

Efficient Horizon Line Detection using Clustering and Fast Marching Method

Ravi Sravanthi, ASV Sarma

Abstract: Video analysis of maritime scenarios typically includes detection of horizon line for reference. The horizon line is the imaginary line, which separates water and sky as well as water and land. The horizon line plays a major role in terms of demarcating the water region in the video frame for further analysis. Considerable research has been aimed at horizon line detection. Various approaches have been reported including (i) Canny based edge detection followed by Hough transform, (ii) machine learning combined with statistical methods. However, the Hough transform has several limitations, in terms excessive analysis time, deviation of estimated line from the actual horizon line, sensitivity to presence of floating objects on the horizon, error due to presence of large number of edges. Present paper describes an efficient method for detecting the horizon line for analysis videos obtained by cameras mounted on floating vessels such as unmanned surface vehicle in maritime and inland scenarios. The proposed method is based on K-means clustering followed by seed based region growing using Fast Marching Method. For detecting the horizon line, two clusters are used in water-sky region like in marine environment images whereas three or more clusters are used in water-land-sky region like in in-land rivers/lakes images. In most cases, the upper part of the frame belongs to sky region whereas lower part belongs to water region. After K means clustering, based on the selection of seed point in lower part of the frame, the water region is segmented using fast marching method from non water regions and hence the horizon line is detected. This proposed method performance is compared with edge detection followed by Hough transform for different datasets. Experimental results show that the proposed method detects efficient line without compromising the processing time.

Index Terms – Unmanned surface vehicle (USV); Horizon line detection; Marine environment scenes, in-land rivers and lakes, K-means clustering.

I. INTRODUCTION

The computer vision and video analytics techniques are becoming increasingly popular for monitoring and surveillance of maritime, inland water bodies and inland waterways. Videos captured from the inside of a floating surface are used for analysis. In marine vehicles, the video analysis is useful to navigation, intruder detection, and debris collection. In the military surveillance, it is useful in detection, identification and tracking of targets moving at a distance near the horizon. Videos of maritime environments usually show a horizon line, which is an imaginary straight line boundary that separates the water and the sky.

Revised Manuscript Received on February 28, 2020. * Correspondence Author

Ravi Sravanthi*, Research scholar, Jawaharlal Nehru Technological University Ananthapuramu, AP, India. E-Mail: sravantisrinadhreddy@gmail.com

Dr ASV Sarma, Professor, Dept., of ECE, PBR VITS, Kavali, AP, India. E-Mail: asvsarma@yahoo.com

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

During video analysis, the horizon line is extracted first as it serves as a reference as well as to limit the image region for further analysis.

Several techniques have been developed for determination of horizon line. Typical methods include statistical method, Canny edge detection followed by Hough Transform etc. Maritime videos taken at locations close to the shore may show water, land and sky. Here, the horizon line or contour is no longer a straight line may have segments that touch the water and the land. Another segmentation method may be required to segment the water region for further analysis.

For the sea line detection Random Sample Consensus (RANSAC) approaches, Hough transform approaches are widely used. The inland water bodies are usually surrounded by land along most of their boundary. Their video frames typically consist of 3 regions, namely water, land and sky. The horizon line may include the boundaries of water and land regions. The complex inland river/lakes environment is different with marine scenarios, shown in fig 1. Therefore, visual inspection of water surface in inland rivers/lakes is still a big challenge to the researchers since it is cumbersome with sky, water surface and waves, water weed, land, trees, grass and buildings. So, it is difficult to detect that uncertainty shape of the water line. Efficient horizon line detection method for sea line in marine environment as well as for water line in in-land rivers/lakes to vision module based on a K-means clustering and Fast marching method is presented in this paper. Experiment result proves that our approach is the efficient one with almost same speed.





Fig 1: Sea line in marine environment (top);



Efficient Horizon Line Detection using Clustering and Fast Marching method

Water shore line in in-land lake environment (bottom); (images from open science framework (OSF) dataset DS3 & DS4) This paper is structured as follows. Related work literature survey is provided in Section II. The proposed horizon line detection method is described in Section III. The results of our method are provided in Section IV. Finally, our conclusions and summary are given in Section V.

