# Detection of Road for Landing of Aircraft in an Unfamiliar Environment: A Comparative Study

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**Abstract—This paper is a comparative study about detecting straight road from satellite images. There are multiple applications of road detection. Here, only straight road is considered for use as a landing strip for aircraft emergency landing. To fully guarantee the safe landing of aircraft, multiple criterions are required to be addressed, for example, buildings and traffic. However, the focus of this paper is only to detect straight road from aerial image to ensure it is feasible to land an aircraft or not. If it is feasible, only then the detection process can move forward to the analysis of non-road objects. To find such road, three different image processing methods are used which are (Canny, Sobel and Prewitt), Fuzzy C-Means (FCM) clustering method and Markov Random Field (MRF) classification model. Each method is used to segment the roads from non-road objects. Since, edge detectors and segmentation models may have broken segments morphological operations are applied to join these broken segments, namely dilation and erosion. Then, the Hough transform is applied to detect a straight road. The results obtained were compared and was concluded that canny performed better as compared to other methods used in this comparative study. But practically none of them were found effective enough as straight road detectors. In the end, some issues are addressed and few solutions have been proposed for future work on this paper.**

***Keywords***—— Aircraft Landing, Hough Transform, Line Detection, Road Detection

## I. INTRODUCTION

Aircraft is an engineering marvel. Since its introduction into the world, it has played a role as a transporter of things, be it civilian transportation, cargo or as a military. Initially, aircraft were prone to crashes, due to the fact that there weren't many effective precautionary measures for the safety of aircraft. As time passed and technology evolved aircrafts adopted different safety measures for self-reliance by adding technologies like automation and has since been improving simultaneously. Hence the laws governing them are changing and allowing the use of aircraft. However, there are still safety procedures that need to be taken firmly. Safety of these aerial vehicles based on rules, regulation and operational readiness. Most important of them is the case of a critical failure, such as communication links going offline due to factors or malfunctioning in the avionics component or other factors that could lead aircraft to go astray. Landing can be difficult in regions unknown to aircraft be it in plain areas or mountainous regions etc. in such a scenario. Although aircraft are assisted by pilot/operators who are experts in finding and navigating the aircraft to a safe zone, an automated process for aircraft that are operating completely autonomous is a different game. Aircrafts are equipped with onboard self-contained systems to support the flying path, one of such system is the downward faced (Forward Looking Infrared & Radiometer) FLIR camera whose actual purpose varies from surveillance to targeting for payloads to drop at target locations, such cameras can be used to take aerial images or if in its absence, (Global Positioning System) GPS guided satellite images can assist an aircraft to detect the safe landing site in its flight path and plan the trajectory and gliding procedure to land safely without any damage or worse i.e. People, buildings etc.

To ensure such an effective method, the system requires not one but set of processes and techniques for each factor in the entire operation of safely landing, such as traffic, buildings, road thickness, cables etc. Here, the prime focus will be on road detection or landing strip at an altitude that is straight curve less for the aircraft to land safely. It is assumed that aircraft is equipped well and will have the help of GPS or surveillance camera mounted on aircraft. Other than that it would further require the assistance of advance computing methods to analyze the aerial image and detect roads to ensure the safe landing which is possible with the methods performed in this paper using Edge detection techniques, FCM for clustering and MRF for classification as preprocessing to remove noise from the image. It has concurred that the methods provided are not the most

effective one rather are used to set a benchmark for future improvements to the work done in this paper. After an image is free from noise, the Hough transform is applied. After successfully detected road which is suitable as a landing strip, this research can move forward towards the detection of ground clearance.

Most of the work done on road detection is done for pattern mapping as done by NI et al. [1], which is a complete extraction of all roads found in the resultant image, which is very useful in mapping the region. Papers referenced in this research work have a similar principle of region mapping be it curved or non-curved roads in the regions known. The main objective of this paper is to omit curved roads, non-road objects and only highlight the roads that have straight path without any degree or curve in the regions that are unfamiliar or alien to the aircraft. This helps the later process of checking if the road has traffic or is surrounded by buildings and roads characteristics such as dimensions of the road (length or width). Currently, no such method related to road detection exists that helps aircraft to land it in areas that at high altitude cannot be detected by the aircraft pilots without any info of that region.

