ON-LINE DATA PROCESSING FOR DREDGING WORK BY AUTOMATIC TRACKING OPTICAL COMMUNICATION SYSTEM

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ABSTRACT

A great number of large-scale marine construction projects have been undertaken in Japan. One example of such a project, the Akashi Kaikyo Bridge, will be the largest suspension bridge in the world when complete. One of the great projects of the century, it has gigantic main tower foundations 81 m in diameter which have to be sunk in water deeper than 50 m. When such large deep structures are to be constructed on the seabed, it is necessary to finish the seabed to a high accuracy in advance. This paper describes a method of automated management in which navigation and dredging information is communicated by means of an automatic tracking optical method. This is an on-line construction management system which combines position information optically transmitted from a land station and seabed topographic data measured from a boat.

1. Introduction

The Honshu-Shikoku Bridges, Kansai International Airport, Trans-Tokyo Bay Expressway and other large government projects are being completed one after another, and a variety of other ocean developments known as "Waterfront" projects are being launched in many districts. This ocean construction work requires foundations involving seabed dredging, base mound preparation and other tasks. When carrying out foundation work, it is very important to fully understand the topographical conditions on the seabed to great accuracy, and to quickly adjust work management to reflect the conditions.

To manage excavations under these conditions, highly accurate measuring techniques based on the latest electronics and high-speed data processing technology are utilized. Positional data (position and height) received from a ground station via an optical communication is combined in real time with topographical data measured on board to create an on-line work management system. This report describes a three-dimensional measuring technique with a resolution of 5 cm based on a personal computer and on-line data processing through an optical communication. The system automatically compensates tide levels. A new method of applying this technique to future ocean development is proposed.

2. Three-Dimensional Probing of the Seabed

2.1 Multi-Fan Beam System

In the field of topographical seabed probes, measurement using a single-beam sonic depth sounder is conventional although side-scan sonar has been used as an auxiliarily method. In ocean work requiring extremely high precision, depth sounders and multi-element devices operating at relatively high frequencies and with narrow beams have been employed to improve accuracy. These methods, however, can only acquire seabed data at points or along lines, so the present difficulties in visualizing the seabed as a surface.

The automatic optical communication system, however, makes use of a "multi-fan beam" which enables a three-dimensional image of the seabed to be formed by electronically scanning ultrasonic emissions in the shape of a fan.

The multi-fan beam technique, which is called the "cross-fan method", measures and records the seabed topography by propagating a fan-shaped beam perpendicular to the ship's course which is then electronically scanned at the moment the received beam crosses at a right angle (see Fig. 1). The directional accuracy of the multi-fan beam is 1°, the transmitted beam is 120° wide and the received beam is 20° wide.

Thus, bathymetric data at a maximum of 120 points can be measured at intervals of 1° by scanning once. The bathymetric resolution is improved by increasing the frequency to 500 kHz. The emitter-receiver unit has been designed as small and lightweight as possible.

Depth soundings acquired by the multi-fan beam are processed with a mainframe or personal computer and the output is in the form of drawings such as cross-sections of the seabed and mesh water depth drawings.

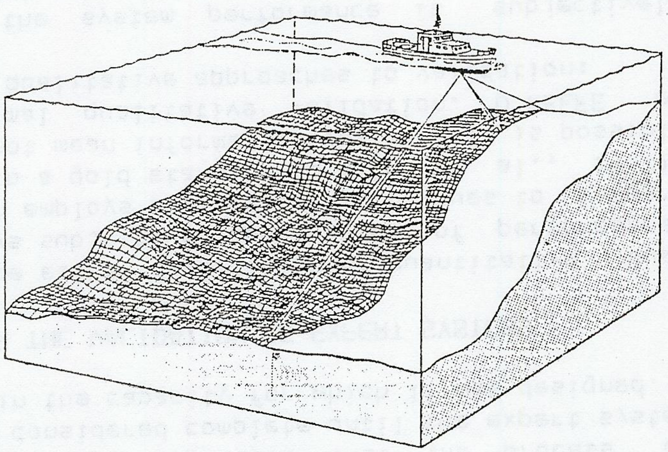

Fig. 1 Multi-Fan Beam system

In this way, the system overcomes the various problems suffered in the past and succeeds in enabling precise data to be acquired. The system may be summarized as follows:

(1) The system achieves a precision of 5 cm in topographical measurements, while the sonar systems of the past reached an accuracy of only 10-50 cm.

