SHADE CORRECTION OF SIDE-SCAN SONAR IMAGERY BY HISTOGRAM TRANSFORMATION

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ABSTRACT - **Systematic intensity variation with range across a sidescan sonar record, or "shading", degrades visualisation, and is particularly distracting when repeated in each record forming a sonar mosaic. Shade variation is difficult to predict, not only because of uncertainties in the instrument function, but also because backscatter variation with incidence angle, and hence range, depends on seabed material. The paper describes a method of shade correction in which the correction is computed from the statistics of the record itself. This is first segmented into a number of classes of seabed material using a statistical classification program, and then column histograms for each different type of material are equalized with each other by a table look-up procedure. The paper discusses the relevance of good segmentation to geometric as well as shade correction for the sonar mosaiccing task**

1. INTRODUCTION

"Shading" is used in image analysis to denote systematic intensity variation across an image due to instrumentation. Almost all raw sonar records are subject to intensity variation with range. This variation is so familiar that it often passes unnoticed on the individual chart record. However it can be a considerable disturbance to the eye and the interpreter when records are combined into a mosaic.

The backscattered sonar echo is attenuated with increasing range, not only because of spreading loss in both directions, but because grazing angle with the seabed normally decreases with increasing range. Hence all survey sonar instruments include some form of TVG (time-varying gain) to reduce the dynamic range of the signal before display. If a number of conditions are satisfied - the gain parameters in the sonar instrument are properly recorded, the elevation beam pattern is known, and the backscatter variation with grazing angle follows Lamberts Law - it is possible to make predictions about intensity variation with range, and to compute a TVG which will compensate reasonably well. However Lambert's Law is an approximation to backscatter variation with grazing angle, suitable only for shallow incidence angles. The true variation depends on surficial sediment, bedrock, or other material forming the seabed surface [1,2]. Hence, even in principle, some form of seabed classification is required before an accurate TVG can be computed. Because computation of a good TVG function is difficult, many instruments in current service today allow the operator to modify the TVG function to optimise the output on a chart recorder, unfortunately without recording the setting. The Klein sidescan sonar in "Ocean Surveyor" the research vessel operated by Geological Survey of Sweden (SGU) is an instrument of this kind. However the vessel is equipped with extensive equipment for digitizing and recording both sonar and navigation data, so the urgent requirement today is to store consistent data on the digital record. To overcome the TVG problem to some extent, the Ocean Surveyor operator is instructed not to change settings after recording has started. However no calibration is carried out.

Chalmers University is collaborating with SGU under the Nordic Industry Fund "ESMAC" (Environmental Seabed Mapping and Characterization) Project in the development of a high quality, semi-automatic mosaiccing package for existing sonar instruments. The method of shade correction presented here forms part of this work, and is designed to cope with backscatter dependance on seabed material, and also with an unknown TVG function. Hence the shade correction must be computed using statistics derived from the image itself. The use of pixel histograms for shade correction is not new: "histogram equalization" to stretch contrast and correct shading in sidescan sonar imagery is described in [3]. However the equalization technique is designed to convert the measured histogram into a uniform histogram, which almost certainly destroys part of the information content of the image. The method proposed here is designed to preserve the characteristic histogram shape for each of the different materials making up the seabed, at least as far as they can be distinguished by a classification program.

2. TRANSFORMATION OF RANGE-DEPENDANT INTENSITY HISTOGRAMS

Fig.1 shows a 800m section from a record made in the Kattegatt using a 380 kHz Klein sidescan sonar. Survey practice is to maintain the height of the towfish constant above the seabed as far as possible, which should give good correlation between incidence angle of the sonar beam with the seabed and slant range - especially as the seabed tends to slope quite gently in offshore Sweden.

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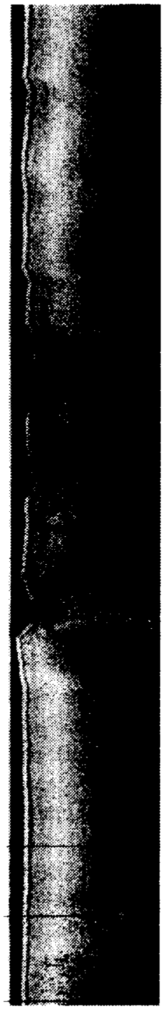

Fig 1 Test Section of 380 kHz Sidescan Sonar record.

