RESOLUTION ENHANCEMENT OF HYPERSPECTRAL DATA FOR OCEAN AND LITTORAL APPLICATIONS

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Hyperspectral imaging systems are receiving increasing attention for a wide variety of coastal applications. Of particular interest is the characterization of littoral environments. Hyperspectral instruments have shown good results when used in land material mapping and depth-mapping applications. The reason is that a hyperspectral imager provides information on scene content that is not obtainable from single-band or multispectral sensors. Many proposed satellite based hyperspectral sensors for littoral application have planned spatial resolution ranging from tens of meters to a hundred meters or more. There is an increasing requirement for higher resolution littoral zone products. In this work, we examine the benefits of combining data from high-spatial-resolution, low-spectral-resolution sensors with data obtained from high-spectral-resolution, low-spatial-resolution imaging sensors. These sharpened data sets are then evaluated with simple statistical measures and a real-world depth mapping algorithm. The process described herein, called Color Resolution Improvement Software Package or “CRISP”, combines information contained in a low-spatial-resolution hyperspectral image with a high-spatial-resolution multispectral/panchromatic image in such a way that the resulting image product has the spectral characteristics of the hyperspectral image and the spatial characteristics of the multispectral/panchromatic image. The result of this sharpening procedure is an image product that is fully exploitable as a hyperspectral image.

Data for these evaluations was collected during a two week experiment in Oahu in the winter of 2009. Sensors participating in this experiment were HyVista corporation's HyMAP sensor and a consumer grade digital camera (Canon XSi). The primary areas of interest are the near shore water and beach areas at Marine Corps Base Hawaii-Kaneohe Bay and the Windward Oahu shore. HyMap provides 126-band coverage across the reflective solar wavelength region of 0.45-2.5 micrometer, with contiguous spectral coverage (except in the atmospheric water absorption bands) with spectral bandwidths between 15 to 20 nanometers. The HyMap instrument has a field of view of 62 degrees with 512 pixels, giving an IFOV of 0.12 degrees. The Canon XSi digital camera collects images with a four element (RGBG) CMOS sensor with 4272 detectors across and 2848 sensors vertically. With a 20mm lens attached, a field of view of 63.6 degrees and an IFOV of 0.0149 degrees is achieved. Custom Canon raw processing software was used to get data from the image files in terms of raw numbers rather than the default "photographic" contrast curves. The Canon camera took data coincident with the HyMap data for every flight line. This resulted in approximately 2000 raw mode image of 14 Mbytes each.

For the initial depth mapping tests, data from a region of open ocean off Kailua, HI was used. To perform a controlled test, synthetic hyperspectral/multispectral pairs were generated were generated from on hyperspectral scene. The synthetic hyperspectral imagery was created by degrading the resolution of the original high-resolution HyMap image using a Gaussian blur filter at kernel sizes of 7, 11, 17 and 37. These roughly correspond to a reduction in resolution of 2, 4, 8, and 16. Synthetic multispectral scenes were generated by resampling the original HyMap image to the same spectral bands as the Ikonos satellite. This allowed us to measure the degree of success by comparing depths derived from the sharpened scene to depths derived from the input hyperspectral data.

Previous studies of the CRISP sharpening algorithm looked at the performance of sharpened data with anomaly detection algorithms and whole scene error metrics (RMS error). Here we look at a real world application of a depth mapping algorithm in order to assess the usability of CRISP in coastal mapping applications. The depth mapping algorithm used here is the "log ratio" technique developed by Stumpf, Holderied and Sinclair. This is a relatively simple technique that can accurately assess clear water depth up to 25 meters. This technique is also stable with regard to bottom type.

The depth analysis was applied to the original control hyperspectral image, the Gaussian blurred image using Gaussian kernel sizes of 7, 11, 17, and 37 (corresponding to 2:1, 4:1, 8:1, and 16:1 factors) and sharpened versions of the Gaussian blurred image. The sharpened data was created by sharpening the blurred hyperspectral data with synthetic four-band Ikonos data. The imagery was compared by calculating depth maps for all of the images and calculating the RMS(error) of the blurred and sharpened depth maps against the "truth" depth map calculated from the original hyperspectral image. The goal of this experiment is not to test the accuracy of the depth mapping algorithm, but to test the accuracy of the sharpening algorithm. As such a comparison with true observed depth is not attempted. Instead the difference between the depth maps from the different derivative data sets and the control high-resolution hyperspectral image are examined. The Gaussian blurred data shows a generally increasing error rate as Gaussian kernel width increases. This is as expected, since the blurred data should show less accurate results in any application. The sharpened data shows generally higher accuracy for depth mapping, with the extreme 16:1 sharpening of the Gaussian37 data having about half of the error rate of its blurred counterpart. All of the sharpened synthetic data sets show error rates less than five percent, corresponding to an actual error of about 25 cm for a depth of five meters. Since the depth mapping algorithm used here has showed an RMS error rate of 30 percent, the error shown by the sharpened data is negligible. That is, the error due specifically to the sharpening process is less than the error in the application by almost an order of magnitude.

For the test of sharpening with the Canon camera, we chose two regions, one taken over land with buildings and other image structure and a second over Kaneohe Bay, where bottom features could be seen, to allow for scene-based registration of the Canon image data to the HyMAP hyperspectral. The evaluation to higher resolution truth is not possible for these experiments. For the land images, we evaluated the quality of the resolution enhancement by comparing the endmember map made by the N-FINDR algorithm on the low resolution HyMAP data and the sharpened HyMAP data. End-members were automatically derived and were used to create a colored fraction plane image. The same end-members were then used to unmix and color the sharpened image. The results of the eight to one sharpening process showed a marked improvement in resolution, with realistic boundaries between the vegetation, shoreline, and buildings. We are evaluating the resolution enhanced Kaneohe Bay data by comparing both the depth map derived from the lower resolution hyperspectral data and the depth map derived from the resolution enhanced data to LIDAR depth maps made nine years ago. These results are not available at this time, but will be included in the actual paper.

Bibliography

Carper, W. J, T. M. Lillesand and R.W. Kiefer, “The use of intensity hue saturation transformations for merging SPOT panchromatic and multispectral image data,” *Photogrammetric Engineering and Remote Sensing*, 56(4):459-467, (1990).

Ranchin, Thierry and Lucien Wald, , “Fusion of High- Spatial- and Spectral-Resolution Images: The ARSIS Concept and Its Implementation,” *Photogrammetric Engineering and Remote Sensing*, 66(1), 49-6, (2000).

Cocks, T., Jenssen, R., Stewart, A., Wilson, I., & Shields, T. "The HyMap airborne hyperspectral sensor: the system, calibration and performance". *Proceedings of the First EARSeL Workshop on Imaging Spectroscopy*, 6 – 8 October, 1998, Zurich (pp. 37–43). Paris, France: European Association of Remote Sensing Laboratories. (1998)

M. Cook, B. Peterson, G. Dial, F. Gerlach, K. Hutchins, R. Kudola, and H. Bowen (2001). "IKONOS Technical Performance Assessment." *Proceedings of SPIE* Vol. #4381-10, 16-20 April 2001, Orlando, Florida, (2001)

Stumpf, R., K. Holderied and Mark Sinclair, "Determination of water depth with high-resolution satellite imagery over variable bottom types", *Limnol. Oceanogr.* 48, 547-556 (2003).

Winter, Michael E., “Fast Autonomous Spectral End-member Determination in Hyperspectral Data,” *Proceedings of the Thirteenth International Conference on Applied Geologic Remote Sensing*, Vol. II, pp 337-344, Vancouver, BC, Canada, (1999).