CSCAP: COAST AND SHORELINE CHANGE ANALYSIS PROGRAM; USING HIGH-RESOLUTION SATELLITE IMAGERY FOR SHORELINE CHANGE EVALUATION WITHIN PORTS

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ABSTRACT

The Coast and Shoreline Change Analysis Program (CSCAP) is being developed to enable National Geodetic Survey (NGS) personnel to use high-resolution satellite imagery to detect shoreline feature change within ports. CSCAP consists of a suite of integrated commercial off-the-shelf software programs as well as a set of procedures for georeferencing imagery and analyzing shoreline change. Additional procedures for compiling shoreline features are currently under development. CSCAP shoreline change analysis data are used as input for updating NOS Nautical Charts and Electronic Navigational Charts (ENC). It is also used to help guide NGS decisions regarding areas which should be scheduled for aerial survey and photogrammetric shoreline compilation.

A major difficulty in making full use of high-resolution satellite imagery is that the standard georeferencing accuracy of the imagery often is not sufficient to allow direct comparison with other shoreline data. To alleviate this problem, the initial image georeferencing is improved by registering it to NOS high-accuracy shoreline manuscripts or GPS reference points using 2D polynomial or rubbersheeting algorithms. The re-georeferenced imagery is then compared to Nautical Charts and to the ENC if available. Discrepancies are noted and used as input into the NGS planning process or the Nautical Chart update process, depending on the purpose of the project.

Development activities currently focus on image georeferencing accuracy assessment, shoreline compilation procedures, and compiled feature accuracy assessment. In addition, new imagery sources are being evaluated as they become available.

INTRODUCTION

The National Geodetic Survey (NGS), a program office in the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA), is tasked with providing shoreline and associated data for mapping our nation’s 95,000 miles of coastline. The Remote Sensing Division (RSD) within NGS, conducts photogrammetric surveys to photograph and when prioritized, compile shoreline and associated data for application to the Office of Coast Survey’s nautical charts. The update cycle for a nautical chart varies from as often as every 6 months to as infrequently as 12 years depending on factors including the rate of cultural and natural changes. This shoreline data is available to the coastal GIS community through the National Geodetic Survey Shoreline Data Explorer website.

The Coast and Shoreline Change Analysis Program (CSCAP), managed by NGS, acquires contemporary high-resolution imagery to evaluate ports. The imagery is accurately georeferenced and compared with the nautical chart to detect changes. The analysis of these discrepancies is used to determine which ports or areas within a port require expensive photogrammetric survey mapping. In addition to change detection, the re-georeferenced imagery can be used for shoreline and associated feature compilation.

CSCAP PROCEDURE

Imagery with the highest available spatial resolution is required to detect changes within ports. To date, NGS has evaluated four primary sources of high-resolution satellite imagery: SPOT, IRS, SPIN2, and IKONOS. The 10 meter spatial resolution of SPOT (SPOT Image, Corp.) and 5 meter spatial resolution of IRS (SpaceImaging, Inc.) panchromatic imagery is not adequate to detect a significant number of charted features within ports. SPIN2 (Aerial- Images, Inc.) panchromatic imagery has a 2 meter spatial resolution which allows for identification of many more shoreline features than are visible on IRS or SPOT imagery (Figure 1). SPIN2 imagery is orthorectified, although not necessarily accurately georeferenced. NGS acquires IKONOS (SpaceImaging, Inc.) panchromatic "geo" imagery with 1 meter spatial resolution that has been map oriented (aligned to conform with a map projection using satellite ephemeris data), but not orthorectified by the vendor. Although IKONOS and SPIN2 imagery provide adequate spatial resolution, they are not georeferenced accurately enough by the vendor for direct use in shoreline change analysis.