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The displayed record contains 1380 columns, or digital samples, extending out to a slant range of about 50m. The sonar signal was digitized with 12 bits precision, although only 8 bits are used to generate in the image. Figs 2-4 show three test regions selected from this record consisting of different seabed material and which appear to be homogeneous out to maximum range The regions might be classified as "mud", "sand", and "rocks" respectively, although the true geological classification is strictly irrelevant. The only obvious range dependency in the "mud" image is the change in mean intensity. However the "sand" region also shows a loss of.contrast at close and far range. At close range the steep grazing angle reduces the difference in backscatter between facing and trailing slopes, while at the longest range much of the variation is lost in increasing sonar shadow. A similar loss of contrast is observable in the "rocks" sample

Figs 5-7 show pixel intensity histograms derived from each region. These were obtained by dividing each image into 8 blocks of columns numbered 0-7. 8-bit pixel intensity histograms were then collected for each block. The images have previously been bottom-tracked so that pixels in the water column could be excluded and blocks containing no valid pixels flagged. Histograms are shown for blocks 2,4,7, together with mean intensity, sd, and sd/mean. which is a measure of contrast in the image at the given range. These histograms and statistics confirm the observations, and the change of histogram shape with range for the sand and rocks region is very noticeable.

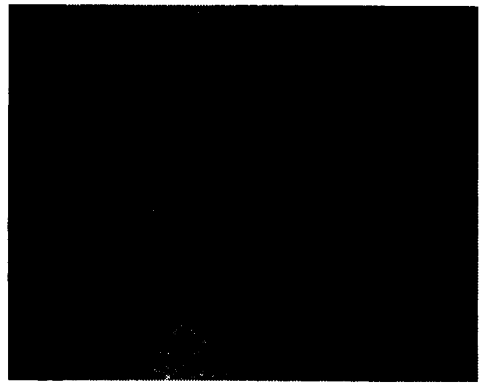

Fig 2 "mud"

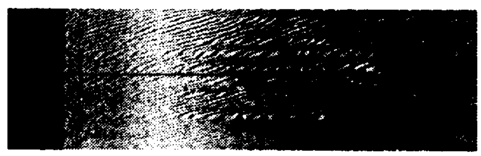

Fig 3 "sand"

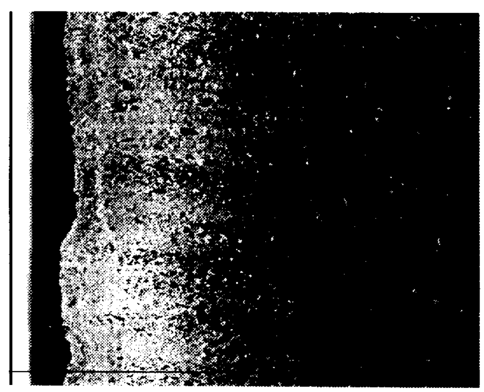

Fig 4 "rocks

Sections of different seabed material selected from Fig 1 and corrected for shade variation with elevation angle.

