3D SONARGRAPHICS - A SEABED SURVEY TOOL

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1. INTRODUCTION

To support the companies expanding offshore exploration and production business, British Gas started a major subsea engineering development programme. It soon became apparent that a common requirement was the measurement of seabed topography and monitoring excavation operations. A review of current practices indicated that most measurements were taken by divers using such instruments as a depth gauge and tape measure which is slow, expensive and not very accurate.

As a result of this assessment it was decided to develop an improved subsea surveying method. Experiments using high frequency narrow beam sonar technology produced useful metrology data. Multibeam bathymetric swath sonars deployed from towfish have been available for a number of years designed for large area deep sea mapping. The Sonargraphics system developed by British Gas is a small scale three dimensional (3D) motion compensated subsea surveying tool. It is a modular design allowing it to be configured for a number of applications and deployment methods. It is particularly useful in areas of poor visibility such as the Morecambe Bay gas fields in the Irish Sea.

This paper describes the principle of operation, the computer programmes to operate the system and some examples of how it has been used in practice. The development work was done at the British Gas Subsea Engineering facility at Blyth Dry Docks, which is part of the Engineering Research Station at Newcastle upon Tyne.

2. PRINCIPLES OF OPERATION

The principle of an echo sounder is well understood and is simply to calculate the distance between a sonar transponder and a reflective surface by measuring the time taken for a transmitted sound pulse to return. The accuracy to which the distance can be measured depends on a number of factors such as, frequency, transducer design, beam width, speed of sound in water, surface reflectivity and reflection angle. Ideally a very narrow beam with minimum attenuation would provide the best results. In reality, as frequency increases narrower beams can be produced but attenuation also increases. To achieve an optimum solution a dual head commercial profiling sonar was chosen with an operating frequency of 675 KHz, a conical beam width of 1.7° (-3dB) and a maximum range of 50 m.

Narrow beam profiling sonars are commonly used to provide information on the seabed and pipelines, operating from a moving platform such as a towfish or a remote operated vehicle (ROV). The two dimensional (2D) data produced requires interpretation by a skilled operator and is not motion compensated.

A modular scanning system has been designed to produce a regular pattern of sound pulses on the seabed which can be translated into a 3D representation of the topography. The system can be configured in basically two different forms of scanning, radial and rectangular. Radial scanning produces a pattern similar to the spokes of a wheel with a high concentration of data at the centre and less at the perimeter. Rectangular scanning produces a parallel pattern with a more even distribution of data points. The available configurations are listed below:

Dual head radial scanning buoy.
Single head radial scanning buoy.
Dual head dual stepper fixed rectangular scanning system.
Single head rectangular scanning buoy.

The components of the modular system are shown in Fig 1.

An example of a dual head radial scanning mechanism operating from a tethered buoy is shown in Fig 2. The buoy is lowered to the seabed using the central lifting wire attached to a clump weight and can be raised up to a maximum operating height of 25 m by use of a remotely operated on-board winch. The sonar heads are mounted 1.5 m apart on opposite sides of a ring gear. The scanning paths are offset by 3 degrees and the ring gear is incremented by 6 degrees for each pair of scans by a stepper motor. The result is a radial scanning pattern as shown in Fig 3.

3. MOTION COMPENSATION

Due to surface wave action and tidal currents the sea is never still, therefore movement of the measuring platform must be taken into account to produce the best possible image from the data. This is achieved by measuring all six degrees of motion, calculating correction factors, then applying the corrections to each individual sonar return point. Motion compensation is common to all configurations of the sonar system and the measured parameters are described in nautical terms below:

ROLL	rotation around the bow to stern axis
PITCH	rotation around the port to starboard axis
YAW (heading)	rotation in the horizontal plane
SURGE (Y)	horizontal motion bow to stern
SWAY (X)	horizontal motion port to starboard
HEAVE (Z)	vertical motion

The most difficult parameter to measure accurately is yaw relative to absolute heading. Magnetic compasses are influenced by local metalwork and rate gyroscopes suffer from long term drift. The only device available that would provide the required accuracy of better than 1 degree is a true north seeking gyrocompass. The most cost effective commercial device available which was chosen is designed for subsea use and employs the same precision gyroscope element used in the guidance of Cruise and Pershing missiles. Accurate measurement of true heading is required for two reasons. The first is that surveys must be referred to true north to relate to subsea engineering drawings. Secondly, multiple surveys of an area could not be accurately merged together without this common reference.

