DIGITAL ACQUISITION OF HIGH RESOLUTION ACOUSTIC SURVEY DATA

A successful commercial product from an academic research programme

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1. INTRODUCTION

Acoustic techniques are widely used in the field of marine geophysics as a means of obtaining detailed geophysical charts of the seabed, sub-seabed (sub-bottom), and sea bed surface. Although there are a wide range of instruments used to obtain the basic acoustic information, there is one common problem; how to present the data to allow accurate analysis and interpretation.

For many years the off-shore industry approach to seabed survey has relied on analogue instrumentation for the collection of data. During a conventional survey data is acquired, displayed onto paper hard copy, and sometimes stored onto analogue tape. The paper record allows the operator to "visually" set up the survey equipment for optimum performance during the data gather. It is the paper record which usually provides the media for geophysical interpretation. Unfortunately the quality of such recordings is poor in terms of resolution and amplitude and often, much of the detail or information of interest is lost. Due to commercial pressure, many surveys are forced to produce records which can be geophysically interpreted on line, either as a final product or as an intermediate analysis. If more advanced post processing and analysis is required, data must be recorded on a replayable medium. The problem with analogue recording is that it is still a poor medium and is not a complete record (ie integrated data, navigation, acquisition parameters). Also, before data can be digitally post-processed the analogue data must be transferred onto an appropriate computer. Data transcription and processing may take many hours to analyse even a small region of seabed data.

Ideally, data should be acquired and stored in a digital format in the field, thus overcoming most of the elementary problems described above. Until recently however, such systems have only been available to the deep seismic market where system cost and physical size of the processors is not a constraint. Digital systems offer many benefits;

- Improved geophysical data interpretation
- Fully calibrated, wide dynamic range data capture
- Real-time 'in the field' data processing
- Fast access to stored, archived data
- Less physical volume for media storage
- Easy system expansion and interfacing to computer networks

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In 1986 GeoAcoustics Limited[1], started a collaborative research programme known as the Sonar Image and Record Enhancement project (SIRE)[2]. The aims of the project were to research and develop hardware and software tools to acquire, process and display high resolution shallow seismic and side scan data using proprietary algorithms and state of the art technology. From this early research the Sonar Enhancement System was developed.

2. PROTOTYPE

Off the shelf processors and standard peripherals were chosen as the platform for development as no alternative architectures were readily available which offered sufficient processing power and flexible upgrade routes. Early development of the system was conducted on a UNIX[3] workstation until the finer points of the design could be finalised. Once this was achieved, a customised workstation was designed and the software transferred. The OS-9 operating system[4] was chosen as it provided a real time operating environment, seen as essential for this type of system. By mid 1988, after several iterations of hardware, the first prototype system was completed. As well as fulfilling the aims of the original SIRE programme, the system had also by this stage been influenced by the requirements of commercial survey companies and the desire for a marketable product. Packaged into a robust case, the Sonar Enhancement System, was to be one of the first of a new generation of geophysical survey tools.

3. THE SYSTEM

The Sonar Enhancement System with GeoPulse Profiler System.

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The standard Sonar Enhancement System comprises of a work station, a colour graphics monitor and an operator terminal. Optional extras include a thermal linescan recorder and a secondary storage device such as a rewritable optical disk drive. Control is provided by a simple menu system on the operator terminal whilst the colour graphics monitor is dedicated to displaying data.

The main features of the Sonar Enhancement System workstation are:

- Four channel data acquisition system
- Large capacity on-line digital recording
- High resolution colour graphics display
- Suite of on-line geophysical processing tools
- Interface to navigation systems
- Interface to linescan and dot matrix printers

3.1 Data Acquisition System

The standard Sonar Enhancement System has a four channel data acquisition system. Each channel has an analogue bandwidth of 20 kHz allowing connection to most existing survey equipment. Sampling is 12 bit resolution with a maximum sampling rate of 10 uS. In addition to the four analogue input channels, there are also connections for trigger input and output. The Sonar Enhancement System uses a trigger to synchronise the data acquisition, which may be external or internally generated. Whichever mode of trigger is used, the trigger output facility provides the means of synchronising other equipment.

All the acquisition parameters (trigger rate, number of channels, sampling delay, sampling window, sampling rate) are fully user selectable allowing maximum flexibility.

3.2 Digital Recording

Digitised data may be stored in real time to either 8 mm helical scan tape, rewritable optical disk or hard disk. The tape option allows up to 2.3 GBytes of data to be stored which equates to between 4 and 25+ hours of data, depending on the data density. The optical disk option allows up to 1 GByte of storage or 2 to 12+ hours, and has the advantage of random access to any file or survey line.

