Rapid and Precise Ship Segmentation for Periscope Imagery

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1. Objective

Develop rapid and precise image segmentation algorithms to extract ship silhouettes from periscope video imagery. Algorithms should preserve fine mast detail and be robust to a variety of complicating factors, including atmospheric blurring, high sea states, and low contrast conditions. The algorithms should exploit multiple video frames and color where appropriate and have the potential to run in near real-time.

2. Background

Since Kollmorgen installed the first-ever periscope on a submarine in 1916, periscope technology has advanced considerably. Very fast optics and multiple imaging bands have greatly improved target detection while high-resolution digital imagery has facilitated increasingly sophisticated image processing. Despite these advancements in periscope imaging technology, targets are still classified as before – by human observation and comparison with known target profiles.

With some 2900 warship classes worldwide, the target recognition task quickly becomes overwhelming for human observers. Time is lost making manual comparisons and range often closes without knowledge of the potential threat. Human observation is severely limited in hull-down conditions, when most of the target is below the horizon as shown in Figure 1. Workload and fatigue become important considerations in the areas of heaviest maritime traffic – which often correspond to submarine operating areas.

Figure 1: A tactically useful ATR algorithm will be able to classify targets by extracting key features while much of the hull remains below the horizon.

Automatic Target Recognition (ATR) will offer several advantages to submarine effectiveness and safety. By providing more accurate classification at greater ranges, it will support faster decision-making. In regions of high target density, ATR can overcome degraded human performance and provide more consistent classification results.

3. Statement of the Problem

With the help of RIPS 2008, Areté Associates has developed an ATR algorithm to classify ships in periscope imagery. As shown in Figure 2, the algorithm begins with coarse information from ship silhouettes, such as moments and angular dimensions, to eliminate incompatible classes and orientations from a database of ships. More computationally intensive comparisons, such as correlation filters, are then applied to the pruned database.

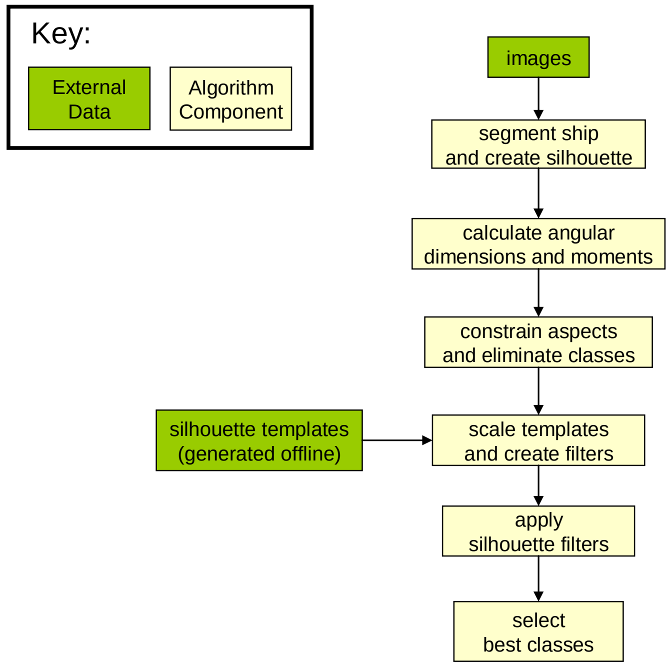

Figure 2: Periscope ATR algorithm flowchart.

Since each step in the hierarchy relies on the initial ship silhouette, robust image segmentation is crucial to the overall success of the algorithm. Ideally, a segmentation algorithm would be robust to atmospheric blurring, variable lighting conditions, high sea states, and land or urban backgrounds. However, our current segmentation algorithm performs poorly under all but the simplest conditions. Current problem areas include choppy seas, low contrast conditions, and the loss of fine mast detail.

As shown in Figure 3, one of the most pressing challenges is the loss or distortion of fine mast detail during segmentation. Since masts are the only visible identifying features of a ship at long ranges (see Figure 1), this loss of detail limits the maximum effective range of the ATR system. Possible solutions for preserving mast detail include stacking multiple video frames to boost signal-to-noise ratio (SNR) or exploiting multiple color bands to separate ship from sky.

4. Project Description

We propose a RIPS project to develop rapid and robust segmentation algorithms to address these pressing challenges. The RIPS team will be provided with color HD video imagery of ships captured under a variety of complicating conditions. Working under the assumption that an operator has aimed the periscope such that the center pixel in the field of view corresponds to a ship pixel, the goal is to rapidly determine which of the remaining pixels belong to the ship and which pixels belong to the background. Detecting the location of the horizon will likely play an important role in accomplishing this efficiently, as one can usually classify all pixels below the horizon as sea. The expected output will be binary images where white pixels are ship and black pixels are background. Additionally, the RIPS team will be provided with simulated data cases and ground truth to measure the performance of the selected algorithms against Areté's current solution.

