New Developments in Surveying and Navigation Technology for OBC Seismic Acquisition

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Summary

Shallow water seismic surveys are a priority for oil exploration worldwide, and ocean bottom cables (OBC) is the main method used in such surveys. Gene Kliewer et al (2007) has discussed many benefits of OBC operation.

In this paper, we give a brief introduction to BGP´s marine seismic acquisition history and present a detailed description of the surveying and navigation technology developed by BGP in recent years. All of these navigation and surveying technologies have been widely used in domestic operations and international activities. Finally, we provide an outlook on the trend of development in surveying and navigation technology applied to marine seismic operations in the near future.

Introduction

In recent years, more than 50% of global oil and gas resources were discovered in the sea. In particular, many of these discoveries were in shallow-water areas. And BGP is an important contractor in shallow water seismic surveys.

In 1994, BGP launched our geophysical services for oil companies in the international market. We completed a PC2000 project in the Persian Gulf, and OBC projects in other shallow water transition zones in Nigeria, Saudi Arabia, and Indonesia. Towed streamer surveys have been carried out in Equatorial Guinea and the North Sea in the years 2006 and 2007. BGP has seen rapid growth in offshore exploration business year after year, which displayed our advanced marine seismic operation capabilities.

At the same time, BGP has gradually developed GEOSNAP navigation and positioning technology, which includes the Hydroplus navigation system, Dolphin integrated navigation system, BPS acoustic positioning system, and the OBCOFFICE post-processing software for shallow water OBC seismic operation.

OBC seismic navigation and positioning

1. Hydroplus navigation system

Hydroplus provides a user-friendly and reliable solution for OBC seismic navigation, positioning, and surveying. From seismic survey line planning, deployment navigation and shooting operation, to data collection, real-time QC of navigation data, Hydroplus offers a perfect data flow from a large variety of hardware sensors, all the way to a complete seismic navigation operation. Hydroplus runs on a standard Windows XP/2000-based PC platform.

Hydroplus seismic navigation software includes the following main functions.

1) Project Manager

Project Manager provides a live overview of project status, allowing one to quickly determine what has and has not been done to date at the project level. Data related to each survey line is stored in its own relational database. The user can create new project data management for a single seismic project or for multiple seismic projects.

2) Survey Datum

Most of the world´s datum systems and projections are supported in Hydroplus and it will work anywhere in the world.

3) Interface to Sensors

Hydroplus will interface with all types of commonly used navigation sensors, including single beam echo sounders, sensors for roll, pitch, and heave, tide gauges, GPS navigation systems (NMEA position type output formats), external header or QC telegrams, and third party data streams.

4) Data Logging Formats

Final positions stored in UKOOA P1/90 or SPS ASCII format, which can contain the positions of GPS antenna, reference point, source/gun, receiver group.
Raw navigation data stored in Results Database in UKOOA P2/94 ASCII format.

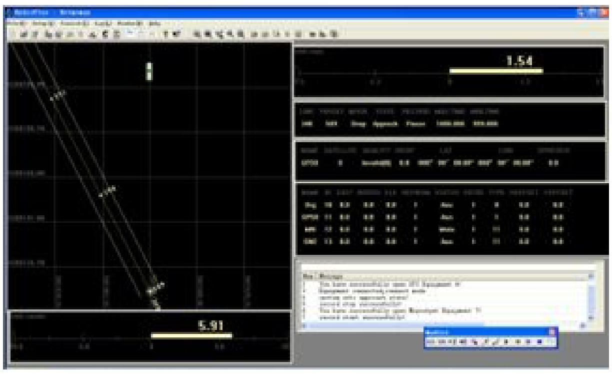

Figure 1. Hydroplus navigation software

5) Application in the Field

Since 2006, Hydroplus has been widely used in OBC operations in the field. It is successfully carrying out navigation and positioning tasks and playing a critical role in our OBC seismic operation.
So far, Hydroplus has been installed in 53 deployment and shooting vessels operated by BGP.

2. *BPS Acoustic positioning system*

The BPS (Benthal Positioning System) Acoustic Positioning System is designed to work with OBC and transition zone (TZ) seismic systems. By adopting the multi-node network of transponders and the integrated LBL & USBL techniques, the BPS system significantly improves the accuracy and efficiency of positioning OBCs. Compared to the traditional 'first break', the system can provide more accurate hydrophone positions (1-m absolute accuracy underwater).

