AN ADAPTATION OF THE AASAP SUBPIXEL ANALYSIS SOFTWARE FOR AUTOMATED BATHYMETRY MAPPING*

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ABSTRACT

The Applied Analysis Spectral Analytical Process (AASAP) has been adapted for automated bathymetric analysis. AASAP is a multispectral image processing software module that performs automated subpixel analysis, i.e., it is able to detect spectral contributions from materials of interest that may occupy only small fractions of image pixels. It does this by identifying and removing unwanted spectral contributions from background materials in the pixels. This provides a means for automatically identifying and removing terrain and surface reflection (sky and sun reflection) contributions from water pixels. It also allows composite depths and bottom materials within pixels to be resolved into individual components, e.g., shallow coral and deep sand. This enables more accurate determinations of the water column and bottom reflectance characteristics to be made. AASAP provides the additional advantage of automatically calculating atmospheric correction factors for the scene being processed. This allows the attenuated bottom radiance to be converted from units of digital number into units of calibrated reflectance, providing a means for automatically calculating depth using a standard regression analysis of logarithmic reflectance. It also allows signatures derived in one scene to be ported to other scenes. The output of the process includes a pixel fraction and depth for each bottom material per pixel, as well as the mean depth and confidence for each pixel.

1.0 INTRODUCTION

Photobathymetry using satellite and airborne multispectral sensors has had mixed success (C. F. Clark et al., 1987; Walker et al., 1990). Although accuracies of derived water depths have been generally good, several factors have affected algorithm performance. These include non-explicit correction for surface reflections of sky radiance and sun glints; non-explicit correction for variations in bottom material reflectance and water column characteristics; inadequate calibration for sun angle, atmospheric, and other environmental factors; and lack of compensation for mixed bottom materials, depths, and column characteristics within individual pixels.

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New photobathymetry software is described here that utilizes subpixel analysis software to explicitly and automatically compensate for the effects of the atmosphere, sun and sky reflections from the water surface, subpixel contributions from exposed land, and variations in the bottom material properties. It also allows for a direct measurement of the scene averaged water column characteristics. This not only provides accurate and uniform depth analysis performance, but it also enables scene-to-scene depth analysis, i.e., bathymetric signatures developed for one scene can be directly applied to scenes of other locations and (or) dates without requiring additional training sets from those other scenes. In addition it provides subpixel-scale depth analysis, i.e., it detects multiple bottom materials and (or) depths within pixels if they occur, rather than just the pixel-averaged bottom materials and depths. This can provide significant added value for hazard analysis, where minimum depth within a pixel and the occurrence of coral or rocks vs sand or vegetation are of primary concern.

2.0 MULTISPECTRAL BATHYMETRY

The phenomenology for deriving water depths in clear water from received pixel irradiances is based on the exponential attenuation of light as a function of distance traveled through the water and on the reflectivity of the bottom, both as a function of wavelength (LY Zenga, 1978; Clark et al., 1987; Philpot,1989; Walker et al., 1990). It is assumed that a multiband log-linear regression model can be used for calculation of depth, even though there are spectral variations in the attenuation and bottom reflectance across the sensor band passes.

The multiband spectrum of a pixel (in digital number units) can be represented by the expression:

$$P(n) = 0(n) + (G(n) * L(n)) \qquad (1)$$

where $0(n)$ and $G(n)$ are the offsets and gain factors, respectively, for the sensor in band n. $L(n)$ is the pixel irradiance in band n at the entrance aperture of the sensor, and it can be approximated by the expression:

$$L(n) = K_1 * L_{atm}(n) + (1 - K_1) * L_{water}(n) \qquad (2)$$

where $K_1 * L_{atm}(n)$ is the contribution from atmospherically scattered solar radiance, and $(1 - K_1) * L_{water}(n)$ is the irradiance emerging from the earth's surface.
$L_{water}(n)$ can be further approximated by the expression:

$$L_{water}(n) \cong K_2 * L_{surf}(n) + (1 - K_2) * (L_{vol}(n) + L_{bot}(n)) \qquad (3)$$

where $L_{surf}(n)$ is the irradiance due to specular surface reflections of the sun (glints) and sky; $L_{vol}(n)$ is due to back scattered radiance from the water column; and $L_{bot}(n)$ is the irradiance component due to reflections from the bottom. K_2 is the fraction of the earth's surface irradiance contributed by $L_{surf}(n)$.