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Runway detection in aerial images by gradient orientations

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ABSTRACT

Target detection and recognition has been a research topic in computer vision for many years. In both economic and military perspective airports are important structure. Economically, as fundamental cargo and passenger transportation stations, airports serve to attract businesses with national as well as global ties. Automatic detection of airports is important to take well-timed military measures in a state of war. Small Unmanned Aerial Vehicles (UAVs) will change our economy by, including advances in agriculture, fast and environmentally-friendly consumer delivery, safe inspection of infrastructure such as gas pipelines, and in aerial photography. Recent advances in the quality of remotely sensed data open new prospects in the field of automatic target detection of geospatial objects. Currently most of UAV navigation systems are composed of GPS/INS integrated navigation system. To give an alternate navigation method when GPS (Global Positioning System) doesn't work on UAV, a machine vision-aided navigation method is proposed to navigate the UAV. The aim of the paper is to detect runways from an aerial image using orientation of gradients and Hough transform aiding automatic target recognition and automatic navigation of air borne vehicles for military purposes.

Keywords: Histogram, **Gradient orientations, Hough transform, Line modelling.**

1. INTRODUCTION

Automatic Target Recognition (ATR**)** is the ability to recognize targets based on the data obtained from either the sensors or from captured images. ATR can be used to identify air and ground vehicles. Research has been done for border security, safety systems to identify subway track object, automated vehicles, using ATR. Google Earth is software which displays satellite images on the Earth's surface of varying resolution. Aerial Runway images are acquired from Google earth.

It proposed a method based on both Bottom-Up (BU) saliency and top-down saliency that exploit the airport runways geometrical relationship (Dan Zhu, 2015). But it is too complex. It provides false output if the image contains more salient region. The visual attention model to locate the airport targets. But the accuracy is very less (Danpei Zhao, 2015). Anisotropic diffusion which provides the noise immunity and Frangi filter detects runway candidates at all possibilities (Abhishek Kumar, 2013). But it cannot detect runway edges. Interference is more and so false detection is possible. In (Aytekin's, 2013) paper, a runway detection method based on textural properties is used. In that Abhishek algorithm is employed as a feature selector over a large set of features. The complexity is very high and the textural feature doesn't give much information. The uses the Sobel operator to get the edge of the runway. Edge image has more unwanted pixels which lead to improper extraction of lines (i.e.) runway (Yinwen Dong, 2011). It proposes a method that describe airport by a set of Scale-Invariant Feature Transform (SIFT) key points and detect it using an improved SIFT matching strategy. But it involves complex computation (Chao Tao, 2010). In this paper, Hough transform mechanism is used for runway detection. After that the detected runway is segmented using line modelling to find out the runway length. By this way, the disadvantages of false detection can be overcome. Also, the complexity is reduced and the target is identified very fast, with high accuracy.

2. METHODOLOGY

The proposed method is to find out the runways in an aerial image taken at an altitude of 5000 ft. Colour histogram equalization is performed as a pre-processing step on an acquired aerial image. The gradient of this image is computed using sobel operator with the assumption that orientation of runway edge points are known. The orientations of the pixels are considered and Hough transform is performed. The detected runway portion is segmented using line modelling and is validated using the mean values and compared with the ground truth. The overview of the proposed system is shown in fig. 1

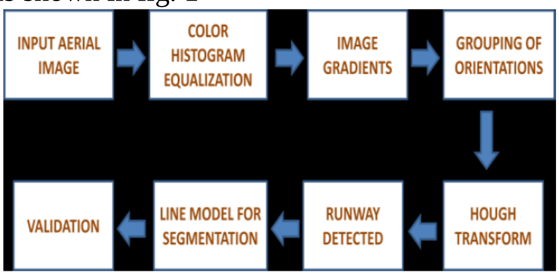


Figure.1.Block Diagram of the proposed method

Image Acquisition: The aerial view of airport runway is acquired using Google Earth. It maps the Earth by superimposing the photographs obtained from satellites, street view images and geographic information system (GIS) onto a 3D globe. As per specifications, small and medium sized UAV's can fly till a maximum height of 5000 ft. Figure.2.Represents the aerial images of airports collected from that height. From this height the width of the runway is around 6 pixels.

Figure.2.Aerial images

Colour Histogram Equalization: In a typical grayscale image, the range varies from 0- 255. The X-axis on the histogram will contain 0 to 255, and the Y-axis will contain the number of pixels for each value. In a dark image, more pixels will be concentrated towards the lower end of the histogram. During equalization, the concentrated values are stretched from 0 to 255. This way, all the available values are utilized and the image will have much better contrast.Fig.4 represents the flow chart of the equalization process.