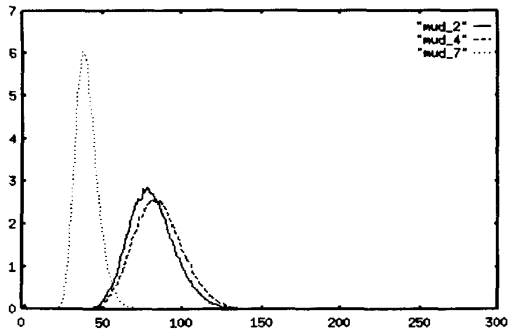

Fig 5 "mud" histograms, columns 2, 4, 7

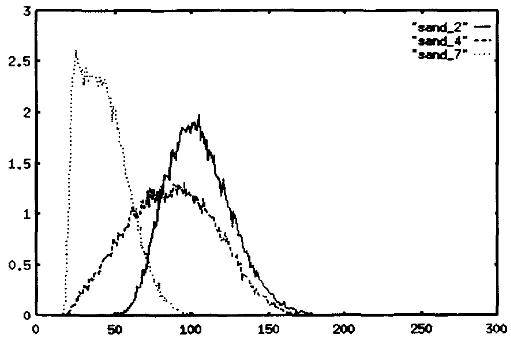

Fig 6."sand" histograms, columns 2, 4, 7

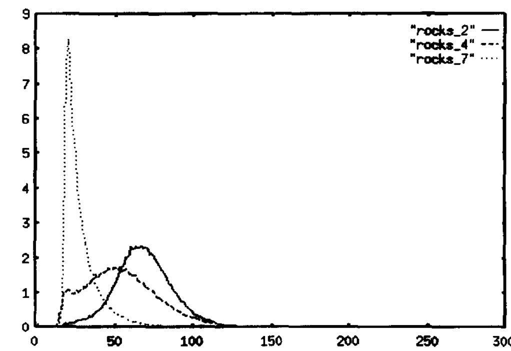

Fig 7. "rocks" histograms, columns 2, 4, 7

A set of pixel intensity look-up tables are now computed for each of the test images which effectively equalize column histograms with one another. This procedure is particularly straightforward here since redundant bits in the 12-bit data can be used to reduce quantization holes in the transformed histograms. A 10 -> 8-bit look-up table is constructed which maps each column histogram on to a target histogram chosen here to be the centre histogram (column 4). When carrying out the shade compensation operation, the look-up tables are interpolated between column centres to avoid shading discontinuities in the corrected image. The shade-corrected test images are shown in Figs 8-10 while Fig 11 shows column histograms for the compensated "rocks" image, indicating the success in matching across the image.

The raw image (Fig.1) shows a significant shade variation following the line of the bottom return due to the elevation beam pattern of the side-scan sonar, modified by the contribution of specular reflection at near nadir incidence. This specular component will also depend on seabed material. Before correcting the test images for shade variation with range, an initial correction is made for this variation with elevation angle, again using statistics gathered on each image. However this correction does not involve histogram transformation so far.

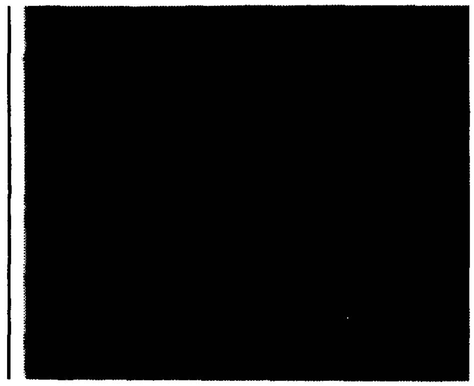

Fig 8 "mud"

Fig 9 "sand"

Fig 10 "rocks"
Test images after histogram-based shade correction

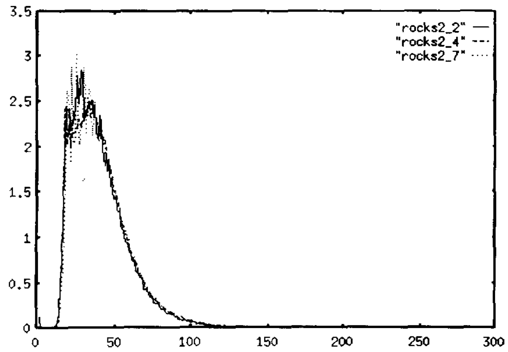

Fig 11 Histograms for columns 2, 4, 7 after shade correction of "rocks" image.

