A Database-based Automatic Cartography Method

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Abstract

At present, GIS data, which contains a large amount of semantic information, has become the main data source for map cartography. In this paper, based on the existing multi-scale database, we study a database-based automatic cartography method to meet the needs of multi-scale map cartography, and replace the traditional process by the intelligent processing of software to shorten the cycle of cartography, improve the productivity of map cartography, and at the same time, reduce the error rate caused by manual work, and improve the overall quality of map production.

1. Introduction

At present, the basic geographic information database is the main data source for map production, and the database is a mode of integrated collection and organization of spatial and attribute information, and GIS data contains a large amount of semantic information. Most of the existing mapping software only uses the spatial coordinate information of GIS data, but ignores a large amount of semantic information (such as element classification and element relationship, etc.) of the original data (GIS data). (Dai, 2013) Due to the lack of semantic information and mapping rule control, GIS data can only exist as a coordinate skeleton in the mapping software. Due to the incompatibility of symbols between GIS software and mapping software, and the loss of semantic information of geographic elements in the process of data conversion, the work of element categorization (hierarchy), element relationship, map symbol design and configuration, etc., must be carried out again in the mapping software, which requires a large amount of manual labor to handle these tasks, which becomes the bottleneck of rapid mapping, and it is difficult to meet the needs of emergency map production. (Kong *et al*., 2022; Qiu *et al*., 2022; Sun *et al*., 2022; Wu *et al*., 2022; Xu *et al*., 2022; Zhang *et al*., 2022; Zhao *et al*., 2018)

In this paper, based on the existing multi-scale database, we study a database-based automatic mapping method to meet the needs of multi-scale map cartography, replace the traditional process by intelligent software processing, shorten the mapping cycle, improve the productivity of map cartography, and at the same time, reduce the error rate of manual work to improve the overall quality of map production.

2. Overall Concept of the Study

There is a clear difference between GIS software mapping and professional mapping software. GIS software has certain mapping functions, but there are obvious shortcomings in map beautification and design, and the maps it designs and produces are difficult to meet the requirements of published maps.The main reason for this is that the two types of software models are different. The GIS software adopts a geographic model (GIS data model) that focuses on the spatial integrity of geographic elements, GIS software adopts a geographic model (GIS data model) that focuses on the spatial integrity of geographic elements, continuity and spatial relationships and the description of related semantic information, emphasizing the spatial analysis function; GIS software can perform simple mapping of GIS data, such as simple configuration of symbols and map surface decoration, lacking professional map editing, color design and visualization expression tools, so this kind of mapping can to some extent meet the general needs, such as simple digital map, and it is difficult to meet the requirements of publication-level map mapping. (Chen *et al*., 2019; Dai, 2013; Qiu *et al*., 2022) The mapping software adopts the cartographic model (map data model), focusing on the effect of geographic information visualization (expression), without paying attention to the completeness of spatial elements and spatial relationships, and usually reduces the accuracy of the geographic location and relationship of some elements to improve the map expression. (Zhao *et al*., 2023)

Database-based map mapping is usually realized by using GIS map expression modeling, intermediate format conversion, software interoperability, and other methods. The map expression model based on GIS integrates geographic data and map expression information, which is conducive to the modification and preservation of map target objects, reduces data redundancy, facilitates incremental updating and multiple expression of maps, and extends the map expression capability of traditional GIS, but this model is still at the stage of formalized description, and no relevant system has been developed yet. Through the method of intermediate format conversion, take map mapping based on GIS data in CorelDraw environment as an example, its main steps are data screening and analysis, data projection transformation, data layering, data editing, symbolization, scale determination and data format conversion (map output), although this method solves the problem of format conversion from GIS data to CorelDraw data, It is difficult to control the conversion process from GIS data to map data, it is impossible to pre-customize the rules for converting GIS data to map data, and there are still problems such as embossing and overprinting and replacing white space after outputting the map data, and the method still involves a large amount of manual editing work such as symbolization, rendering, normalization, data editing, etc. in CorelDraw. The interoperability method between software can realize the conversion of ArcGIS data to CorelDraw data, but according to the type of elements, it is necessary to perform "copy + paste" several times, or convert EMF operation several times, and the data will be lost after the conversion of notes, symbols, colors and other information.These methods basically solve the data conversion from GIS software to mapping software, but there are still problems such as low accuracy and large amount of semantic information of the data is lost (e.g. element classification, attributes, relationships and symbolic representations). (Chen *et al*., 2019; Chen *et al*., 2023; Dai, 2013; Kong *et al*., 2022; Qiu *et al*., 2022; Wu *et al*., 2022) Cartographic software requires a great deal of manual processing for element classification, relationship expression, attribute expression, symbol design and configuration, and color design from the converted data to the production of maps that meet publication requirements. (Zhao *et al*., 2023)

