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Image-based Ship Pose Estimation for AR Sea Navigation

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Abstract. Vision-based AR registration technology is based on finding the known four-points in a camera image. However there are many obstacles and noises in sea environment such as wave, wake, sun-reflection, and so on. Moreover we have to use not only the camera image but also navigational information such as AIS or radar information. This paper describes the process of computer image processing and utilize of AIS information to estimate ship pose and which is to overlap the computer-generated navigational graphical information upon a display device on the bridge.

Keywords: Augmented Reality, Navigational Information, Ubiquitous, AIS

1 Introduction

Although various electronic marine navigational devices are introduced such as ECDIS (Electronic Chart Display and Information System), ENC (Electronic Navigational Char) and GPS (Global Positioning System), marine accident has been being reported that it is mainly caused by human errors such as missing obstacles and wrong making decisions. For example, a study of 6,091 accident claims over $100,000 concerning all cases of commercial ships which are conducted by the UK P&I club over a period of 15 years, reported that about 62% of the claims were known that is contributes to human errors [1] and moreover ATSB (Australian Transportation Safety Bureau) [2], MAIS (Marine Accident Investigation Board) [3] and TSB (Transportation Safety Board of Canada) [4] are significantly including humans errors into accident-causes.

Most of navigator always looks down and analyzes the information of ECDIS/RADAR and compares outside view information with the devices. However during this time, they are placed in blindness circumstance for outside information and sometimes it is caused to happen near accident like as collision or missing

[1] Please note that the LNCS Editorial assumes that all authors have used the western naming convention, with given names preceding surnames. This determines the structure of the names in the running heads and the author index.

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obstacles. Augmented reality is effective displaying technology which can provide dual information in a single display, overlapping computer-generated graphical information with real camera image. Therefore the technology has the advantages on displaying navigational information directly on the screen and providing clear images when weather is not clear. Homography matrix represents relationship between real-world and camera coordinate and it is commonly defined by a 4x4 matrix for 6 degree of freedom and this is needed four-points of a camera image at least. However we are hard to find detectable objects to define a specific plane in sea environment. Therefore we use camera image as well as AIS (Automation Identification System) information.

2 Related work

Because of advantage of AR technology, various industries have been researching in their products, for example detecting lane vehicles and avoiding collision between aircraft. [5] In case of marine application, many studies are suggested to find floating objects on sea surface, such as pixel profile analysis technique for horizon detection, Lucas-Kanade optical flow for extraction robust feature points [6], automatic identification by using ARPA radar for tracking vessels [7] and so on. In AR, navigational object are overlaid on camera and are positioned in their real geographic location. Other projects employing AR are Galileo Augmented Maneuvering, Galileo Augmented Rescue and Galileo Augmented Logistics. They all exploit high accuracy and reliability of Galileo, the Europe's navigation satellite system.

3 AR-based Sea Navigation

This paper introduces the process of finding ship's homography pose matrix using camera image and AIS information. Basically ship is always floating upon sea surface and nearby horizontal line. Therefore if we could find horizon line, then we can define respective roll/pitch angle. And AIS can provide azimuth and other ships' location. Fig. 1 describes the process flow from CCTV to final AR-Navigation image.

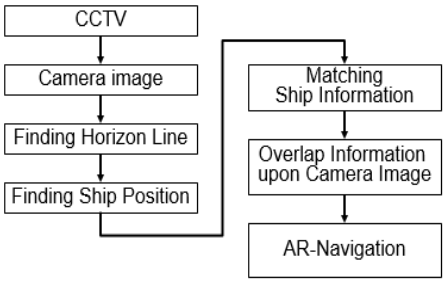

Fig. 1. Process of computer image processing to build AR-based sea navigation scene.