The BPS system is comprised of five main components: Master Control Unit (MCU), Transducer, Transponders, Programming Unit, and PC-based OBCPos real-time positioning software (Figure 1). Table 1 shows the key specifications of BPS system.

Table 1. Key specifications of BPS.

Positioning accuracy	±1 meter
Maximum acoustic range	500 meters
Operation depth	200 meters
Maximum number of nodes	4000
Maximum speed of boat	5 knots
Frequency brand	34 to 50 kHz

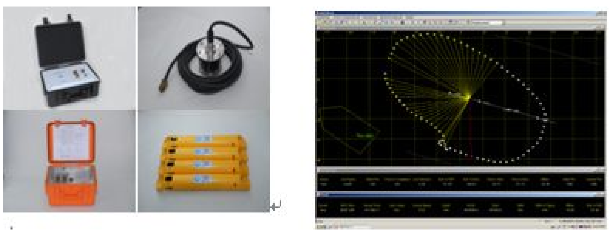

Figure 2. BPS acoustic positioning system

In order to verify the positioning accuracy of the BPS system, we have carried out experiments in the field.

We provide a detailed description of one field test here.

We first fixed the acoustic transponders on aluminum pipes staked into the lake bed and then obtained accurate an absolute position of each transponder by GPS RTK method.

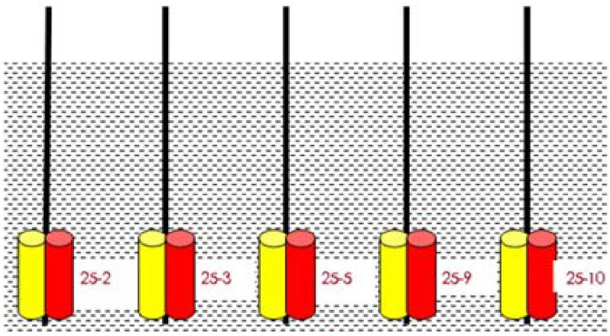

Figure 3 Experiment in field

Table 2 shows the final positions of transponders on the lake bed we used to estimate the accuracy in OBCPos software. We compare the coordinates obtained through OBCPos with those from GPS RTK method. The maximum difference is 0.589m in x and 0.89 m in y.

Table 2 The positioning results compared with RTK

Transponders	North(x)	East(y)	Diff in x direction	Diff in y direction
25-2	4352321.11	345773.26	0.39	-0.46
25-3	4352282.09	345704.00	-0.59	-0.89
25-5	4352257.53	345657.17	-0.33	-0.17
25-9	4352236.09	345618.89	-0.58	0.11

3. *Dolphin navigation system*

Dolphin is an integrated navigation and control system designed by BGP to meet the needs in challenging environments of multi-vessel distributed operations such as ocean bottom cable and shallow water seismic operation. Dolphin delivers a unique blend of centralization, data management, advanced positioning techniques, and flexible configuration. These features not only improve the acquisition quality and the production management, but also reduce the cost of operation.

As shown in Figure 4, The Dolphin system is comprised of nine main modules : Main , NavCaculator, NavDataLogger, NavControl, NavDisplay, NavInterface, NavLineDesign, NavNetwork, and Navproject.

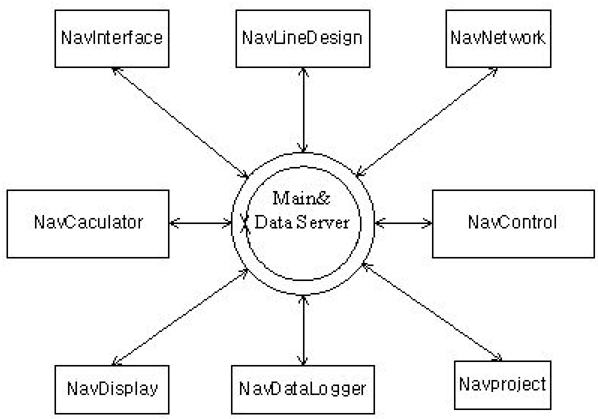

Figure 4. Main modules in dolphin system

The system has the following features: Centralized remote control, robust deployment navigation, Kalman filter navigation, Synchronized seismic acquisition, Real time QC control, and Navigation data logging with industry standard formats.

