Design and Implementation of Lightning Analysis Software Based on Lightning Location System Data

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Abstract This paper discusses the steps about how to design and implement software based on lightning location system data and its localization map. The system contains four major modules such as real-time lightning monitoring, historical query, lightning intensity zoning, lightning disaster statistics, *etc*. The system is able to automatically generate real-time lightning monitoring image, lightning animation, and lightning intensity zoning image, which contributes to the high accuracy of the calculation results and the efficiency of data analysis. The paper also points out the deficiencies of software life cycle management and proposes actionable solutions.

Key words Lightning location system data (LLSD); System design; UML; Object-oriented design (OOD); Systems development life cycle (SDLC)

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Lightning disaster is a destructive natural disaster and brings huge risks, and it has threatened people's lives and property safety for a long time[1]. Analysis on the temporal and spatial laws of lightning distribution plays a crucial part in the decision-making system. With the rapid development of computer graphics technology, graphic visualization technology can quickly convert a large amount of irregular meteorological data into static or dynamic charts, which could be better presented to the researchers and scientists in a more intuitive way and help them to easily identify patterns. Combining lightning-related data, computer graphics technology, and geographic information system, it provides a solid platform for lightning research and also provides a useful exploration for the integration of GIS and lightning fields[2].

Some researchers have achieved certain results based on their experiments: Lu *et al.* [3] used GIS to design and implement visual map components. Gao *et al.* [4] proposed to calculate the lightning strike density by Kriging interpolation. Wang[5] developed an open-source platform called MeteoInfo, a GIS visualization component, which provides the infrastructure for meteorological data analysis, overlay, and visualization.

In traditional gridding analysis, it usually takes much longer time to complete the data analysis. This paper proposes an innovative solution to tackle this issue, and it has already successfully applied by Heilongjiang, and is illustrated as an example to describe the design and implementation of lightning protection software.

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1 Design and implementation

1.1 General design The system intends to provide several functional modules, namely the lightning zoning diagram module, the lightning real-time monitoring module, the lightning history module, and the system setting module. The system architecture diagram is shown as Fig. 1.

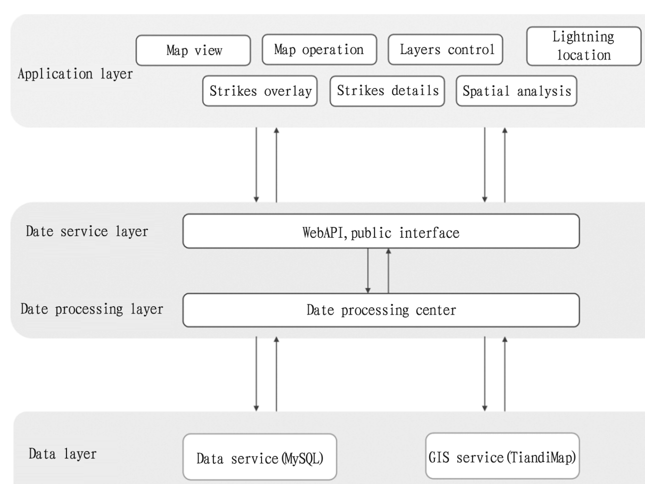

Fig. 1 Architecture of lightning analysis software

1.2 LLSDA design The unified modeling language (UML) is a general-purpose, developmental, and modeling language in the field of software engineering that is intended to provide a standard way to visualize the design of a system[6].

Lightning location system data analyzer (LLSDA) serves as the foundation of the entire project, and is responsible for the data structure, abstraction, source data analysis, analysis and other functions of lightning data. The design follows the object-oriented design (OOD) concept and the S. O. L. I. D software principles for the UML design of LLSDA. The design relies on an abstract interface instead of entities which increases the maintainability and reusability of the software. LLSDA's UML is shown as Fig. 2.

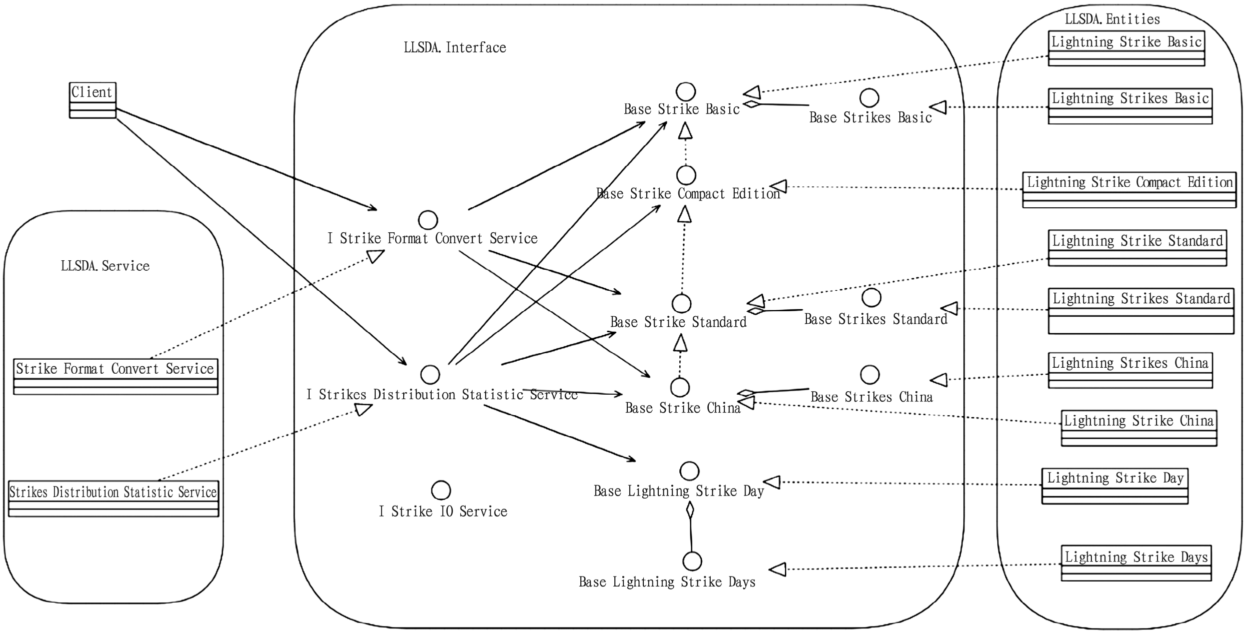

Fig. 2 LLSDA's UML

1.3 Lightning intensity zoning According to the LLS data, the lightning intensity zoning is carried out according to the following steps [7-8].