3.1 Finding Horizon Line

A navigation scene is almost divided into two side of area, the first one is sky area and the other one is sea surface. Hence almost of researches are starting their work with finding a horizon line. Ettinger et al. [8] introduced an algorithm that uses regional covariance in a gray scale images. Lipschutz et al. [9] compared five algorithms for automatic detection of the horizon line in marine images. These five algorithms includes a method based edge detection and Hough transform (H-EDHT), a covariance based method (H-COV), a new histogram based method (H-HIS) and two combinations of H-EDHT with the latter algorithms: H-EDHT-COV and H-EDHT-HIS. Wang was use to pixel profile method to detect sea-coast line in an image, calculating differentiation between vertical pixels' intensity and Oliver was used the external hardware (Inertial Power Station) to define candidate area to analyze images. However if there are some obstacles upon horizon line such as a bridge, then it gives inaccurate result. Fig. 2 describes the pixel profiling result and above a bridge and mast are interrupting pixel profiling, because the vertical pixels intensity has high gradient like as near area of horizon line.

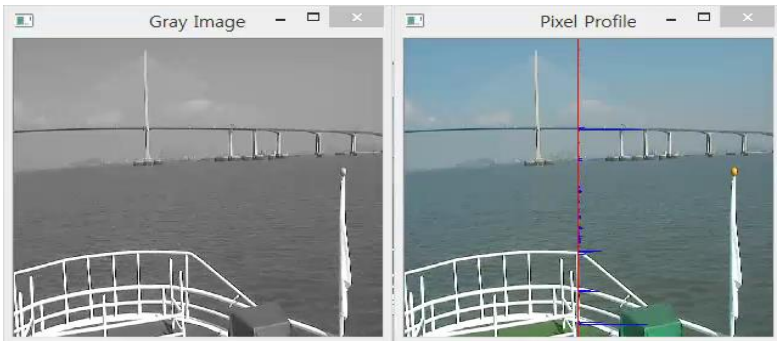

Fig. 2. Gray scale image (left) and result of pixel profiling (right): the pixel profiling and Hough Transform were disturbed by the bridge.

3.2 K-means Clustering

Therefore we uses k-means clustering method to solve this problem by using the characteristic nearby sea-sky boundary. K-means is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem. K-means clustering [10] is a method commonly used to automatically partition a data set into k groups. It proceeds by selecting k initial cluster centers and the iteratively refining them as follows: [11]

1. Each instance di is assigned to its closet cluster center.
2. Each cluster center Cj is updated to be the mean of its constituent instances.

The algorithm converges when there is no further change in assignment of instances to clusters.

In this work, we initialize the clusters using center area and we use a Euclidean distance metric. And we set the clustering number to two clusters because we should divide an image into sky and sea-surface and Fig. 3 shows that result which is representing a candidate of horizon line. The bridge is still shown at above image, however the boundary of sea-sky line is clearer. After that, we try to find horizon line in sampling images acquired along the candidate horizon line again to finding the exact horizon line.

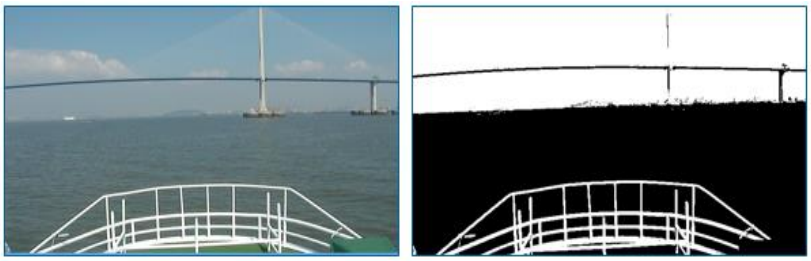

Fig. 3. Original CCTV image (left) and 2-means clustering result (right): 2-means clustering can divide the image into sky side and the other side well.

3.3 Random Sampling

The clustering algorithm returns candidate horizon line and it have to be refined. We do second pixel profiling analysis in the randomly sampled images along the candidate line and extract the changing point from 0 to 1 or 1 to 0. Fig. 4 shows a concept of random sampling and its image processing result.

