Waterline Detection for Autonomous Surface Vehicles

Amittai Siavava, Mingi Jeong, Alberto Quattrini Li

A Survey of Existing Works

1. Existing Methods

The most common approaches to waterline detection are:

1.1. **Use of Hough transforms with RANSAC.** This is an edge-based method for waterline detection. A raw test image is resized and fed through a CNN , producing a a segmentation mask that follows the contour of the boundaries between the water and any obstacles and the sky.

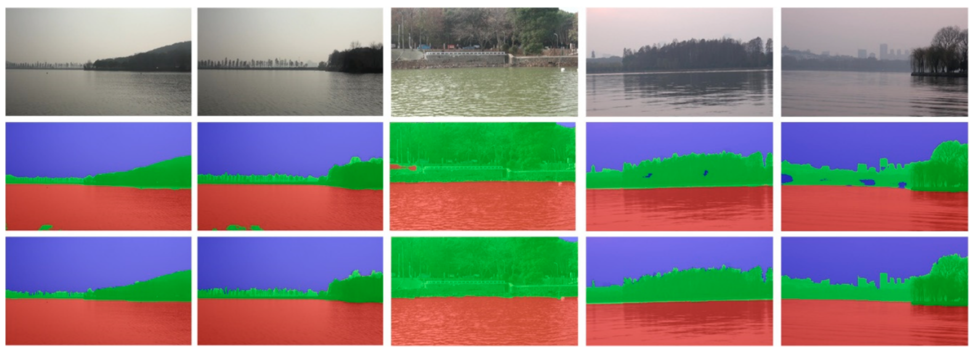

Figure 1. Semantic segmentation example [3].

To effectively extract the waterline, post-processing is done as follows:

(i) First, a median filter is applied to the segmentation mask, reducing narrow protrusions such as sailboat masts.
(ii) Binary edge detection is then applied to isolate the pixels on the boundary between the water and the sky.
(iii) A probabilistic Hough transform is applied to the edge-detected image, producing a set of possible lines and further cutting out shorter lines. Only the pixels composing a long edge are retained.
(iv) Finally, linear regression is performed using RANSAC to reduce the influence of sharp edges on the contour.

Network	**Precision**	**Recall**	**Accuracy**	**F_1 Score**
Half-Conv 80x80	0.932	0.982	0.954	0.956
Half-Conv 160x160	0.964	0.991	0.977	0.978
Full 80x80	0.972	0.987	0.979	0.979
Full 160x160	**0.984**	**0.993**	**0.988**	**0.988**

Figure 3. Experimental results presented by authors [1].

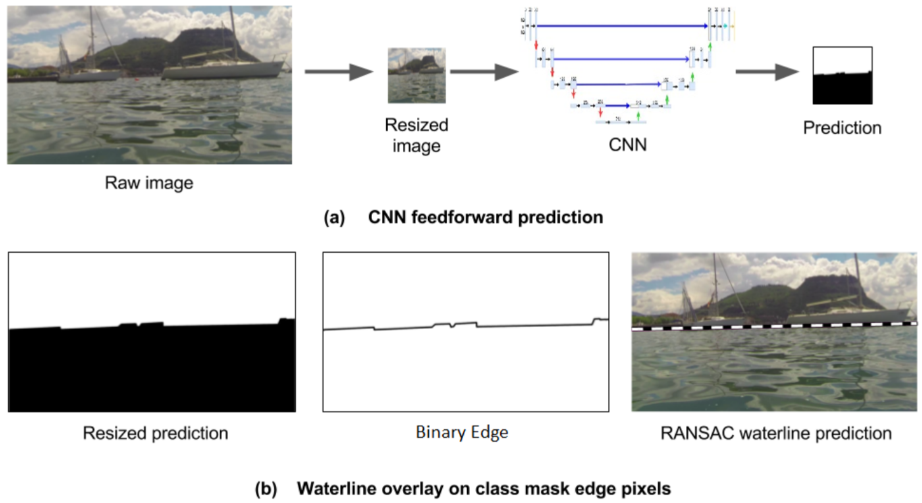

FIGURE 2. Hough transform + RANSAC method for waterline detection [1, 4].

1.1.1. *Disadvantages.* As with any edge-based method, two key challenges must be overcome[4].

(i) Minimization of false negatives (noise).
(ii) Efficient and robust identification of the waterline from the noise.

1.2. **Regional-based Approaches.** Regional-based waterline detection algorithms seek to exploit regional features such as color and texture to more effectively isolate the waterline. One of the most common approaches works as follows:

(i) First, detect the sky region using some of its properties with the assumption being that the waterline separates the sky from the water. Features used to detect the sky can include position, color, texture, and row gradient.
(ii) Pick out the pixels that are likely to be waterline pixels by using the sky region as a reference. This can be done by using the sky region as a mask and applying a threshold to the color or texture of the pixels in the sky region.
(iii) Finally, use RANSAC to fit a line to the pixels

1.2.1. *Disadvantages.* In some cases, the sky region does not border the water in some parts of the image. In those cases this method does not work well. To counter this, Zarifar et al. [2] propose a method that combines the regional-based approach with an edge-based approach, and picks the waterline based on the results of both methods.

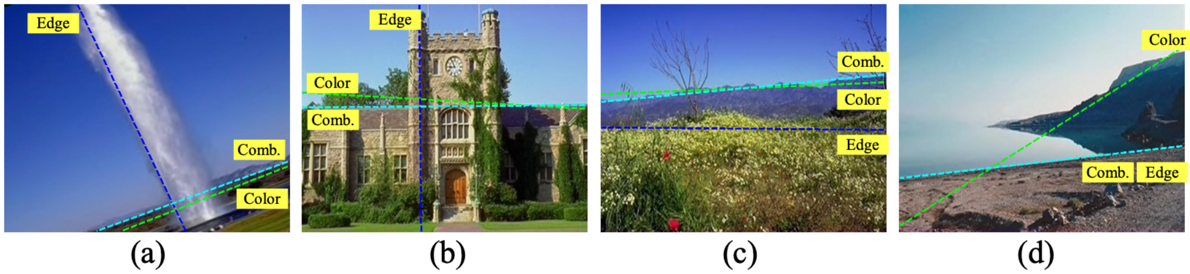

FIGURE 4. Examples of individual and combined results using region-based and edge-based methods [2].

While the combined method works better, it also results in computational redundancies, since multiple, different methods have to be run on the same image.

References

[1] Lorenzo Steccanella et al. "Deep Learning Waterline Detection for Low-Cost Autonomous Boats: Proceedings of the 15th International Conference IAS-15". In: Jan. 2019, pp. 613–625. ISBN: 978-3-030-01369-1. DOI: 10.1007/978-3-030-01370-7_48.

[2] Bahman Zafarifar and Hans Weda. "Horizon detection based on sky-color and edge features". In: *Journal of Applied Mechanics-transactions of The Asme - J APPL MECH* 6822 (Jan. 2008). DOI: 10.1117/12.766689.

[3] Wenqiang Zhan et al. "Adaptive Semantic Segmentation for Unmanned Surface Vehicle Navigation". In: *Electronics* 9.2 (2020). ISSN: 2079-9292. DOI: 10.3390/electronics9020213. URL: https://www.mdpi.com/2079-9292/9/2/213.

[4] Wenqiang Zhan et al. "Effective Waterline detection for unmanned surface vehicles in inland water". In: *2017 Seventh International Conference on Image Processing Theory, Tools and Applications (IPTA)*. 2017, pp. 1–6. DOI: 10.1109/IPTA.2017.8310127.