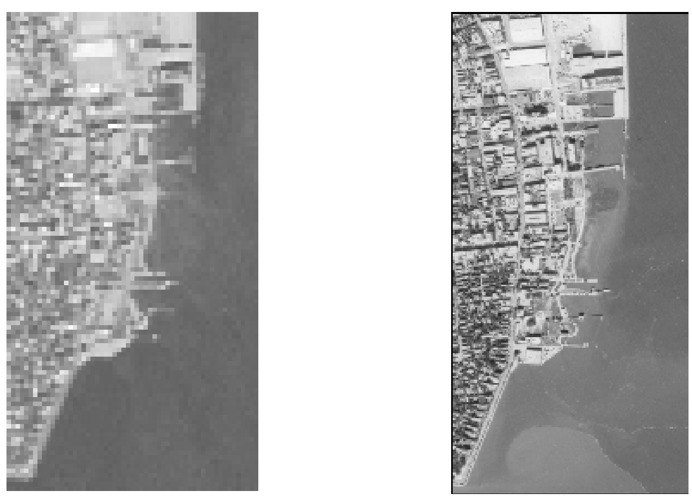

Figure 1. Charleston, SC: IRS (5 meter spatial resolution) and SPIN2 (2 meter spatial resolution) imagery. Notice the increased spatial resolution of the SPIN2 image.

Georeferencing
In order to georeference satellite imagery within CSCAP, reference information (Ground Control Points or GCPs) must be obtained from maps or from GPS observations. The most accurate reference maps currently available for port areas are either raster scanned T-Sheet shoreline manuscripts produced by NOAA or vector digital cartographic feature files produced by NGS, NOAA (Byrnes et. al.,1991, Crowell et. al., 1991). At the present time, raster T-Sheets are not georeferenced when RSD receives them, so georeferencing must be the first step when they are used for reference data.

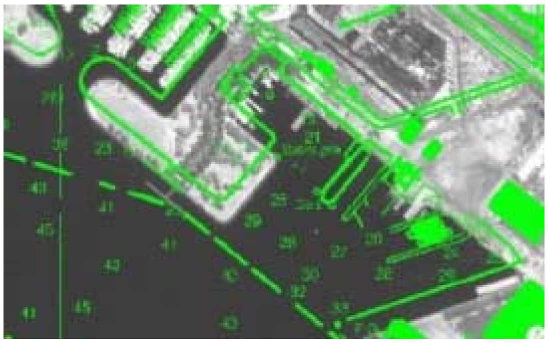

Figure 2A. San Diego, CA: IKONOS image registration before re-georeferencing. The image and nautical chart (green lines) are not accurately registered.

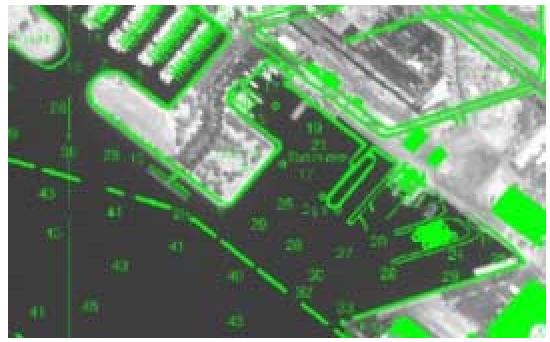

Figure 2B. San Diego, CA: IKONOS image registration after re-georeferencing. The image and nautical chart are accurately registered. Some features are charted but are not visible on the imagery while other features appear to be newly constructed.

Well-defined points that are distinguishable on both the image and the reference map are chosen as GCPs. Since two-dimensional polynomial transformations are being used, the GCPs as well as the features of interest must be at or near the same elevation, in this case, the shoreline plane of reference. After the appropriate GCPs have been selected, those with the largest RMS errors are eliminated from the transformation. As the selection of GCPs narrows, an even distribution of points across the image must be maintained. Typically, first and second order polynomial transformations using 20 to 40 control points have yielded satisfactory results.

GPS data points can also be used as control for satellite imagery georeferencing. Six to eight distinct, well distributed points are selected from an image. The points must be clearly discernable on the ground as well as in the image, and should be at or near the shoreline plane of reference. To ensure that the correct points are obtained, both a detailed location map and an image subset are supplied to the Office of Coast Survey Navigation Services Division field personnel (Figure 3). Differentially corrected GPS points are obtained with typical horizontal accuracy of 0.5 meters. When NGS receives the GCP coordinates, the image is georeferenced using a first-order polynomial transformation.

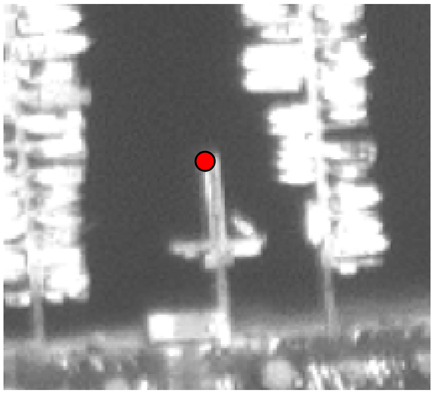

Figure 3A. Image location of a GPS point used in the image georeferencing process.