Database-based automatic cartography is based on the analysis of the standard specifications and quality of the existing basic data, formulate several sets of completely open data pre-processing principles and an extensible rule base to meet the needs of commonly used multi-scale mapping, and replace the traditional process by intelligent processing of the software to shorten the cycle of mapping, thus greatly improving the speed of emergency mapping. In this paper, based on the open-source software QGIS development, in the form of Python plug-ins to achieve the map mapping rules management, map symbol management, automatic configuration of map notes, automatic configuration of map symbols, map element relationship processing and other functions, to achieve automatic mapping, greatly reducing the database to map into a map of the process of manual workload to improve the productivity of map mapping, and at the same time reduce the error rate of the product caused by manual work, and improve the productivity of map mapping. At the same time, it reduces the error rate of products brought about by manual work and improves the overall quality of map preparation. (Chen *et al*., 2021; Chen, 2023; Qiu *et al*., 2022; Sun *et al*., 2022; Xu *et al*., 2022; Xu, 2023)

By designing the data pre-processing and conversion system and the fast map mapping plug-in system as shown in the figure, the processing technology of GIS data information and element configuration rules is embedded into the open source GIS software QGIS, enhancing its map data processing and map mapping functions, so as to improve the efficiency of map mapping and shorten the mapping cycle.

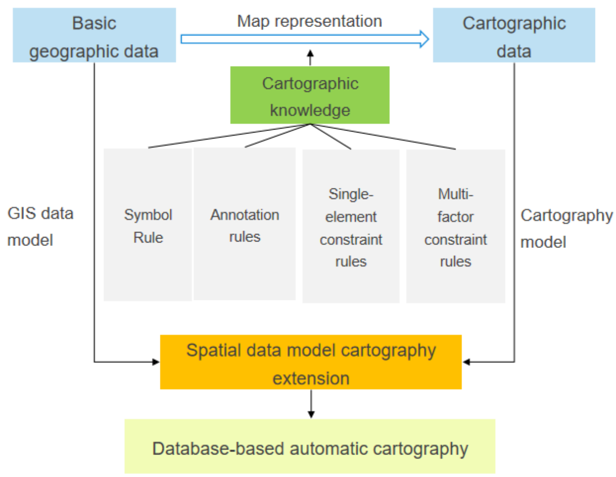

Figure 1. Overall technical approach.

3. Main Research Contents

The database-based automatic mapping system makes full use of the API provided by QGIS, and designs a plug-in in QGIS to extend the map data processing and mapping functions of the mapping software. (Chen, 2023; Xu *et al*., 2022)

The automatic map mapping plug-in system based on the spatial database developed by QGIS Python plug-in development technology includes two subsystems, the data preprocessing and conversion system and the fast map mapping system, with a total of data preprocessing module (Data Processor), map symbol library module (Map Symbol), map rule library module (Map Rules) and map mapping module (Map Builder). There are four modules: Data Processor, Map Symbol, Map Rules, and Map Builder. The first module is the data pre-processing and conversion system, and the last three modules are the automatic map mapping system.

3.1 Data Preprocessing Module

This module is mainly responsible for converting the original GIS data stored in the spatial database into the mapping data in QGIS.

