A Position-coding Terminal Device for Ships Based on BeiDou Navigation Satellite System

Xin Su¹² and Weifeng Zhou*¹
¹ East China Sea Fishery Research Institute, Chinese Academy of Fishery Sciences, Shanghai 200090, China
² College of Marine Sciences, Shanghai Ocean University, Shanghai 201306, China
*Corresponding author, Email: zhouwf@ecsf.ac.cn

Abstract. Considering massive amounts of location data will consume excessive memory and inefficient when performing a spatial query, a new ship position-encoding device was designed by combing the navigation, positioning and communication functions of the Beidou navigation satellite system and Geohash coding technology. An efficient index algorithm based on Geohash encoding was applied to improved efficiency, especially to solve the problem that massive ship position data occupies massive amounts of memory resources when searching for rescue ships near a wrecked ship, improve rescue efficiency, reduce energy consumption, realize high device utilization, one-key multi-use, and higher automation. Experimental results prove the ship position encoding method is better than the traditional device in terms of the spatial query of nearby ships and reducing the storage space consumption.

1. Introduction
Offshore operations are high-risk industries, especially small offshore vessels, which have poor disaster tolerance and are prone to accidents. Small ships are the focus of maritime search and rescue. To ensure the people’s safety of offshore operations, China must pay more attention to ship management, safety production, and maintain order on the sea.

Due to the lack of base stations at sea, the positioning and communication of ships on the sea cannot rely on ground communication means and methods. BeiDou navigation satellite system is abbreviated as BDS, is an autonomously constructed and independently operated global satellite navigation system currently in practice in China. With the successful launch of the last global networking satellite of "BDS-3", the deployment of the BDS constellation has been fully completed. Globally, the BDS provides high-precision, high-reliability positioning, navigation, and timing services for all types of users around the clock and all-weather, and has short message communication capabilities. This provides technical feasibility for the positioning and communication of this device.

Directly recording, storing and managing longitude and latitude ship position data are the basic applications of the current vessel monitoring system (VMS). Based on satellite navigation and positioning technology, users can obtain location information more conveniently, but massive spatial location data and its analysis, processing and storage require high-performance computers and optimization algorithms, especially when a ship needs rescue in a disaster. At present, VMS can only perform search calculations directly based on the location of the wrecked ship (floating-point latitude and longitude data). At this time, when calculating the distance between each ship position at a certain time, the calculation is large, the time is long and more memory resources are occupied.

Geohash is a geocoding algorithm that alternately divides the earth's surface in the direction of longitude and latitude, which uses a binary number to represent two-dimensional spatial floating-point
longitude and latitude information. The lower-level unit grid of Geohash is obtained by dividing the upper-level unit grid [1]. It is essentially a spatial Z-curve filling. The 4 Geohash grids in “Z” shape belong to the same parent grid. Their binary codes have the same prefix [2], which provides technical possibilities for quickly-search of nearby rescue ships. Geohash has now been used in quick search for points of interest, area data query, etc. Using Geohash to encode, record and store position information can effectively save communication resources and storage space for ship position management. And when it is necessary to find the neighboring ships of the ship of interest (such as the shipwrecked) in special circumstances, it directly performs character prefix matching operations with the ship of interest (such as the shipwrecked), which can quickly match and find nearby ships[3], effectively reducing the waiting time for rescue.

This research aims to combine BDS navigation and positioning, communication technology and Geohash coding technology to solve the problem of ship position management at sea, with emphasis on solving the problem of massive ship position data occupying massive amounts of memory resources when finding rescue ships near the wrecked ship, improving rescue efficiency and reducing energy consumption, at the same time, heightening device utilization, achieving one-key multi-use and enhancing automation.

2. Structure and Performance

Combining the unique short message two-way communication function of BDS with Geohash coding technology, realizes the coding of the ship’s position at sea through the hardware device, and sends the code to the command center on the shore. The device can encode the ship position information represented by the two-dimensional data of latitude and longitude in real-time and send it to the back-end database of the command center in form of short messages so that when the ship is in distress, it can quickly find nearby ships according to the code and facilitate rescue.

The main components include BDS’s Radio Determination Satellite Service (RDSS) unit, upper computer, lower computer, and alarm equipment (figure 1).

