilities or 'confidence scores' are then compared to determine the shape of the extracted feature.

II. LITERATURE REVIEW

Computer vision is everywhere-in security systems, manufacturing inspection systems, medical image analysis, Unmanned Aerial Vehicles, and more.

[3] describes the pixel values of a digital image as the measured sensor values - samples of a filtered visual signal. A shape is mathematically described as the characteristic function of a union of a few connected subsets. These signals are called shape images. Shape images have only two different intensity levels-0 and 1 but as a result of the impulse response of the filter (determined by the optical system) called the point spread function (PSF), the image is smoothened and hence exhibits various intensity levels [3].

Various steps need to be taken to preprocess the image before the required feature is extracted. Morphological operations is one such technique which can be applied in order to suppress noise and sharpen the forms and contours in the image. These techniques consist of a convolution between the image and kernel matrix, which has lower dimensions and specific values to obtain desired effects in the resulting image. More specifically, the erosion and dilation techniques are combined[4].

The Hough transform is a popular technique used in the field of image processing and computer vision. Hough transformation uses the slope intercept method to find points in an image that form a straight line [5]. Since slope intercept is used, Hough transform works in the two dimensional space. A line segment's midpoint and length are extracted by analyzing the voting distribution around a peak in the Hough space[6]. [7] gives two other interpretation to the Hough transform and also extends this to help find general classes of curves in images.

[8] presents an image- based positioning system for drones. Algorithms that used the OpenCV library functions detected predefined characteristic landmarks. The images were sent to the ground system were the processing was done. The coordinates are adjusted and sent to the onboard controller to command the drone to position itself right above the landmark and hence the landing isuthorized.

Shape detection algorithms have many applications.They are also useful in ship detection as well. Images from optical remote ensing satellites can be processed for realtime detection of ships. It is however a challenge due to the relatively low resolution and complicated background. In the algorithm proposed in [9] Gaussian and median filter are used to reduce the periodical and pepper noise generated by the camera sensor system. Then, mathematical morphology processing is employed to remove the background interference and thus enhances the ship targets. Next, statistic analysis is performed on inspected and neighbor areas to distinguish the suspected ship target and pure-sea, land, islands or strong waves.

OpenCV provides an easy-to-use computer vision framework and a comprehensive library with more than 500 functions that can run vision code in real time [10]. It has C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS and Android. OpenCV library using C++ is used to build this shape detection algorithm as well, the important aspects of which are highlighted below.

III.METHODOLOGY

The captured images are given as input to the code. The image is subjected to k-means clustering which is a robust colour clustering mechanism. The cluster corresponding to the shape being identified is further processed.

The first step is to convert the image containing the cluster to grayscale [11]. Colour images require thrice as much processing power as grayscale images do. As long as the colour information provides no value to the algorithm, it is wise to convert the image to grayscale and carry out the rest of the processing on this image. Next, the image is blurred using a 3x3 kernel of 1s: $\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\1 & 1 & 1\\1 & 1 & 1\end{bmatrix}$.

Blurring is a low pass filtering option that filters out the noise in the image. Noise always changes rapidly from pixel to pixel because each pixel generates its own independent noise. Kernel with 1s is an averaging filter where pixel value is replaced by the average value of the 8 pixels around it. By suppressing the noise, gradual changes can be seen that were invisible before. Therefore a low-pass filter can sometimes be used to bring out faint details that were smothered by noise. Next, the Canny edge detector function is used to extract the edges in the blurred image. Canny edge detector is a multistage algorithm:

A. Preprocessing- already done by blurring the image in the previous step

B. Calculating gradients- Gradient at every point in the image is calculated. Sudden changes in the gradient indicate the presence of an edge. Gradient magnitude and edge are calculated as follows:

$$m = \sqrt{G_x^2 + G_y^2}$$

$$\theta = \arctan\left(\frac{G_y}{G_x}\right)$$

Where, G_x and G_y are gradients in the x and y directions respectively.

C. *Nonmaximum suppression*- The direction of the edge is always perpendicular to the direction of the gradient. Hence, the edges are located. If the intensity of the edge is above the upper threshold which is given as input to the user, the edge is a sure edge and the pixel is retained. If it lies below the lower threshold, it is discarded.