(2) The fine 1^o directional increment of the sonic depth sounder improves the bathymetric resolution. Conventional sonic sounders had a resolution of 3-8^o.

(3) Past measurements always included the effects of oscillations of the vessel. Now the oscillation compensator enables the seabed directly below to be mapped.

(4) Previous single beam systems could only just map the seabed sequentially, while this system is capable of measuring continuously at 120 points within a width three times the water depth at any one time.

(5) The conventional types of sonic depth sounder were labor and time intensive at all stages from measurement to analysis/drawing stages. This new system obtains very reliable data in real time using rapid processing techniques.

Thanks to the development of this system, the topographical data can now be obtained to unprecedented high precision.

2.2 Structure of the System

The multi-fan beam system comprises the equipment shown in Fig. 2.

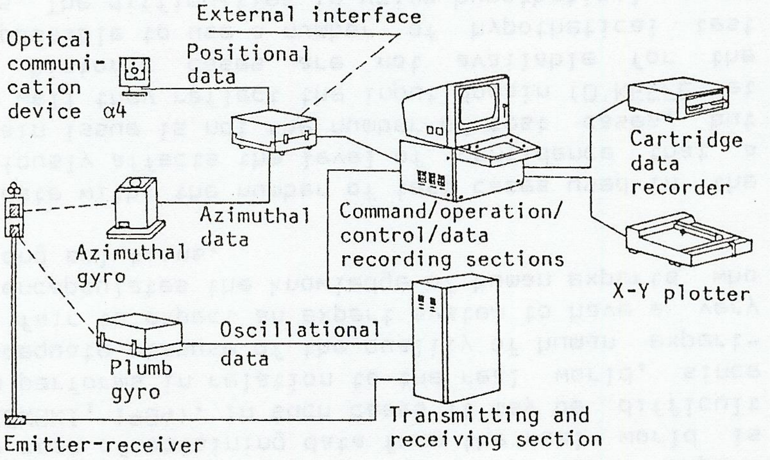

Fig. 2 Structure of the System

(1) Beam emitter-receiver

This consists of a transmitting element, which radiates an ultrasonic beam 1^o by 120^o in width, perpendicularly to the forward motion of the vessel, and a receiving element of 128 channels which scans the reflected signal.

(2) External interface

The external interface inputs the data about position, azimuth and oscillations of the vessel, but excludes the topographical data.

(3) Transmitting and receiving section

This section transmits and receives the ultrasonic beam according to the requirements of the control section. It detects the echoes reflected from the seabed and outputs the signals necessary to calculate oceanic data to the calculating section and a video signal to the control section. As it is output, the data is electronically corrected for the oscillations of the vessel.

(4) Command/operation/control/data recording sections

The command & operation sections set the conditions of measurement, and the control section manages the output to each item of equipment, the submarine data, and the video data. Finally all the data are recorded onto cartridge-type magnetic tapes.

2.3 Sequence of Data Processing

A flow chart for the data processing and output of this system is shown in Fig. 3. The water depth measurements are compensated for varying acoustic velocity due to the effects of water temperature, salt and other factors, and the values are matched with the positional data. The data is read onto a 40MB hard disc and used to produce various graphic displays. The basic graphic is a mesh sounding diagram, in which the integral values of differences in each mesh point correspond to the quantity of soil removed by dredging. The data is also plotted into an aerial view, cross-sections, a chart of changes in soil quantity and others.