All data is stored in the SEG-Y[5] format, allowing easy transfer of data to other off line processing or interpretation systems. Data may be stored raw (as digitised), or processed (after enhancement). Systems equipped with two storage devices may store both raw and processed data simultaneously.

3.3 Graphics Display

All digitised data may be displayed on the colour graphics monitor as a 256 level grey scale image, scrolling in real time. Up to four channels can be displayed simultaneously with any section zoomed as required. Because the system can acquire and save up to 10,000 samples per channel per shot, zooming has the effect of revealing more information rather than simply stretching the original image.

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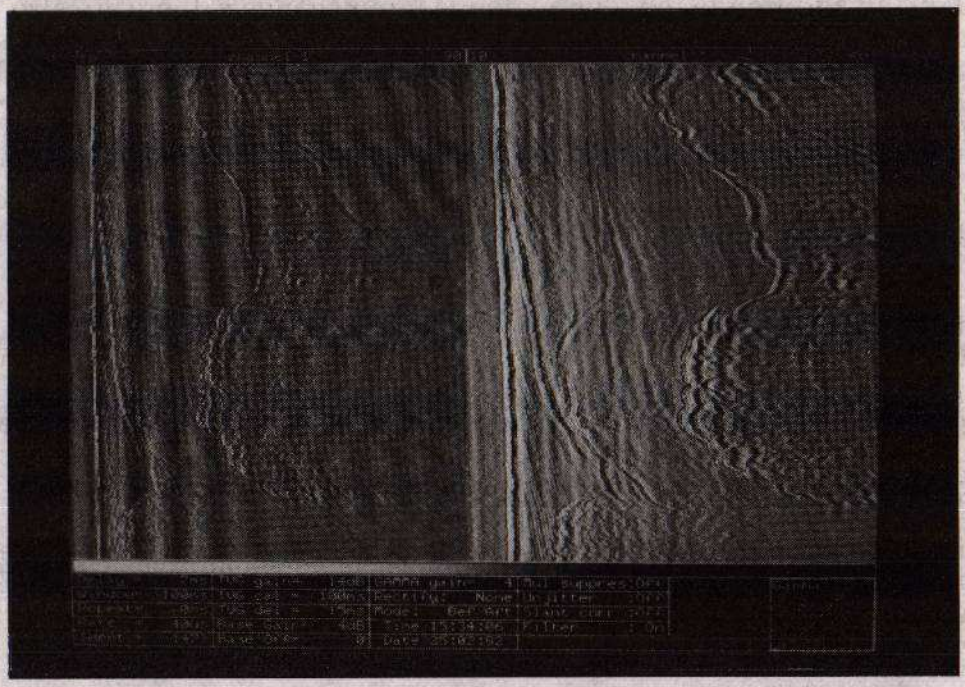
A range of gain and palette facilities are available to adjust the data to obtain the optimum visual image. These include:

- Base gain and offset (1 dB steps)
- Time varied gain (dual slopes with variable rate and delay)
- Rectification (positive, negative or full wave)
- Contrast stretching (gamma control)
- Four standard colour palettes
- Any user defined palette (256 from 16 million colours)

Status areas on the graphics screen show the settings of many of the above facilities together with the status of key processes and the scale of the displayed data traces. Again, all of the parameters are fully user selectable giving the operator the maximum flexibility.

A real time wiggle trace of the current data line (oscilloscope type display) may also be displayed along side the grey scale image to allow analysis of the data signatures, and help with initial system set up and data quality assurance.



Graphics screen showing raw and processed versions of sub-bottom profiler data.