## II. METHODOLOGY

### *A. Using Edge Detection Technique:*

It is well known that edge representation is one of the decent methods of extracting useful information without loss of most of the data. The image reconstruction is possible using edge mapping; this saves the process of compression of data or storing unwanted data [2]. Considering that edge detection alone cannot clearly get continuous segments. Since broken segments are expected. Dilation operation can be used to connected and bridge the broken segments and make a right use of edge detection.

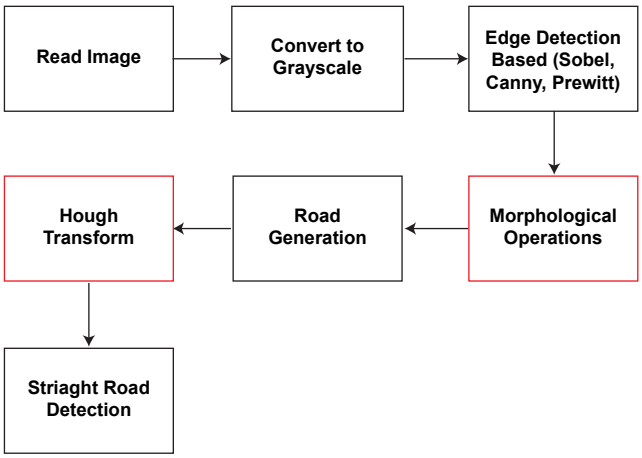


**Fig. (1)**. Flowchart of edge detection technique for road extraction.

As shown above, in figure 1, Using edge operator as in [3] this method initially:

1) Takes an aerial image from forward looking camera

2) Convert to greyscale, since we do not require colour or luminance for this task

3) Smoothing filter: Gaussian Filter also known as Gaussian smoothing is a spatial domain filter for smoothing, its main focus is to remove noise or details [4]. Smoothing effect is applied to reduce components of high frequency hence, it is low pass filter.

4) Edge Detection Operator: Boundary of an image or object in an image is called edge. Edges have importance since they can be used to extracted arbitrary shape or other features [5].

*a) Canny*

Also known as Canny edge detector, it consists of multiple steps to detect edges that are: The Process of Canny edge detection algorithm can be broken down to 4 different steps: first Gaussian Filter then Finding Intensity Gradient of the Image after that Non-maximum suppression in end Hysteresis threshold where it is decided if one is edge or not using two threshold values, minimum value and maximum value [6] .

*b) Prewitt*

It is an edge detection technique that looks at two types of shapes horizontal line and vertical line. It uses a convolution matrix known as masks.

*c) Sobel*

Same as Prewitt uses a mask. However, the main difference between Prewitt and Sobel is that the mask cell values in Sobel can be altered based on the situation. However, it is not against the rules of Sobel operator masks i-e sum of values in masks is 0.

5) Discard small connected components to remove small components that are smaller than no of pixels.

6) Morphological Operations uses convolutional method to modify the pixels surrounding certain pixel one by one [1], such as Dilation operation after detecting the edges with some edge detecting method, these edge lines might be broken or separated to ensure they are in consistency and the edges are not separated or eroded. Use of dilation morphological operation is conducted to ensure that edges are joined.

Since the edges are thin lines, dilation of type line is used. Dilation adds a pixel to the neighbours of the input pixel using structuring element e.g. square, round, plus, line. Applying this operation ensures that broken edges are enlarged hence joining to separate components, but since line could become very thick a clean operation is used which is dilation followed by erosion and then bridge dilation is used to even further ensure that broken components are connected such as broken road segments.

7) Edges that are still smaller in size than the defined threshold are omitted.

8) Hough Transformation: After noise is removed using image processing. A transformation technique is used to detect arbitrary shape i-e. Line by using the technique known as Hough transform is applied [7].

Duda et al. [8] Introduced a method called "Generalized Hough transform". Hough transform is used to detect shapes and lines such as a curve or nonlinear shapes. Traditionally Hough transform's application is to find lines in edges but its main idea is to find lines in an image but not as discrete pixels in an image rather in terms of slope intercept formula [9] as shown below;

$$y = mx + c \quad (1)$$

But equation (1) does not support vertical lines which are denoted as;

$$x = a \quad (2)$$

So "ρ" (rho) and "θ" (Theta) parameters were formed which are used to define a pixel or point in image where "ρ" denotes distance from origin to pixel from straight line and "θ" denotes angle between that line and origin and x-axis in such a way that that line is connected to x-axis to the closest point as shown in figure 2, and equation (3) is formed.