Roll and pitch are measured by precision electrolytic transducers either from within the gyrocompass or independently. The angle of the tether wire is measured by means of an X Y axis gimbal device. The length of the wire is measured from either the sonar returns from the clump weight, or by a rotary transducer.

Lateral movement, surge and sway, and vertical movement, heave, are determined by combining the roll, pitch and gimbal angle measurements and using the tether wire length to calculate the geometric displacement. A mathematical model in the software allows the position of both heads to be known at any point in the survey relative to the clump weight which is the reference datum point on the seabed.

The effect of motion compensation using the single head rectangular sonar buoy is illustrated in Fig 4, Fig 5 and Fig 6, using data from trials in Blyth Dry Docks. In Fig 4 the sonar buoy is static and a number of significant features can be identified. To the left is a large step change in the seabed level, in the background is a dock wall and in the foreground two features are resting on the dock bottom. One feature is a regular rectangular shape, the other is a two humped irregular shape. In Fig 5 the image is shown with no motion compensation with the buoy being moved several degrees in all six directions, simultaneously. Fig 6 shows the image after compensation has been applied.

The motion compensation is not perfect due to a number of factors such as, data dispersion, rate of change of movement and accuracy of motion measurement. However, it can be seen that there is a significant improvement from the unrecognisable image of Fig 5. In the majority of applications the sonar buoy would be relatively static with several degrees of roll and pitch with some lateral displacement and heading modulation due to subsea currents. The compensated image in this case is virtually as accurate as a static survey.

The performance of the survey system has been evaluated over a range of operating conditions. For example for a 900 m² survey with the sonar buoy 10 m above the seabed the measurement accuracy would be approximately

+/- 100 mm. The image resolution can be significantly better than the accuracy, depending on the level of interpolation selected. The maximum area which can be surveyed is 6000 m^2 and the maximum practical data density is 16,000 data points at 1 degree by 0.9 degree scan spacing using rectangular scanning.

4. DATA RECORDING AND PROCESSING

A suite of computer programmes has been developed to control the scanning mechanism, record and process sonar data, and display the resulting images. This includes a number of algorithms to produce surface rendering, contour and volume processing of the data and implemented in such a manner as to minimise data processing times. The software has been produced in C programming language and the operating system is Unix. A workstation computer is used to run the software and starbase graphics is used for the image displays.

First the scanning system configuration is selected which determines the scanning method and compensation type. The SURVEY program controls the scanning sequence and records the compensation and sonar data. A typical 4000 point survey at the maximum 25 m above the seabed would take 15 minutes to record.

When a survey scanning sequence has finished the compensation data is examined using the GRAPH program which displays all the motion parameters measured. If the rate of movement is excessive or excursions too great the survey is rejected.

When a survey has been completed satisfactorily the compensation data is applied and the next stage is to edit the data. The raw data is first automatically processed to remove any noise glitches then manually edited using the CLEANUP program. In this program each scan is examined individually in section relative to its plan position and unwanted points such as those caused by fish or umbilicals are removed. It is very difficult to emulate the ability of the human brain to rapidly assess the significance of each data point in a complete survey, therefore this process is currently done manually.

When editing is complete the survey is displayed using the VIEW program. The VIEW program can display the data in a 3D wire frame or coloured grid form.

The image can be zoomed, rotated and viewed from any angle. This assists in visualising features in the survey and examples are shown in Fig 4, Fig 5, Fig 6 and Fig 8.

