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Research on classification and prediction technology of underwater navigation adaptation area based on gravity anomaly data

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Abstract: *In this paper, the classification and prediction technology of underwater navigation adaptation area based on gravity anomaly data is studied. Firstly, the gravity anomaly reference data is processed by interpolation encryption, and the region division and adaptation calibration are completed by cluster analysis. Secondly, latitude and longitude are selected as the attribute index, and the adaptive area classification prediction model based on CRNN neural network is established. Finally, another set of gravity anomaly data is used to predict the migration of the model, and the validity of the model is verified. The research shows that the adaptive region classification and prediction technology based on gravity anomaly data can significantly improve the accuracy of underwater navigation. The research is of great significance for establishing an accurate and efficient underwater navigation system.*

Keywords: *Underwater navigation, Gravity anomaly, Adaptation area, Cluster analysis, CRNN neural network*

1. Introduction

Underwater navigation is one of the key technologies for underwater vehicles to perform tasks. In military, civil and other fields, underwater vehicles are playing an increasingly important role. However, in underwater environment, the traditional navigation methods such as inertial navigation, satellite navigation and so on are greatly limited[1-3]. Therefore, gravity aided navigation, as an important navigation method, is based on the matching selection of regions through gravity anomaly data. Gravity anomalies arise from the uneven distribution of materials inside the Earth, resulting in differences between the actual gravity field of the Earth and the theoretical model. Significantly changing gravity anomaly regions provide higher positioning accuracy for navigation, while flat regions affect accuracy [4]. Choosing the right area is very important to the navigation accuracy of underwater vehicle [5].

Three problems are proposed in this paper: The first problem is to use the reference data A of gravity anomaly with 1'×1' resolution in Annex 1 to divide the region and complete the adaptation calibration, involving the fine division based on Annex 1; The second problem is to select feature attribute index X based on the calibration result Y, and establish the adaptive area classification prediction model F, focusing on the selection and modeling of feature attribute index X of the adaptive calibration result Y. The third problem examines the migration prediction and applicability of system F to the gravity anomaly data B in Annex 2. The establishment of accurate regional adaptive region classification prediction model will help to improve the accuracy of underwater navigation. Solving these problems will help to build an effective underwater navigation system.

The application of gravity anomaly data in underwater navigation has significant advantages. Gravity anomaly data can reflect the fluctuation of underwater terrain and provide high-precision positioning information for spacecraft. At the same time, the gravity anomaly data is hidden and not easy to be interfered by the enemy. However, how to effectively use gravity anomaly data for adaptive region classification prediction is a challenging problem. Firstly, it is necessary to interpolate and encrypt the gravity reference map of the study area, and then analyze the selection of the adaptation area according to the gravity anomaly variation of the navigation area of the underwater vehicle provided by the reference map.

In this paper, through the study of three problems, the aim is to establish an effective classification

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and prediction model of gravity anomaly data fit area. Firstly, by processing and dividing the gravity anomaly reference data, the adaptive calibration of each region is completed. Then, based on the adaptive calibration results, the appropriate attribute index is selected and the classification prediction model is established. Finally, the applicability of the model is verified by the migration prediction. The research of this paper will help to improve the accuracy of underwater navigation and lay a foundation for establishing an accurate and efficient underwater navigation system.

2. Materials and methods

2.1 Data Collection

In this study, A reference data of gravity anomalies with a resolution of 1 '×1', the values of longitude, latitude and gravity anomalies, and another set of reference data of gravity anomalies B were collected for migration prediction and to discuss the applicability of the F system to the new data.

2.2 Research Methods

The research method of this paper mainly includes the following steps:

(1) Gravity anomaly reference data processing: First, gravity anomaly reference data A with 1'×1' resolution is processed, including interpolation encryption and outlier elimination, to obtain more accurate reference data.

(2) Regional division and adaptation calibration: Using the processed benchmark data, the region is divided and the adaptation calibration of each region is completed. This step is mainly realized by cluster analysis method.

(3) Establishment of adaptive area classification prediction model: Based on the results of regional division and adaptation calibration, latitude and longitude were selected as feature attribute indexes to establish a CRNN neural network based adaptive area classification prediction model.

(4) Model migration prediction and verification: Another set of gravity anomaly data B is used to predict the migration of the established model to verify the applicability of the model to the new data.

(5) Model evaluation and optimization: Compare and analyze the advantages and disadvantages of the clustering algorithm used, and evaluate and optimize the model.

(6) Result discussion: The applicability of the model is discussed according to the prediction results of the model to provide reference for practical application.

Through the above steps, this paper establishes a classification and prediction technology of underwater navigation adaptation area based on gravity anomaly data, and verifies its effectiveness.