II. LITERATURE SURVEY

In this section, various existing horizon line detection methods are discussed along with their merits and demerits. [1] proposed hybrid technique to separate the sky region with other regions by combining edge-based and a new color-based horizon detection technique. Sky line is detected by using the chromatic changes in the clear sky areas without depending on other parts of the image for manually annotated set of images. Accuracy of the position and angle of the detected horizon line is detected and is compared with Canny edge detection followed by Hough transform technique. Proposed method got 40% lower average error than the edge based detector. But, it is not suitable for embedded applications due to the expensive color based detector. Based on gradient information and energy function optimization technique, [2] proposed algorithm to detect sky region for 1000 different images. But, It needs prior knowledge of sky region. To detect the horizon /sky line, to focus on visual geo-localization based on accurate detection of skyline, to develop algorithms for semantic segmentation [3] proposed classical feature learning method, patch-wise method, deep-learning network classifier training methods(FNN, SegNet) respectively for publicly available CH1 data set. But, learning techniques are more complex. For marine environments, to separate sea and sky regions, horizon line is detected based on algorithms H-COV-LUM,

H-HC, H-LSC, H-MED, H-REM related to canny edge detection and Hough transform for 9 test images [4]. H-COV-LUM algorithm provided the highest accuracy while H-REM algorithm provided the large speed.[5] proposed algorithm for marine environments to detect the sky line from the sea region and also to mark targets on images acquired by both infra-red (IR) as well as visible light cameras. They used combination of edge detection and the Hough transform (EDHT) and a statistical criterion .The former one is used to detect several candidate lines in the image and later one is used to find the optimal line among the candidates. [6] proposed an algorithm for saliency-based SSL (sea sky line) detection in optical images based on cubature Kalman filter (CKF) method from "XL" USV images and compared the results with Hough transform and Radon transform.

[7] proposed one system to extract the horizon line from each video using QHLD (quick horizon line detection) method and calculated an angle between the line and the horizontal border of the video shot. Compared the accuracy of the algorithm with edge detection and Hough transform and proved that the proposed method is slow process method. Sea-sky, soil-sky and forest-sky lines are detected in [8] using intensity based and K-means clustering method based on existence of a unique light field that occurs in

imagery. Computation mean time is computed for authors own dataset and proved that intensity based method is faster than K-means clustering method. Sky-land line is detected in [9] using a classification map instead of an edge map. Machine learning and Dynamic Programming (DP) techniques are used to detect the horizon line. SVM DCSI and CNN DCSI classifiers average absolute errors are compared for City data set, Basalt Hills data set and Web data set. [10] Proposed an algorithm for detecting the objects in marine environment, for presenting graphical model for semantic segmentation of marine scenes and for estimating USV obstacle-map. It was single-step algorithm used a Gaussian Mixture Model (GMM) by using precomputed training data. Sky-ships/land-sea lines are detected on Marine obstacle detection dataset.

[11] Proposed the land detection algorithm (LDA) to extract the land area of the image. The K-means Quick Horizon Line Detection (OHLD) algorithm is used to find sky-land (SL) line and the gradual edge level decrease (GELD) algorithm is used to find land-sky(HL) line for 150 real images of Gdynia harbor and its neighborhood. But, algorithm effectiveness depends on manually tuned parameters. Machine learning technique is proposed in [12] to detect the waterline and objects using CNN. This approach is made with a pixel-wise segmentation of the current image to generate a binary mask that is separating water and non-water regions and hence from that mask, the position of the waterline is calculated using INTCATCH Vision Dataset, and the Obstacle Detection Data Sets. The most positive and most negative gradient positions are computed in the algorithm [13] along multiple vertical stripes in the image and established a line through these points using the RANSAC (RANdom SAmple Consensus) algorithm [14].

Due to certain challenging conditions like haze, lighting reflections, weather conditions, complex environments, all the algorithms can face a big problem. Land-sky demarcation and land-water demarcation is also very significant in some applications. This demarcation line is not always in straight line manner and if so leads to false horizon detection.