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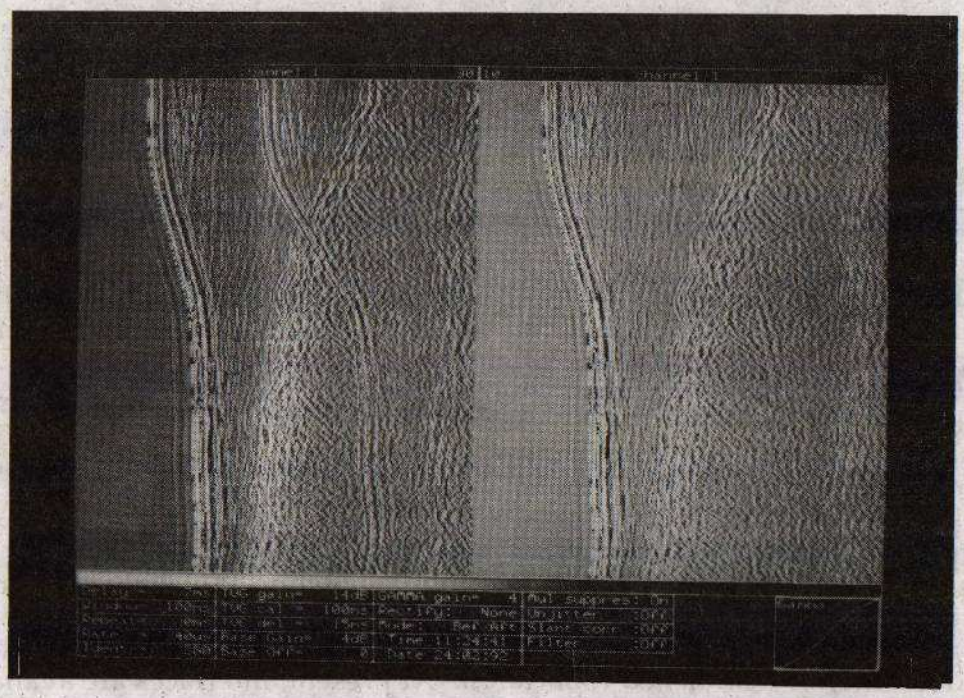
3.4 Processing

One of the most important features of the Sonar Enhancement System is its ability to perform data processing on line. All the processes operate on a continuous trace to trace basis in real time and can be applied to all, or selected channels as required. The main enhancement facilities include:

- Digital band-pass filtering
- Automatic bottom tracking
- Multiple suppression
- Unjittering (wave motion compensation)
- Slant range correction (for side scan data)
- DC component removal
- Water column noise removal

Digital band-pass filtering; independent upper and lower frequencies and roll off rate allow any band pass filter to be defined. This allows data which is corrupted due to power supply interference, ship noise etc, to be cleaned up for display, whilst preventing loss of information through the use of pre-digitisation analogue filters.

Bottom tracking; a bottom tracker is essential for many processes, especially multiple suppression, unjitter and slant range correction. The bottom tracker detects and tracks the sea bed and passes the position data to the other processes. The algorithm automatically adjust the search window, thus optimising its performance. Coloured markers can be placed on to the image to assist the operator in fine tuning the bottom tracker and also to check that it is detecting the bottom correctly.



Screen image showing effects of multiple suppression on right hand side.

Long multiple suppression; multiple echoes, due to multi-path reflections within the water column, can often cause great problems during shallow seismic surveys by masking the true data. A proprietary algorithm has been developed which can detect the multiple position and suppress the multiple interference so as to reveal the underlying features. The first multiple position is estimated using the bottom position from the bottom tracker. The data around this area is then correlated with the sea bottom wavelet to determine the multiple position more accurately. The multiple image is then suppressed in such a way so as to reveal any features which may have been previously hidden.

Unjittering; this facility allows compensation for image jitter due to wave motion (heave/swell etc) without the need for any motion detecting hardware (accelerometers etc). By using the sea bed position from previous traces, a statistical analysis can be made and the next seabed position predicted. By adjusting the bias of the bottom position between the detected and the predicted position, the data can be smoothed very effectively, without adversely affecting the bathymetric information.

Slant range correction; a proprietary algorithm allows correction of side scan images to compensate for geometric distortions due to the altitude of the fish above the sea bed. By using the bottom tracker, variations in fish height can be continuously compensated for, creating a correctly scaled image.

DC component removal; this is automatically applied by some of the other processes such as multiple suppression. It may also be manually selected to remove any DC offset which might be on the signal and would affect the image quality.

Water column noise removal; assuming the bottom has been detected successfully, it is possible to blank out the data prior to the bottom. This is useful for generally tidying up an image.

3.5 Navigation Interface

An RS232 port enables any string of ASCII characters to be added to the data for annotation purposes. This data may originate from any source, such as a navigation computer, and can be in any format up to 32 characters long. A more sophisticated interface has been developed which identifies specific navigational information and places it in special fields of the SEG-Y format. In certain cases the information (such as water depth, fish altitude etc) may be used directly by processing algorithms. In addition to inputs from external sources, annotation may be input from the keyboard and numbered fix marks may also be entered using a "hot-key".

3.6 Printer Interface

A parallel printer port allows connection to a wide selection of printers. The printed image duplicates the image displayed on the colour graphics screen, therefore any printer can display up to four channels with full annotation. Since many thermal printers can print up to 4096 points per line, and the system can acquire and store up to 10,000 points, the printed image is usually of a higher resolution than the screen image and not merely a stretched replication. At present, interfaces are available for most popular linescan printers from suppliers such as EPC, Dowty and Raytheon, and common dot matrix printers.