RGB images consist of three channels. So they can be split into three separate channels and histogram equalization can be applied on each channel and combined back together.Colour histogram equalization renders the runway in the input image to be more prominent. The equalised image is used further. Fig. 5 shows the aerial images before and after histogram equalisation.

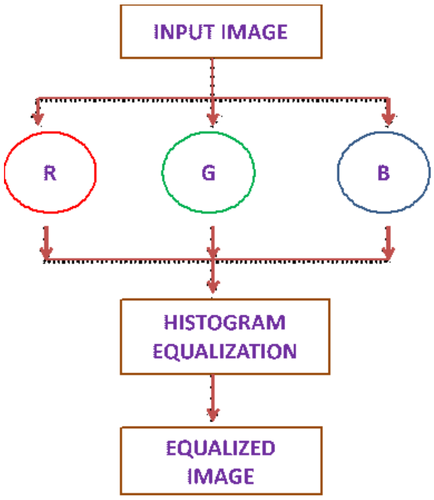


Figure.3.Flowchart for histogram equalization

Figure.4 a) Original image b) Equalized image

Gradient Image: The gradient of an image measures colour intensity changes. It provides two pieces of information. The magnitude of the gradient shows the changes in the image, while the direction shows the changing direction. The gradient magnitude and orientation is given by,

$$mag(\nabla f) = \sqrt{G_x^2 + G_y^2} \approx |G_x| + |G_y| \qquad (1)$$

$$ang = \tan^{-1}(G_y/G_x) \qquad (2)$$

Where G_x is the image filtered by horizontal mask and G_y is the image filtered by vertical mask. The angle varies from -180° to +180°.

Sobel mask:

$$\boldsymbol{x} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad \boldsymbol{y} = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

The above masks are moved over the entire image. The mask ‘x’ gives gradient along x-axis and the mask ‘y’ gives gradient along y-axis. By combining both the gradient magnitude and gradient orientation are obtained. Sobel outperforms other operators due to immunity to noise and detects almost all edge points accurately. The gradient magnitude and orientation are obtained from formulas mentioned above. The orientation ranges between -180° and +180°. Runway may be in any orientation in a given image. The magnitude and orientation image looks as shown below.

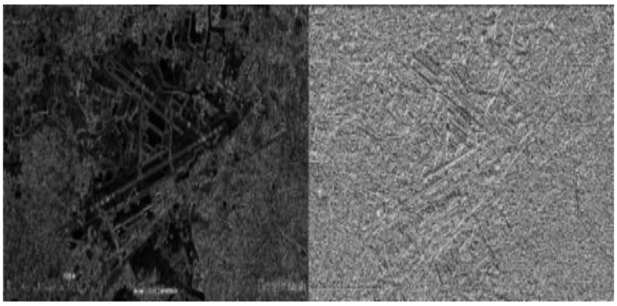


Figure.5 a) Magnitude b) Orientation

Grouping of Orientations: An important fact is that the points along the runway border are in the same orientation. So the pixels with the same orientation have to be grouped together. Runway in an aerial image can be in any orientation in between -180° and +180°. The pixels with the same orientation are grouped together in the range of [-180°, -160°], [-170°, -150°], [-160°, -140°], ….. [160°, 180°]. In order to avoid more number of groupings, overlapping blocks of angles have been chosen. Finally 37 binary images are obtained for each orientation block. Next step is grouping of pixels, if and only if there are pixels having same orientation with its 3X3 and 5X5 neighbourhood. This removes additional pixels apart from the runway region. At last white pixels will be crowded in the runway region. But no continuous lines are obtained. These points have to be linked by Hough transform.

Hough Transform: The Hough transform is a technique for feature extraction which uses a voting procedure to find imperfect instances of objects within a certain class of shapes. The voting procedure is done over a set of parameterized image objects.

