DIGITAL SIGNAL PROCESSING FOR IMPROVED BOTTOM TRACKING

Hydrographic Surveying in Dense Aquatic Vegetation

It can be difficult to detect the true bottom depth beneath dense Submersed Aquatic Vegetation (SAV) using current hydrographic echo sounder systems. High acoustic reflectivity of the vegetation can result in depth declarations within the vegetation canopy. This leads to underestimating bottom depth and overestimating dredging quantities required.

This is demonstrated at a harbour, densely colonised with a robust bladed seagrass. Two echo sounder systems were used simultaneously - one a widely used single-beam hydrographic echo sounder; and the other a similar system designed to detect SAV. Dramatically different results are attributed to differing signal processing approaches. This is further explored by evaluating alternative Digital Signal Processing (DSP) approaches using recorded raw digital signals from the vegetated harbour. Several easily implemented approaches are identified and described, which could significantly improve bottom tracking performance without expensive sensor hardware changes.
An echo sounder transmits short monotone acoustical pulses into the water column. The system receives the echoed pulse and measures elapsed time, which translates to distance. Modern echo sounders use DSPs to make rule-based bottom detections. These rules are typically based on the echoed pulse amplitude and width. While this approach generally works well, there are naturally occurring conditions, such as dense schooling fish, fluidised mud bottoms, and SAV, for which accurate bottom depth determination fails.

Site Description

The survey was conducted in Wood Island Harbour channel, Maine (a US Army Corps of Engineers small boat harbour along the New England coast) during July 1998, the month of peak seagrass density. A channel section 150 ft wide by 2,200 ft long (NE/SW orientation) was surveyed with six longitudinal transects at a 25-ft transect spacing. The sandy-bottomed channel had depths ranging from 8 to 18 ft (MLLW), and the south-western portion of the channel was heavily colonised with eelgrass (Zostera marina), an ecologically important seagrass species with robust blades growing to lengths in excess of 3 ft.

Equipment and Data Processing

The resident system on the survey vessel was an Odom EchoTrac 3200 MKII (Odom Hydrographic, Baton Rouge, LA) with a 200-kHz, 8-degree transducer. The systemâ€™s DSP detects the bottom when the echo peak exceeds a specified width and is within a specified tolerance from the previous bottom detection. The second system is the Submersed Aquatic Vegetation Early Warning System (SAVEWS), which uses the Biosonics DT4000 digital sounder (Biosonics Inc, Seattle, WA) with a 420-kHz, 6-degree transducer. The SAVEWS DSP examines the distribution of echo peak depths within a region of adjoining pings and selects the most commonly occurring depth mode to output. Additional features and processing, described elsewhere, are used to estimate SAV height and density. SAVEWS was temporarily installed on the survey vessel. Each system records data at different rates and uses separate real-time differentially corrected GPSs for georeferencing. Following the survey, data from both systems were corrected for tide and merged to a single file based on pairing closest outputs from each system. The resulting data set contained over 8,000 paired data points.

Survey Results

SAV conditions, delineated by SAVEWS, ranged from unvegetated in the northeastern end to dense (100 percent coverage) tall (>3 ft) vegetation towards the Southwest end of the channel. Depth results for the two systems were in close agreement for unvegetated areas but Echotrac depths were increasingly less than SAVEWS depths as SAV coverage increased. This discrepancy is statistically significant for all vegetated areas (Figure 1). No separate physical ground truth measurements were made to determine absolute accuracy of each system, however, earlier work has shown that SAVEWS depth determinations are accurate for a wide range of SAV densities. This discrepancy averaged 0.24 ft over the 7.6-acre area surveyed (computed as a plant-coverage-weighted average), corresponding to a volumetric bias of 2,900 cubic yards.

Exploring Alternative Processing Techniques

Because sensitivity to small targets increases with the frequency of the transmitted pulses, it is reasonable to expect that echoes from the seagrass were stronger in the 420-kHz SAVEWS signal than the 200-kHz Echotrac signal. The fact that bottom detections from the Echotrac are frequently within the vegetation canopy suggests that the problem lies in the signal processing and not the signal itself. To investigate DSP options, a single transect, collected by SAVEWS, was selected for processing using different bottom-tracking algorithms. A colonised echo intensity plot of this transect (Figure 2) shows key features of vegetated and unvegetated areas. The bottom is the strongest echo return in unvegetated areas (pings 180-240) and frequently, but not always, in vegetated areas (pings 640-760). Within a localised area (say +10 pings) the bottom depth changes little compared with the top of the SAV canopy. This is attributed to the naturally patchiness of SAV. Echo intensity for a single pulse in a vegetated area (Figure 3) illustrates the reflectivity of vegetation above the bottom.

Two DSP approaches are tried, each with two variations. In the first and simplest approach, a single feature is used to detect the bottom without regard to adjoining pings. These two features, illustrated in Figure 3, are the peak and the trailing edge. Peak feature depth is output at the peak in signal voltage without a peak width test or a depth tolerance test. This is intended to serve as a baseline for comparison with other techniques, since it is a simplistic version of the DSP within the Echotrac system. Trailing edge feature depth corresponds to the depth at which the signal drops below -50 dB. This depth is further corrected for pulse duration since it is not a leading edge feature. This is one of the basic bottom tracking signal features used in the SAVEWS processor. In the second approach depth declarations generated from the single feature approach are post-processed with an 11-element moving mode filter. At each position of the filter window, the most common value is picked, similar to the SAVEWS bottom-tracking algorithm. Within a localised region, bottom depth would be expected to change very little but plant height or other bottom irregularities would be more variable; thus, the true bottom should occur around the modal value, even if it is not correctly detected by the single-feature detector.

DSP Results

The resulting depths for each DSP approach are illustrated (Figures 4 and 5) along with the estimated height of eelgrass (portrayed in green), as determined from SAVEWS. When the green line converges with the other lines, vegetation is absent. The single feature depths (Figure 4) show generally good agreement in areas of low eelgrass density. In dense SAV, peak feature depths frequently â€˜spikeâ€™ up into the vegetation canopy, becoming shallower than trailing edge depths. In most cases, the trailing edge feature depths track the apparent bottom in Figure 2; however, in a few instances, they exhibit spikes above the apparent bottom. The effect of mode filtering (Figure 5) is to greatly reduce, but not entirely eliminate, the apparent â€˜spikingâ€™ of depth in dense eelgrass. Both mode filtered variants were within 2 inches of each other, except for a single spike in mode filtered peak around ping 680.

Conclusions

The tendency of a conventional bottom-tracking DSP to underestimate true bottom depth in seagrass areas was observed and confirmed. The trailing edge depth feature appears to be less affected by vegetation than the peak depth feature for bottom tracking. The success of both features is improved by mode filtering; however, this needs some qualification. Mode filtering has the effect of throwing away outlying points, which may or may not be appropriate. For vegetated sandy-bottom conditions, the true bottom depth changes very little over a region of 10-20 adjoining pings and mode filtering works well to discard errant depth features attributable to the vegetation canopy. Conditions may arise where an apparent outlier depth measurement is an object significant to navigation, such as a boulder or a wreck. Therefore, this approach should be used cautiously and some â€˜intelligenceâ€™ may be required through development of additional features.

This preliminary study demonstrates the feasibility of improving bottom-tracking performance of single-beam echo sounders in vegetated environments. This can be achieved with minor changes to the DSP and without the expense of new sensors. The performance of these alternative processors should be investigated further under a wider range of conditions and similar approaches in multibeam systems should be implemented and tested.

References

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