III. METHODOLOGY

In the literature, different techniques are reviewed to address the horizon line detection in multiple environments. Gradient and edge based approaches are mostly involved to solve the problem. But, these methods result in straight lines with particular slopes based on the orientation of the vehicle. Therefore, these methods cannot detect uneven horizon lines accurately. In most cases, in-land lakes horizon line is not in straight line. In this environment, these methods are not helpful to the vision module. In the literature, machine learning techniques are mentioned and these methods rely on a pretrained data for accuracy and are typically slow. The method proposed in this paper robustly detects the exact horizon line when compared to edge based approaches without compromising computational time and accuracy.



A. EDGE BASED FOLLOWED BY HOUGH TRANSFORM APPROACH

This method can be summarized as follows.

- 1. Read the video and convert video into frames.
- 2. Convert RGB image into Gray image
- 3. Pre-process the image using smoothing techniques. Apply a 9 pixel-by-9 pixel Gaussian filter with standard deviation
- 4. Apply Canny edge detector to the pre-processed image
- 5. Apply the Hough transform to the edges map[16].
- 6. From step 5 find the longest line i.e desired horizon line.

B. K-MEANS CLUSTERING

K-means is a method for classifying a number of objects into a predefined number of groups/clusters. classification is done by the similarity of each object to the center point of each cluster. The K-means clustering or Lloyd's algorithm is an iterative and data-partitioning algorithm. K clusters are defined by centroids, where K is chosen before the algorithm starts. The algorithm[17] is summarized as below.

- 1. A number of centroids or cluster centers are selected randomly.
- 2. Then each point is assigned to a cluster that its center point has smallest distance from the corresponding point. So, all points to each centroid compute point-to-clustercentroid distances. Here, Squared Euclidean distance is considered. In this, each centroid is the mean of the points in that cluster and is calculated as,

$$d(o, c)=(o-c)(o-c)'$$

where 'o' is an observation or point and 'c' is centroid.

3. The center points are updated. This updating is done in two ways.

Batch update: with the closest centroid assign each observation to the cluster

Online update: if the reassignment decreases the sum of the within-cluster, individually assign observations to a different centroid, sum-of-squares point-to-cluster-centroid distances.

- 4. With new centroids all the points are divided into new clusters.
- 5. This process is repeated until cluster assignments do not change, or the maximum number of iterations is reached.

$$Ci(t) = \{0j \colon \parallel 0j - \mu i(t) \parallel \leq \parallel 0j - \mu i \ast (t) \parallel \} \ldots (1)$$

for all i*=1,2....,k & j=1,2,....n

$$\mu i(t+1) = \frac{1}{|Ci(t)|} \sum_{0 \neq Ci(t)} 0j \qquad(2)$$

Where C_i(t) denotes the ith cluster at iteration t

O_i denotes the sample being placed in one of the clusters and

 μ_i denotes the centroid of the cluster.

k denotes number of clusters.

n denotes the number of points.

The equation(1) represents different points are assigned to different groups and equation(2) represents the center points of clusters are updated.

C. PROPOSED METHOD

The proposed algorithm is a combination of K-means clustering method and Fast Marching Method.

K-means clustering algorithm separates the sea, land, sky regions in the case of in-land lakes/rivers related image by taking number of clusters as greater than 2(here K=3). In the case of marine related images, it separates the sea, sky regions by taking two clusters (K=2). The horizon line defines that separates the water region to non water region

After clustering, to detect horizon line Fast marching method is used. It segments an object using grayscale intensity difference weights calculation from the intensity values at the seed locations. The acquisition system is placed in the vision module and hence that captures the images. This system floats on the water and logically the lower part of the image is almost water part. Due to this reason, to extract the water cluster from other clusters, seed point is chosen at the last row, middle portion of the image. In this way, segmented water region is achieved and hence the horizon line is detected.