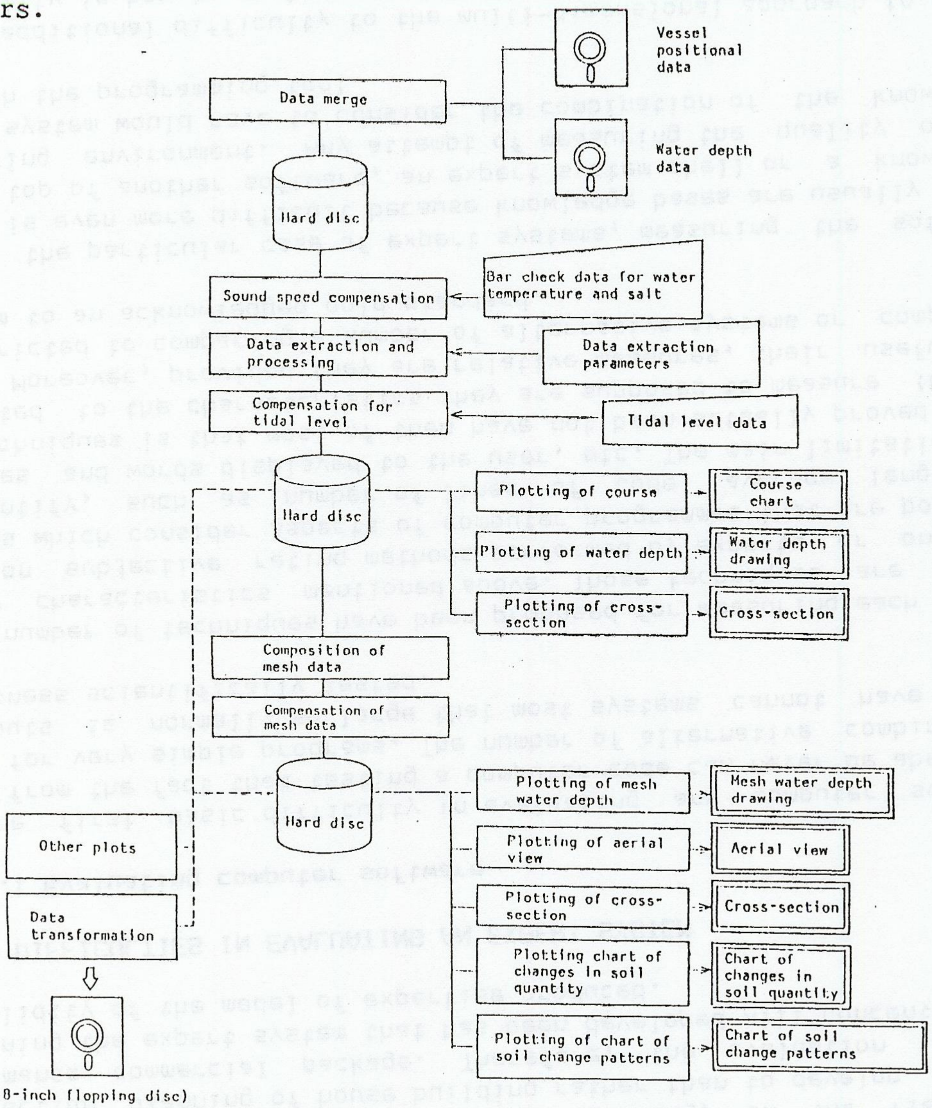

Fig. 3 Sequence of Data Processing

3. On-line Data Control by Optical Communication

3.1 Outline of the On-Line System

The amount of topographical data, which is continually acquired at 120 points per second, is far more abundant than in conventional systems because of the sequential measurement method. Furthermore, calculating the absolute depth values necessitates the extremely complicated process of matching each sounded value with the appropriate positional data every second.

This system allows the positional data, as measured on land, to be transmitted every second to the ship through an automatic-tracking optical link, thus realizing the on-line processing system described in Fig. 4. A 32-bit personal computer is used instead of a mainframe computer to process the approximately one hundred thousand data points, and the development of this system has allowed this three-dimensional topographical data to be applied to work management for the first time.