1) Centralized remote control

Centralized management and remote control has become a technical highlight of the Dolphin integrated navigation system because of the application of the wireless network technology. The entire OBC operation fleet is under a unified management through an internal wireless network on board (Figure 5). During the installation of the integrated navigation system, we can transfer the configuration files via this wireless networks on board. During operation, it is possible to change the configuration files for other vessels from the host vessel. The remote control also reduces the number of navigators in the fleet and ensures the safety of the most important configuration data (such as line data, GIS databases, and system configuration data) in the field operations.

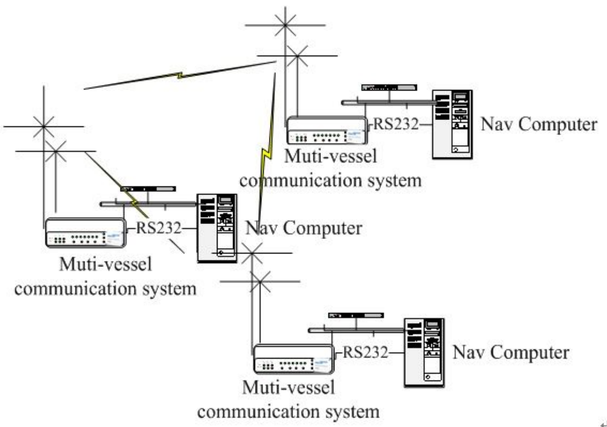

Figure 5. Wireless networks in dolphin system

2) The Kalman filter

The Kalman filtering technique is an effective method for obtaining dynamic positioning data. It can significantly improve the dynamic positioning accuracy of moving objects. In order to get an accurate, reliable, and smoothly tracked navigation vessel in real-time, the Kalman filter is applied to the Dolphin integrated navigation system in real-time navigation and positioning.

When we use information from GPS and Gyrocompass to determine the tracks of our vessels in real time, the position and the heading information of the vessel are individual observations at a given time interval. Qin at el (1998) described that the Kalman filter addresses the general problem of trying to estimate the state of a discrete-time controlled process that is governed by the linear stochastic difference equation:

$$x_k = \Phi_{k,k-1} x_{k-1} + \Gamma_{k-1} w_{k-1} \quad (1)$$

and the measurement equation,

$$z_k = H_k x_k + v_k \quad (2)$$

where x_k is the state vector, w_k and v_k are the random variables representing the process and measurement noises.

The matrix $\Phi_{k,k-1}$ in equation (1) relates the state at the previous time step to the state at the current step, in the absence of either a driving function or process noise. Although $\Phi_{k,k-1}$ may change with each time step in practice, we assume it is constant here. The system dynamic noise matrix Γ_{k-1} relates the optional control input to the state. The matrix H_k in equation (2) relates the state to the measurement vector z_k .

The Kalman filter gives a better solution than individual observations because the dynamic model adds information about the system that improves our estimate of the most probable position.

In the case we do not have enough observations to solve a static least squares solution we can still update, and improve, our state estimate using the observations we have.

In our simple situation here, we could imagine having just an East observation, which we could incorporate into the filter in the normal way to give an improved

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updated state. This is important in Dolphin for those shots where there is a node with no observations to it. The Kalman filter allows Dolphin to keep operating. This can be compared to static least squares solution, which solves the problem of small data gaps by using a pre-processing phase to interpolate through the gaps. Of course in real time we cannot interpolate from future data, and hence we use the Kalman Filter to overcome this.

The Dolphin integrated navigation system uses the Kalman filter to calculate the navigation nodes on vessel and the predicted time of shooting in real time. It was utilized in the module named the network computing thread.

3) Robust Deployment Navigation

The Robust Deployment Navigation techniques give the client an effective means of seismic deployment navigation; it can significantly improve the efficiency of the production. the Dolphin integrated navigation system predict the time when the deployment vessel arrived at the designed geophones´ position in real-time and send out a buzzer signal to inform the deployment employees.

4) Synchronized seismic acquisition

The synchronization between the shooter and recorder is the most important problem we need solve as shown in Figure 6. So we develop one equipment named GPS synchronization controller which it provides the interface to the seismic recording systems and the source gun control system through its own interfaces, the Synchronize controller.