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D. Thresholding with Hysteresis- If the pixel lies in between the upper and lower thresholds, the neighboring pixels if:

1) Have the direction in the same bin as the central pixel
2) Gradient magnitude is greater than the lower threshold
3) They are the maximum compared to their neighbors (nonmaximum suppression for these pixels), then these pixels are marked as an edge pixel

This process is looped till the picture changes no more.

The next step in shape analysis is to find contours. Contours are simple lines that connect continuous points of the same intensity. The function cv2.findContours() is used to find the contours. It takes in three arguments, first one is source image, second is contour retrieval mode, third is contour approximation method. Contour approximation method, cv2.CHAIN_APPROX_SIMPLE is used in

First, circles are detected using HoughCircles function. It works on the "voting" space created by Hough Transform. To detect the other shapes, approxPolyDP is used. It takes the points of the contour (result of findContour()) as inputs and reduces the number of points such as to fit it to a polygon with lesser sides than the number of sides in the contour.

After the points are extracted, they are mapped to the specifications of each shape and a confidence score is given. The specifications that are compared are the number of sides, relative distance between the points (length of the sides) and the angle between the sides. The angle between the sides is calculated using the cosine formula.

Weights are given to the different characteristics by trial and error method to obtain the best possible results. The confidence score is indicative of how close the figure in the image is to the standard polygon. The confidence score of the shape in the image is hence the probability that it is that standard shape. Hence, if the confidence score for the shape being the square is the highest, then the shape under consideration is a square. This confidence score method makes sure that the shape in the image matches the closest standard polygon. Hence, this method works best for unclear images that are taken from an altitude since they cannot be classified as a square or a triangle with 100% probability.

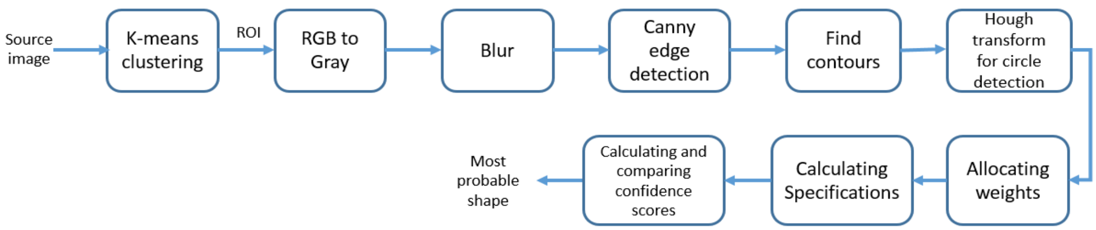

Fig. 1 Block diagram of the algorithm

IV. RESULTS AND ANALYSIS

The captured images are given as input to the code. The image is subjected to k-means clustering which is a robust colour clustering mechanism. The cluster corresponding to the shape being identified is further processed.

Images for the image processing task are obtained from the CHDK enabled Canon PowerShot S110. CHDK (Canon Hack Development Kit) is a firmware enhancement tool that helps highly customize Canon devices and run application specific scripts on the camera. The camera is mounted on the drone, with the lens placed parallel to the ground. The images are retrieved from the SD card after the flight. Alternatively, the images can also be wirelessly transmitted to the laptop at the ground station using a telemetry system. Given below in Fig.2 are some of the images used for testing the code. Fig3,4,5 gives the results for three images. The code detects a star, circle and a cross.

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Fig. 2 Few of the source images with the following shapes: a. red circle, b. purple triangle, c. blue semi-circle and d. orange star.