The simplest case of Hough transform is the linear transform for detecting straight lines. The straight line can be described as y = mx + c, in the image space and can be graphically plotted for each pair of image points (x, y). In the Hough transform, the straight line is not considered as image points instead, in terms of its parameters, i.e., the slope parameter m and the intercept parameter c. In the parameter space the straight line y = mx + c can be represented as a point (c, m) which is shown clearly in Fig. 7. But this will give rise to unbounded values of m and b. For computational reasons, it is therefore better to use a different pair of parameters, ρ and θ, for the lines in the Hough transform. These are the Polar Coordinates which is shown in Fig. 8

The distance between the line and the origin is represented by ρ, while the angle of the vector from the origin to the closest point is represented by θ. Using this parameterization, the equation of the line can be written as $\rho = x\cos\theta + y\sin\theta$. It is therefore possible to associate with each line of the image a pair $(\rho$, θ) which is unique if θ € [0, Π) and ρ € R, or if θ € [0,2Π) and ρ € R. The (ρ, θ) plane is sometimes referred to as Hough space for the set of straight lines in two dimensions.

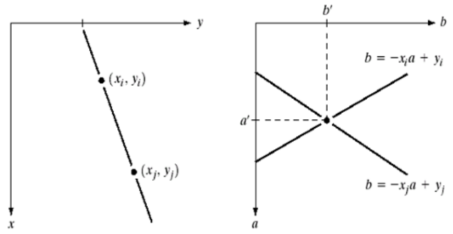


Figure.7a)Cartesian space b) parametric space

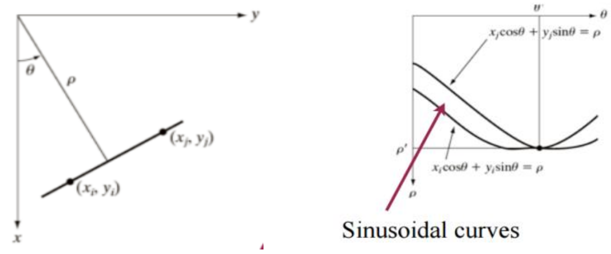


Figure.8.Polar coordinates

Slope intercept line equation

In ab plane (parametric space) $y_i = ax_i \quad b = -ax_i + y_i$

2 points (x_i, y_i) and (x_j, y_j) lie on the same line and has parameters associated with it intersects the line associated with (a', b') at (x_j, y_j) where (x_i, y_i) is the slope and $a'b'$ is the intercept of line containing and(x_j, y_j).

The normal representation of a line in polar form is $\rho = x\cos\theta + y\sin\theta$.The algorithm is

- Initialize accumulator H to all zeros
- For each edge point (x,y) in the image

For θ = gradient orientation at (x,y)

ρ = x cos θ + y sin θ

H(θ, ρ) = H(θ, ρ) + 1

end

- Find the value(s) of (θ, ρ) where H(θ, ρ) is a local maximum.

For each of the 37 images, a long line will be detected. The endpoints of the line are found. By obtaining the 2 coordinates, the length and orientation of each line can be obtained. The problem now is that runway is detected in only one of the 37 images. The image containing the runway has to be identified. So the next step is to segment out region of line from the original image.

Line Model for segmentation: At the end of Hough transform the line segment having runway is detected .The end points of the line are also known. To segment out the required portion the coordinates of the end points has to be known. If the detected line is vertical or horizontal, the coordinates can be easily obtained by either incrementing (or decrementing) row or column values. But runways may be present in any orientation, so obtaining coordinates require a model. The runway line model is nothing but the slope-intercept equation $y = mx + c$ where m is the slope of the line and c is the intercept. The slope is found by $m = (y2 - y1)/(x2 - x1)$ where $(x1, y1)$ and $(x2, y2)$ are the coordinates of the end points. If x1 and x2 are same, then m reaches infinity. For that case, slope is considered null and if slope is null, the intercept is taken as x1. The intermediate coordinates are obtained by running a loop by incrementing x1 and corresponding y values are obtained by the slope-intercept equation. Also width of the runway is around 6 pixels. Thus, the thickness of the line detected is varied accordingly. Thus all the lines detected are segmented in all 37 images.

Runway Validation: The binary image obtained in the last step is multiplied with the gray scale of the original image (point to point multiplication). The following assumptions are made for runway validation: The length of the runway lies between 300 to 600 units. The mean of the runway region lies between 4 and 8. Now 37 images with segmented portion containing information from original image are obtained. In each image, it is tested whether the detected region follows the assumptions made. These assumptions yield an accuracy of 100%. Thus, the proposed methodology is simple, fast and accurate.

3. RESULTS AND DISCUSSION

The main objective is to detect runways from an aerial image with cluttered backgrounds as it can help a UAV to automatically detect airport targets and help in automatic landing in the case of GPS failure. The test images are to be taken from a height of 5000ft. The software used to obtain the aerial images is Google Earth. The resolution of the image is 1116 X 659. The format of the image obtained is '.jpg'.