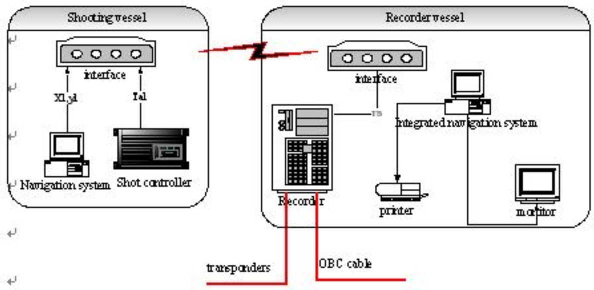

Figure 6. Synchronized seismic acquisition

5) Real-time QC control

The Dolphin integrated navigation system also provides users with a powerful means of quality control. It can monitor the required operation data in each operation vessel in real time for the QC purpose. It can provide a customized display window on the display monitor in the host vessel; and let the navigators monitor the operation and QC information for the slave vessels.

Furthermore, the Dolphin integrated navigation system also provides the quality control interface for the gun control system in the shooting vessel. Regardless whether the user is in the shooting vessel or the host vessel, he or she can input the sub-gun shooting time, the gun depth, and the air pressure data in their own display window (Figure 7) to allow navigators and the crew supervisor to know the daily operation.

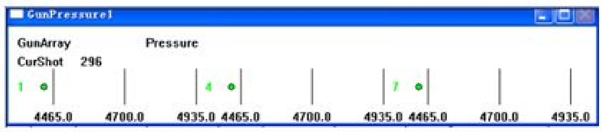

Figure 7. The gun QC information in Dolphin system

6) Navigation data

The Dolphin system provides users with a variety of international standard seismic navigation data. These data formats include navigation and positioning data formats such as the original UKOOA P2/94 format, UKOOA P1/90, or SPS format.

7) Field operation test

We performed a field operation test in the Bohai Sea, China. The gun control system used in the test was BIGSHOT and the recording system was SERCEL 408UL. We used our GPS synchronization controller for the field seismic acquisition to verify the synchronization between the recorder and the gun controller system. It also verified whether the width of the signal pulse for the time break was 200 ms as designed. Table 3 lists the predicted shot time and actual shot time of some shots we completed.

Table 3. Shot statistics from the Bohai Experiement

Line	shot	Shot time			Predict shot time			difference
		h	m	ss.sssss	h	m	ss	ms
s1001	1003	10	56	31.327053	10	56	31.32	0.053
s1001	1005	10	57	43.613053	10	57	43.61	0.053
s1001	1006	10	58	19.518053	10	58	19.51	0.053
s1001	1007	10	58	55.759054	10	58	55.75	0.054
s1001	1008	10	59	31.633056	10	59	31.63	0.056
s1001	1010	11	0	43.938061	11	0	43.93	0.061
s1001	1011	11	1	20.148053	11	1	20.14	0.053

The data in Table 3 show that the predicted shot time is consistent with the actual shot time. We can also get a clear description of the signal width of the time break, which are 200 ms and the same as in the system setup. The only exception is the thirtieth shot whose large error was caused by the interference from the grounding line (Figure 8).

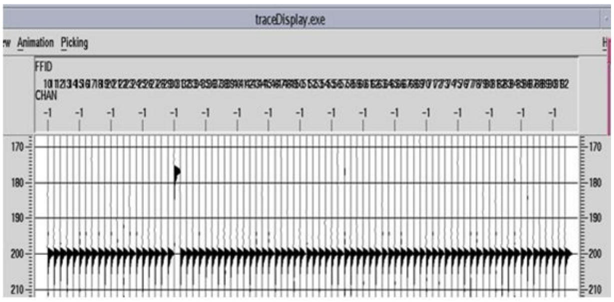

Figure 8 TB signal

Conclusions

In recent years, we have developed surveying and navigation technologies in OBC seismic operations. These newly-developed technologies have provided the much needed solutions to a suite of practical problems. As we know, any product or technology successfully utilized in our industry is the result of a complex, integrated and long-term development process. One prerequisite of successful development for our system is the continuous support from the industry. With the rapid development of the global network technology, we have integrated the OBC seismic operation management and navigation technology with the network-based, centralized, visualization technology. This advancement has dramatically improved BGP's ability to acquire high-quality seismic data that meets the most demanding challenges of oil and gas exploration.

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