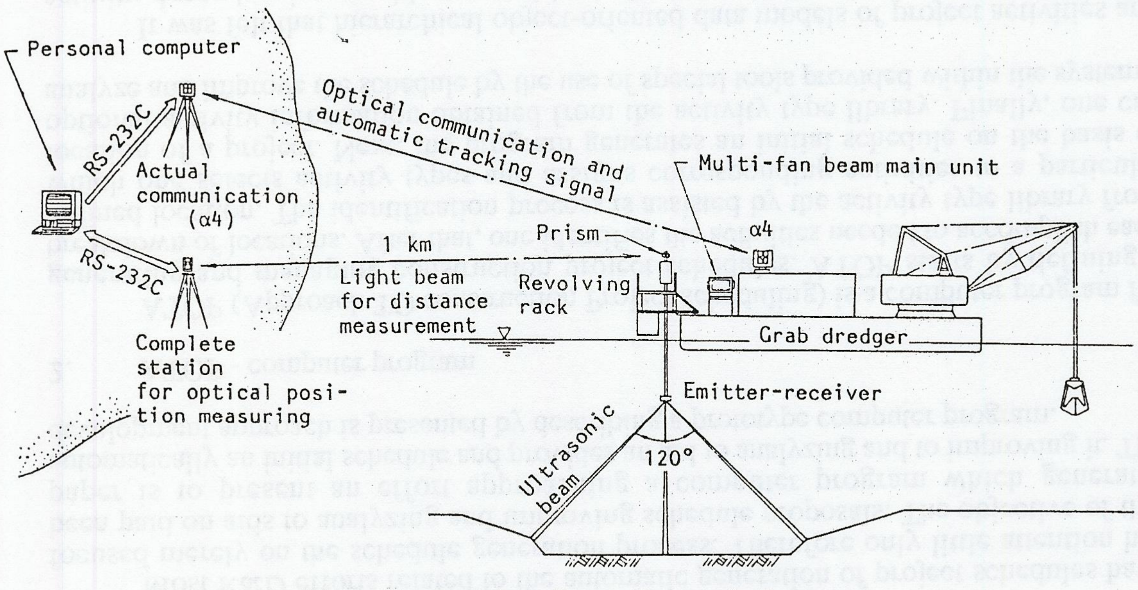

Fig. 4 On-Line Data Control System

3.2 On-Line Positional Measurement by Optical Link

Positional measurement is based on the on-line system illustrated in Fig. 5. The land-based unit first measures the position of the prism on the vessel and makes a coordinate transformation of the data using a personal computer. After being recorded, this positional data is transmitted to the ship along with time data by the automatic tracking optical communication system, enabling the vessel to be guided highly accurately in real time.

The device tracks automatically using guide beams radiated from both the fixed and mobile stations. The deviation from the center of the optical axis is detected, and then the adjustments needed to bring the beam into the center of the optical axis are made by driving servo motors on the X and Y axes. The position measurement system also has the function of guiding the vessel along the measuring line specifically planned, and this is called the "ship position guidance system". The data is displayed on a CRT and the captain maneuvers the ship according to this information.

3.3 Characteristics of the System

As described above, the on-line data control system consists of a high-precision optical range finder, an automatic tracking optical communication and a personal computer. The system measures the position of a prism on the vessel and calculates the coordinates from the data using the personal computer. After being recorded, the data is transmitted along with time data to the vessel through the optical communication, enabling the vessel to be guided very accurately on a real time basis. The characteristics of the system are as follows:

(1) Real time positional control is made possible by transmitting positional data through an optical communication and displaying it on-line.

(2) The optical range finder, which is compact, light, simple to operate and multi-functional, accurately measures the position of the vessel.