The most useful method of data display is the CONTOUR program. The image resolution and contour steps can be individually selected and the presentation is similar to an ordnance survey map. Once processed in this form the data can be interrogated to provide dimensioned sections through the survey and the volumes of selected features. By this means subsea excavation work can be monitored at each stage and relevant data provided to the operations superintendent. An example is shown in Fig 7. Individual surveys can be combined using the MERGE program to increase data resolution or to cover larger areas.

Data from the high resolution graphics monitor can be printed at any time using an A4 thermal colour printer, larger prints can be produced using an X Y plotter. Contour prints can be scaled to match engineering drawings.

5. APPLICATIONS

The British Gas Subsea Engineering Test Facility, has an artificial seabed in one dry dock and sonar test features have been constructed in two of the three dry docks. These features have been used to develop the scanning and compensation methods and the 3D Sonargraphics system has been used to monitor a number of excavation equipment trials on the artificial seabed.

In the later stages of development a number of surveys were undertaken associated with other companies operations to fully test deployment and compensation methods in the conditions experienced offshore. The Sonargraphics system has been used successfully in the applications listed below:-

6.1 Oil Platform Drill Cutting Mud Mound Survey
6.2 Subsea Pipeline Isolation Valve Template Excavation
6.3 Subsea 42 inch Pipeline Expansion Loop Excavation

The subsea isolation valve template excavation survey is shown in VIEW form in Fig 8 with an illustration of the excavation method.

6. SUMMARY

A modular 3D Sonargraphics survey tool has been developed which can provide dimensioned, high resolution images which are compensated for platform movement. The system is operated from a user-friendly suite of software which can be used to interrogate the data. The sonar buoy configuration can be deployed from virtually any offshore structure or vessel. A licence has been granted to a major offshore survey company and the system is available on a commercial basis. The 3D Sonargraphics system offers a significant improvement in small-scale subsea excavation survey and imaging methods.

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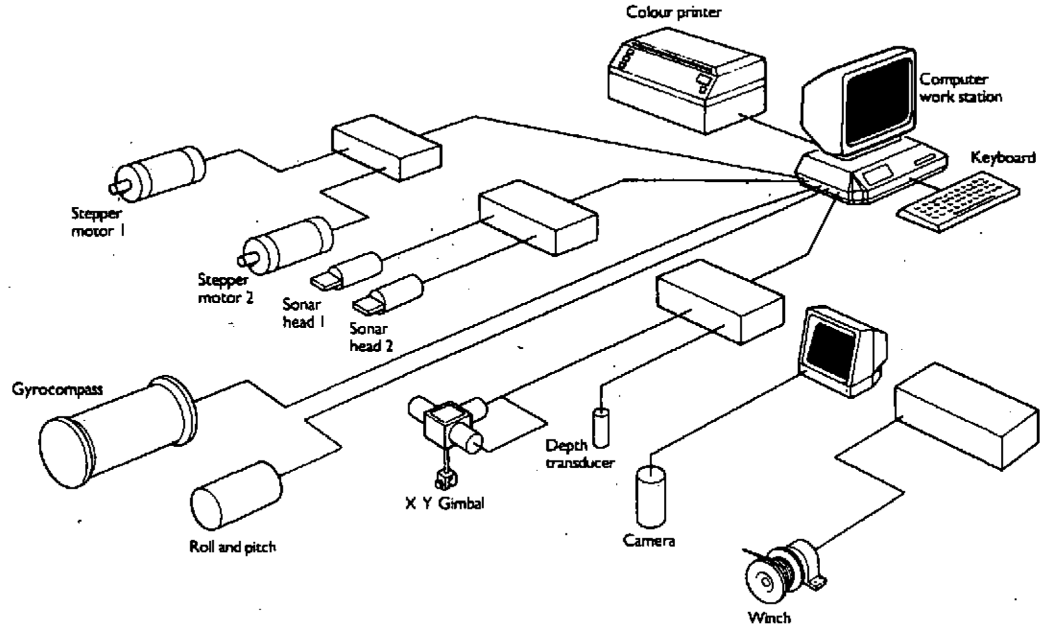