The proposed algorithm is summarized as

Step1: Read video

Step 2: Convert video into frames

Step 3: Find frame size

Step 4: Convert RGB into HSV image

Step 5: Apply K-means clustering on HSV image based on saturation and intensity

Step 6: Choose number of clusters as 2 for finding sea-sky horizon line and greater than 2 for sea-land-sky horizon line. Step 7: Set seed point

Step 8: Determine the water region cluster from the seed point by calculating weights for image pixels based on gray scale intensity difference

Step 9: Segment the water region from the image using the gray scale intensity difference weight array.

Step 10: Perform morphological operations.

Step 11: Trace region boundaries of segmented binary

Step 12: Extract horizon line from traced line.

IV. RESULTS AND DISCUSSIONS

The proposed algorithm was implemented in MATLAB R2018a on a system with Intel Core i5 and 8GB RAM and a CPU with a speed of ~1600 MHz. In order to evaluate the proposed method, two different datasets are considered. One is MODD (Marine Obstacle Detection Dataset) dataset another one is OSF (Open Science Framework) dataset. In fig 2, (a),(b), (c), (d) images are taken from MODD dataset while (e),(f),(g) images are taken from OSF dataset. The first column represents the original images taken from dataset. The second column represents the edge based followed by Hough transform results. The last column represents the proposed method results. The fig 3 represents that the horizon line detection results from proposed method. It is observed that the proposed method horizon line is accurate and hence not in straight line as in Hough transform. The resultant line is almost closer to the expected horizon line. Table(1) represents the processing time for both methods and number of clusters used in the proposed method for different datasets.



Efficient Horizon Line Detection using Clustering and Fast Marching method

For more number of clusters, K-means algorithm execution time is increased when compared to Hough transform. But the horizon line accuracy is good, from fig (g). It is Original frame edge based and Hough transform proposed method

important to notice that the execution time is almost same or decreased in proposed algorithm with efficient horizon line.

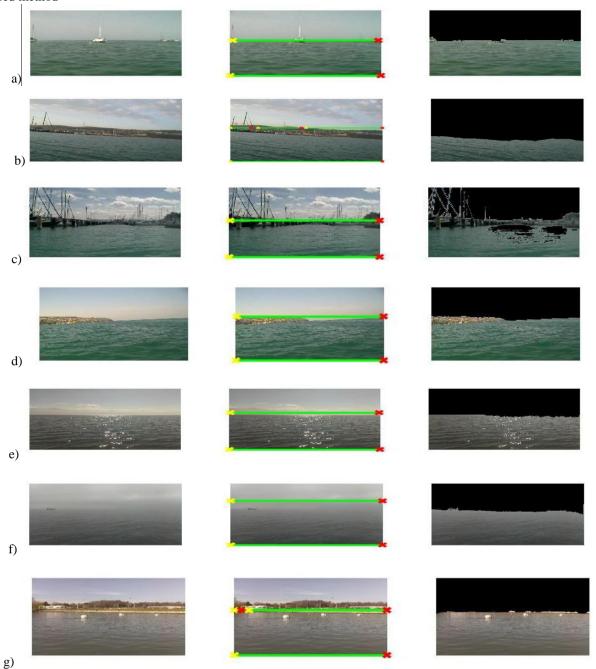


Fig 2: Horizon detection first column: original frame; middle column: edge detection and Hough transform; last column: proposed algorithm;(a) –(g) images taken from MODD and OSF dataset.





