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A SENSOR FUSION APPROACH TO COASTAL MAPPING

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INTRODUCTION

NOAA's National Geodetic Survey (NGS) is responsible for mapping the national shoreline. This shoreline provides the critical baseline for demarcating the United States' marine territorial limits, including its Exclusive Economic Zone; and is used in updating NOAA nautical charts and management of coastal resourses.

NGS conducted a data fusion research project in collaboration with the Joint Airborne Lidar Bathymetric Technical Center of Expertise (JALBTCX) and other NOAA partners. In March and April of 2004, hyperspectral imagery, topographic lidar data, and high-resolution digital color imagery were collected simultaneously aboard the NOAA Citation for coastal project areas in Florida and California.

The data are being used to support a number of research objectives, including shoreline extraction and feature attribution, and coral reef mapping. The details of the simultaneous data acquisition with three different sensors are presented along with preliminary results from our shoreline mapping research.

STUDY SITES

Two study areas in Florida (Desoto Beach and St Pete Beach) and one in California (Morro Bay) were selected for the sensor fusion research project (Figure 1). The Desoto Beach area contains gently sloping sandy beaches, while St. Pete Beach is characterized by a heavily developed back barrier environment. Morro Bay has a rocky coastline with an elongated sandy spit.

Figure 1. Location map depicting sensor fusion research sites.

AIRBORNE DATA ACQUISITION

An Applanix, medium format, digital sensor system (DSS), an Optech ALTM 50 kHz LIDAR and an ITRES CASI-2 Hyperspectral Imager were installed on a NOAA Citation Jet. One goal of this research was to collect geo-referenced data from all three sensors. To facilitate accurate geo-referencing, each sensor had its own inertial measurement unit (IMU). A single GPS antenna was used for all three sensors. This signal was split three ways to accommodate the three sensors.

The data were acquired at a flying height of 4500 ft and at a flying speed that ranged between 130-160 knots. All data were flown either into or away from the sun, in order to avoid sun glint on the hyperspectral and digital imagery. Additionally, factors such as swath width, sensor integration times, and field of views were taken into account during the planning phase of this project in order to achieve sufficient overlap and avoid data gaps.

FIELD DATA ACQUISITION

For each study site, approximately 25 ground control points were occupied with GPS, for 15 minutes in order to assess the horizontal positional accuracy of the digital imagery and CASI-2 Hyperspectral products (Figure 2a). The post-processed accuracy of the 25 ground control points was at the centimeter level.

Spectral signatures of coastal features were also collected for each study site using a handheld Analytical Spectral Device (ASD) FieldSpecPro spectrometer (Figure 2b). Targets thought to be homogeneous and large enough to be seen in the hyperspectral imagery were identified. For each target, eighty spectral signatures were acquired using the absolute reflectance mode and then averaged. This produced a spectral signature for each target that spanned the 400 – 2500 nanometer range of the electromagnetic spectrum.

Figure 2. a) collecting the GPS position of well defined points in St. Pete Beach, Florida
b) collecting spectral signatures of features along the coastline using an ASD

hand held spectrometer.

DATA PROCESSING

A radiance hyperspectral data cube, consisting of seventy-two spectral bands at a spectral resolution of 8 nanometers spanning the 430-970 nanometer range of the electromagnetic spectrum, was collected for each study site. The GSD for each image scene was 2.0 meters in the across track and 2.4 meters in the along track. An important step in hyperspectral processing is converting the data from at-sensor radiance to reflectance. The data collected at all three study sites were atmospherically corrected using the Empirical Line Method. This method involves the use of field spectral reflectance signatures acquired during the time of data acquisition.

Lidar data with a 1 meter point spacing in the along and across track was post processed using Optech's proprietary software. A digital elevation model (DEM) with a post spacing of 1 meter was used for data fusion in this research project.

The digital photographs were imported into Socetset, a digital photogrammetric workstation. The DSS imagery was geo-referenced using direct geo-referencing from blending of the GPS/IMU data. Fifty-centimeter ortho-photograhs were created, using the lidar DEM, to correct for terrain displacement. Figure 3 represents a sample of these datasets for the Fort Desto Beach area.

