Research on Dynamical Visualization of the Spatio-temporal Process of Seawater Temperature and Salinity

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1. Introduction

The ocean is constantly changing. The data of seawater temperature and salinity have the characters of multiple spatial and temporal scales [1]. In time scale, marine environmental information has the characters of climatology scale variation (i.e. era, age), and regular pattern of seasonal variation; it also has the characters of weather-scale variation, and the time scale needs to be days or hours. In spatial scale, the data value change on depth and horizontal dimension, which is the data change with the latitude and the region.

Marine numerical model is an important source of marine environmental data [2]. In ocean numerical model calculations, the direct processing of data is often "invisible". Researchers need to wait passively for the final results, and then visualize the results by using a variety of mapping software. Inappropriate or error in calculation is not easy to be found in this process, causing tremendous waste of subsequent calculations. The visualization of data is an important way for professional study to put forward hypothesis and test the results [1].

Analysis and visualization of spatio-temporal process of seawater temperature and salinity data can: ①verify the reliability of data model and the accuracy of results; ②understand clearly the regular variation pattern of phenomenon within a time segment; ③ simulate and forecast behaviors that may occur in the future. In this paper, the prototype system of China Digital Ocean (CDOPS) is introduced as an example, from the perspective of dynamical visualization of spatio-temporal process of the exporting data from the seawater temperature and salinity numerical model, to study spatio-temporal analytical methods of elements and to solve the key issues in system construction. After the Spatio-temporal analysis of data, a spatio-temporal visualization framework and a mechanism of data preprocess, storage and management were proposed; the 3D data visualization is realized by 3D visualization engine and data real-time schedule.

2. Spatio-temporal analysis of seawater temperature and salinity data

2.1 Data source:

The data used in this paper are seawater temperature and salinity numerical model exporting data collected and stored by Chinese National Marine Data & Information Service Center. These data are unified 3D grid data-field, including seawater temperature and salinity prediction data, the following seven days' data are forecast everyday, and the data is updated daily; re-analysis data, which are two files of each day, one year or more data were generated at one time, and update irregularly; statistical analysis data are average monthly data of all years, and there are 12 data files in total, updated annually. The range of statistical analysis data are around the world, while others are of the Northwest Pacific.

2.2 Spatio-temporal analysis of data:

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There are three methods commonly used in analysis of three-dimensional field data, which are: ①slicing, dicing, drilling and other conventional multi-dimensional analysis methods; ② Plenty of statistical analysis functions in multi-dimensional database (such as average value, maximum, minimum, sum and, variance, etc.); ③ Researchers make custom analysis functions according to demand [3]. This article is to study the spatio-temporal analysis methods of 3D data from the perspective of dynamical visualization of data on time dimension, spatial dimensional and comparison between the visualization results of different elements.

2.2.1 from the perspective of time dimension:

Seawater temperature, salinity values are constantly changing, which is the main characteristic making marine data different from other data [4]. Visualization of the historical data of a time series can facilitate finding the regular variation pattern of the phenomenon for researchers. In this article, the visualization of elements in time dimension is summarized as follows: ①time-dependent curves of the values of single elements; ②dynamic cloud-images of time-dependent process of one data layer; ③dynamic cloud-images of time-dependent process of arbitrary section (cross section) of three-dimensional data field;

2.2.2 from the perspective of spatial dimension:

In spatial dimension, the distribution characteristics of the seawater temperature and salinity in different regions can be intuitively shown on a frame of stationary image. And the study on the visualization of elements in spatial dimension mainly focuses on the changes of element value in depth dimension. The methods are summarized as follows: ①depth-dependent curves of the values of single elements; ②dynamic cloud-images of changing process in depth dimension; ③ 3D visualization of data.

2.2.3 Comparative analysis of the visualization of different elements:

Seawater temperature affects sea water salinity, and the change of seawater temperature and salinity affects the change of its density, sound velocity, carbon dioxide content, as well as the growth and distribution of the fish. In this article, methods of seawater temperature and salinity comparative analysis are summarized as follows: ① in a single window, one element is shown as cloud-image and another element is shown as numbers on the cloud-image; ② of the same time, multi-elements expression in multi-window.

2.3 The spatio-temporal visualization framework:

In this paper, an extensible GIS-based visualization framework of marine 3D scalar field information is created, based on the characters and application demands of seawater temperature and salinity data, to provide an integrated spatio-temporal dynamic visualization environment of data. The spatio-temporal analysis visualization methods mentioned above are split, from the technology point of view, into several "basic visualization method units" which include single point value visualization method, two-dimensional graphics methods, cloud-image method, numerical map plotting, and 3D visualization method. These methods are packaged and flexibly combined for different analysis requirements.

In data access layer, data are acquired from the database through data manipulation class. According to the acquired data types, data manipulation class include point method, line (to obtain the points set of a time series or the a points set of a depth series) method, surface method (to obtain a plane, or the plane set of a time series), and volume method (to obtain three-dimensional data of a certain time, or three-dimensional data of a time series).

Basic visualization methods unit is realized in the business logic layer. It is noteworthy that 3D visualization method is realized by separating the data rendering method and external operations, in which the rendering of data is realized through 3D visualization engine.

The presentation layer is to achieve the visualization of Spatial-temporal process by combination of the basic visualization methods unit, such as the dynamical visualization of surface data on the time dimension and

depth-dimensional, is realized by send parameters and called cloud-image method, through controlling rendering data and rendering time interval to reach the purposes of dynamic simulation.

