Automated Change Detection and Classification System

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EXTENDED ABSTRACT

ACDC OVERVIEW

This paper describes an Automated Change Detection and Classification (ACDC) system being developed by the Naval Research Laboratory (NRL) for the Mine Warfare group at the Naval Oceanographic Office (NAVOCEANO). ACDC autonomously detects features in sidescan imagery, classifies the features, searches through historical and dynamic databases of previously detected features and performs change detection (i.e., determines whether the feature is new or pre-existing, relative to earlier surveys). The system also clusters the detected features and performs “area matching” to minimize false detections. NRL is investigating other applications, such as augmented cognition systems, warning and alert systems, and autonomous “de-clutter” mechanisms for electronic displays, which could leverage one or more components of ACDC.

The NRL ACDC system [1] is comprised of five key components: Computer-Aided Detection (CAD), Computer-Aided Classification (CAC), historical and dynamic databases, Feature Matching (FM), and Area Matching (AM), summarized in the following sections.

CAD and CAC Components

CAD is a real-time detection algorithm capable of sensing - in sidescan imagery - objects with bright spots and shadows (figure 1). Mine-like objects, also called mine-like echoes or simply clutter, show up in the image as bright spots with adjacent shadows that face perpendicular away from the nadir (or centre of the scan track). Features of various shapes and sizes can be discerned by the dimensions of the shadows; the size of the shadow varies as a function of both beam angle and feature size [2].

CAC uses an adaptive filter to “complete” the feature’s bright spot, based on the shadow, and then classifies the feature based on the dimensions of the shadow and completed bright spot (figure 2).

Databases

Three databases support classification and change detection. The first is an historical database (DB-H) containing imagery from past sidescan surveys, snippets of classified features, and attributes pertaining to the features (figure 3). The second is an ideal shapes database (DB-S) containing ideal depictions of real features

Lohrenz, M.C.; Gendron, M.L. (2005) Automated Change Detection and Classification System. In *Visualisation and the Common Operational Picture* (pp. 8-1 – 8-4). Meeting Proceedings RTO-MP-IST-043, Paper 8. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

that might be encountered during a survey (figure 4). The third is a geospatially searchable vector feature database (DB-V) that stores the classified historical features and facilitates the fast retrieval of these features based on geospatial areas of interest. The retrieval process corrects for estimated position errors (e.g., feature migration, Global Positioning System errors) using geospatial bitmaps of increasing resolution [3]. A two-step search attempts to match each new object with one in the DB-H. If all attempts fail, then the object is marked as a new object not seen before in the historical data (figure 5).

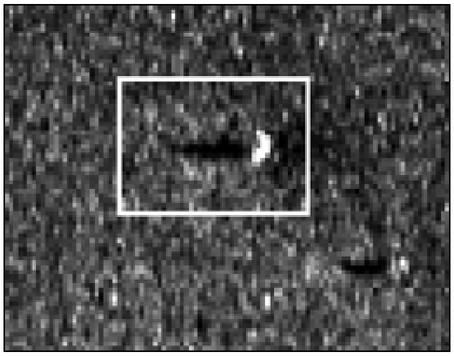

Figure 1: Feature Detected by CAD.

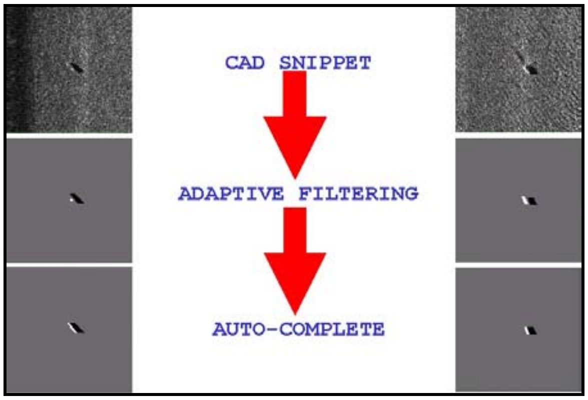

Figure 2: Graphic Depiction of CAC Process.

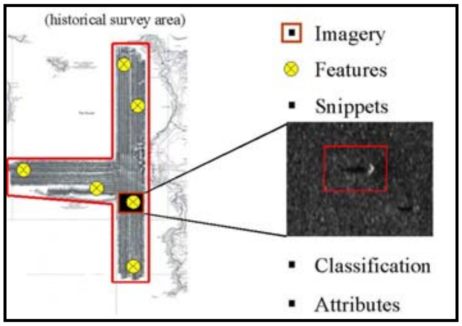

Figure 3: DB-H Record Descriptors.

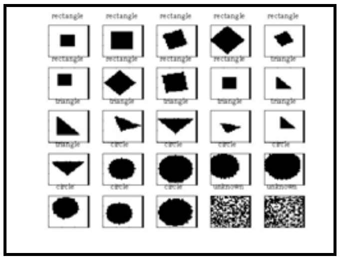

Figure 4: Sample Shapes in DB-S.