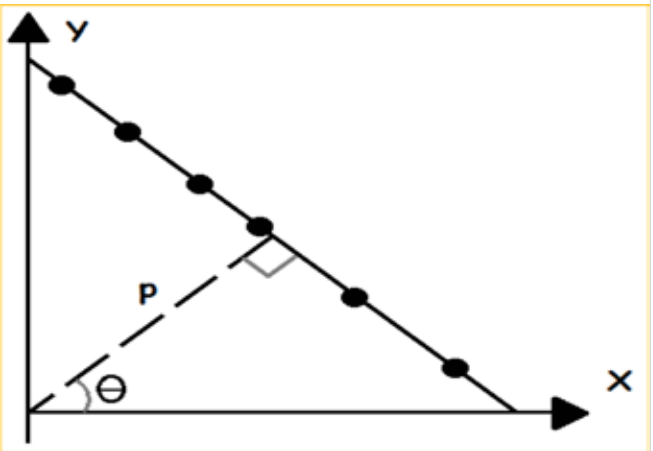


**Fig. (2)**. Rho and Theta representation for a straight line.

$$y = -(\cos(\theta) / \sin(\theta)) * x + \rho / \sin(\theta) \quad (3)$$

Since the above equation (3) cannot be used for properties of lines in Hough space since it gives excessive value to slope the equation was converted to equation (4) known as "normal form by Hessel".

$$\rho = x * \cos(\theta) + y * \sin(\theta) \quad (4)$$

The formula is applied on each pixel and infinite lines are drawn over the point each denotation is then converted to Hough plane which shows each pixel in a sinusoidal shape known as Hough space as shown in figure 3. This process is repeated for each edge pixel until it is the end of the matrix or image. This transformation method has been successfully used to find shapes in the image.

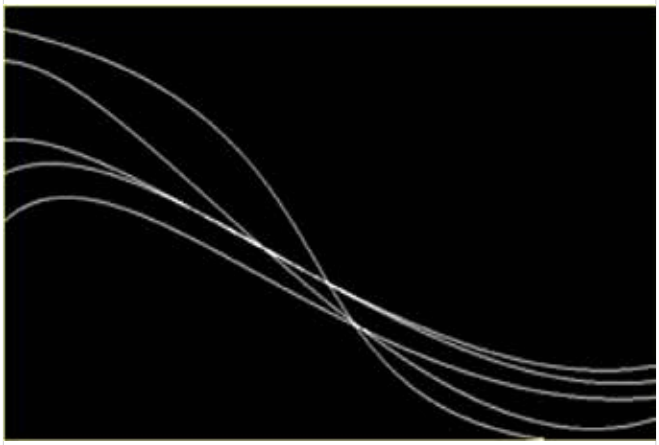

**Fig. (3)**. Hough Space.

9) Straight road extracted for aircraft to land.

*B. Using Fuzzy C Mean Clustering Method:*

FCM is used to group different objects into the same regions or segments having similar characteristics such as grey value and calculate the segment centroid. One of the factors that differ from other clustering or segmenting algorithms is that FCM can have the same data points assigned to more than one segments. Being unsupervised the computational time for this algorithm is considerably long. The effectiveness over noise is limited and some segments have noise due to its random initial point selection but, still, it performs adequately in image segmentation than other clustering models [10]. This method follows the same approach as an edge detection method process but instead of using edge detection uses FCM to segment data into segments of the same type as shown in figure 4.

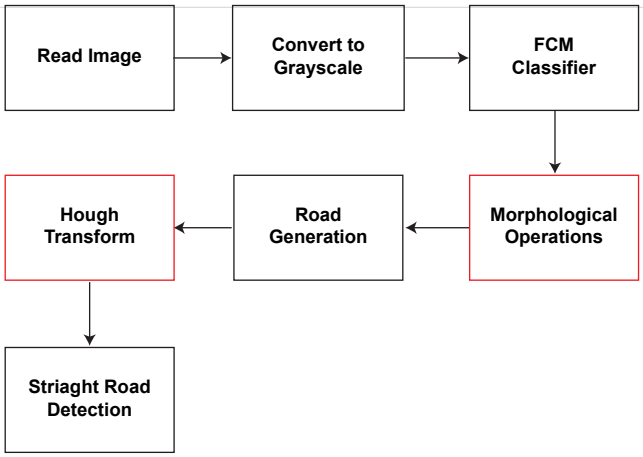


**Fig. (4)**. Flowchart of FCM

### C. *Using Markov Random Field Classification Method:*

MRF can be used for classification at the pixel level choosing random pixels as initial points [11]. It can be used to segment different object based on the characteristics known as Markov property. In this case, we first segment the road and then separate the road from the rest of the objects in the image as was done by Yong et al. [12]. In this method, the MRF segment method is used as shown in figure 5. There is only one difference i-e instead of edge technique, FCM or MRF segment method is used to find the segmented data by segmenting similar pixels with characteristics such as intensity.

