Design and Implementation of ROV Submarine Cable Inspection Decision Support System

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Abstract. According to the requirements of field survey and following data management in submarine cable inspection by ROV (Remote Operated Vehicle), this paper analyzes the characteristics of TSS350 cable tracker and underwater video inspection data, designs a reasonable system architecture, implements real-time monitoring and data management of submarine cable inspection based on underwater navigation & positioning, fully integrates various types of data, and improves the management and utilization of submarine cable inspection data and maintenance capability of submarine cable.

1. Introduction

In the offshore wind power, oil & gas and other infrastructure, due to the complex submarine environment in the routing area, serious seabed erosion may cause the submarine cable exposure and threaten its safety. Therefore, regular inspection of submarine cable route’s position and buried depth, detection of submarine cable route obstacles and submarine cable exposure can reduce the probability of submarine power damage and provide guarantee for submarine cable safety. The conventional techniques for inspection of submarine pipeline mainly include: marine pipeline instrument, magnetometer, side scan sonar, etc. With more and more application of ROV, there are a lot of technologies based on ROV to complete submarine cable inspection, such as underwater submarine camera, TSS350 system (see in figure 1), underwater sonar, etc. The British TSS350 cable tracker system is specially designed for cable detection. Based on electromagnetic detection, it can obtain the relative relationship between the cable node and the equipment’s transducer. With the support of high-precision underwater positioning data, it can obtain the high-precision continuous coordinates of the cable. With the underwater camera carried by ROV, it can obtain overall status of the submarine cable and provide basic data for cable maintenance [1].

Figure 1. ROV Submarine Cable Inspection by TSS350 Cable Tracker
But for a long time, the navigation & positioning, TSS350 cable tracker and video inspection are all completed by independent software system. Among them, Navigation & Positioning software is often used for ROV navigation & positioning generally, DeepView for Windows is often used for TSS350 as control, data display and data recording software, while video inspection is often completed by other multimedia software [2]. In this operation mode, Navigation & positioning data, cable detection data and video inspection data are fragmentary and independent with each other, all kinds of data can not be organized and managed through their internal spatial and temporal relations. Among them, TSS cable tracker data as an unique instrument to obtain high-precision location and buried depth of submarine cable, its data is not fused with ROV positioning data to obtain absolute geographic coordinates of submarine cable in real time, so its function is not fully explored. And the spatial attribute of shooting location implied in video data is not reflected, which makes query of video data extremely difficult, so that the inspection data acquired at huge cost is not fully utilized.

In order to improve the maintenance of submarine cable, decision support system for ROV submarine cable inspection is developed based on GIS technology. Based on the high-precision underwater navigation & positioning data in ROV inspection, the real-time positioning data and TSS350 data of ROV cable detection are fused. Through the construction of spatio-temporal database, all the relevant submarine cable inspection data is stored and managed unifiedly to make full use of data.

2. System architecture

2.1. Data requirement analysis
In order to design a reasonable system architecture, the characteristics of different data types in the system need to be classified and studied. ROV submarine cable inspection mainly involves the following four types of data:

Navigation & Positioning data of operation ship: output by GNSS, compass, etc., it’s responsible for surface positioning of operation ship, it’s the source of all position data, with high data accuracy, its data update frequency is generally 1Hz, and the amount of data is small.

ROV underwater navigation & positioning data: output from ultra short baseline underwater acoustic positioning system (USBL) and attitude sensor, its data accuracy is low compared with GNSS, its data update frequency is generally 0.2Hz, and the amount of data is also small.

TSS350 cable detection data: its the most important data of submarine cable inspection. The equipment outputs relative relationship between the cable node and the equipment transducer. After fused with ROV underwater navigation & positioning data, continuous three-dimensional coordinates of the cable can be acquired.

Video inspection data: collected by underwater camera installed on ROV, detailed status of submarine cable and its surrounding area can be obtained through the camera. Due to high resolution and high frame rate of 24fps, the amount of data is large, and its unstructured feature causes great difficult for video data query and retrieval.

2.2. Modules in ROV submarine cable inspection decision support system
According to the business requirement and data characteristic of ROV submarine cable inspection, ROV submarine cable inspection decision support system is based on GIS technology. It includes two subsystems: ROV submarine cable inspection real-time monitoring subsystem and data management subsystem (see in figure 2).
Among them, ROV submarine cable inspection real-time monitoring subsystem based on high-precision underwater positioning is used for field data monitoring and acquisition in ROV cable inspection. Based on the underwater positioning equipment, the subsystem takes the precise spatial position of ROV and submarine cable as the core, realizes the functions of real-time data fusion calculation, intuitive 2D electronic chart/3D visualization and real-time cable profile curve during the ROV submarine cable inspection, so as to ensure the inspection quality and efficiency.

ROV inspection data management subsystem is mainly used for the organization, management, and analysis of inspection data [3]. Due to the particularity of video data and TSS350 cable detection data, the existing data management system can’t realize the complete management and scientific organization management of time, space, attribute, multimedia and other information in the inspection data, and lacks the submarine cable inspection business. Based on the characteristics of data acquisition, time and space management of S350 and ts50, the data acquisition and storage system is based on the characteristics of data acquisition, data collection and spatial management.