Fig. 1 Components of modular 3D sonargraphics system

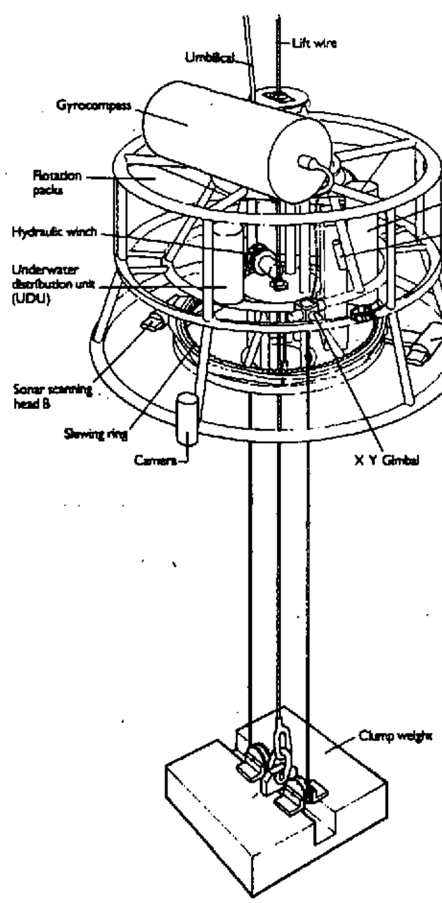

Fig. 2 CI Dual head rotary scanning sonar buoy

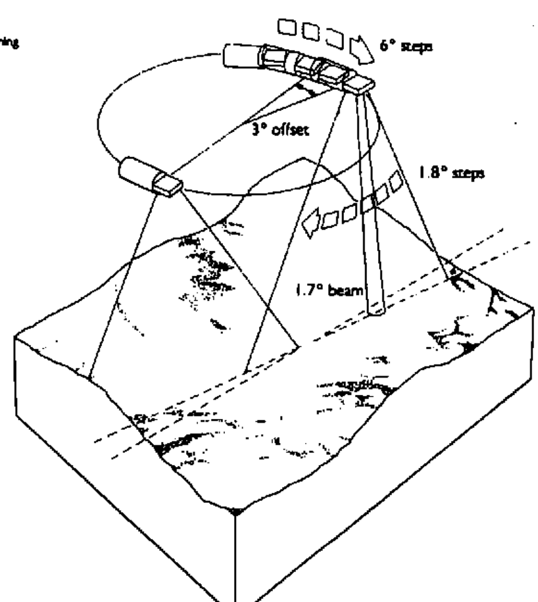

Fig. 3 Radial survey method

