SARSHIPS: A COMPONENT-BASED SYSTEM FOR SHIP DETECTION ON SAR IMAGES

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ABSTRACT: This paper discusses several issues and solutions in the component-based ship detection approach using SAR imagery, which include: (1) the connected component analysis algorithms specifically designed for large SAR images; (2) the component grouping algorithm based on the sizes and distances of the components to reconstruct the whole vessel, which is also be used to filter out some of the image artifacts and interferences; (3) the generation of land masks using the localized dataset of the highest resolution from the GSHHS database.

INTRODUCTION

Radar, including its modern form of Synthetic-aperture radar (SAR), has long been used for detecting ships due to the fact that the metal surfaces and sharp angles of ships, in contrast with the surrounding sea water, give out high signal returns. Comprehensive surveys and comparative studies exist in research literature (Crisp, 2004a; Greidanus, 2004b).

Generally, the ship detection process comprises the steps of the significant pixels extraction, the pixels grouping to form target objects, the filtering of the signal objects from that of artifacts and interferences, and the estimation of the physical/geometric parameters of the ships. This paper discusses several issues in the component-based ship detection approach and our solutions to these problems, which include:

• The Connected component analysis (Shapiro, 2001) for large images. High-resolution or long pass of SAR images often render the recursive labeling algorithm unsuitable because of the high demand on computer memory. Our solution is to use the classical row-by-row labeling algorithm with run-length encoding, which effectively eliminates the dimensional constraint for the input images;

• The component grouping algorithm. Larger ships may have different responses to radar signals on different parts of their surfaces, resulting in separated components for the same ship. We provide a grouping algorithm (Yuan, 2007) based on the sizes and distances of the components to reconstruct the whole vessel. This grouping algorithm is a distance measure but takes into account of the size similarity of the two involved components. It can also be used to filter out some of the image artifacts and interferences when needed;

• The localization of land masks. Ships are supposed to be in water, so signals from land should be masked out. Visual navigation also needs the information of shorelines. High-resolution land masks have polygons with very large number of vertices. This consumes large amount of computer memory and drastically slows down the water-or-land testing. Our solution is to use the highest resolution GSHHS database (Wessel, 1996) for the construction of high-quality land masks and a generic polygon clipping algorithm (Vatti, 1992) to localize the shorelines to the region of interest.
Figure 1 shows the SarShips user interface and an application of the above-mentioned solutions to the ship detection using an ERS-2 SAR image (8000×8200 pixels). The GSHHS database is used to generate the land masks and the thumbnail in the navigator.

**COMPONENT-BASED SHIP DETECTION**

Component-based ship detection is an application of feature extraction from binary images in machine vision. Given a preprocessed binary image, the Connected Component Analysis (CCA) is applied to extract neighboring pixels into components. There are two classes of labeling algorithms in CCA: the classic row-by-row and the more modern recursive. The recursive labeling algorithm has a concise and elegant implementation, but its memory use is prohibitive when the components become too large. The row-by-row labeling algorithm processes one image row at a time with possible discontinuities, so it needs an extra pass to merge labels for the same components. We integrate run-length encoding into this row-by-row labeling algorithm to drastically reduce the memory consumption for very large components.

Large ships have different responses to radar signals on different parts of their surfaces, resulting in separated components for the same targets. We use a simple grouping algorithm based on the sizes of the components and the distances among the components to reconstruct the whole ships. The grouping function is chosen as \( f(s_1, s_2) = \frac{\sqrt{k s_1 s_2}}{(s_1 + s_2)} \) where \( s_1 \) and \( s_2 \) are the sizes of two components and \( k \) is an adjustable parameter that needs to be determined only once for all images of the same type. This symmetric function is a distance measure but
Figure 2. The effect of component grouping before (left) and after (right).

takes into account of the size similarities of the two components being examined. Two components are considered to be belong to the same ship if the value of the grouping function is no larger than the distance between them. All unique pairs of components are tested to reconstruct the whole ships from possible disconnected parts. An sample result of this grouping function is shown in Figure 2.

The extracted and regrouped components are then put through the component filtering stage. The size, dimension, and aspect-ratio filters eliminates the components that are either too large or too small to be a ship in the real world.

Subsequently, the land masking filter eliminates the components with locations in non-water areas. We use the highest resolution dataset from the Global Self-consistent, Hierarchical, High-resolution Shoreline Database (GSHHS) in this application for two purposes: as a visual guide for browsing/navigating the SAR images, and as land masks for component filtering. In practical use, the localization of the database

CONCLUDING REMARKS

To demonstrate the performance of the system described in this paper, a sample ERS-2 image of dimension 8000×8200 pixels, which is shown in Figure 1, takes less than 8 seconds when processed on a 3 GHz Pentium 4 PC running Java Virtual Machine 6. The system architecture is sketched as in Figure 3.

This paper describes the major stages in ship detection using SAR imagery. The system involves several thresholds for the various stages, such as the image binarization threshold for CCA, the parameter for component grouping, the thresholds for components filtering. To some extent, they determine the success or failure of the detection system. Careful selection based on the problems at hand is necessary. Other detection errors can be observed due to the inaccuracy of the GSHHS database and the geo-references of the images. There are not much can be done from the system’s side.

A relatively new source of assistance for ship detection comes from the Automatic Identification System (AIS) that are mandatorily fit to the larger vessels since 2004. With this down-to-the-seconds information, the routes of the ships may be obtained to help identify the targets on the
satellite images. Since AIS transmits VHF signals, the data availability is limited by the effective relay among the AIS-equipped ships and the AIS base stations. Although satellite-equipped AIS receivers start to service, their frequency of coverage is still low.

Newer generation of SAR satellites, such as the TerraSAR-X, can generate images with up to 1-meter resolution and multiple polarizations. They provide new opportunities and challenges to the ship detection systems including our SarShips. We are working on such images to further improve its usability.

REFERENCE