

Single Beam Acoustic Seabed Classification Technology from QTC

Acoustic Seabed Classification is the organization of bottom types (seabeds, lake beds, river beds) into discrete units based on a characteristic acoustic response.

Rationale

Seabed classification can be done visually, mechanically, and acoustically. All visual methods (divers, video, photography) and mechanical methods (divers, grab samples, cores, probes) are slow and manually intensive, thus expensive and not suited to extensive survey work. Acoustic methods, can cover large areas quickly as there is no need to stop the survey vessel. The power of acoustic seabed classification is the ability to apply visual or mechanical classifications over much larger areas than point data alone would allow; that is, the sediment properties obtained from the point samples can be applied with confidence over entire regions that have been mapped acoustically.

Acoustic classification with single beam echosounders is simple to deploy and operate, does not require sophisticated survey platforms, and has been demonstrated to provide detailed, highly descriptive information, including:

- sediment classification
- geotechnical properties
- biological influences
- habitat suitability

Tools

Acoustic remote classification of the seabed requires an acoustic data acquisition system, digitization of the data, and a set of algorithms that analyze the data to determine the logical acoustic classes. The data processing relies on the extraction of characteristic features from the seabed echo. Dedicated seabed classification systems consist of integrated hardware and software. Quester Tangent provides a suite of three products designed to provide accurate and repeatable classification from less than 1 metre of water to over 2000 metres, depending on the echosounder used. The products are:

- QTC VIEW 5.5 (QTC5.5) – acquisition hardware that interfaces to most echosounders
- QTRT – software for data acquisition control and delivery of real-time seabed classification results
- QTC IMPACT – software for post processing digital echo trace data

This suite of products provides a user the following options

- Use an analogue echosounder with QTC5.5 and QTRT for real-time seabed classification, while, if desired, logging the raw data to post process in QTC IMPACT.
- Directly post process data acquired with a QTC-supported fully digital echosounder in QTC IMPACT, and, if desired, add QTRT for real-time classification.

Technology

Quester Tangent's products take a dataset representing a complex, highly variable target, the seabed, and reduce it to a minimum set of descriptors (echo features) while maintaining information to distinguish one seabed from another. This approach, predicated on detecting changes in substrate, encompasses three main steps:

- echo digitization – the sampling of a voltage varying with time as the acoustic energy of the returning echo is converted to electrical energy at the transducer. The data contain water column and seabed information. To minimize data volumes a window surrounding the seabed/water interface is retained for processing. The technology uses the first echo return only from the seabed. This maximizes accuracy and repeatability, and obviates problems associated with attempting to capture and process the multipath (second) echo. The second echo could, for example, be influenced by external factors such as sea state or the bottom of the survey vessel.
- echo description – a series of algorithms is applied to extract many features relating to the echo shape. The character of the returned echo trace is controlled by features of the seabed, thus generating signatures that can be grouped in classes representing different seabed types. The algorithms for this process are:
 - Cumulative amplitude and ratios of samples of cumulative amplitude
 - Amplitude quantiles
 - Amplitude histogram
 - Power spectrum
 - Wavelet packet transform
- echo classification – the features generated by the algorithms are statistically processed to generate the three principal components describing each record. This process isolates the most useful features use to describe seabed variability and enable grouping the records into classes representing seabed composition.

Approach to Classification

The technology can be used to provide either “supervised” or “unsupervised” classification. Supervised classification relies on a pre-defined classification catalogue as a reference. However, if the initial data were a complete survey with no predetermined classification, then unsupervised processing will define the classification, and ground truthing or correlation with other data will provide identification of the physical nature of each class.

QTC5.5 can be used to acquire data for subsequent unsupervised classification in QTC IMPACT. In addition it can simultaneously provide real-time classification, if supplied with a catalogue. QTC IMPACT software can generate unsupervised classification (i.e. generate a map of acoustic diversity) or can create catalogues for use in QTC5.5, or for future supervised processing of data in QTC IMPACT.

