LUT Wrap Up

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LONG-TERM GOAL

The overall goal of this work is to refine and validate a spectrum-matching and look-up-table (LUT) technique for rapidly and accurately inverting remotely sensed hyperspectral reflectances to extract environmental information such as water-column optical properties, bathymetry, and bottom classification.

OBJECTIVES

My colleagues and I have developed (Mobley et al., 2005) and evaluated (Mobley and Lesser, 2007; Dekker et al., submitted; see also my report on contract N0001409M0362) new techniques for the extraction of environmental information including water-column inherent optical properties (IOPs), shallow-water bathymetry, and bottom classification from remotely-sensed hyperspectral ocean-color spectra. We addressed the need for rapid, automated interpretation of hyperspectral imagery. My research centered on development and evaluation of spectrum-matching algorithms, including the generation of confidence metrics for the retrieved information.

My objectives in the current project are to “wrap up” the previous developments by (1) documenting the “lessons learned” about what works well and what does not, (2) clean up the computer codes, (3) create more extensive databases of remote-sensing reflectances R_{rs} so that the existing algorithms can be applied to a wider range of environments, (4) prepare a User’s Guide for the processes of creating new databases and processing images with the algorithms previous developed, and (5) training Navy personnel as needed in how to run the computer codes.

APPROACH

The LUT methodology is based on a spectrum-matching and look-up-table approach in which the measured remote-sensing reflectance spectrum R_{rs} is compared with a large database of spectra corresponding to known water, bottom, and external environmental conditions. The water and bottom conditions of the water body where the spectrum was measured are then taken to be the same as the conditions corresponding to the database spectrum that most closely matches (by some chosen metric) the measured spectrum. In previous LUT work, we have simultaneously retrieved water column IOPs, bottom depth, and bottom classification at each pixel from image remote-sensing reflectance spectra.

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Although this is much to ask from a simple R_{rs} spectrum, we have shown that all of this information is uniquely contained in hyperspectral reflectance signatures and that the information can be extracted with considerable accuracy.

We have evaluated numerous options for applying the basic LUT algorithms. These options include matching the closest k R_{rs} spectra, rather than just the closest one ($k = 1$), spectral and spatial smoothing of image spectra before processing, and spatial smoothing of retrieved values after processing, and different spectrum-matching metrics for determining the "closest" match. We have also quantified the errors in the LUT R_{rs} database generation associated with the use of unpolarized (scalar) radiative transfer calculations (using a special version of HydroLight), compared to exact (but very time consuming) calculations that include polarization (You et al., 2009).

Given the previous successes─and a few failures─of our spectrum-matching and look-up-table algorithms, it is now time to clean up the computer codes, incorporate the algorithms and processing options that provide the best results, and document the results via a User's Guide and publications.

WORK COMPLETED

The LUT retrieval algorithms work well if the underlying R_{rs} database adequately describes the imaged environment. Occasional poor retrievals have been shown to be due to inadequate R_{rs} databases, e.g., ones in which the absorption and scattering properties of the water were assumed to be correlated, when in reality they were not. To avoid this problem, more extensive databases must be created, which can be computationally expensive with the present computer code. (One reason for the use of inadequate databases in some previous work was the multi-week run times that would have been needed to create larger databases.)

I am therefore replacing the existing version of EcoLight in the database generation code with the newly developed EcoLight-S code (Mobley, 2010), which can be optimized to run much faster but with a negligible change in the computed R_{rs}. (The run time savings come primarily from not solving the radiative transfer equation to the same depth at all wavelengths, especially at wavelengths beyond 700 nm where the bottom has no influence on R_{rs} if the water is more than a few meters deep.) The EcoLight-S development is described in my separate report on contract N0001409C0044. After completion of the new code, additional databases will be created for a wide range of water and bottom types.

I have previously written over 300 pages of formal notes summarizing the results of my investigations of various algorithms and techniques for improving the products retrieved from imagery, including techniques for estimation of retrieval errors. I am now condensing those notes, and adding new material as needed, to create the User's Guide.

Clean up of the image processing code is underway. The previous code was developmental and not user friendly; the new code is more automated, user-friendly, and its use is documented in the User's Guide now in preparation.

RESULTS

Example results of the LUT algorithm development and comparison with other techniques are shown in the report on contract N0001409M0362 and will not be repeated here. Results of the work on the present contract are still in-house in the form of draft reports and computer codes.

IMPACT/APPLICATION

The problem of extracting environmental information from remotely sensed ocean color spectra is fundamental to a wide range of Navy needs as well as to basic science and ecosystem monitoring and management problems. Extraction of bathymetry and bottom classification is especially valuable for planning military operations in denied access areas. We believe that the final LUT software will find applications to a wide range of ocean image processing problems both within the Navy and in the broader science community.

TRANSITIONS

Various databases of water IOPs, bottom reflectances, and the corresponding R_{rs} spectra, along with spectrum-matching algorithms and code have been transitioned to Dr. Paul Bissett at WeoGeo, Inc. for processing his extensive collection of SAMPSON imagery acquired in coastal California and Florida waters, and for use in comparisons of LUT and LIDAR bathymetry. Code for display of retrieval results has been given to S. Phinn and colleagues at the Univ. of Queensland, Australia. The final versions of the LUT algorithms, spectrum matching code, and databases will be transitioned to the Naval Oceanographic Office; that transition is being managed by P. Bissett of WeoGeo, Inc.

RELATED PROJECTS

This LUT wrap up work is being conducted in conjunction with Dr. Paul Bissett at WeoGeo, Inc, who is separately funded for his development of a Library Appliance in which the LUT retrieval algorithms can be run along with other image processing algorithms. The comparison of the LUT technique described here with other techniques was supported by contract N0001409M0362. The development of the EcoLight-S code, which is being incorporated into the final database generation code for this project, was supported in part by contract N0001409C0044.

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PUBLICATIONS

Mobley, C. D., 2010. *EcoLight-S 1.0 Users' Guide and Technical Documentation.* Sequoia Scientific, Inc., 40 pages. Copy available on request from the author.