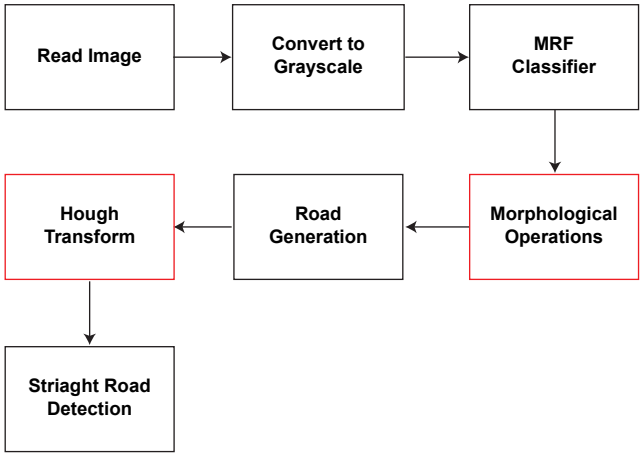


**Fig. (5)**. Flowchart of MRF

### D. *Compare and Analyze:*

After the results from A, B and C methods are extracted truth table (table 1) is used to analyze the results and conclude which one is better. The Performance in the truth table is measured by the means of how each method has effectively performed and detected road which is suitable enough for the landing of an aircraft.

## III. DATASET

Work is simulated on Matlab 2016 environment. A set of 200 samples high-resolution image data is extracted from Google Earth's licensed GEO EYE 1 satellite, resolution of 0.46m of remote sensing imagery through Google Earth Pro [13]. These aerial images are at an altitude of 2000 ft. Each image is from different areas of Pakistan of an urban and rural region.

## IV. EXPERIMENT & RESULTS

### A. *Edge Detection Based*

As shown in figure 6, Canny performed better compared to Sobel and Prewitt. However, noise is still present even after applying a smoothing operator before edge operators. In terms of road detection, Canny has still left some non-road objects which can be an issue in case of detecting landing strip for aircraft landing. While applying Prewitt and Sobel's results are almost the same with few differing pixels as shown in figure 7 and figure 8, but most of the noise is removed by it in default. Results varied in different sample images.

### B. *Fuzzy C Mean (FCM)*

As shown in figure 9, FCM was not able to detect the road using its clustering method. Due to the fact that some objects in sample images have identical grey levels to the road. Hence it is unable to cluster the road from non-road objects such as buildings. Results varied in different sample images.

### C. *Markov Random Field (MRF):*

As shown in figure 10, Classification based on MRF provided accurate results where the images grey level didn't match with each other and successfully separated road objects from non-road objects that helped Hough transform to find the straight path, but in Fig. 10. Some of the crops grey levels matched the roads connecting and considered as one and merged them in the same segment. Hence some images had a right starting point of landing but ending point of the landing strip ended over the crop. Results varied in different sample images.

Most of the detections were accurate. However, 57% were correct detections while 43% were either not detected or inaccurate detections such as considering building boundaries as roads.

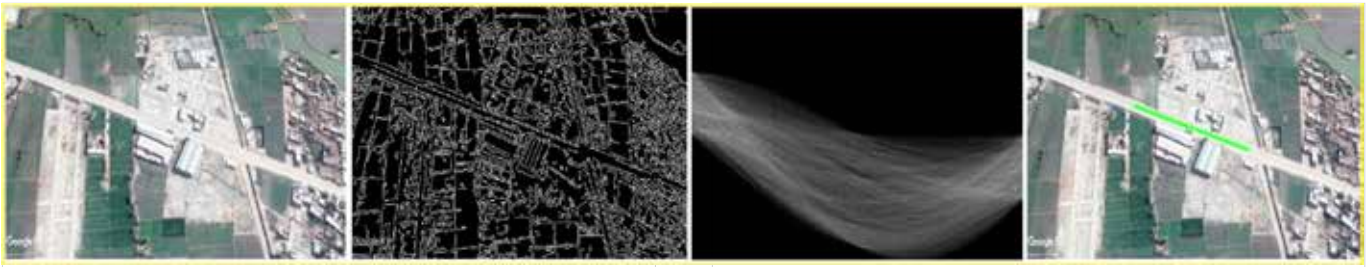

**Fig. (6)**. 1st image is original, 2nd after applying Canny operator followed by Hough transformation and Result (green line in the last image).