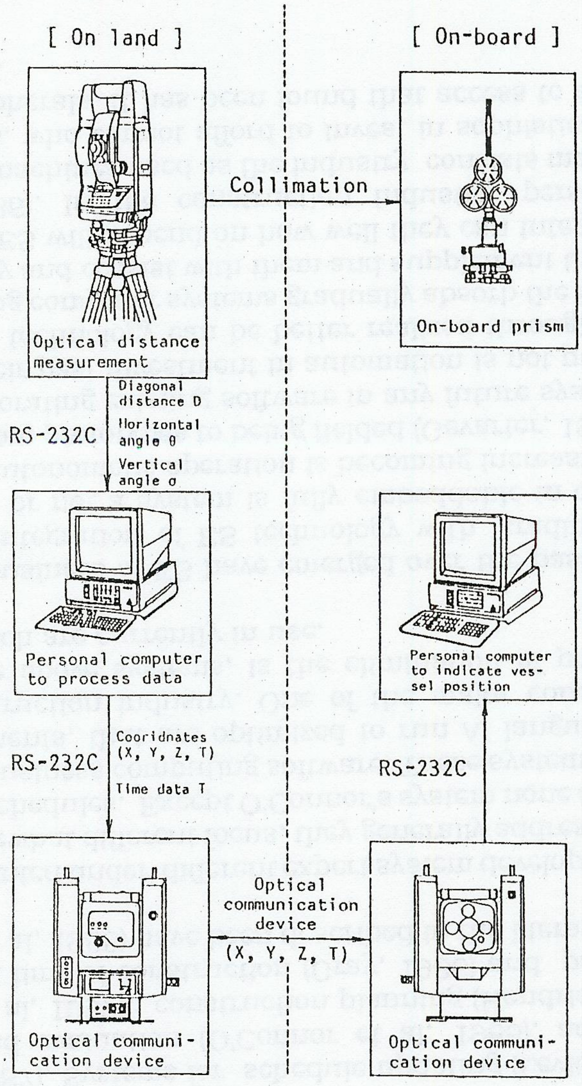

Fig. 5 Optical Communication System

(3) By adopting an automatic tracking system, the optical communication can be used for automatic tracking and data transmission at the same time.

(4) A conventional radio transmission system necessitates legal procedures and a license, and is capable of communicating over a range of 4 km.

(5) The system changes the data input program to suit every type of optical range finder used for data communication. Compatibility with other equipment is excellent.

A combination of optical range finder and optical link has made it possible to gather a vessel's positional data more easily and accurately than with conventional radio communications with no problems of jamming or legal procedures.

4. A Practical Example of On-Line System Use

So far in this report, the integrated system consisting of a three-dimensional ocean probing technique and an on-line data control technique has been introduced. The development of the probing technique has led to superior equipment, and the on-line control system has made data processing more functional.

Using this system, precise measurement of topography and real-time use of the data for work management have become possible, and the range of applications has expanded. A large number of actual projects have proved the practicality of the system.

Some examples of its use and development are as follows:

4.1 Management of Filling and Dredging Work

The system is able to control 100 thousand points of topographical data by dividing the measured sea area into a mesh. The data at each mesh point can be used for various kinds of work control such as control of topographical conditions and the amount of material dredged or filled. Changes in soil quantities as well as the trend of changes is calculated from the integral value of depth changes at each mesh point. Fig. 6 is an example of a three-dimensional display indicating the measured quantity of mortar laid under water. The measured amount is equal to the actual quantity of mortar placed.