(1) Data processing. According to the quality control method, below records should be eliminated from the source. First, the positive ground flashes using the 2-station positioning algorithm. Second, records with the absolute value of current intensity less than 2 kA, greater than 200 kA. Third, the lightning current intensity of less than 15 kA.

(2) Classifying the current intensity according to the percentile method (Table 1).

Table 1 Percentile method

Percentage P//%	Intensity F//kA	Level
$P \leqslant 60$	$F \leqslant 34.43$	1
$60 < P \leqslant 80$	$34.43 < F \leqslant 46.52$	2
$80 < P \leqslant 90$	$46.52 < F \leqslant 61.17$	3
$90 < P \leqslant 95$	$61.17 < F \leqslant 78.96$	4
$P > 95$	$F > 78.96$	5

(3) Gridding and putting the lightning records into grids according to their latitude and longitude.

(4) Calculating the Ng value based on the number of lightning strikes per grid, and using Kriging interpolation to process the density values.

(5) Using the Jenks natural breaks algorithm, the ground flash density is divided into three levels: high, medium and low. It is superimposed into the GIS map, and plotted as the following lightning density map (Fig. 3).

Jenks natural breaks method is a map grading algorithm. The algorithm considers that the data itself has breakpoints, which can be graded by using the characteristics of the data. The calculation formula is as follows:

$$SSD_{i-j} = \sum_{k=1}^{j} A[k]^2 - \frac{\left(\sum_{k=1}^{j} A[k]\right)^2}{j-i+1} (1 \leqslant i < j \leqslant N)$$

where SSD is variance; i and j show the i^{th} and j^{th} elements; A shows array with length N; k shows the k^{th} element in A.

In traditional computing model, each calculated result should be processed through read from database, data analysis and data visualization which is time-consuming. While in our proposed solution, all results using the same input parameters will be stored at database before visualizing, thus the duplicated analysis processes are removed, and it significantly increases the efficiency compared with tradition method.

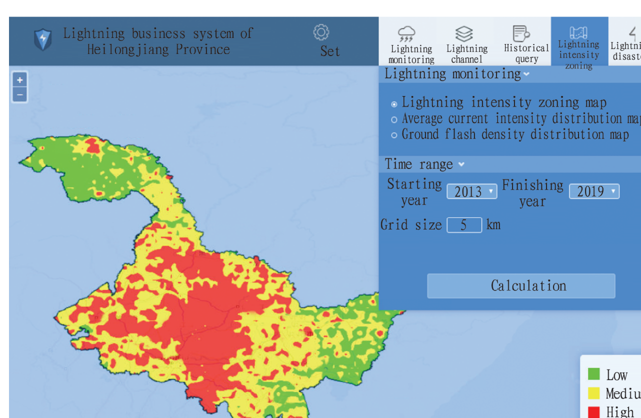

Fig. 3 Lightning intensity zoning in Heilongjiang Province from 2013 to 2019

2 Potential questions and prospects

2.1 Calculation limit and solutions The premise analysis of lightning refinement is the grid. Assuming a grid of 1 km × 1 km for the entire Heilongjiang province, the number of grids will be approximately 1.7×10^4. And, the lightning records of Heilongjiang Province in 2008 is 31 209 times. The amount of calculation for judging each lightning is $1.7\times10^4\times31\ 209 = 5.27\times10^8$ times. If users need to calculate ten years of data for one country, it will result in tens or even hundreds of hours of computational time, which is clearly unacceptable.

For the calculation limit problem, a distributed system is a solution. That is to calculate the grid points separately and combine the result together later to get an overall analysis result.

2.2 Storage limit issue and solutions The earliest available lightning location data in China can be traced back to 2005. With the accumulation of time, the storage and management of data are also limited by time. In the face of the above problems, a solution named vertical scaling is proposed, which means, to increase the server performance. This is an unsustainable solution because that it is predicted that humans will reach the limits of Moore's Law in 2025, although there are more optimistic predictions[9-10]. In general, the performance and storage of a single server are subject to objective bottlenecks and limits.

The author believes that horizontal scaling is a sustainable solution to the above problems. In terms of storage limits, MYCAT, a MySQL-based database sharding middleware, will be a potential solution. It's a high performance, scalable enterprise database clusters implemented by low-cost parallel computers.

3 Summary

Based on lightning location data, this paper describes how to design and implement a lighting business system based on the example of Heilongjiang Province. The system can be used for real-time lightning monitoring, historical analysis, lightning channel, and other analysis. Through the above system, automatic and accurate analysis is realized, and the problem of high error rate and low efficiency relying on manual analysis is solved.

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meteorological services, strengthen the observation of sunshine and other meteorological elements, analyze and evaluate the value of solar energy use in each period according to the daily, monthly, and annual changes of solar energy resources, formulate a reasonable plan for light energy conversion, analyze the zoning of solar resources, provide technical references for the site construction of photovoltaic power generation industry, maximize the use and development of renewable resources, protect the ecological environment, and seek happiness for mankind.

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