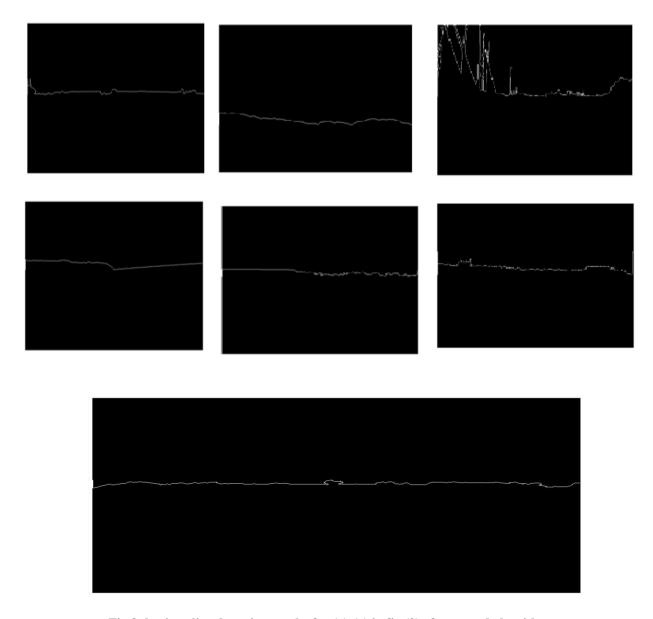


Fig 3: horizon line detection results for (a)-(g) in fig (2) of proposed algorithm.

Table 1: Processing time per one frame for edge based and Hough transform approach and proposed method. Number of clusters in each dataset is listed.

| Dataset | Processing Time In Seconds (One Frame) | | Number Of |
|---------|--|-----------------|-----------|
| | Edge Based Hough Transform Method | Proposed Method | Clusters |
| Modd1 | 0.66 | 0.65 | 2 |
| Modd2 | 0.66 | 0.74 | 2 |
| Modd6 | 0.68 | 0.77 | 2 |
| Modd12 | 0.67 | 0.54 | 2 |
| Osf-Ds2 | 0.68 | 0.64 | 2 |
| Osf-Ds3 | 0.69 | 0.63 | 2 |
| Osf-Ds8 | 0.68 | 0.94 | 3 |

V. **CONCLUSION**

An efficient method for determination of horizon line in maritime videos which involves clustering followed by seed based region growing using fast marching method has been presented. The video is assumed to have been taken from the inside of a floating surface vehicle and that the central portion at the bottom of the video frames corresponds to water. For maritime video analysis, the developed method provides more realistic horizon line and relatively faster execution compared to the conventional method based on edge detection and Hough transform. The developed method separates the image pixels into two clusters corresponding the water and the sky.



Efficient Horizon Line Detection using Clustering and Fast Marching method

Taking the centre pixel of the bottom row as a seed pixel, water region is grown using seed based region growing technique and fast marching method. The obtained horizon line will provide the water-sky boundary. Any floating obstacles at the horizon may get classified into either water or sky regions and correspondingly modify the horizon line. The obtained horizon line represents the boundary of the water region.

The developed method can also be applied to video analysis of inland water bodies, where the horizon line covers both water and land. In this case, the image is divided into 3 clusters corresponding to water, land and sky regions. Assuming that central portion at the bottom of the video frames corresponds to water, the central pixel of the bottom row is taken as a seed pixel to grow the entire water region using seed based region growing technique and fast marching method. The obtained horizon line represents the boundary of the water region. In both maritime and inland scenarios, the obtained horizon line accurately defines the water region, which can be used for further analysis. For proper investigating the objects in water and for proper navigation of this vision module, horizon line detection is primary step. After this line detection, vehicle concentrates only on the water region. In this paper, we compared an efficient horizon line detection method based on K-means clustering and fast marching method to the edge based followed by Hough transform method.

The existing method is the more general method to detect the horizon lines. But it is failed to detect the actual shape of the horizon except straight line. In order to get the actual shape of the horizon, some methods are used. But, these methods are complex rely on pre learning data and has low speed. Some hi-fi cameras itself detects the horizon accurately. But, these are expensive. This proposed method is detected the irregular horizon line efficiently without compromising the speed. The limitation of this algorithm is predicting the number of clusters. In future work, automatic detection of water from the clusters without choosing the seed point can be investigated.