3. Solutions of Key Issues

3.1 Data Preprocessing:

Data preprocessing is the process of convert data format, add meta-data information, check data quality, and load to the data warehouse. In this research, historical data are converted to unified binary file, and splited by layer on the depth dimension. The metadata are organized in XML format, to record the data source, format, definitions and other descriptions. Method for data quality checks is: first, the integrity checks, including: data volume, number of files, file naming, etc.; and then proceed to internal data range checking: based on the data amount, mining n fixed coordinate position, comparison the data value with the same time conventional statistical data, that in the tolerance range that is considered to be qualified; and finally the border consistency checks, including the time and space boundaries consistency [5].

3.2 Data Storage and Management:

The data in CDOPS (including: observation data, survey data, data products and business data, etc.) are stored in the data warehouse by data subject. Data products of seawater temperature and salinity are stored in the conventional hydrological subject. Refer to object-oriented and feature-based Spatio-temporal data model, a "hierarchical object model" is used to organize data. Firstly split data by layer on depth dimension, and then store the data in Oracle on BFILE format, the virtue of this method is faster storage, small number of records, faster read and easy for SQL retrieval.

3.3 3D visualization engine

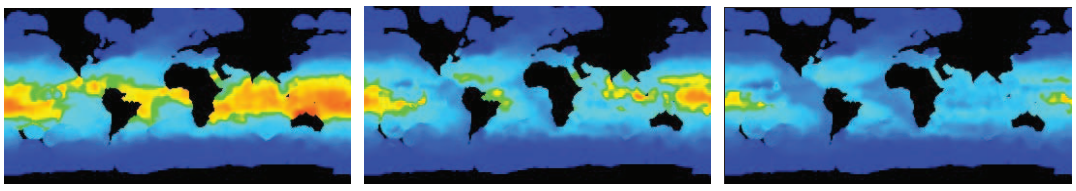
Through the development of 3D visualization engine named SeaGeo to achieve the separation of data rendering and external operation, which make the whole system more flexible. The implementation of SeaGeo is divided into three levels: the base level is Microsoft DirectX Utility Library (DXUT), the use of DXUT simplifies the usage of windows API and DirectX3D API, so that can make Directx programming more efficient; the core of middle layer is data manipulation class named CSeaGeoData and 3D implementation class named CSeaGeo3D, CSeaGeoData used to read data, build data mash for real-time rendering, CSeaGeo3D used to the establishment of the corresponding color relationships, real-time rendering, scene and light management; the core of top layer is interface control class named CSeaGeoCtrl, which provide interfaces to the external and carry on message mapping.

3.4 Data Real-Time Scheduling

In the procedure of data visualization, with the changed of observational region, the procedure need to constantly update data blocks in client's memory. If the data I / O and rendering are arranged on a single thread, due to data scheduling makes the image display on a standstill constantly. To solve this problem, firstly, create multiple data buffer, and then exchange the data content between buffers by using the multi-threading technology. In addition, when rendering, sleep 40 microseconds for rendering each frame, so that CPU can save a lot of time without affecting the visual effects.

4. Results and Conclusion

The dynamical visualization of statistical analysis data are shown as below:



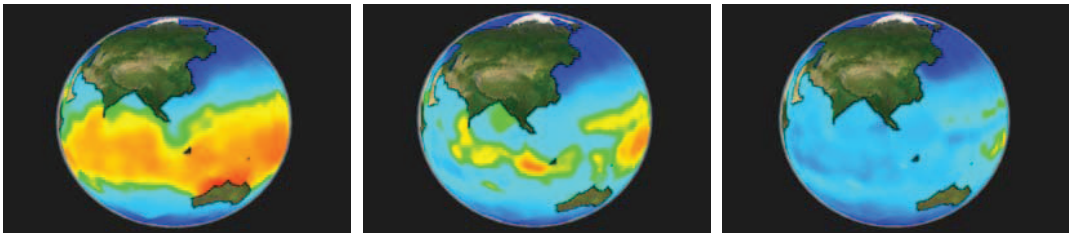


Figure 1 Dynamical Visualization of statistical analysis data on depth dimension
(Left: sea surface; middle: -75m; right -125m)

The data analysis and simulation of Spatial-temporal process of seawater temperature and salinity is important issues in the construction of Chinese Digital Ocean Prototype System. This article took the perspective of dynamical visualization to research analysis methods of Spatial-temporal process of 3D data field, have designed a dynamical visualization framework of 3D scalar data field, realized the dynamical visualization of seawater temperature and salinity in time dimension and space dimension, and visualization of comparative analysis of the different elements.

5. references

[1]Su Fenzhen. Spatiotemporal Process in Marine Geographical Information System. Post Doctoral dissertation, Institute of Remote Sensing Applications, Chinese Academy of Sciences, 2003.

[2]Wang Yueshan. Data Assimilation---- its Cause, its Meaning and Main Procedures. Marine Forecasts, Feb., 1999, Vol. 16, No. 1.

[3]Zhang Yong. Multi-dimensional Analysis of Environmental Data in Changjiang (Yangtze) Estuary and Surrounding Area Based on GIS. Doctoral dissertation, Ocean University of China, 2008.

[4]Zhang Tianyu. Research on Marine GIS Field Model. Doctoral dissertation, Institute of Geographic and Natural Resources Research, CAS, 2004.

[5]Wang Xinhua, Luo Siwei, Liu Xiaoning2, Ren Zhihua, Sun Huanan. Quality Control and Software Development about A-format Data of National Basic Automatic Weather Station. Meteorological Monthly, March 2006, Vol.32 No.3.

[6] Environmeantal Simulation Laboratory, Inc. Introduction of Marine Explorer, 2000.

[7] Tang Ze sheng. “The Visualization of Three-dimensional Data Sets”, Tsinghua University Press, Beijing, 1999, 156-163.