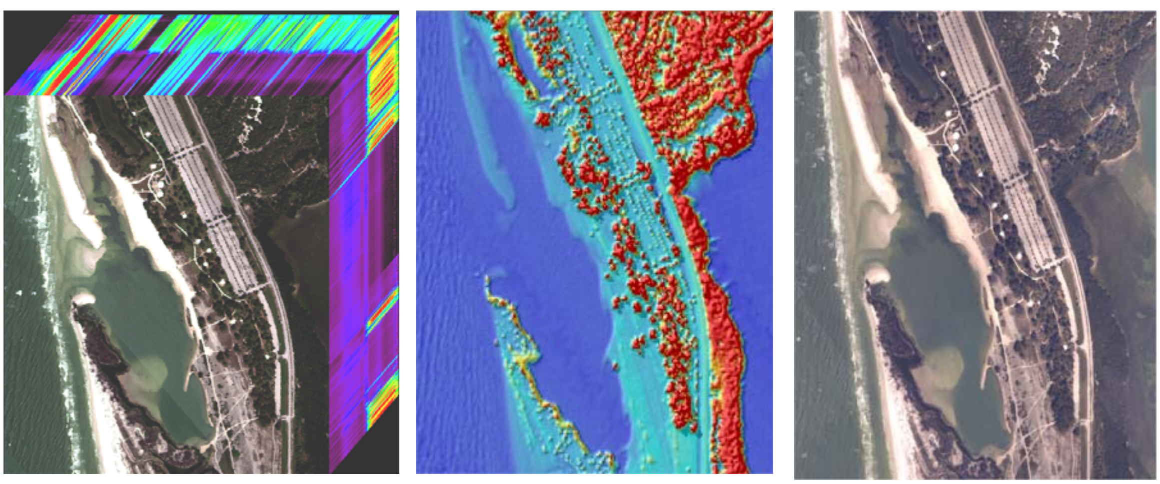

Figure 3. The final sensor fusion products consisted of a 72-band hyperspectral cube with a 8 nm spectral resolution, a 1 m digital elevation model, and a 0.5 m ortho-photograph, respectively.

SENSOR FUSION FOR SHORELINE MAPPING

The lidar data points were processed through NGS' VDatum vertical transformation tool (http://chartmaker.ncd.noaa.gov/bathytopo/vdatum.htm), then interpolated to a grid to create a DEM referenced to the appropriate tidal datum, such as mean high water (MHW). With the lidar DEM referenced vertically to MHW, a zero-contour was extracted which represents the MHW shoreline (Figure 4) . In previous studies, NGS researchers have shown very good agreement between a lidar-derived shoreline created using this method, and shoreline compiled manually from stereo photography.

The next step was to perform a classification on the CASI-2 hyperspectral data. A classified thematic map was created from the CASI-2 hyperspectral data using the Mahalanobis Distance Classifier (Figure 4). This thematic map contained sand, pier and seawall classes. It is important to note that regions of interest were only chosen for features representing the outer coastline areas.

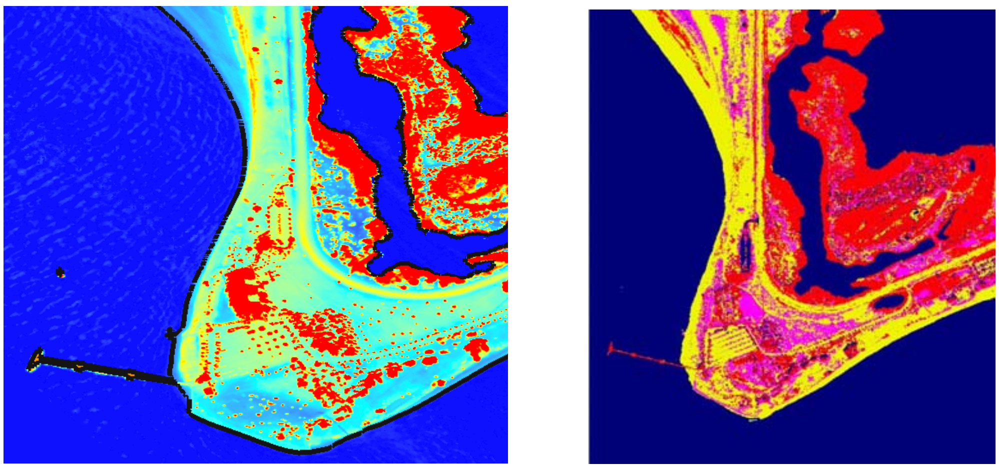

Figure 4. Lidar-derived shoreline superimposed on lidar DEM and Mahalanobis Distance classified image, respectively.

We then used GIS software to intersect the lidar-derived shoreline with the classification image so the shoreline vector would pick up the attributes from the classified thematic map (Figure 5).

Figure 5. Feature attributed, lidar-derived shoreline, superimposed on an ortho-photograph.

CONCLUSION

Future work will focus on improving the classification results using decision-level fusion. Through continued studies of this type, NGS seeks to increase efficiency in NOAA programs and improve the available information about the coastal environment, to better serve our constituents. An additional goal is to increase contracting opportunities and further cooperation with private sector service providers.

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