The main functions of the preprocessing module include data conversion, data extraction, interest point extraction, annotation preprocessing, data processing, etc. The overall structure, as shown in the figure, is divided into ten functions: defining projection, cropping data, generating color bands, river gradient, merging elements, splitting layers, rotating angles, calculating intersection points, color matching in the management area and interrupting intersecting lines, and each of these functions can be used independently, which enables the combination of functional modules. Each function can be used independently, so that the combination of function modules can be realized. (Zhao *et al*., 2018) The data preprocessing module is shown in the figure below.

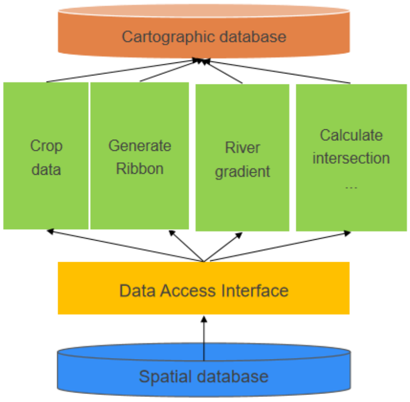

Figure 2. Data preprocessing module.

3.2 Automatic Mapping Module

The automatic cartography module performs automatic cartography on the basis of the uniform format data obtained by the pre-processing module. Based on the GIS data obtained by the data pre-processing module, it realizes automatic conversion of GIS data into cartographic data, automatic notation configuration, element symbolization and other intelligent processing based on the support of map symbol library and rule library.

According to the descriptive mapping knowledge and process mapping knowledge involved in the mapping process, the mapping rules under the same scale are categorized into two types, one is the expression rules and the second is the constraining rules, and are divided into single-element constraining rules and multi-element constraining rules according to whether the elements are single or not. Multi-element constraining rules are further divided into element capping, conflict processing, spatial relationship expression, association constraints, and notation intelligent configuration rules.

After the configuration of the symbol notation rules, knowledge rules and finishing rules is completed, the automatic mapping can be performed.

3.2.1 Symbol Notation Rules: The symbol annotation rules module is used to manage the symbol annotation rules for map creation, which consists of two parts: symbol annotation style library and symbol annotation rules library. (Zhang *et al*., 2022)

The layers are categorized into point, line, and area layers based on different element types. The table structure of the symbol rule table and the annotation rule table is shown in the following table.

Name	Description
LayerName	Layer Name
SymbolName	Symbol style name
ExtraInfo	This layer corresponds to a symbol that is not a single symbol and requires this field to record additional information.

Table 1. Symbol rules table.

Name	Description
LayerName	Layer Name
LabelName	Annotation style name
ExtraInfo	The annotation corresponding to this layer requires this field to record additional information if it is rule-based.

Table 2. Annotation rules table.

3.2.2 Knowledge Rules: The first is the symbol order rule. The layer order determines the final appearance of the various symbols. If the face layer is on top of the point or line layer, then the line and point layers will be hidden. Therefore, the Layer Symbol Order Rules module allows the user to define the order of the layers. For a line layer such as a highway, its symbol is a double line with upper and lower layers, when multiple line layers are stacked together, the relationship between the upper and lower layers needs to be strictly controlled, so this module provides a symbol level function to configure the order of symbols in different symbol layers.

Layer symbol order table, mainly including the layer name, whether to open the symbol level, the symbol layer unique code and layer priority.

Name	Description
LayerName	Layer Name
IsSymbolLevel	Whether to turn on symbol levels, if so the order will be defined for each symbol level of a symbol.
SymbolLayerID	Symbol Layer Unique Code
LayerOrder	Layer priority, which determines the order in which layers are drawn.

Table 3. Layer symbol order table.

Multi-element hiding rule: Requires user-defined Multi-Element|Hide rules, which can be automatically processed based on the rules. The result is essentially a field in the layer that indicates whether an element is shown or not.

Name	Description
LayerName	Operational layer name, the corresponding layer type should be point.
ObstacleLayerNames	Obstacle layer name, corresponding layer type should be point or line.
MinInterval	Minimum interval between symbols on the actual drawing in

	millimeters, default value is 0.2, users can adjust according to the actual needs of their own.