REFERENCES

- Zafarifar, Bahman, and Hans Weda, "Horizon detection based on skycolor and edge features." In Visual Communications and Image Processing 2008, vol. 6822, p. 682220. International Society for Optics and Photonics, 2008.
- Shen, Yehu, and Qicong Wang. "Sky region detection in a single image for autonomous ground robot navigation." International Journal of Advanced Robotic Systems 10, no. 10 (2013): 362.
- Ahmad, Tougeer, Pavel Campr, Martin Čadik, and George Bebis. "Comparison of semantic segmentation approaches for horizon/sky line detection." In 2017 International joint conference on neural networks (IJCNN), pp. 4436-4443. IEEE, 2017.
- Gershikov, Evgeny, Libe Tzvika, and Samuel Kosolapov. "Horizon line detection in marine images: which method to choose?.' International Journal on Advances in Intelligent Systems 6, no. 1
- Lipschutz, Ilan, Gershikov Evgeny, and Benjamin Milgrom. "New methods for horizon line detection in infrared and visible sea images.' Int. J. Comput. Eng. Res 3, no. 3 (2013): 1197-1215.
- Wang, Bo, Yumin, Su, and Lei Wan. "A sea-sky line detection method for unmanned surface vehicles based on gradient saliency." Sensors 16, no. 4 (2016): 543.
- Praczyk Tomasz. "A quick algorithm for horizon line detection in marine images." Journal of Marine Science and Technology 23, no. 1 (2018): 164-177.
- Boroujeni, Nasim, Sepehri, S. Ali Etemad, and Anthony Whitehead. "Robust horizon detection using segmentation for UAV applications." In 2012 ninth conference on computer and robot vision, pp. 346-352. IEEE, 2012.

- Ahmad, Touqeer, George Bebis, Monica Nicolescu, Ara Nefian, and Fong Terry. "An edge-less approach to horizon line detection." In 2015 IEEE 14th international conference on machine learning and applications (ICMLA), pp. 1095-1102. IEEE, 2015.
- Kristan M, Sulic V, Kovacic S, Pers J. Fast image-based obstacle detection from unmanned surface vehicles. In: IEEE Transactions on Cybernetics; 2015. Vol. 46: p. 641-654.
- 11.]Praczyk, Tomasz. "Detection of land in marine images." International Journal of Computational Intelligence Systems 12, no. 1 (2018): 273-281.
- Steccanella, L., D. D. Bloisi, A. Castellini, and A. Farinelli. "Waterline and obstacle detection in images from low-cost autonomous boats for environmental monitoring." Robotics and Autonomous Systems 124 (2020): 103346.
- Wang H, Wei Z, Wang S, Ow CS, Ho KT, Feng B. A vision-based obstacle detection system for Unmanned Surface Vehicle. In: IEEE International Conference on Robotics, Automation and Mechatronics; 2011. p. 364-369.
- Fischler MA, Bolles RC. Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography. Communications of the ACM; 1981. Vol. 24: p. 381-395
- J. Canny, -A computational approach to edge detection, IEEE Transactions on PAMI, vol. 8, 1986, pp. 679-697.
- R. O. Duda and P. E. Hart, —Use of the Hough transformation to detect lines and curves in pictures, Comm. ACM, vol. 15, 1972, pp. 11-15.
- M. Mignotte, "Segmentation by Fusion of Histogram-Based k-Means Clusters in Different Color Spaces," IEEE Transactions on Image Processing, vol. 17(5), pp. 780-787, 2008.

AUTHORS PROFILE



Mrs Ravi Sravanthi received her B.Tech Degree in Electronics and Communication Engineering from PBR VITS, Kavali, JNTU Anantapuramu, A.P, India in 2002, Technology in VLSI design from Master of Satyabhama University, Chennai, Tamilnadu, AP in 2010 Now she is pursuing Ph.D from JNTUA Anantapuramu, AP, India. Her research area is in image and video

processing.



Prof. ASV Sarma presently working as a professor in ECE department, PBR VITS, Kavali. He received his B.Tech Degree in Electronics and Communication Engineering from Sri Venkateswara University, Tirupati, India in 1979, Master of Technology from IIT Kharagpur in 1981. He did his Ph.D in IIT Madras, TN, India. He has 33 years of research

experience and 4 years of teaching experience. His current research Interest includes machine vision, machine learning and video analytics. He has published 21 research papers in National and International journals.