3. SHADE CORRECTION WITH SEGMENTATION

In the previous illustration, three homogeneous rectangular regions were selected from the survey line by eye. However a method is required which will gather statistics from a set of irregularly shaped regions. It is impractical to carry out the required segmentation manually, so computer segmentation of the image is required both for statistics gathering and correction. There has been increasing interest in computer techniques for classifying sonar imagery since the publication by Pace of a method using the spatial frequencies in the sonar image [4]. This technique does not rely on estimates of the absolute backscatter coefficient, which are not available from a conventional side-scan sonar instrument (because of the unknown incidence angle at the seabed). The method used here is based on features used by the Norwegian Computing Centre for sediment classification from Simrad EM1000 Multibeam data [5], omitting the feature related to local backscatter coefficient ie:

a) "Pace feature" derived as in [4],
b) A texture feature derived from the GLCO (grey-level co-occurrence) matrix - "contrast),
c) local sd/mean.

Fig 12 shows the segmentation of Fig 1, using the above features. The program was trained to discriminate three classes, "mud,sand,rocks", with a fourth class for unknowns or outliers. An auxiliary image is generated in which each pixel is labelled with the corresponding class number. Shade correction is carried out in two passes of both images together. The first pass is used for histogram collection, and look-up table generation. The second pass is used to equalize histograms. The result is shown in Fig 13. The initial correction for shade variation with elevation angle was applied to the whole image using statistics gathered from a selected region. This correction program has not been modified to collect statistics separately for regions determined by the classification program.

Shade correction in. has clearly gone wrong in a few places at far range due to outliers in the classified image. However the correction at short range near the bottom return is more seriously in error. This is attributable to misclassification of blocks containing the bottom return visible in Fig.14. The classifier is unable to cope with the extreme shade variation near the bottom return., together with changes to the backscatter statistics at steep grazing angles. Thus there seems to be a vicious circle in which shade correction is required to achieve good segmentation of the image and good segmentation is required for shade compensation. However there are several possible ways round the to reduce this problem, including the naive one of giving each block containing the bottom return the class of its longer-range neighbour. However the classification program is not ideal for the current purpose so it would be better to start from a program specifically designed for segmentation instead.

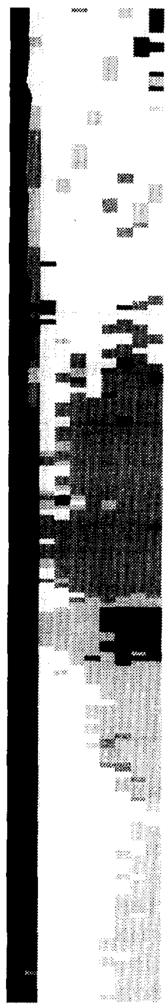

Fig 12
Segmentation of Fig.1

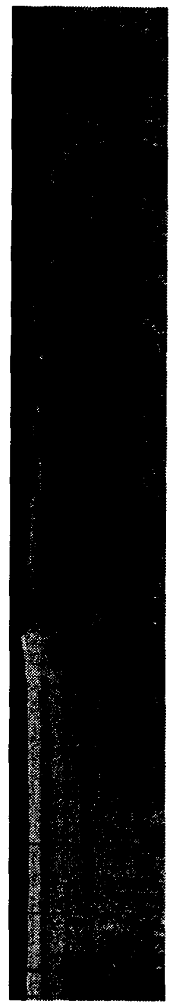

Fig 13
Fig1 after shade-correction

4. DISCUSSION

The shading method relies on stable statistics for each seabed type which is distinguished in the classifier. These may be difficult to obtain from a single survey line, so it can be better to generate histograms from the entire set of lines making up a survey area. The same target histograms can then be used for all the records in a mosaic of the survey records. This has the important advantage of equalizing shading across the entire set of records.

The sediment classification program is not ideal for the segmentation task, since classification is based on rectangular blocks of 640 pixels, 40 rows x 128 columns, occupying an area of roughly 0.5m x 0.5m on the seabed. This block size may be adequate for the geological purpose, but leads to a distinct "blockiness" in the classification. A better solution would to use a program specifically designed for segmentation, and able of following irregular region boundaries, such as the fractal procedure described in [6]. This has the further advantage that geometric correction between overlapping records in a mosaic could be carried out by alignment of segmentation boundaries.

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