Table 4. Multi-element hiding rule table.

Annotation stamping sequence rule: According to the type of geographic elements to be annotated, map annotations are divided into three categories: point annotations, line annotations, and area annotations. Each type of note has its own characteristics, and the rules of note configuration are different. Map annotations should be placed in a suitable location to ensure that map readers can understand at a glance the map annotations and map symbols are noted between the correlation between the relationship, to avoid confusion with the surrounding other annotations or map symbols, resulting in the annotation instructions are unclear, confusing map readers map cognition. The spacing of notes must be adapted to the morphological characteristics and distribution area of geographic elements, to facilitate the formation of continuity in the reader's vision and cognition, to strengthen the clarity of the notes indicating the geographic elements and the totality of its own meaning expression. Conflicting notes and overlapping of elements may cause obstacles to map reading. (Zhao *et al*., 2023)

The Annotation Stamping Sequence Rules table mainly contains the layer name, the annotation priority, whether to enable the symbol barrier, and the symbol priority.

Name	Description
LayerName	Layer Name
LabelOrder	Whether to turn on symbol levels, if so the order will be defined for each symbol level of a symbol.
IsNotCovered	Symbol Layer Unique Code
LayerOrder	Layer priority, which determines the order in which layers are drawn.

Table 5. Annotation stamping sequence rules table.

3.2.3 Decoration Rules: The Decoration Rules module is used to manage the decoration elements of map cartography. The Decoration Rules library includes Legend Rules, Inner (Outer) Contour Rules, Scaling Rules, Grid Rules, and Left (Right) Corner Notation Rules. Users can configure the finishing elements required for map production and save the parameters to the rule base for later use in layout generation.

Name	Description
LayerName	Layer Name
AliasName	legend alias
ExtraInfo	This layer corresponds to a symbol that is not a single symbol and requires this field to record additional information.
LayerOrder	Legend order
InnerPosition	Inner contour position
InnerSize	Inner contour size
OuterPosition	External contour position
OuterSize	External contour size
ScaleBarPosition	Scale position
MapGridSet	Longitude and latitude network setting method, divided into the interval distance (degrees) and the number of bars (bars) two kinds of methods.
MapGridX	Parameters in the horizontal direction of the latitude and longitude network.
MapGridY	Parameters in the vertical direction of the latitude and longitude grid.
LfLableContext	Content of note in lower left corner
LrLableContext	Content of note in lower right corner

Table 6. Decoration rules table.

3.2.4 Automatic Cartography: The cartographic knowledge base module is based on cartographic rules, which are the compilation basis for map drawing. This module is mainly the key supporting part for realizing automatic cartography, which organizes and manages cartographic knowledge and experience in the form of a rule base to support the automatic processing of map data.

Based on the unified format data obtained by the pre-processing module and various mapping expression rules configured by the user, the map generation module performs automatic mapping. Based on the GIS data obtained by the data pre-processing module, it realizes automatic conversion of GIS data into QGIS mapping data, automatic notation configuration, element symbolization, and other intelligent processing based on the support of the map symbol library and the rule base.

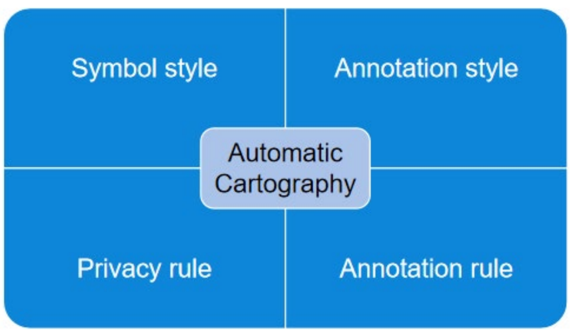

Figure 3. Automatic cartography module.

4. System Implementation

4.1 General structure

Making full use of the open source spatial database GeoPackage, the development platform is designed to develop the desktop version of the data preprocessing software module to realize the preprocessing of data in the public version of the database.