Fig. 4. Random sampling process along with candidate horizon line

3.4 Pose estimation

Horizon line can be a reference feature to calculate own-ship condition. Fig. 5 shows how to calculate roll/pitch angle by using horizon line. Location and Pose information of target ships which is retrieved from navigation devices is quite differ from appearance location in display device. Because depending on the location of AIS or GPS antenna, it has a lot of distance error depending on ship's length. Therefore we need to analyze to find ship in a camera image in the first, and then if there were AIS information then we compare with the analyzed data. Almost of floating object is under or near a sea-sky boundary line. Therefore we can define ROI area to extract ship features in the image as well. We use saliency algorithm and canny edge detector to analyze the image, which is proposed by Achanta et al. [12].

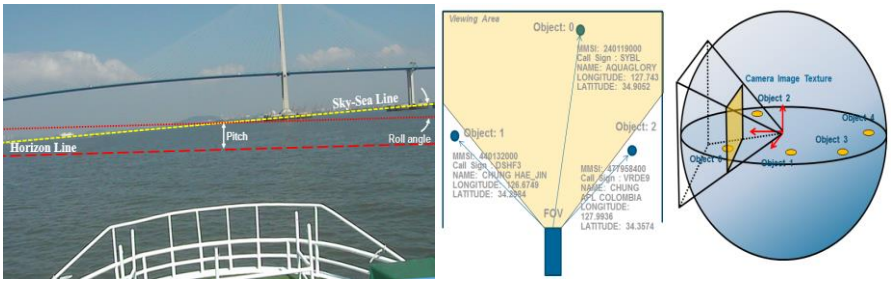

Fig. 5. Horizon line and calculate pose (left) and area filter by using AIS and GPS data (right)

4 Implementation

We built prototype and examined using AIS decoded data as follows:

Table 1. Decided AIS data table

MMSI	ROT	SOG	LONGITUDE	LATITUDE
440010340	128	30.3	127.481200	34.351600
440013000	128	0	127.697600	34.922000
440148760	128	1	128.087500	34.925200
440155000	0	13.8	129.151700	34.930700

Fig. 6 shows the result of planar registration upon sea surface and overlaid detected object information on camera image in coastal area.

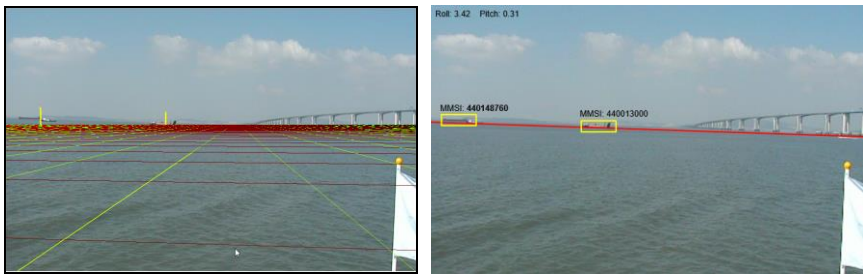

Fig. 6. Planar registration upon a sea surface (left) and Result of ship and horizon line detection (right)

5 Conclusions

This paper describes the pose estimation process with camera images and AIS information. And we use k-means algorithm and pixel profiling method to find horizon line in a navigating image as well as canny edge detector and Hough transform. Moreover we use AIS data to estimate target ship position and use Saliency map to find traffic ship in a camera image. And finally, we built an augmented reality based navigation scene image with those information. We conclude that the proposed algorithms are appropriated for shore environment and we can get proper horizon line and pose information. In this paper, all the algorithms examined in a still image however the algorithms can be used also in video stream, which is the subject of future research. And also, the proposed system is based on CCTV and computer image processing therefore the performance is influenced by sea condition for example, the low light condition such as foggy, dark-night, heavy rainy days. Therefore we intend to apply a thermal camera to acquire the consistent images in poor weather condition in the future research.

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