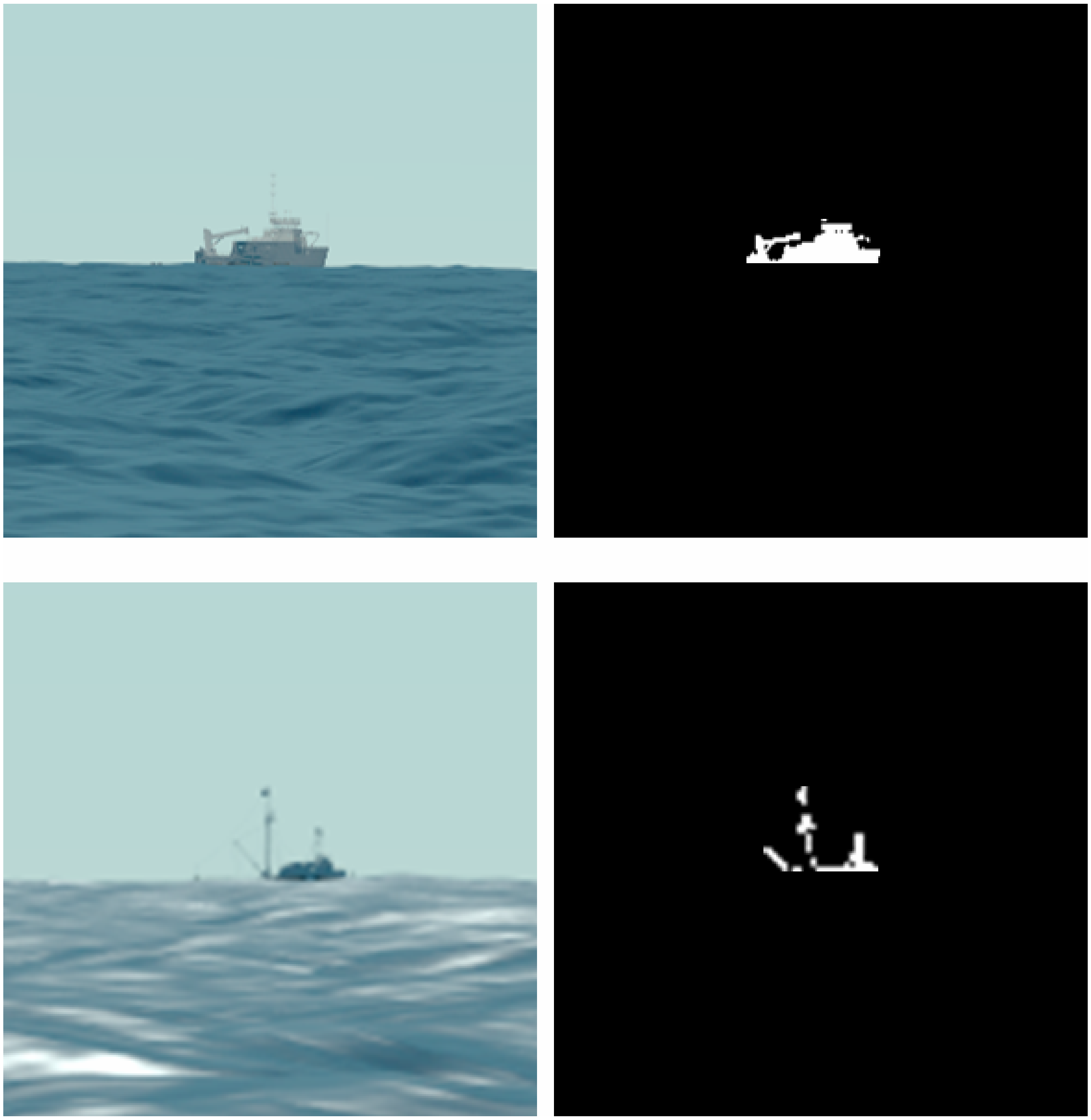

Figure 3: Loss of fine mast detail during segmentation.

5. Recommended Task Outline

The following is a recommended task outline:

Task 1: Research the literature to identify candidate segmentation algorithms.

Task 2: Select promising algorithms and test against the provided simulated imagery and compare performance to Areté's algorithm.

Task 3: Develop a metric to quantify the algorithm performance on the provided simulated imagery. The metric should value the preservation of fine mast structure.

Task 4: Apply algorithms to real data to verify if similar performance is achieved on real data as on simulated data. Add refinements as necessary.

Task 5: Confirm refinements in Task 4 do not degrade performance in Task 2.

Although algorithm performance will be measured using simulated data, we emphasize that these algorithms must work on real data. Therefore, Tasks 2 and 4 should not necessarily be done in sequence and can be done in parallel.

6. Deliverables

1. A **final report** containing a summary of your literature review, an algorithm description, and test results.

2. A **code package** containing standalone algorithm source code (in Matlab or C/C++), documentation, and an example case.

3. A **site visit** to present final results and hand off deliverables.

7. References

Cheng, H.D., Jiang, X.H., Sun, Y., Wang, J., 2001. Color image segmentation: Advances and prospects. Pattern Recognition 34, 2259–2281.

W. Skarbek, A. Koschan, Colour image segmentation – a survey, Technical Report, Tech. Univ. of Berlin, October 1994.

B. Bhanu and R.D. Holben. Model-Based Segmentation of FLIR Images. *1EEE Transactions on Aerospace and Electronic Systems*, 26(1):2-11, 1990.

W.-N. Lie, "Automatic target segmentation by locally adaptive image thresholding," *IEEE Trans. Image Processing*, vol. 4, pp. 1036-41, July 1995.

D. L. Milgram. "Region extraction using convergent evidence." Computer Graphics Image Processing, 11:1-12, 1979.

D. Nair and J. K. Aggarwal. A focused target segmentation paradigm. In *Fourth European Conference on Computer Vision*, volume 1, pages 579–588, Cambridge, UK, April 1996.