Towards Robust Water Region Extraction For Maritime Surveillance

Amir Ghahremani, Egor Bondarev, Peter H.N. de With
Department of Electrical Engineering, Eindhoven University of Technology, Netherlands

Abstract

Although the concept of region of interest (ROI) is well known in video analysis, finding a suitable ROI has been hardly addressed in practical maritime surveillance such as for vessel detection and tracking. Videos from maritime surveillance cameras may contain irrelevant regions, such as shorelines, bridges and piers. As a result, non-relevant moving objects (e.g. cars on the shorelines) can be misleadingly detected by a vessel or ship surveillance system. This paper proposes a robust water region extraction method based on spatiotemporally-oriented energy features in combination with a mean shift clustering algorithm. The method targets not only the conventional RGB surveillance data, but also data from thermal cameras. Experimental results reveal that the proposed method performs water segmentation correctly for 93.67% of pixels on RGB and 94.7% of pixels on thermal sequences on the average, even in the presence of islands or other complex shoreline shapes.

1. Introduction

Region of interest is a known concept for natural scene analysis and region labeling. However, besidest water regions and possible vessels, a maritime surveillance camera also captures irrelevant parts of a scene (e.g. shorelines, sky and vegetation). Consequently, a vessel detector may erroneously detect irrelevant objects. Therefore, a maritime surveillance system is proposed that first segments and identifies maritime regions and then analyzes the objects located in the extracted water region. Despite the importance of ROI detection for maritime surveillance, at present, robust methods have not been proposed earlier for maritime region detection [4, 6–8, 10].

Due to dynamic behavior of the surroundings in the maritime environment, it is a challenging task to extract the water regions in a surveillance image. Our objective is to design a method to extract the water map of a maritime scene, in order to later combine it into a vessel detector. In our research, two specific challenges are addressed: (1) RGB and particularly thermal scene analysis which are difficult to analyze, and (2) regions with complicated shorelines and islands which have irrelevant moving objects appearing in the scene. Our full paper on water region extraction has been accepted for the IS&T Electronic Imaging 2017 conference [9].

2. Water Segmentation Pipeline

The proposed method consists of the following four steps. First, we extract an 8-bin histogram of spatiotemporally-oriented energy features [2, 3, 5] for each pixel. The histogram bins store the following information: two static horizontal and vertical energy orientations, five dynamic energy orientations (flicker, rightward, leftward, upward, and downward motion) and one so-called lack-of-structure feature. Second, we smoothen the extracted feature space using the mean shift algorithm [1, 2]. Third, we propose a Raster-Order based Labeling Algorithm (ROLA) to group the pixels into coherent regions of structures, based on their smoothed feature vectors. Finally, we apply our water region identification criteria. In this step, we accumulate the smoothed energy histograms of pixels to generate an energy histogram for each cluster. Then, based on discriminative water pixel characteristics (high flicker, lack of structure, restricted static horizontal and vertical energies), we jointly explore the bins of corresponding energy histograms against experimentally defined criteria to detect water clusters. Some scenes introduce specific challenges, e.g. when moving vessels or clouds or windblown vegetation hamper accurate water extraction from static images. Therefore, we have adopted also a temporal averaging technique, which enables removal of irrelevant dynamic objects from consideration. Fig. 1 illustrates the proposed processing chain of functions. For more detail, see [9].

3. Empirical Validation and Conclusions

The validation reveals a detection rate of 93.7% of prelabelled pixels in RGB and 94.7% of pre-labelled pixels in thermal sequences. For RGB sequences, on average 4.2% of background pixels are falsely segmented as water (false positives) and 2.1% of water pixels are falsely detected as non-water (false negatives). For thermal sequences, average false positive rate is 2.8%, while 2.5% of pixels are falsely detected as non-water. Figure 2 illustrates 4 RGB and 4

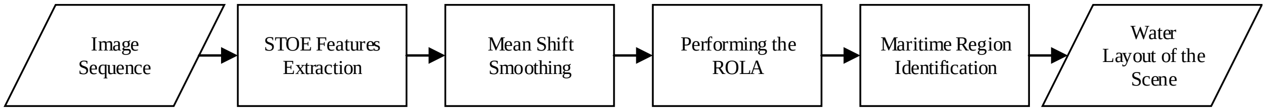

Figure 1: Function chain of processing steps of the water segmentation method.

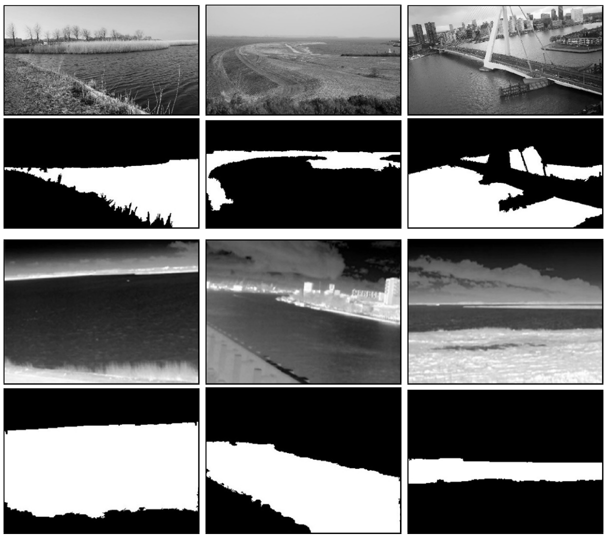

Figure 2: Water extraction results. Each pair depicts the original frame and the water extraction result.

thermal image examples, respectively. We have validated the method on non-standard challenging scenes, containing islands and several types of shorelines (city, vegetation), to illustrate the robustness of the water region extraction method. We present further detailed results in [9].

The following findings can be highlighted. The dynamic behavior of objects and the methods threshold dependency are the main reasons for the false detections. Therefore, we plan to combine other features (e.g. artefact structure detection by directional Hough transform) to define stronger criteria preventing regions from incorrect labeling.

The method highly depends on threshold values, which makes it hard to tune. Consequently, there are cases where the method detects non-water regions as water or vice versa. For example, if the scene contains sky pixels which are connected to a non-wavy water region, there is a chance to detect the sky as water.

Despite the importance of ROI detection for maritime surveillance methods (like vessel detection, tracking and classification), state-of-the-art methods lack an accurate water extraction in a pre-processing stage. Although there exist a few algorithms extracting the water regions using classifiers and/or features like color, texture and spatiotemporal statistics of pixel groups, these methods were all only evaluated on scene datasets with simple texture.

This paper has proposed and validated a method that is robust in water extraction from various scenes on rivers, channels, lakes and sea sides, having shorelines with complex shapes, islands, bridges, and windblown vegetation. Besides this, the validation datasets were captured from different camera heights, during day and night time and in variable weather conditions (e.g. sunshine, clouds, wind, rain).

Another important contribution is the method ability to extract water regions in thermal images. Thermal sensors provide a beneficial modality for the maritime surveillance tasks, since they are able to capture data even during nights and foggy situations. Due to the low resolution of thermal images, water extraction becomes an even more challenging task. To our best knowledge, methods on water extraction from thermal data were not yet reported in literature. The new presented method features attractively high water detection rates (93.7 - 94.7% on the average), even for thermal images.

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