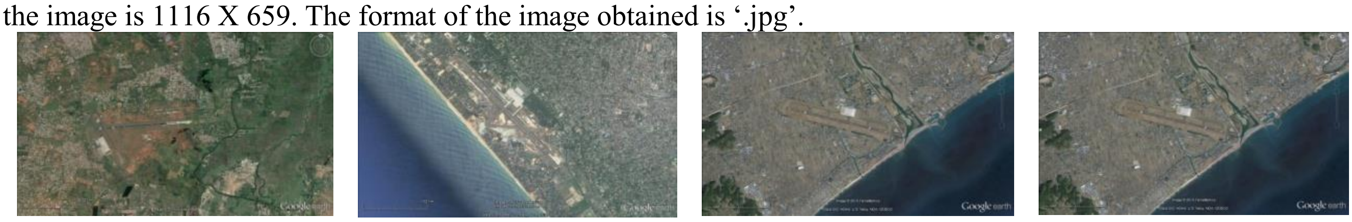
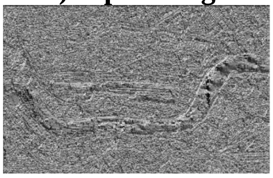


Figure.9.Test images

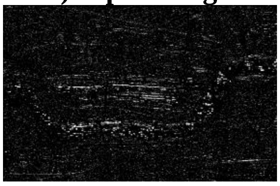
a) Input image

a) Input image

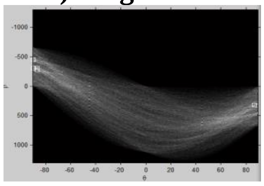
c) Magnitude



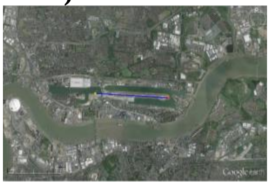
d) orientation



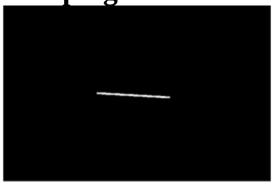
e) Grouping of orientations



f) Hough transform



g) Runway detected



h) Segmented runway

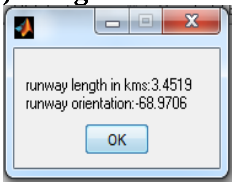


Figure.10 (a-i). Results

i)msgbox: Fig 10 shows the input aerial image containing runway. The colour histogram equalized image shows the runway more predominantly. This is then converted into a gray scale image and the image gradients are found using Sobel method. Magnitude and orientation images are obtained from gradient image. Orientation varies from -180° to 180°. Pixels with same orientation are grouped. Hough transform is applied to the image to link the pixels to obtain a long line. The detected runway is then segmented using line model and then is validated using the mean value and ground truth. Message box displays the runway length in terms of kilometres and the runway orientation. Runway length in terms of number of pixels can be converted into kilometres. Google earth shows bar scale at the left bottom of the image. It is found that for the image in Fig. 11, 225 pixels correspond to 1523 metres (i.e. 1.523 km). Calculation is

225 pixels = 1.523 km

x pixels = x * 1.523 / 225 km.

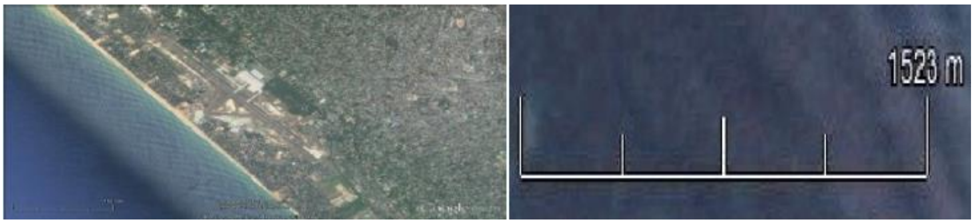


Figure.11.Bar Scale

Thus the runway length is found in kilometres. The proposed methodology is very accurate and gives 100% result when checked with the ground truth.

4. CONCLUSION

The above methodology is very fast to match with the speed of operation of UAV and the runway is detected within 10-12 seconds. The proposed methodology involves detection of runway based on the gradient orientations which was never used earlier. The proposed work is rotation and illumination invariant. The data set contain runway nearer to shore lines, roadways and other linear features. But this algorithm avoids content interference and produce accurate results. The work can be extended to determine the latitude and longitude values of the runway using the concept of geo-referencing. The system can be used by UAV for autonomous landing when GPS failure occurs. This method has scope in automatic target detection for military affairs and civil aviation.

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