Research on ocean current visualization method based on particle

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Abstract. NetCDF network general data format is a common data format used to store meteorological data such as ocean current field. However, the ocean current data in NetCDF format can not be read directly on the web for dynamic visualization. To solve this problem, this paper takes the Pearl River Estuary area as the research area, adopts the sparse algorithm based on local Moran’s I index and improved point center buffer to dilute the ocean current data, converts the ocean current point data into particle data by using the vector synthesis calculation method of ocean current data, and designs specific JSON data structure for data storage. After completing the pre-processing of the visualization data of ocean current based on particles, a dynamic visualization display platform of ocean current particles is built on the Web side, and the JSON data of ocean current is read. The space-time dynamic visualization effect of ocean current data in the form of particles in the format of NetCDF is realized, and the static and intuition problem of ocean current visualization is solved.

1. Introduction

NetCDF (Network Common Data Form) is developed by the Unidata project scientists of the American University Atmospheric Research Association for the characteristics of scientific data. It is an array-oriented data description and coding standard suitable for network sharing. NetCDF files were originally used to store data in meteorological sciences, including attribute data such as sea temperature, salinity, water level, wind field, and flow field in the ocean. It has now become a file format for many data acquisition software. At present, MATLAB, GeoDa, ArcGIS and other tools can read and visualize data from NetCDF files, but the visualization of ocean current data is mostly displayed in the form of static arrows, and the visualization effect is not good[1].

The particle system is a computer graphics research result proposed by Reeves W.T in 1983[2]. The flow field visualization method based on the particle system regards the moving fluid particles in the flow field as particles, and simulates the change of the entire flow field with the help of the generation, flow and disappearance of the particles, so as to simulate wind, fire, clouds, etc. Natural scene[3]. At present, a lot of related research work has been done on particle system-based flow field visualization, Kruger J[4] proposed a particle system for interactive visualization of the flow field on a uniform grid, which uses GPU to perform advection processing of particles. This method allows the interaction and rendering of millions of particles, providing a way for large-scale flow field visualization analysis effective measures. Chandler Jennifer[5] has developed an improved k-d tree representation, which can effectively and accurately locate and interpolate the neighborhood of changing particles. Lin[6] used the particle system method to construct a flow field dynamic map symbol expression model, and expresses a good visualization effect by applying it to ocean data visualization.
Aiming at the static and non-intuitive problem of NetCDF ocean current data dynamic visualization on the Web side, the particle-based ocean current visualization data preprocessing method solves the problem that ocean current data cannot be directly read on the Web for visualization, and realizes the NetCDF format ocean current data in The dynamic visualization effect based on the particle form on the Web.

2. Preprocessing method of ocean current data based on particle

The Pearl River estuary is located in the northern part of the South China Sea. The situation of the sea area is complex and there are many islands. The sea water movement is affected by runoff, topography and meteorological conditions at the same time. The study of the ocean current changes is beneficial to the navigation, fisheries and other fields.

2.1. Ocean current data extraction

The hourly current point data volume in the Pearl River Estuary current area is 704373. When the visualization is performed, the data volume is so large that it affects the visualization speed of the ocean current, and the flow field symbol coverage problem may occur, which affects the visualization effect. Therefore, it is necessary to thin out the ocean current data before visualization.

2.1.1 Local Moran's I index method based on spatial autocorrelation

In this paper, the local Moran's I index method based on spatial autocorrelation is used to screen the singular values of current data. The reason why the global Moran's I index is not used is that considering the wide range of the overall current area and the large deviation of the current values with geographical location, it is normal to choose the local Moran's I index.

Figures 1 and 2 are the Moran scatter plots and cluster maps obtained after univariate local Moran's I analysis of ocean current velocity and flow direction using GeoDa tools. The flow velocity Moran's I index reaches 0.996, and the flow direction Moran's I index reaches 0.932. They all have a strong spatial correlation. It can also be seen from the figure that there is a relatively obvious local spatial aggregation relationship between the two. There are five forms of spatial aggregation relationship, namely, insignificant relationship, high-high aggregation, low-low aggregation, high-low aggregation, and low-high aggregation. High-high aggregation and low-low aggregation mean that the area’s velocity near the area with high flow velocity is also high. The velocity in the vicinity of the smaller velocity area is also small, which is in line with the basic characteristics of ocean current[7]. The high-low aggregation refers to the local high-velocity aggregation area in the low-velocity area, and the low-high aggregation refers to the local low-velocity aggregation area in the high-velocity area. These are the singular value data of ocean currents, and in the process of data thinning, the data points of other current should be preserved, so higher data weight is given.

![Fig.1 Moran scatter map and clustering map of ocean current velocity](image)
2.1.2 Ocean Current Thinning Algorithm Based on Improved Point Center Buffer

The ocean current thinning algorithm based on the point center buffer is based on a certain ocean current point as the center, making a circular buffer according to the set radius, and filtering all ocean current points in the buffer according to a specific thinning method. However, the algorithm uses a fixed radius for data thinning. When zooming to view detailed ocean currents in a certain area, the problem of low data resolution and large data errors will occur. In response to this problem, this paper designs an improved method for the algorithm. The main idea of the improvement is to change the method of thinning at different scales. The actual operation is reflected in the setting of the buffer radius. According to many experiments, the best calculation method for obtaining the buffer radius according to the current map scale is obtained:

\[
R = \frac{k \times \text{scale}}{100}
\]  

(1)

Where R is the buffer radius, scale is the current map scale, k is the reference scale, and the value of k is set according to the ocean current visualization area and the original data density of the ocean current. Moreover, scale as the current map scale should be based on the ocean current visualization area and the original ocean current data density in the limited range. Excessive thinning will occur when the scale is too small. Invalid thinning will occur due to the original data density when the scale is too large. The improved algorithm can avoid the disadvantage that the original algorithm cannot provide more accurate ocean current data according to the zoomed map range, and enhance the visualization of ocean currents.