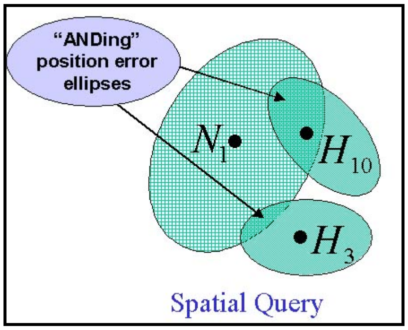

Figure 5: Searching the DB-V.

FM and AM Components

Change detection is accomplished via the FM and AM components of ACDC. FM inputs wavelet coefficients to a neural network and matches historical features (extracted from the fast-searchable DB-V) with newly detected and classified features (figure 6). Such wavelet networks are proven to match features well and are used extensively in face recognition [4], for example. AM matches larger areas (i.e., bounded regions of clustered features) to reduce the false detection rate of the FM component. The AM component uses a separate wavelet network and a single-pass clustering algorithm, also developed by NRL (figure 7).

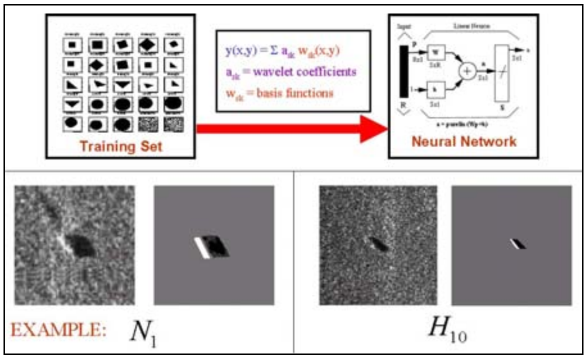

Figure 6: FM Wavelet Network.

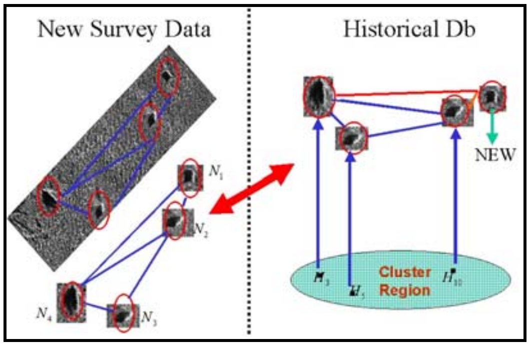

Figure 7: AM Wavelet Network and Clustering.

RELATED EFFORTS

Concurrent and future work planned in support of this project includes a structured task analysis of manual contact detection, classification and clustering strategies to fine-tune the automation of these functions. Unfortunately, different analysts often “call” contacts differently, and even an expert analyst might detect or classify the same contact differently on repeat trials. Presumably, the benefits of a successful automated ACDC system will be faster, more accurate, and consistent/repeatable detection and classification, ultimately resulting in reduced labour and time requirements and safer, more successful mine countermeasures operations. To realize these potential benefits, NRL will perform statistical analyses of manual vs. autonomous methods of detection, classification and clustering as part of ACDC validation and verification.

Additionally, NRL is investigating the potential for adapting one or more components of ACDC in support of other applications that require contact detection, classification, and change detection. Applications being considered include augmented cognition systems, warning and alert systems, and autonomous “de-clutter” mechanisms for electronic displays. For example, the Defense Advanced Research Projects Agency (DARPA) BAA01-38 states that a primary goal of augmented cognition systems (e.g., helmet-mounted displays) is “to extend by an order of magnitude or more the information management capacity of the human-computer interface for the warfighter”. The automated CAD, CAC and change detection algorithms developed for ACDC could be leveraged in support of this goal. Likewise, warning and alerting systems (e.g., on a vehicle) require CAD, CAC, and change detection functions to autonomously detect potential threats (e.g., another vehicle on a collision course) and suggest evasive actions.

The development of an autonomous declutter mechanism for electronic displays would involve detecting (CAD) and classifying (CAC) displayed features (e.g., geospatial points, lines, areas, and text labels) and clustering those features into regions of common density. The clustering algorithm developed for the AM component of ACDC calculates a numerical measure of clutter density that considers the number and size of objects that have been clustered in a given area, as well as the scale or resolution of the dataset. The displayed features could then be decluttered based on some maximum density threshold, which would be determined by parameters such as feature type/size/colour, display application, and user expertise.

ACKNOWLEDGEMENTS

Development of the ACDC system is jointly funded by the Office of Naval Research (ONR), the Space and Naval Warfare System Command (SPAWAR), and NAVOCEANO under program elements 0602782N, 0603207N, and OMN, respectively. The authors thank Doug Todoroff (ONR 32), Captain Robert Clark and Mr. Ed Mosley (SPAWAR PMW 150) and Jim Hammack (NAVOCEANO N4) for their support of this project. The mention of commercial products and company names does not imply endorsement by the U.S. Navy. Approved for public release; distribution is unlimited.

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