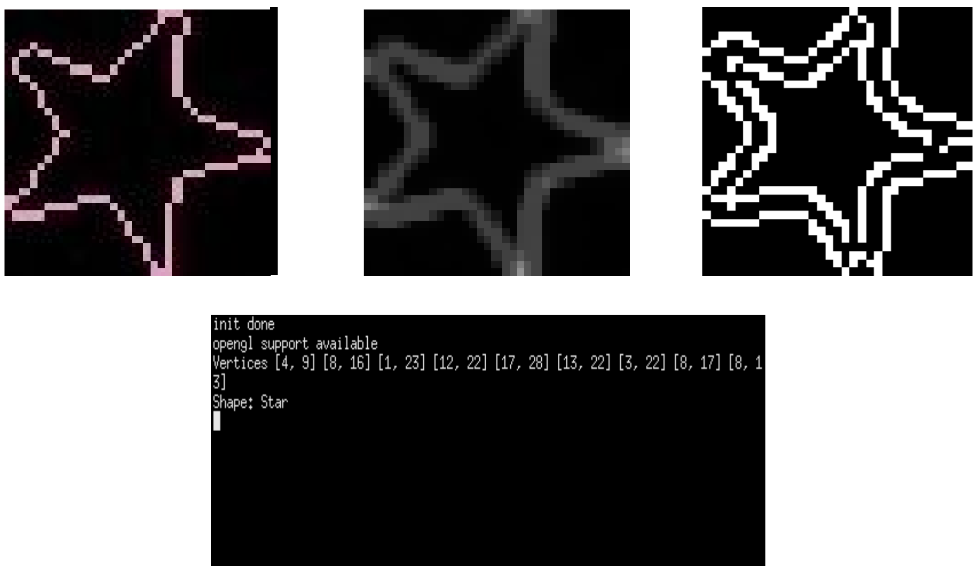

Fig. 2 Shape:Star; a.The isolated shape after ROI extraction from source image; b. Gray smoothened image; c. Image after canny edge detection; d. Terminal showing the position of the identified vertices and and the shape that it matches with.

Fig. 3 Shape:Cross; a.The isolated shape after ROI extraction from source image; b. Gray smoothened image; c. Image after canny edge detection; d. Terminal showing the position of the identified vertices and and the shape that it matches with.

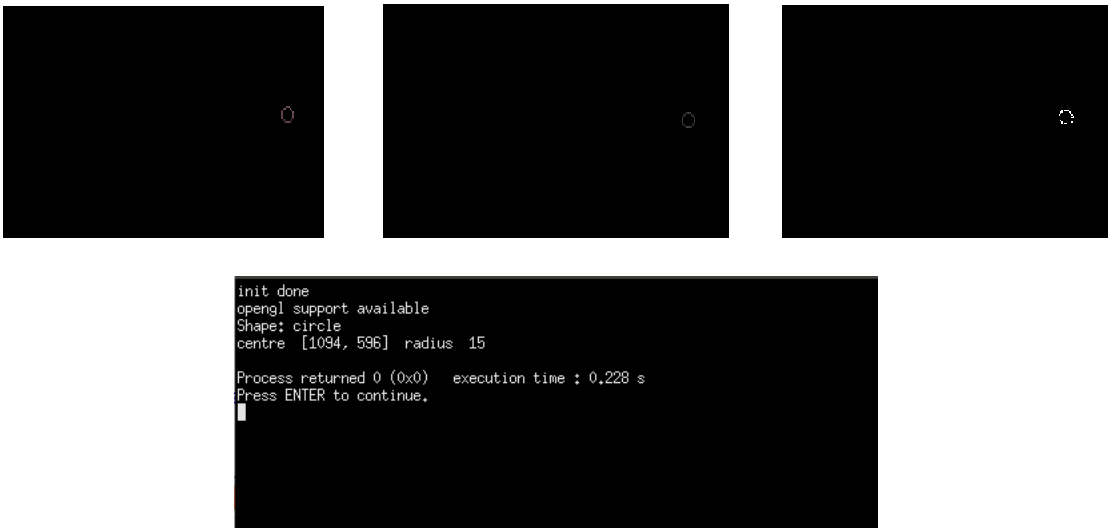

Fig. 4 Shape:Circle; a.The isolated shape after ROI extraction from source image; b. Gray smoothened image; c. Image after canny edge detection; d. Terminal showing the position of the identified vertices and and the shape that it matches with.

The algorithm has shown about 87% accuracy. One reason for failure is when the colour of the image and the background cannot be distinguished clearly. For instance, blue shape on green background. Another reason for incorrect matching of shape is when the picture is too grainy and hence the canny edge detector detects more edges and hence more vertices than it should.

V. CONCLUSION

The algorithm presented in this paper is useful in the detection and classification of the shape of an object in the image. It is especially tailored to give the closest matching shape when the image is taken from an altitude like the images taken from UAVs. The code has been written in C++ using the OpenCV library. OpenCV is computationally efficient, open source and especially designed for real time applications. The code was tested using images taken by a Canon S110 mounted on a UAV. The code has shown an accuracy of 87%. Different mechanisms to denoise and extract the ROI can be explored along with tweaking the weights assigned to the geometrical characteristics to get better results.

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