Procedure

The unsupervised classification process to move from a data set to a map of the seabed follows a number of well defined steps:

- **Data loading** – load digitized raw echo trace data (time-series) collected by a QTC VIEW or by a suitable digital echosounder. Visit www.questertangent.com for a current list of supported echosounders.
- **Apply quality control** – inspect and ensure bottom picks are accurate, echoes are not clipped or noisy, and have sufficient dynamic range. Edit or apply filters as required.
- **Generate features** - apply the suite of classification algorithms to generate features describing the echoes. This will generate 166 features for each record. Each set of 166 features is called a Full Feature Vector (FFV).
- **Data reduction** – reduce the FFVs to their three principal components using a standard statistical routine, Principal Components Analysis. These first three components are labeled Q1, Q2 and Q3. Thus each record from the seabed is represented by its three Q-values.
- **Cluster** – plot the three Q-values in Q-space, initially as a single class, and apply 3-D clustering to separate the data into logical classes. Records from seabed types with similar acoustic signatures will tend to cluster in the same area of Q-space, thus delineating discrete acoustic classes to be associated with ground truth information. Clustering can be done manually, or using an objective Automated Cluster Engine, ACE.
- **Output results** – complete classification. The classification result is output as a "*.seabed" file, a comma-delimited ASCII file, ready for import to almost any GIS or mapping software. A description of the .seabed file is given below in Table 1.
- **QTC CLAMS processing** - the "*.seabed" file can be imported into QTC CLAMS software for interpolation and the assignment of similarity colours (acoustically similar classes are automatically assigned similar colours). Output from QTC CLAMS is a geoTIFF, XYZ file, Surfer grid file or regular TIFF image.

The classification result generated above can be stored as a catalogue to be used for real-time classification with QTRT, or for supervised processing of other data sets in QTC IMPACT.

Product Details

The main features of the individual classification products are as follows:

QTC VIEW 5.5 data acquisition hardware

- High rate of data digitization permits classification as shallow as 80cm below the transducer
- Sophisticated AGC ensures very high dynamic range
- Low power consumption - 15W @12-36 VDC
- Interface to survey computer via USB
- No calibration required for unsupervised classification

QTRT software

- Acquisition software for QTC5.5 or QTC5, provides excellent real-time control during acquisition with intuitive views and options for data quality assurance.
- Simultaneous data logging for post-processing and real-time classification display
- Real-time seabed classification results overlaid on ENC
- Supports BSB, S57 and GeoTIFF charts

QTC IMPACT

- Software only solution for classification of QTC VIEW or digital echo sounder data
- Flexible processing options for detailed research, or simple automated processes
- Supports both unsupervised or supervised classification approaches
- Accurate bottom picking, quality control and echo trace visualization
- Automated, objective clustering determines class assignments
- Processed data presented as simple GIS-ready ASCII file