Figure 3B. Ground crew member obtaining GPS observations for point referenced in Figure 3A.

Accuracy Assessment
After georeferencing has been completed, the resulting image is checked for positional accuracy. Final image georeferencing accuracy using GCPs obtained from a map is the combination of errors produced during reference map creation, reference map georeferencing, and image registration. Reference data errors range from about 0.5 meters for GPS positions to 1.5 meters or less for T-sheets compiled during the 1970s and 1980s (Crowell, et.al., 1991).

To illustrate typical accuracy of image georeferencing using reference maps, the following additional errors were computed for an IKONOS image of Tacoma, WA:

Source of Errors:	**RMSE X**	**RMSE Y**	**Total RMSE**
T-sheet Georeferencing	0.19 meters	0.46 meters	0.49 meters
Image Registration	2.20 meters	1.80 meters	2.80 meters
Combined RMS Errors	2.39 meters	2.26 meters	3.29 meters

The same Tacoma, WA IKONOS image was compared with an independent source of higher accuracy. In this case, 33 GPS observation check points with an average horizontal accuracy of 0.495 meters were analyzed. RMS X error was 1.69 meters, RMS Y error was 1.86 meters, and total RMSE was 2.51 meters when distinct points visible on the image were compared with the GPS point data supplied by the Office of Coast Survey

Navigation Services Division field operations . The circular error at the 95% confidence level for this image is 4.34 meters, when computed according to National Standard for Spatial Data Accuracy procedures (Federal Geographic Data Committee, 1998). Because two-dimensional georeferencing techniques were used, these accuracy assessment statements are only valid for points at or near the shoreline plane of reference.

To date, overall georeferencing accuracy of IKONOS imagery in San Diego, Tacoma, WA and Galveston, TX has been assessed by NGS using GPS check points. A summary table of these accuracy results follows:

Imagery Evaluated	**Reference Source**	**RMSE X**	**RMSE Y**	**Total RMSE**	**CE at 95% Confidence Level**
San Diego	Raster T-sheets	5.02 m	1.58 m	5.28 m	8.07 m
San Diego	GPS Data Points	1.44 m	1.44 m	2.04 m	3.53 m
Galveston	Vector Digital Cartographic Feature Files	2.00 m	1.02 m	2.24 m	3.69 m
Galveston	GPS Data Points	1.38 m	1.16 m	1.81 m	3.11 m
Tacoma	Raster T-sheets	1.69 m	1.86 m	2.51 m	4.34 m

Based on preliminary findings, it appears that using GPS for reference data increases the positional accuracy of the image.

Change Analysis

After the imagery has been georeferenced, it is then used for comparison to the raster Nautical Chart or vector Electronic Navigational Chart. Much of the imagery that NGS has obtained was received only a month or two after the acquisition date. This imagery provides an excellent means for comparing "current" conditions with the representation of the shoreline on the charts. NGS personnel view the imagery as a base layer in a GIS along with the raster or vector chart. Descriptions of differences between the chart and image are recorded along with the geographic location of each discrepancy. Changes noted include natural shoreline change as well as changes in manmade shoreline features such as piers, breakwaters, wharves, and bulkheads (Figure 4).