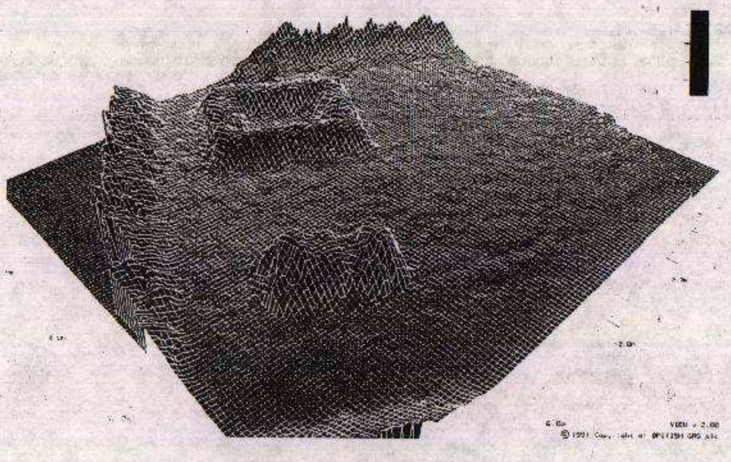

Fig. 4 Static survey with motion compensation

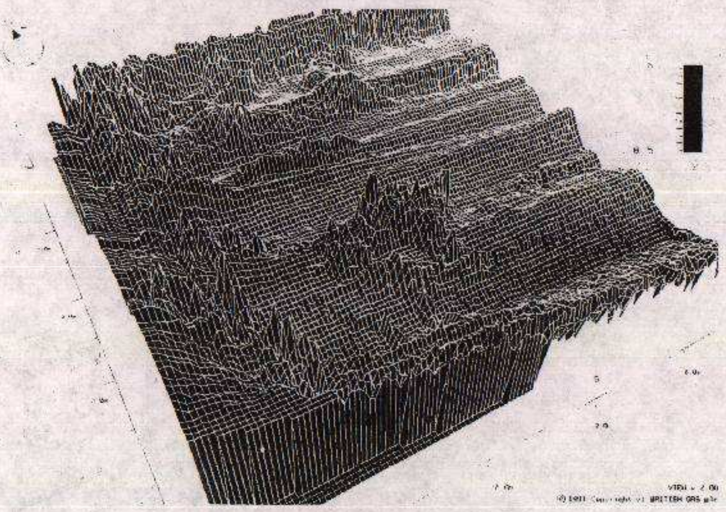

Fig. 5 Moving survey without motion compensation

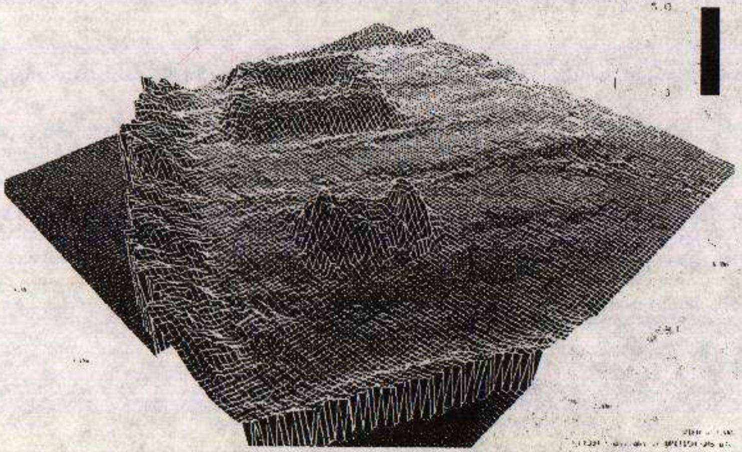

Fig. 6 Moving survey with motion compensation