Results

QTC IMPACT's final output is a data table in comma-delimited ASCII, the *.seabed file, as illustrated below, ready for import into GIS systems or mapping software for correlation analysis and chart production.

```
20020629,130044565,459046.64,6391565.26,-16.74,3.50688839,4.80144691,5.53823996,73,31,04,CLASS_04,BRISTOLBAY,20020629,180-1256,1,31598
20020629,130044565,459039.67,6391547.39,-16.74,3.76193619,5.15492630,5.35759115,88,45,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31599
20020629,130044565,459033.18,6391530.71,-16.74,3.94836569,5.56753254,5.36549187,90,16,13,CLASS_13,BRISTOLBAY,20020629,180-1256,1,31600
20020629,130052376,459086.59,6391608.22,-16.74,3.80727029,4.50204706,5.35253811,97,68,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31601
20020629,130052376,459090.17,6391627.22,-16.74,3.56124330,4.87952328,5.34849310,99,45,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31602
20020629,130052376,459093.49,6391644.81,-16.74,3.15812778,5.25479698,5.44480944,88,01,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31603
20020629,130052376,459078.06,6391562.97,-16.74,3.48449183,4.80661488,5.49290037,77,19,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31604
20020629,130052376,459074.50,6391544.12,-16.74,3.69095230,5.09069872,5.34871387,95,58,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31605
20020629,130052376,459071.19,6391526.54,-16.74,3.84349418,5.67339134,5.35787678,76,05,13,CLASS_13,BRISTOLBAY,20020629,180-1256,1,31606
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20020629,130100247,459122.39,6391625.94,-16.78,3.64113069,4.96888161,5.33101463,98,56,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31608
20020629,130100247,459127.73,6391643.03,-16.78,3.35211301,5.29924774,5.43109798,96,12,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31609
20020629,130100247,459102.50,6391562.39,-16.78,3.41151595,4.50575972,5.49443102,62,25,04,CLASS_04,BRISTOLBAY,20020629,180-1256,1,31610
20020629,130100247,459096.82,6391544.25,-16.78,3.57588291,4.98137712,5.32614088,98,33,07,CLASS_07,BRISTOLBAY,20020629,180-1256,1,31611
20020629,130100247,459091.48,6391527.20,-16.78,3.77097106,5.52929449,5.33657932,63,09,13,CLASS_13,BRISTOLBAY,20020629,180-1256,1,31612
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Table 1: A typical *.seabed file

Sample Data	Description	Details
20020629	Date stamp	ccyymmdd
130044565	Timestamp	hhmmsshs
459046.64	Longitude or Easting	Full flexibility in position format
6391565.26	Latitude or Northing	Full flexibility in position format
-16.74	Depth in metres, displayed as a negative	float in metres
3.50688839	Q1 – represents Q-space value Q1	float values
4.80144691	Q2 – represents Q-space value Q2	float values
5.53823996	Q3 – represents Q-space value Q3	float values
73	Represents class Confidence	%
31	Represents class Probability	%
04	Represents class ID	nn
CLASS_04	Represents class Name	string
BRISTOLBAY	Source vessel or survey name	string
20020629	Source date stamp	ccyymmdd
180-1256	Source data set name	string
1	Source FFV channel or file ID	numeric
31598	Source FFV file record index	numeric

Table 2: Description of the *.seabed file

Applications

Quester Tangent’s seabed classification technology is equally at home in either marine or fresh water environments. It has been used for survey areas as small as 100 meters by 100 metres, to a project which provided classification of the entire eastern Bering Sea. Some typical applications of the technology are:

Environmental

Seabed Classification is a highly appropriate tool for environmental applications. This includes:

- **Identification of habitat** - e.g. for fisheries management purposes
- **Quantification of habitat** – e.g. for biomass estimations
- **Environmental monitoring** – e.g. for assessment of environmental health
- **Environmental clean-up** – e.g. in the case of spills of hazardous or polluting materials
- **Monitoring change** - Acoustic seabed classification is the only technology offering the capability to rapidly determine and monitor over varying periods of time, the biological health of a seabed, using relatively low cost, conventional survey techniques.

Military

- **Mine Counter Measures** – this technology can determine the risk for mine burial and provide an assessment of “geo clutter” to hide mines within sea floor features
- **Anti-submarine Warfare** – the QTC VIEW provides real-time data on seabed acoustic reflectivity which is a key information type for the algorithms used in submarine detection.
- **Route Survey** – mapping sediment type near strategic installations is a key component of site clearance activities.

Ports and Harbours

- **Security** - Port and Harbour security is an important application of the technology. This applies not only to the standard military security applications as above, but to regular Port and Harbour operations as well.
- **Monitoring** - regular, repetitive conventional surveys of the harbour combined with seabed classification techniques provide a relatively low cost option to accurately monitor the seabed within a harbour.
- **Hazards to navigation** - seabed classification provides an appropriate technology to establish and maintain safe routes into and out of the harbour, both from a navigation viewpoint and from a military viewpoint, i.e. threat of mines.
- **Environmental** - in addition to security related applications, the technology has numerous environmental and other benefits for harbour operations.


Hydrographic

The technology is increasingly being used to add value to hydrographic surveys. Seabed classification data can be readily acquired during survey exercises, at relatively low cost.

General

Other areas of application include

- **Coastal zone management** – locate offshore materials for beach replenishment
- **Dredging** – identification of source materials, (aggregate mining), and tracking of dumping of dredged material.
- **Commercial fishing** – identification of fishing grounds, reduction of by-catch by increased efficiency.
- **Oil and Gas Industry** - cost savings for offshore site / cable and route survey, environmental compliance surveys.

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