![Figure 1. The Schematic diagram of the hardware structure](image-url)

BDS’s RDSS unit uses the BDS navigation and communication satellite RDSS (Radio Determination Satellite Service) payload for positioning and communication. BDS’s RDSS unit integrates RDSS radio frequency transceiver chip, power amplifier chip and baseband circuit, etc., which can completely realize all functions of RDSS transceiver signal, modulation and demodulation. With high integration and low power consumption, it is very suitable for the needs of large-scale system applications. The BDS’s RDSS unit is connected to the lower computer in this device through serial communication and is used for positioning solution and short message sending combined with the encoding result of other ship information. (1) The BDS’s RDSS unit receives the carrier signal containing the ranging code and navigation message sent by the BDS’s navigation satellite through the
antenna. When the latitude and longitude position information of the ship obtained by the navigation satellite signal positioning and solution, it will be transmitted to the lower computer; (2) After the lower computer finishes encoding the Geohash, the lower computer transmits the encode result to the BDS’s RDSS unit through the input serial interface. Combined with the ship ID and other ship information, the BDS’s RDSS unit sends a short message to the shore-based ship position management command center through the antenna.

The upper computer is a computer that directly sends control instructions to the lower computer. The upper computer transmits the set instruction to the lower computer through the serial port. The upper and lower computers in this device communicate through the RS232/RS485 serial port. Serial communication uses a pair of transmission lines to achieve two-way communication. The upper computer is determined by the user (or a pre-set program) to issue operation instructions, whose control instructions are: (1) whether to execute the coding program and send the code; (2) control the alarm to turn on/off, and give an alarm prompt for the current position.

The lower computer is a computer that directly controls the equipment to obtain the equipment status. The lower computer in the device connects and controls the BDS’s RDSS unit and the alarm. In the device, whose lower computer is realized by a single-chip microcomputer. The single-chip microcomputer solidifies the encoding program (figure 2) for the one-dimensional conversion of the ship's two-dimensional latitude and longitude position information in the program memory (ROM) to realize its function of encoding the ship's position data. When the lower computer receives the "start/stop code" command from the upper computer, start/stop: (1) Communicate with the BDS’s RDSS unit through the serial port (RS232), read the ship positioning data input by the BDS’s RDSS unit, and store the ship’s latitude and longitude position data in the data register (RAM); (2) Execute the solidified Geohash coding program to encode the ship's latitude and longitude position data stored in the register; (3) Output the coding result to the BDS’s RDSS unit, and finally send it to the shore-based ship position management command center, and then algorithms of efficient nearest neighbor query, spatial query, and continuous query were proposed with the help of Hash table, linked list and Geohash of moving object position.

In the device, when the lower computer receives the command to "turn on/off the alarm" from the upper computer, the lower computer turns on/off the alarm through a transistor, meanwhile controls the BDS’s RDSS unit to send an alarm signal to the shore-based ship position management command center. After that, the result of Geohash coding calculated according to the current latitude and longitude position is sent out to alarm.

The alarm is to remind or warn yourself or the surrounding ships in an emergency state by sounding and illuminating. The alarm is connected to the lower computer through a triode, the lower computer can make a sound through a high and low level voltage, as the one connected to the base of the triode is a low level. When the ship breaks down or encounters an emergency, the upper computer is determined by the user (or a pre-set program) to issue an operating instruction, and transmit the "open/close alarm" instruction to the lower computer. At this time, the lower computer turns on/off the alarm according to the instructions sent by the upper computer, the transistor is turned on, and the alarm can be turned on (ON) or closed (OFF). When the ship encounters danger, control the alarm, one-key alarm, and give an alarm for the current position.
3. Implementation Method

The BDS’s RDSS unit receives the carrier signal containing the ranging code and navigation message sent by the BeiDou navigation satellite system through the antenna and calculates the longitude and latitude position information of the ship obtained by the navigation satellite signal positioning and solution, and the longitude and latitude position information of the ship obtained through the calculation through the data interface (RS232) is transmitted to the lower computer.

When the upper computer directly sends the control command to the lower computer:

1. When the upper computer sends a "start/stop coding" command to the lower computer through RS232, the lower computer starts/stops: (1) Communicate with the BDS’s RDSS unit in the device through the serial port (RS232), and the lower computer generates Interrupt, enter the reading program, read the ship positioning data input by the BDS’s RDSS unit, and store the two-dimensional ship latitude and longitude position data in the data register (RAM); (2) execute the solidified Geohash code program and store it in the register; (3) Output the encoding result to the BDS’s RDSS unit, then use the BDS’s RDSS unit to send the encoding result of the lower computer to the ship position, combined with the ship ID and other ship information, to the shore-based ship position management command center in the form of short messages.

2. When the ship breaks down or encounters an emergency, the command set "turn on the alarm" issued by the upper computer is transmitted to the lower computer through RS232, and the lower computer can trigger (turns on/ON) the alarm through the transistor to realize one-key alarm, with the simple operation; When the ship is out of danger and is in a safe sailing state, the upper computer sends the command set of "turn off the alarm" to the lower computer, and the lower computer triggers (turns off/OFF) the alarm through the transistor to turn off the alarm with one button, to save resources.