Symbol library module includes two parts: symbol library and symbol library management software module. (Chen *et al.*, 2021; Wu *et al.*, 2022; Xu, 2023) The map mapping rules module consists of two parts: the map mapping rules library and the rules library management software module.

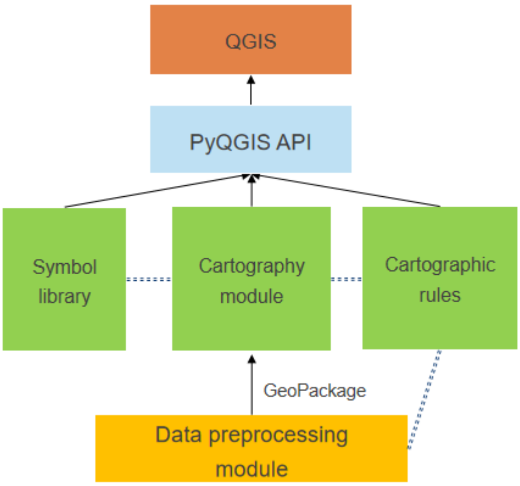

Figure 4. General structure.

4.2 Logical Structure

The logical structure is divided into 4 layers, data storage layer, service layer, interface layer and application layer. (Xu *et al.*, 2022)

4.3 Data Organization

The requirements for geographic entity type data are shown in the table. The overall logical organization of the database mainly includes the symbol rules table, the annotation rules table, the layer symbol order table, the annotation stamping order table, and the refinement rules table.

Indicator		Specific requirements
Spatial reference frame	Coordinate system	Geographic coordinate system CGCS2000 or WGS84, data before deformation of coordinates.
Data storage	Data format	Common formats for geographic information data, such as tab, shp, mif and other common data formats.
	Data availability	No missing data files, redundancy, unreadable data, etc.
	Organizational structure	The naming of storage folders should follow certain naming rules, and strive for a clear structure, concise name, clear and have a high degree of recognizability.
Data description property	Minimum Fields	FID (number), Shape (geometric type), ENTIID (geographic entity identifier), NAME (geographic entity name), ELEMID (element identifier), CLASID (type code)

Table 7. Requirements for geographic data table.

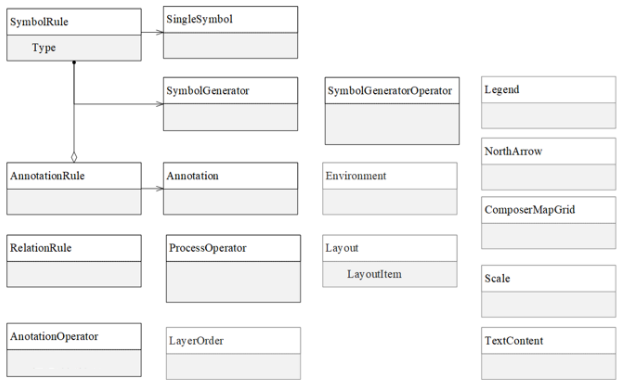

Figure 5. Overall logic of the database.

4.4 Application Effect

The application effect of the multi-factor symbol conflict handling rules is shown in the figure.

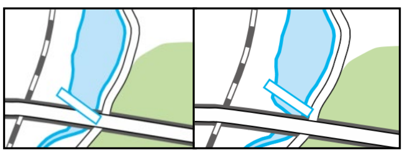

Figure 6. Before and after applying rules.

5. Conclusion

Based on the in-depth analysis of domestic and international research progress on database mapping technology, according to the guiding ideology and requirements of automatic map mapping technology research, and analyzing the status quo of spatial database mapping business, the overall idea of spatial database map mapping automation technology is designed, and the database automatic map mapping software system under the environment of QGIS platform is researched and developed, so that the key technologies of map mapping, such as automatic conversion of spatial database, automatic extraction of symbols, automatic configuration of symbols and intelligent configuration of annotations, can be realized. The system realizes the key technologies of map making such as automatic spatial database conversion, automatic element extraction, automatic symbol configuration and intelligent annotation configuration.

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