CUBE: Extended Applications

Many hydrographers consider the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm a useful aid in processing bathymetric data and Ã¢â‚¬ËœmeasuringÃ¢â‚¬â„¢ survey quality. This paper discusses extending the use of CUBE to include determining multi-beam echo sounder (MBES) offset parameters and navigation offsets between overlapping survey lines.

One critical process in MBES surveying is determining system offset parameters by conducting a patch-test. Roll offset is typically recognised by unrealistic bottom slopes. Pitch, time and yaw offsets are recognised by seafloor features appearing dis-
placed when surveyed on different lines where survey speed and/or direction vary. Detecting displacements is difficult in shallow water because they are often comparable to the MBES navigation uncertainty. Determining the optimal system offset parameters in a shallow water patch-test presents a challenge for hydrographers.

CUBE-aided Test

CUBE estimates of depth uncertainties can be used to determine MBES offset parameters. The technique is demonstrated using a portion of the Shallow Survey 2005 Common Data Set collected in Plymouth Harbour, UK with a Reson 8125 MBES. The data was processed in CARIS HIPS and a feedback loop was estab-
lished which returned through the HIPS Vessel Configuration File (VCF). The CUBE algorithm was used in the feedback loop to estimate depths and depth uncertainties. The CUBE-aided patch-test assumes that there are uncertainties associated with individual MBES measurements and ancillary data. Consequently, a CUBE-aided determination of system-offset parameter is more robust than a determination using the traditional approach, which assumes no random errors in the data.

Implementation

In the CUBE-aided patch-test, depth uncertainties are determined for a spatially restricted set of bathymetric data. The system-offset parameters in the HIPS VCF are redefined and the data is processed again through HIPS and CUBE to obtain a revised set of depth uncertainties that should differ from the initial set. The difference indicates how to further redefine the offset parameters to reach a min-imum set of uncertainties. The CUBE-aided patch-test uses specific survey lines to emphasise one system offset or another. For determining the time and roll offsets, portions of Reson 8125 data from the Shallow Survey 2005 Common Data Set were select-ed based on their depths, speeds and reciprocal orientation of the track lines.

Time and Roll

The estimation of CUBE depth uncertainties was initially made using the original VCF time offset entry of zero and then repeated several times using different values. A min-imum was achieved when the time offset was 0.02s. Roll offset is normally determined as half the difference in cross-track slope of the bottom when surveyed from opposite direc-tions. The CUBE-aided scheme for determining the roll offset does not look directly at cross-track bottom slopes but rather views the depth uncertainties as having a component due to any slope differ-ences. A minimum in depth uncertainty was achieved when the value for roll offset was -0.66 degrees, which is very close to the original VCF entry of -0.68 degrees.

Pitch and Yaw

The determination of pitch offset used the overlapping, reciprocal survey lines 13 and 14. The determination of yaw offset used lines 12 and 14 that are parallel, partially overlapping and running in the same direction. Optimal offset values were determined to be 0.92 degrees for pitch and 0.31 degrees for yaw, whereas the original VCF entries were both zero.

Assessing Offsets

The CUBE-aided patch-test provided optimal values for time, roll, yaw, and pitch offset parameters based on a few lines chosen from the Shallow Survey 2005 Common Data Set. The impact of optimising the offset parameters for the Reson 8125 was assessed using the entire inshore area of the Shallow Survey 2005 Common Data Set. The depth uncertainties were estimated using the original offset parameters and then re-estimated using the revised optimal offset parameters. The optimal offset parameters resulted in a reduction in estimated uncertainties compared to those associated with the original offset parameters. Figure 3 shows the percentage reduction in uncertainty, which clearly increased with depth.

Assessment

When developing the total propa-gated uncertainty for a survey sound-ing, the horizontal uncertainty in position of the sounding is required. A CUBE-aided technique for evaluating navigation performance during a particular survey is shown in Figure 4. North-south and east-west slopes are estimated separately using the CUBE depths for the MBES data from two overlapping survey lines. The spatial offset between the two sets of seabed slopes indicates relative differences between the navigation data for the two survey lines. This proced-ure was applied to a pair of Reson 8125 survey lines from the 2002-2003 Morocco Maritime Survey near Cap Spartel, Morocco. The survey site, survey results and a highlighted subsection are shown in Figure 5. The navigation data for the two lines were shown to be offset N/S by 0.62m and offset E/W by 0.27m. The navigation offsets determined by this procedure are consistent with results expected for the half-metre Sky Fix GPS used as primary source of navigation.

Re-navigation

Joint processing of data from the two overlapping Cap Spartel survey lines that exhibited navigational offsets resulted in the CUBE depth uncertainties being elevated by cross-coup-ling between the true bathymetry and the offsets in navigation. The navigation data for one of the survey lines was modified, as depict-ed in Figure 4, and the data for both survey lines was jointly re-processed through HIPS and CUBE. The new set of depth uncertainties was different from the set prior to correcting the navigation data: a 15% reduction in total variance in comparison area. This reduction was a direct result of having optimally re-navigated one of the two overlapping survey lines.

Further Benefit

The data from the same two Cap Spartel survey lines was processed separately by CUBE, each with its original navigation. The data from the survey line with the modified navigation data was also separately processed.

Concluding Remarks

It has been shown that the estimated uncertainties of depth from CUBE may be used in determining optimal values for MBES time, roll, yaw and pitch offset parameters. This extend-ed application of CUBE is well suited for patch-tests conducted in shallow water. It has also been shown that CUBE can be utilised for assessment of navigation offsets, provided there are pronounced changes in seabed slope that are detectable in the overlapping areas of multiple survey lines. This extended application of CUBE can be used to estimate the relative offset between two sets of navigation data but cannot be used to estimate the accuracy of either set.

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