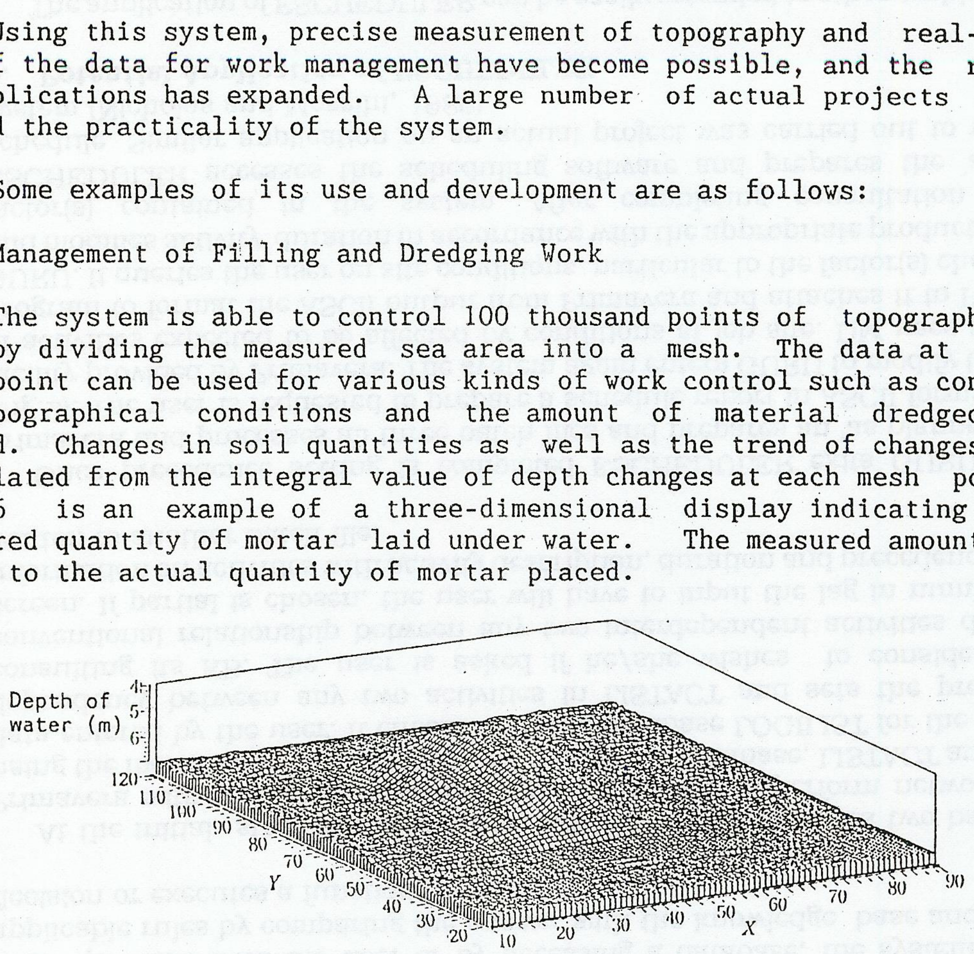

Fig. 6 Example of Data Output

4.2 Real-Time Work Management for Construction of Pipelines and Similar

Measured values are displayed on a CRT and XY plotter in real time. This allows many types of work to be controlled while checking the display. The precise measurement of the vessel's position, transmission by automatic tracking optical communication and the guidance system can be used for a variety of work.

4.3 Surveys of Drift Sand and Secular Changes to the Coastline Caused by Scouring and Other Phenomena

Various problems associated with preservation of the coast, such as coastal erosion or silting of harbors have arisen. To solve these problems, collection of accurate mesh bathymetric data in the object sea area is necessary to estimate future changes in the seashore on the basis of secular change.

A database for such coastal changes is also being prepared.

4.4 Survey and Control of Scouring Around Structures

Since conventional sonic depth sounders radiate a single beam directly downwards, measurements of scouring around structures appears difficult. In this system, on the other hand, such measurements can be carried out as shown in Fig. 7. Using this system has yielded excellent results in scouring surveys and has helped work management during footing protection and investigations into changes after the completion of work.

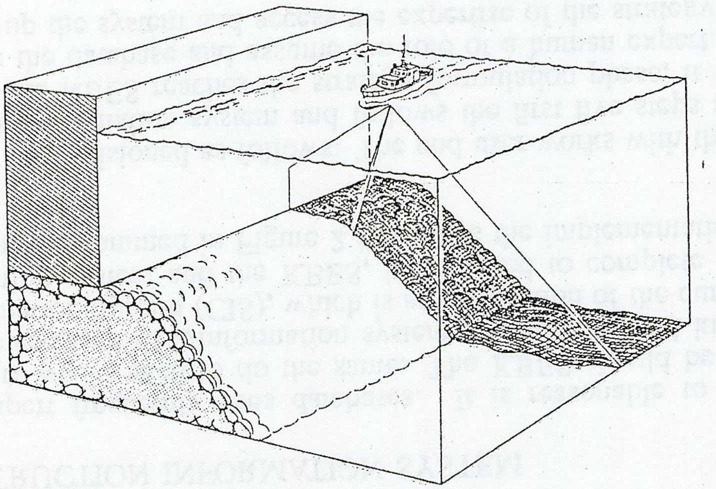

Fig. 7 Survey of Scouring Around Structures

5. Conclusion

This system was used in several work management situations for submarine work. The system was expanded and various versions were developed to fulfil the particular needs. In this way, the integrated system was completed and its practicality proved during actual work management and surveys into coastal preservation.

The technique was developed as described as part of the "Extensive Marine Survey System" which won the Civil Engineering Society Award in 1986, and the system itself received the "Technical Encouragement Prize" from the Japan Waterways Association in 1988. The assistance and cooperation of many people in this work is greatly appreciated.