3. Features of ROV submarine cable inspection decision support system

The system implements rich modules and business functions in order to meet the business requirements of ROV submarine cable inspection, including:

3.1. Hardware device management.

In order to realize real-time monitoring of submarine cable inspection based on underwater ROV navigation & positioning, it is necessary to install GNSS, attitude sensor, ultra short baseline (USBL), TSS350, altimeter, depth meter and other equipment on operation ship and ROV to obtain accurate position and attitude information of the ship and ROV in real time (see in figure 3). The system can access all the above equipment in real time to complete data receiving, interpretation, processing and fusion calculation. In order to solve the problems of multiple measuring devices, fast update frequency and real-time display of the system, the system introduces distributed data processing technology and optimized scheduling algorithm adapts to multi-core CPU for high-frequency concurrent data to routes the data into multiple independent data processing modules and displays them asynchronously. There are many steps of data fusion in the system, which requires high precision for each step. The system solves this technical difficulty by fine equipment calibration and precise data fusion algorithm in the software.
3.2. Data fusion of surface positioning system (GNSS), ROV underwater positioning system and TSS350 cable detection system

TSS350 cable tracker system is an unique technical equipment to obtain high-precision position and buried depth of submarine cable. Its raw data in measurement mode only contains relative coordinates of the submarine cable node relative to TSS350, and no absolute geographic information is included (see in figure 4). So this data is unfavorable for subsequent data management and analysis. By fusing ROV real-time position, TSS350 installation position and submarine cable relative coordinates, the system can obtain the continuous absolute geographic coordinates and buried depth of submarine cable nodes, which greatly improves the application value of TSS350 cable detection data.

3.3. 2D electronic chart display

ROV inspection requires real-time visual guidance based on electronic chart, which can provide auxiliary information for operators to guide ROV along the submarine cable. During the process of ROV submarine cable inspection, each target (ROV, TSS350, seabed terrain and operation ship, etc.) has obvious geographical space characteristics [4]. Combined with cartographic visualization method in GIS, the system can display real-time position, trajectory track, submarine cable detection curve and cable design material in electronic chart. In addition, critical regions such as cable exposure can be marked according to real time inspection data, which will be used as an important guidance information for following treatment.

3.4. 3D visualization of submarine cable inspection

Each element (ROV, TSS350, seabed terrain and operation ship, etc.) during the process of ROV cable inspection operation has typical 3D space characteristics. The system further uses the 3D visualization technology to display the 3D model of each element involved in the inspection of ROV cable and the 3D terrain of the seabed in real-time in 3D scene, showing the relationship between various elements.
(see in figure 5). It can truly reflect the real-time operation situation on site, and provide auxiliary decision-making information for field operators.

![3D Submarine Cable Detection Scene](image1)

**Figure 5.** 3D Submarine Cable Detection Scene

### 3.5. real-time and multi-angle monitoring of submarine topography and cable buried state

According to the requirements of field operation, ROV submarine cable inspection real-time monitoring module records and displays the cable position data and buried depth data detected by TSS350, and automatically generates cable longitudinal section and transverse section curve combined with the preliminary sweep survey topographic data of submarine cable routing area, which directly reflects the relative relationship between submarine cable, seabed terrain, cable exposure and other abnormal conditions from different angles (see in figure 6), it provides practical decision support information for field operators.

![Longitudinal Section and Transverse Section Curve](image2)

**Figure 6.** Longitudinal Section and Transverse Section Curve Generated Automatically During Submarine Cable Inspection

### 3.6. Multi-source heterogeneous data organization and management based on time, spatial and routing mileage

ROV submarine cable inspection involves various types of data, in particular, the video inspection data is very large in amount and it does not have geospatial attributes. Therefore, the system records shooting time stamp of each video frame in the data acquisition module. ROV video data is associated with the geographical coordinates by the time stamp, in this way, the spatial coordinate is assigned to each frame of video data. In addition, mutual data query and retrieval between video data, geospatial coordinate, and submarine cable node routing mileage is realized. finally, multi-source heterogeneous submarine cable inspection data can be centrally stored and effectively retrieved by the system [5]. Multiple types of spatial query based on electrical chart display are also included in the system, so that effective technology method is provided to make full use of the expensive submarine cable inspection data.
3.7. Data interoperation
In order to interoperate with other systems, the system supports import of many different formats of AutoCAD, ArcGIS and other commonly used software, such as design data, historical inspection data and other files for analysis. At the same time, according to user’s requirements, submarine cable node coordinates, burial status and corresponding seabed topography data obtained from the inspection can be exported to CAD graphic files or text files, which can provide data for subsequent comprehensive map drawing, integrated GIS management system and other subsequent further applications [6].

4. Conclusion
ROV submarine cable inspection decision support system includes two parts: ROV submarine cable inspection real-time monitoring and inspection data management based on underwater navigation positioning. By introducing GIS technology into submarine cable inspection, it realizes the full integration of various types of data, and improves the management and utilization of TSS350 cable detector data and video detection data. In the future, the system can be further combined with the operation and maintenance requirements of submarine cables, enrich the data types and expand its application scope.

5. References
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