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4. NEW DEVELOPMENTS

Recently, GeoAcoustics completed a contract to equip the MV Ocean Surveyor, belonging to the Geological Survey of Sweden (SGU), with three specially developed systems. New features include a multi-channel receiver and data acquisition system which has up to eight channels, each with a complete set of analogue receiver functions enabling direct connection to hydrophones. Receiver functions include:

- Base gain -20 to +40 dB
- Time varied gain 0 to +40 dB, variable delay and rate
- High pass filter 2 to 20,000 Hz, 5 Hz steps
- Low pass filter DC to 20,000 Hz, 50 Hz steps
- Twelve bit A to D converter, 300 kHz maximum throughput

All of the above are controlled through the operator terminal and all of the parameters are recorded with the data in the SEG-Y format for each shot. An optimal gain control allows the base gain to be adjusted automatically, maintaining a constant level from channel to channel on a shot to shot basis.

The benefits in adopting a multi-channel approach over a single channel system are; the signal to noise ratio improvement to the data, the suppression of multiple signal interference and the ability to determine velocity parameters for sediments below the seabed. The principle behind marine seismic profiling is to transmit a pulse of acoustic signal through the water into the seabed and to monitor the returned reflected signals. These reflected signals arise whenever the transmitted signal encounters a change of impedance. Such impedance changes occur at the water to seabed interface and underlying boundaries where there is a change in sediment type. In order to make the most of this multi channel data set, special processing is required:-

4.1 Normal Moveout Correction and Stacking

Normal moveout (NMO) correction and stacking is a special case of seismic data processing. The processing examples discussed previously can all be applied to the incoming data one channel at a time. The NMO and stacking, however, must be applied to a group of channels. Presently, up to 6 received channels of data can be processed in real-time.

Conventional high resolution seismic profiling is normally achieved using a surface towed transmitter source followed by a streamer containing an array of receiving elements. For shallow profiling the streamer array elements are usually electrically connected together to produce a summed output from the acoustic signals received from each individual receiving element. The source and receiver transducers are chosen for their ability to optimise the acoustic signal energy in the downward vertical plane, ie to achieve high resolution penetration into the seabed. At the same time the transducers are insensitive to the horizontal plane in order to minimise surface noise and direct signal return effects. The distortion effects due to the geometry of the array are not taken into account, for example the signal arriving at the first receiver in the array travels a different propagation path to the signal arriving at the last receiver in the array.

The desired effect of the NMO correction is to suppress the distortion on the positions of the seismic horizons. In a multi-channel system, NMO corrected traces may be stacked to improve the signal to noise ratio and to suppress seabed multiples. Compaction processes in the sediment cause a velocity gradient to occur which affects the transmission time of the signal propagating through the media. For constructive stacking of the multi-channel data the NMO correction must apply an accurately determined velocity profile. In order to maintain real-time processing the velocity gradient is approximated to linear gradient and a constant velocity profile is assumed for the water column.[6]

5. CONCLUSION

The Sonar Enhancement System is rapidly becoming the preferred system for data acquisition in both commercial and research geophysical survey fields. Through a programme of continual development the system has evolved from a basic research tool, into a powerful, reliable, high specification survey tool. The chosen hardware platform ensures that systems can be easily modified or upgraded to keep abreast of developments.

Currently in development is a new data acquisition system, needed to fulfil the demands of the commercial survey market. New facilities will include;

- Independent, fully controllable front end.
- Multiple asynchronous triggering.
- Expandable number of analogue channels (8, 16, 32 etc).

Planned developments for the future include the addition of integrated facilities for chirp profiling and multi frequency side scan sonar. The ultimate aim is to provide a fully integrated high resolution survey system in a simple compact package.

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1 GeoAcoustics Limited was known as Ferranti ORE Limited until May 1991.

2 The SIRE project was a collaborative research programme between GeoAcoustics Limited, Heriot-Watt University and The British Geological Survey. Additional contributions were made by Dr Larry Mayer of The University of New Brunswick, Canada.

3 UNIX is a trade mark of AT&T Laboratories Inc.

4 OS-9 is a trade mark of Microware Inc.

5 Society of Exploration Geophysicists "Y" format.
K. M. Barry et al, GEOPHYSICS, Vol. 40, No. 2, April 1975.

6 A. Settery & D. Tamsett. A Marine Survey System for Real Time Multi Channel Acquisition and Processing of High Resolution Seismic Profiler Data. Presented at Hydro '92, Dec. 92, Copenhagen.