Figure 2. The Geohash coding flowchart in the single-chip microcomputer
4. Experimental Results and Analysis

4.1. Comparison Test of Memory Resource Consumption

Since Geohash converts the two-dimensional double-precision floating-point (double) data in the latitude and longitude space into one-dimensional string encoding, it effectively reduces the storage space occupied by terminals and single-chip computers of BeiDou navigation satellite system.

First, to ensure the accuracy of the ship's position data, the device calculates the memory footprint of 10,000 floating-point ship position data, and define the ship's latitude and longitude data with double-precision floating-point variables. Besides, for the traditional method to calculate the spatial distance between two longitude and latitude points through Euclidean distance, it is also defined as double data. The calculation results are as follows: longitude, latitude and spatial distance are \(3 \times 10^4\) pieces of data, while the memory space occupied is 240896 bytes (bytes); for the grid-encoded data, in order to meet the accuracy requirements of the ship location, the longitude and latitude data are divided into grids 20 times. The result of the division is: the string encoding length is 8, and the spatial resolution is 20m. The memory size of the encoded data is 104856 bytes (table 1). It can be concluded that grid coding reduces the consumption of memory resources and uses memory resources more efficiently.

| Ship position data type                                      | Memory usage (Unit: Byte) |
|-------------------------------------------------------------|---------------------------|
| Spatial two-dimensional latitude and longitude coordinates   | 240896                    |
| Geohash one-dimensional string encoding                     | 104856                    |

4.2. Analysis

The effective use (sufficient) of memory resources has a positive impact on the improvement of program operation efficiency and data calculation.

(1) Memory space occupation

On the other hand, the encoded one-dimensional character string can represent the two-dimensional latitude and longitude coordinates, while the traditional ship position is stored in the form of two-dimensional data of latitude and longitude. For example, in the fishing vessel monitoring system (VMS), the position information is directly stored and managed by the latitude and longitude [4]. In addition, the update frequency of the BeiDou navigation system is 3 minutes, which is equivalent to sampling once every 3 minutes to record the dynamic characteristic data of the fishing boat [5]. However, the fishing state of the fishing boat lasts for several hours, and the ship position data is massive. Therefore, the memory usage of the two-dimensional latitude and longitude data stored by the traditional VMS is large.

(2) Distance calculation method

On the other hand, the length of the encoded string can reflect the spatial distance. Different string lengths indicate different spatial distances, and the longer the encoded string, the smaller the spatial distance. However, the traditional method of calculating distance is to solve the Euclidean distance between a pair of latitude and longitude, earth radius, trigonometric function, etc., mainly based on multiplication, and the speed of multiplication is nearly 10 times faster than that of addition and subtraction. In addition, the CPU performs bit operations (and, or, not, and XOR) at the same speed as addition and subtraction. Therefore, the calculation of Euclidean distance is relatively slow in terms of operations [6]. Compared with the grid coding method, the calculation method is more complicated, the operation reusability is low, and the single calculation consumes more memory.

5. Conclusion

To sum up, this device combines BeiDou navigation and positioning, communication technology and Geohash coding technology, based on the ship's real-time spatial latitude and longitude position information, and encodes massive spatial data on-site to solve the problem of marine ship position
management. In particular, it solves the problem that massive ship position data occupies large amounts of memory resources when searching for rescue ships near a wrecked ship, improves rescue efficiency, reduces energy consumption, realizes high device utilization, one-key multi-use, and improves automation.

6. Acknowledgments
This work was financially supported by the National Key R&D Program of China (2019YFD0901405).

7. References
[1] Xiang L G, Wang D H and Gong J Y 2017 *Geomatics and Information Science of Wuhan University* Organization and efficient range query of large trajectory data based on geohash 42 pp 21-27
[2] Amir H, Ahmed M and Francois D 2017 *Pers Ubiquit Comput* Data fusion in automotive applications-Efficient big data stream computing approach 21 pp 443–455
[3] Wonhee C and Eunmi C 2017 *Cluster Computing* A basis of spatial big data analysis with map-matching system 20 pp 2177–2192
[4] Zhou W F, Cui X S, Fan W, He Z H, Yu L P, Dai Y and Wang L H 2015 *World Sci-Tech R & D* Location-based information service’s applications and its prospects in marine fisheries 37 pp 611-617
[5] China Satellite Navigation System Management Office 2015 BD 420006—2015 BeiDou/Global Navigation Satellite System (GNSS) timing unit performance requirements and test methods
[6] David A P, John L H 2015 *Computer Organization and Design* (China Machine Press) p 536