3. Model establishment and solution

3.1 Adaptive calibration of each region

3.1.1 Model establishment

Firstly, the abnormal values in the data are analyzed, and on this basis, the data is divided into the following steps: insert the Raida criterion, remove the abnormal data, write the new data group into the "processed data.xlsx", and output the number of processed and deleted data in the command line window)

Outliers are processed by the above method, and on this basis, the data is divided. According to the definition of gravity outliers, it can be seen that:

$$\mathrm{G}_{\text{anomaly x}} = \mathrm{G}_{\text{real x}} - \mathrm{G}_{\text{theory x}} \tag{1}$$

That is, the difference between the actual gravity $\mathrm{G}_{\text{anomaly x}}$ at position x and the theoretical gravity $\mathrm{G}_{\text{real x}}$ at position x.

In order to accurately analyze the gravity outliers in the 1 '×1' region, the region surrounded by four adjacent longitude and latitude data points is taken, the four coordinate points are named ABCD and their

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gravity outliers are statistically analyzed to calculate the variance:

$$S^2 = \frac{1}{4}\sum_{i=1}^{i=n}(\mathrm{G}_{\mathrm{anomaly\,i}} - \overline{\mathrm{G}_{\mathrm{anomaly\,ı}}})^2 \tag{2}$$

Among them:

$$\overline{\mathrm{G}_{\mathrm{anomaly\,ı}}} = \frac{1}{4}\sum_{i=1}^{i=n}\mathrm{G}_{\mathrm{anomaly\,i}} \qquad (i = 1, 2 ,3 , 4...) \tag{3}$$

The data in "Processed data.xlsx" is quantified by the above formula, and the "quantized data.xlsx" is output.

3.1.2 Solution of the model.

The main contents are as follows: (1) on the basis of the above, cluster analysis is carried out on MATLAB software (including three kinds): fuzzy clustering, K-means clustering and Gaussian mixture clustering.

(2) The quantized data are clustered by three kinds of clustering (fuzzy clustering, K-means clustering and Gaussian mixture clustering), and the clustering results are visualized by scatter graph.

(3) The codes for generating the three models and the graphics for dividing the regions can be seen.

(4) The division results and eigenvalues of each region after the three clustering results are calculated and presented in the command line window.

(5) Suitability calibration (label Y) output of each region.

3.2 Classification label prediction of regions.

3.2.1 Establishment of the model.

According to the analysis of the problem, the neural network model is used to predict the classification label of any region.

In this paper, CRNN neural network prediction model is used to predict, the specific operation steps are as follows:

The 3.1 part "quantized data .xlsx" is used for Gaussian clustering analysis and the clustering result is output as "the result includes taxonomy .xlsx".

3.2.2 Solution of the model.

The data in the "results include classification group .xlsx" are used to predict the GRNN neural network (the first 10, 000 groups of data are training sets, and the rest are prediction sets), and the relative error between the predicted value and the actual value is calculated.

(relative error values are all placed in "GRNN forecast error value .xlsx" and will also appear in the command line window.).

The first 10000 groups of data are selected as the training set, and the remaining data as the test set, in which the longitude and latitude of the training set is taken as the training input set P; the classification value of each region is taken as the training output set T, and the training index data is set up to get the network training model. On this basis, P is used as the test set.

If the predicted value Y is obtained by substituting the above model, there is:

$$\mathrm{W} = \frac{|\mathrm{T}' - \mathrm{T}|}{\mathrm{T}} * 100\% \tag{4}$$

Where: W indicates the relative error of the predicted result

"GRNN prediction error value" was used to calculate its characteristic value (presented in the command line window), and the histogram of error frequency was output (Figure 1).

Output result: mean is -0.0605, median is 0.4, standard deviation is 0.8969, range is 2.5714.

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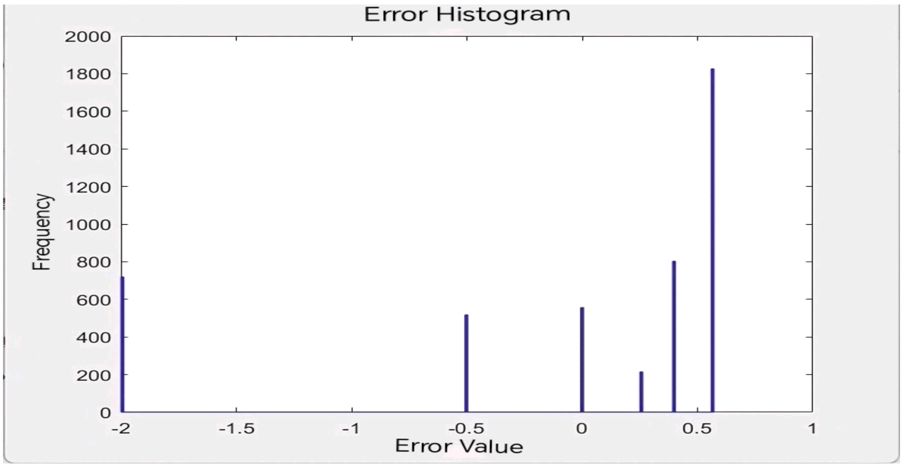

Figure 1: Histogram of error frequency

3.3 Migration prediction and discussion

3.3.1 Data processing and quantification

According to the problem analysis, data is preprocessed according to the established CRNN - neural network model (outliers are excluded, new data sets are written into "processed data.xlsx", and the number of processing and number of rejection is output in the command line window).