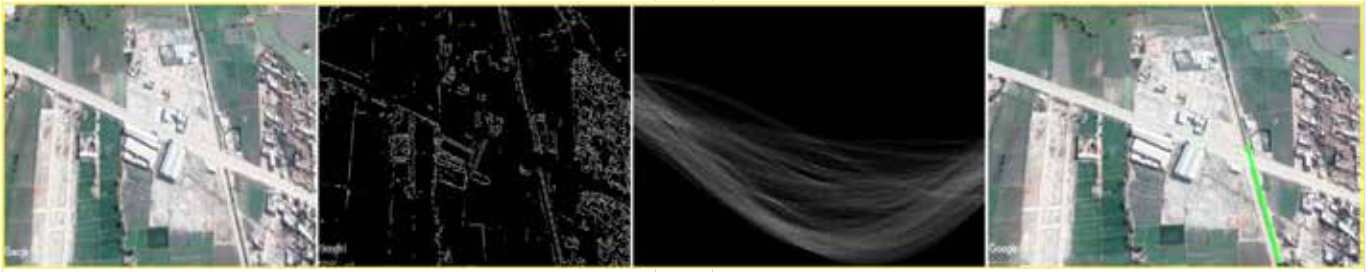

**Fig. (7)**. 1st image is original, 2nd after applying the Prewitt operator followed by Hough transformation and Result (green line in the last image).

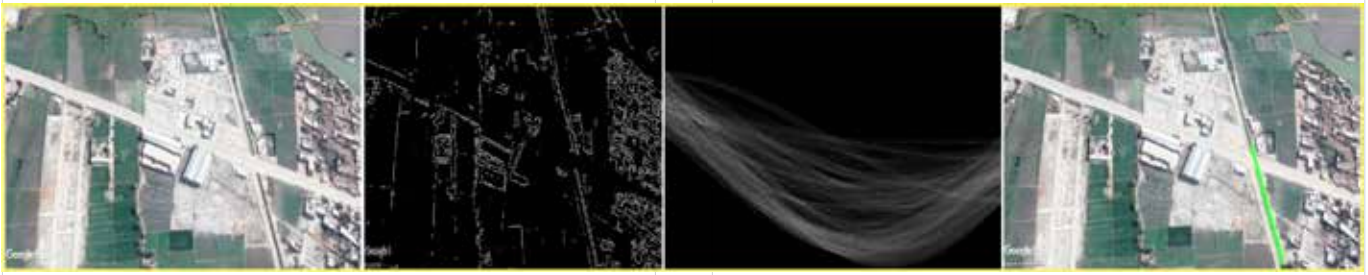

**Fig. (8)**. 1st image is original, 2nd after applying the Sobel operator followed by Hough transformation and Result (green line in the last image).
**Note: similar result as Prewitt.

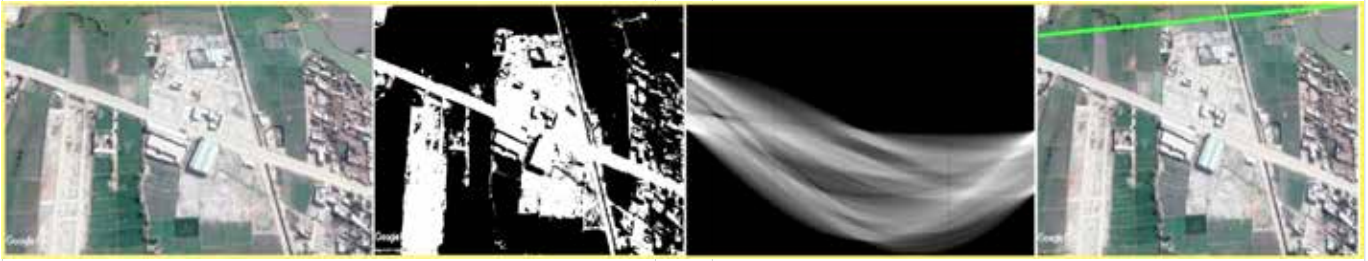

**Fig. (9)**. 1st image is original, 2nd after applying FCM clustering method followed by Hough transformation and Result (green line in the last image).