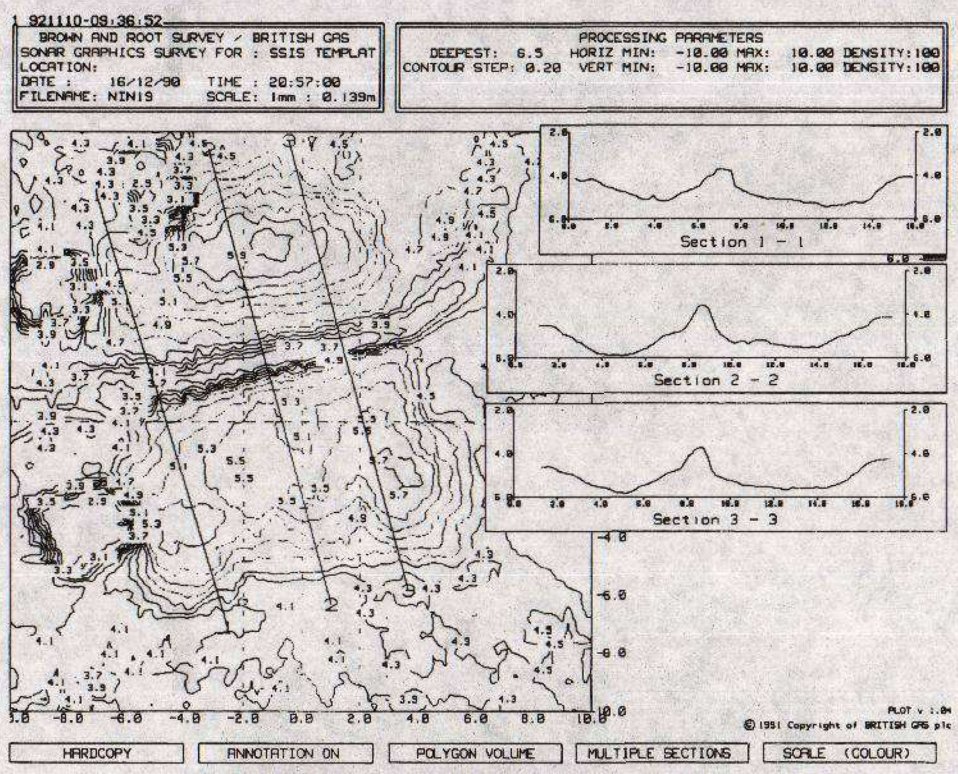

Fig. 7 Contour display with sections and depths relative to sonar buoy

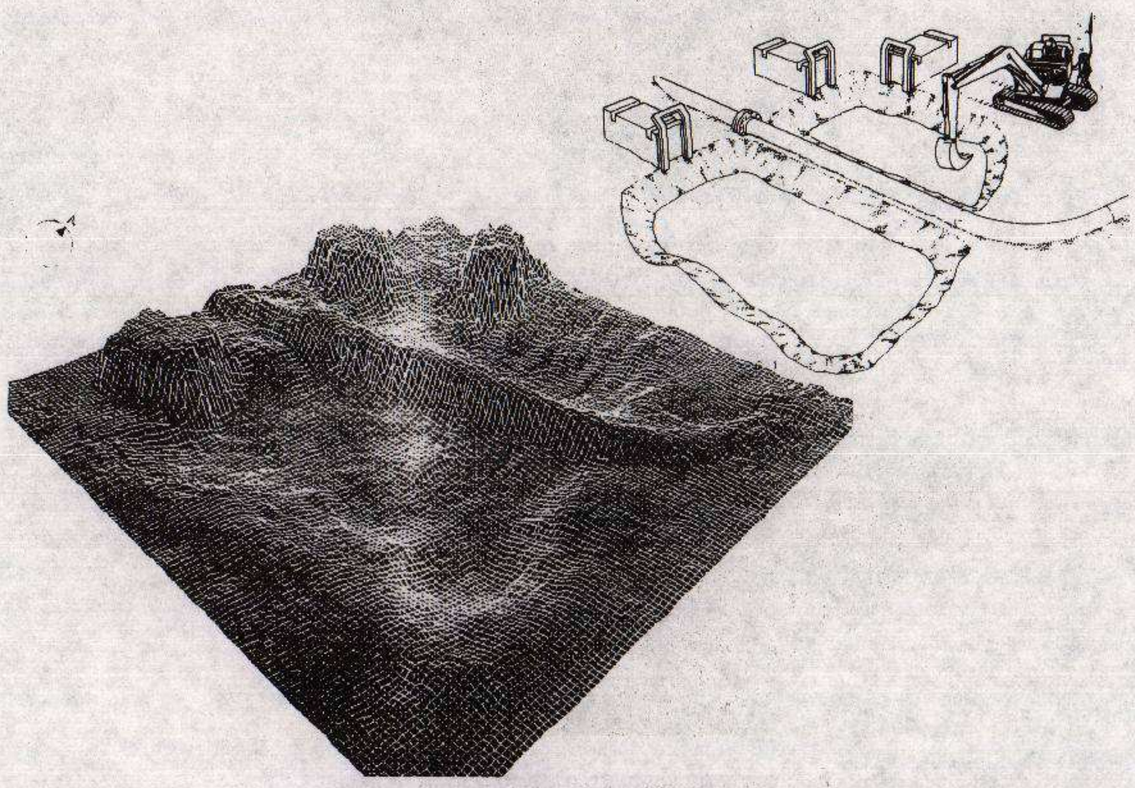

Fig. 8 VIEW display of a subsea isolation valve template excavation