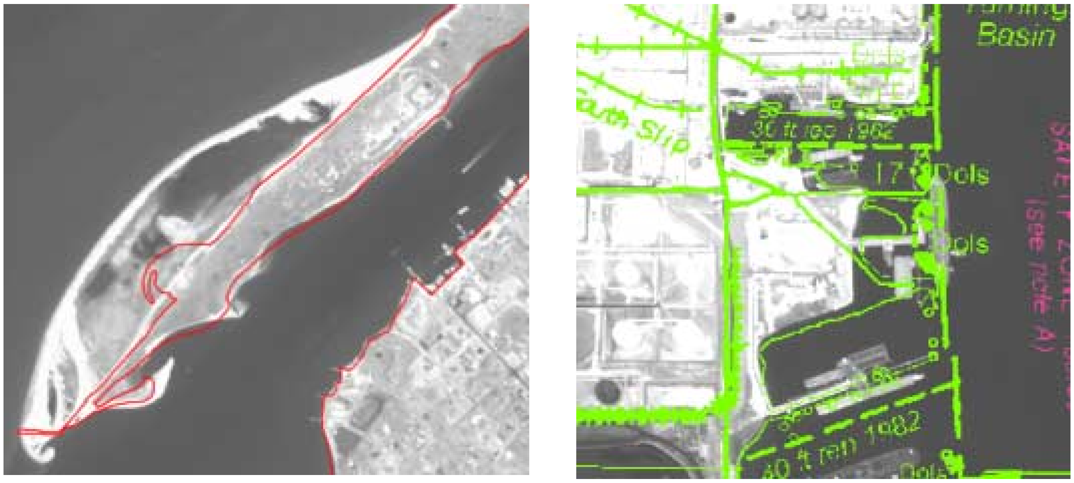

Figure 4. 1992 photogrammetric shoreline (red) and a March 1998 NOAA nautical chart (green) are compared to an August 2000 IKONOS image to assess change for Galveston, Texas.

Compilation

In addition to change analysis, efforts are underway to assess the accuracy of shoreline compiled from high-resolution satellite imagery. Subsets of an IKONOS image of Galveston, TX were compiled by three NGS employees (Figure 5).

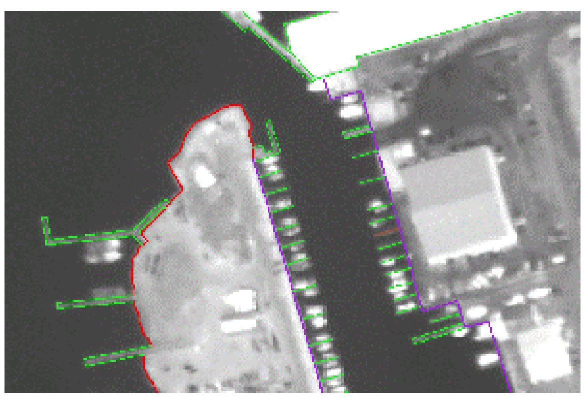

Figure 5. Shoreline features compiled from IKONOS imagery at Galveston, TX.

To assess the accuracy of compiled features, 18 distinct GPS observations were compared with discrete points from the compiled vector shoreline. RMS errors were computed for each compiler and are as follows:

Compiler	RMSE Y	RMSE X	Total RMSE	CE at 95% Confidence Level
1	0.94	1.71	1.95	3.38
2	0.97	1.11	1.47	2.54
3	1.34	1.32	1.88	3.26

The average total RMSE for all three compilers was 1.76 meters, and the circular error for discrete points derived from the imagery at the 95% confidence level ranged from 2.54 to 3.38 meters. The 3.38 meter circular error tolerance does not meet the 1 meter NGS standard requirement for mapping within ports. However, for certain nautical chart applications, timely delivery of IKONOS derived shoreline is more desirable than labor intensive, highly accurate photogrammetric shoreline. These are preliminary results based on IKONOS imagery of a specific geographic area and may not be applicable to other locations.

CONCLUSIONS

The Remote Sensing Division (RSD) of the National Geodetic Survey manages the Coast and Shoreline Change Analysis Program (CSCAP) to make more efficient use of its remote sensing resources to map our nation's coastline. CSCAP uses high-resolution contemporary imagery such as 2 meter SPIN2 orthorectified imagery, and 1 meter IKONOS non-orthorectified imagery to detect shoreline changes when compared with nautical charts.

NGS personnel improve the initial geometric accuracy of the imagery supplied by the vendor to meet requirements for identifying shoreline changes through two-dimensional techniques. Well-defined points near the shoreline plane of reference are chosen from an accurate base map (NOAA's georeferenced raster T-Sheets or vector digital cartographic feature files) or from GPS observations. The imagery is then rectified to conform to the geometry of these reference points, resulting in imagery that is georeferenced to within 2 to 5 meters of the National Spatial Reference System position. Shoreline compiled from satellite imagery could be used where the demand for high temporal resolution outweighs standard NGS accuracy requirements.

CSCAP is currently used as a planning tool to help set priorities in determining which regions require photogrammetric mapping. CSCAP provides a cost effective means to update nautical charts within selected ports. With limited funding resources for Federal Government mapping, areas of interest could be expanded to include port approaches and open coastal areas given dedicated funding. CSCAP provides reliable and contemporary updates that promote national commerce by improving safe navigation within our ports.

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