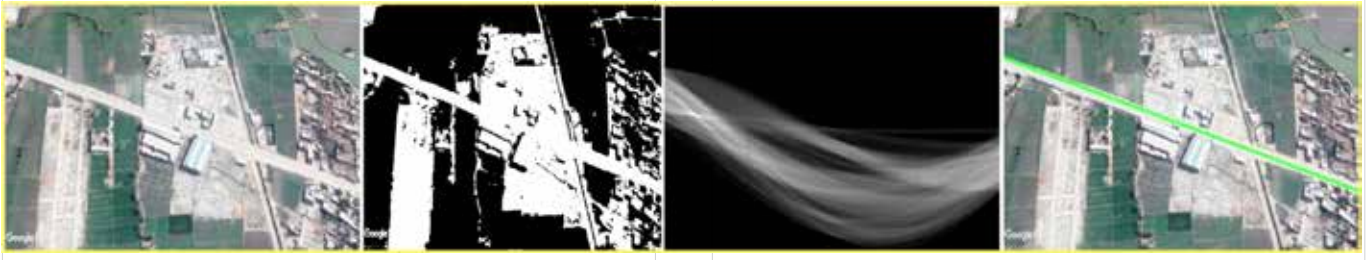

**Fig. (10)**. 1st image is original, 2nd after applying MRF classifier followed by Hough transformation and Result (green line in the last image).

**Table 1.** The truth table for comparison of different methods compared

| Method | TP | FP | TN | FN |
|---|---|---|---|---|
| Sobel | 59% | 35% | 3% | 3% |
| Canny | 76% | 23% | 0% | 1% |
| Prewitt | 58% | 32% | 3% | 7% |
| FCM | 48% | 32% | 12% | 8% |
| MRF | 44% | 35% | 9% | 10% |

Results compiled are compared and observed to see the outcome on each sample. Samples, where no line is detected, are considered as true positive if a line is detected but is not on the road but over the non-road objects is considered as false positive, if road exists but not detected is considered for a false negative category and correct line detection as straight road is considered as True positive. Canny had the most correct detections while MRF had most incorrect detections.

## V. CONCLUSION

This comparative study about finding a straight road that is suitable enough to land an aircraft which is the first step for landing strip detection and effectively land an aircraft. It showed that edge detection based techniques perform reasonably but not effective. Canny performed better of the three in detecting roads because roads have continuous edges, though Canny operator also detects other non-road objects such as buildings, nonetheless were removed or minified using morphological operations such as cleaning and bridging to link broken segments. In practical use, Sobel and Prewitt's results have suggested that they are below the threshold of practical usability of road detection. Hence in more than half possible options, the results were negative. On the other hand, FCM clustering method had difficulty in differentiating objects such as roads and roof of buildings which are placed parallel to road and have commonly similar colour or geometrical spectrum hence they are placed in the same segment that is why the morphological operations performed have little effect on the segment that erases the shape of roads for detection of landing strip for emergency landing. MRF classifiers had the same response, as a number of segments increases in MRF, the detection of the road becomes even more problematic as each segment takes chunks of roads that are merged with building and separate it to rest of road which is also kept in other segments. Overall, the results of methods experimented were not practically feasible enough to ensure methods effectiveness to detect straight road. Hough transform played its role in detecting the line, but the main cause of the error was due to the segmentation preprocess.

## VI. FUTURE WORK

This paper used conventional versions of edge, classifiers and cluster models. A lot of room for future is present in this paper since this paper only focuses on the comparative study using conventional models and application of Hough transformation to find the straight line (straight road) over the road, which is just the first step in safely landing an aircraft on a landing strip in an unfamiliar environment. However, it must be noted that the application for it to fully practically work still requires calculating and estimating the probability of landing safely on the newly detected landing strip by not just finding the road but also calculating characteristics such as length of the road. Road thickness is as important as other factors. Such as, the thickness of road should at least support the width of the fuselage of an aircraft if not the wingspan. Even before the landing, it is also important to detect the traffic in the area that could lead to collateral damage such as vehicles and buildings.

These issues may better be addressed using improved classification/ clustering methods such as k-means (supervised or unsupervised), Naïve Bayes classifiers or instead of going for geometrical arbitrary shapes, choosing colour spectrum and classify each object with spectral characteristics, this may become more adequate. Applying Hough transform on such a method could provide better insight.

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