3.3.2 Actual Category label Calculation

Gaussian cluster analysis was performed with "quantized data.xlsx" and the clustering result was output as "result contains classification groups _ for prediction.xlsx". The data in "Results contain taxonomic groups.xlsx" is used as the training set, and the data in "Results contain taxonomic groups.xlsx" is used as the prediction set for GRNN neural network prediction (Note: The result contains the classification group.xlsx is the file in question 2), and calculates the relative error between the predicted value and the actual value. The relative error values are all put in the "GRNN prediction error value."

GRNN prediction error value" was used to calculate its characteristic value (presented in the command line window), and the histogram of error frequency was output (Figure 2).

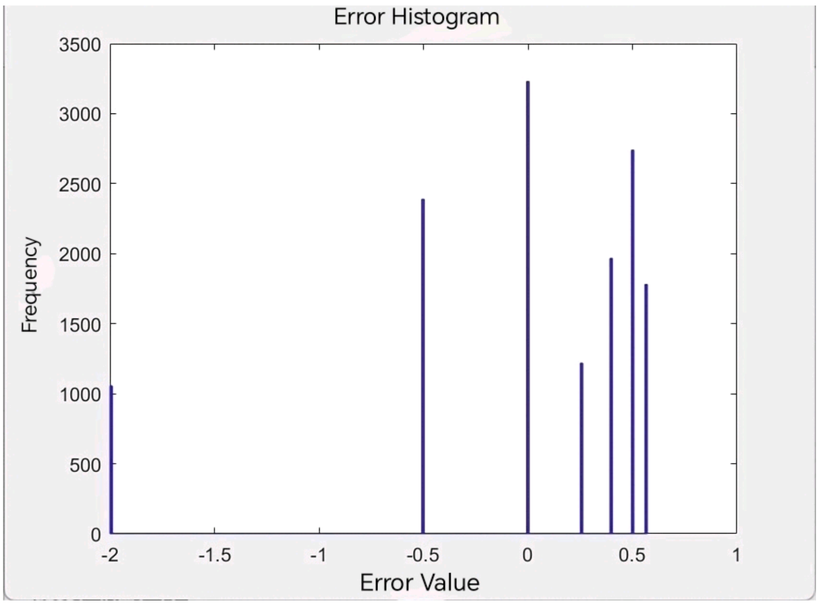

Figure 2: Histogram of error frequency

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4. Conclusion

In this paper, the classification and prediction technology of underwater navigation adaptation area based on gravity anomaly data is studied. Firstly, the region division and adaptation calibration are completed. Secondly, the adaptive area classification prediction model is established. Finally, the validity of the model is verified. The results show that the adaptive region classification and prediction technology based on gravity anomaly data can significantly improve the accuracy of underwater navigation. The research of this paper lays a foundation for the establishment of accurate and efficient underwater navigation system. Follow-up studies can continue to optimize the model, improve the prediction accuracy, and further verify the effectiveness of the model in practical applications.

References

[1] Li Z .Optimizing Matching Area for Underwater Gravity-Aided Inertial Navigation Based on the Convolution Slop Parameter-Support Vector Machine Combined Method[J].Remote Sensing, 2021, 13.DOI:10.3390/rs13193940.

[2] Chenglong W, Bo W, Zhihong D, et al. A co-occurrence matrix-based matching area selection algorithm for underwater gravity-aided inertial navigation [J]. IET Radar, Sonar Navigation, 2021, 15(3): 250-260.

[3] Kundu S , Parhi D R .Navigation of underwater robot based on dynamically adaptive harmony search algorithm[J].Memetic Computing, 2016, 8(2):125-146.DOI:10.1007/s12293-016-0179-0.

[4] Wang L, Sun D, Liu Q, et al. Matching area selection of an underwater terrain navigation database with fuzzy multi-attribute decision making method [J]. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 2019, 233(4): 1133-1140.

[5] Information Technology; New Information Technology Data Have Been Reported by Researchers at Southeast University (Matching area selection of an underwater terrain navigation database with fuzzy multi-attribute decision making method) [J]. Computers, Networks Communications, 2019.