2.2 Vector synthesis calculation of ocean current data

The ocean current data values are stored in the NetCDF file in the form of \( f(\text{time}, \text{siglay}, \text{nele}) \). According to the specified time (time), flow layer (siglay) and grid index (nele), the lon (longitude), lat (Latitude), u (velocity in the true east direction) or v (velocity in the true north direction) composed of ocean current data. To visualize the ocean current based on the particle system, it is necessary to establish a data expression relationship between the particle system and the ocean current. By designing a suitable ocean current data grid for storing ocean current data information, and establishing the corresponding quantitative and positional relationship between the ocean current data and the particles through the grid, the density of the particles and the particle motion trajectory can be determined through the data grid, thus achieve the visualization of ocean currents in the form of particles. Therefore, in addition to being able to directly read the latitude and longitude data to determine the specific location information; it is necessary to perform vector synthesis calculations on the velocity components u and v to obtain the actual velocity and direction of the ocean current.

In the process of vector synthesis, the calculation methods of flow velocity and flow direction are as follows:

\[
\text{speed} = \sqrt{u^2 + v^2}
\]  

(2)
\[
\text{direction} = \begin{cases} 
\frac{180}{\pi} \times \arctan \frac{u}{v}, & u > 0, v > 0 \\
\frac{180}{\pi} \times \arctan \frac{u}{v} + 180, & u > 0, v < 0 \\
\frac{180}{\pi} \times \arctan \frac{u}{v} + 360, & u < 0, v < 0 \\
\frac{180}{\pi} \times \arctan \frac{u}{v}, & u < 0, v > 0 
\end{cases}
\]

_{speed_ is_ the_ real_ flow_ velocity_ after_ vector_ synthesis_ of_ \(u\) and \(v\), _direction_ is_ the_ real_ flow_ direction_ value_ after_ vector_ synthesis_ of_ \(u\) and \(v\), the_ flow_ direction_ value_ is_ the_ angle_ value_ of_ the_ clockwise_ rotation_ starting_ from_ the_ north_ direction_ of_ 0_ degrees, and_ the_ value_ is_ taken_ The_ interval_ is_ \([0, 360)\)._ The_ flow_ direction_ value_ is_ used_ as_ an_ index_ to_ judge_ the_ flow_ direction__, and_ provides_ a_ data_ source_ for_ the_ particle_ trajectory_ when_ the_ particle_ movement_ is_ realized._

2.3. Data storage structure design

JSON is a lightweight data exchange format with simple data analysis, fast data interaction, and wide compatibility, and can support data reading from different browsers and operating systems. This article designs a specific JSON data structure, stores the processed data in this structure, and reads, renders and displays it on the Web. The JSON data design structure is shown in Table 1.

| Data variable | Detailed description |
|---------------|----------------------|
| ParameterName | Identify ocean current velocity and direction data |
| ParameterUnit | Data unit: m/s |
| dx/dy         | Data grid longitude/latitude span |
| lat1/lat2     | The start/end latitude value of the area |
| lon1/lon2     | The start/end longitude value of the area |
| nx/ny         | Number of horizontal/vertical grids |

The header in the table is used to store the information of each field, including the visualization area range, etc., and the data is to store specific data. The data is stored in an array, and each grid data is stored in the manner of "from left to right, top to bottom" according to the set starting latitude and longitude and data grid longitude/latitude span. The advantage of this data storage structure is that it can avoid storing the latitude and longitude data of each ocean current particle in the area and the ocean current data at the same time, which can increase the data reading speed to a certain extent.

3. Realization of ocean current visualization system based on particle

Based on the open source JavaScript library Leaflet, ArcGIS online base map service, combined with the particle-based ocean current visualization data preprocessing method, this paper designs an ocean current particle dynamic visualization system.

The experimental data in this paper is the Pearl River Estuary ocean flow field data in NetCDF format from June 18, 2020 to July 14, 2020, with a time resolution of 1 hour. Figure 6 shows the overall effect of visualization of ocean current particles in the Pearl River Estuary region. Through the time selector and the time axis to display the current situation at a certain moment, when the mouse moves within the current area, the lower left corner area displays the current position's current velocity and flow direction in real time.
Through the thinning of ocean current data, vector synthesis calculation, and data storage structure design, the ocean current data can be visually displayed in the form of dynamic particles on the visualization platform. It can be seen from Figure 6 that the current effect in the form of dynamic particles can intuitively show the real-time situation and flow trend of the current, and the velocity of a certain area can be directly observed through the particle color and motion speed. Compared with the current visualization effect represented by static symbols mentioned in the previous paper, the method designed in this paper is not only more intuitive in the overall effect, but also convenient to observe the real-time changes of current, and achieves an ideal visualization effect.

4. Conclusion
Aiming at the problem of dynamic visualization of Pearl River Estuary ocean current data in NetCDF format, this paper completes particle-based ocean current visualization data preprocessing by improving data thinning algorithm, ocean current data vector synthesis calculation, and data storage structure design, and establishes a data expression relationship with the particle system. The constructed flow field visualization system realizes the dynamic visualization of NetCDF ocean current data based on particles. It can be seen from the experimental results that this method achieves an ideal Web-side dynamic visualization effect for ocean current data in NetCDF format, which solves the defects of the previous static and non-intuitive ocean current visualization methods, and improves the reality of ocean current simulation sense.

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