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Article

An Automatic Derivation Method for Creation of Complex Map Symbols in a Topographic Map

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Abstract: The topographic map plays a very important role in economic construction. In the process of drawing topographic maps, different symbols represent different ground objects, but the symbols representing complex ground objects are often complicated and difficult to create. Moreover, the creation process of complex map symbols can seriously affect the efficiency of topographic map production. Therefore, this paper proposes an automatic derivation method for creation of complex map symbols in a topographic map. The data used are new geographic entity data under the background of Chinese new fundamental surveying and mapping situation. Firstly, four derivation modes of complex map symbols are summarized, including feature-point mode, centroid mode, feature-line mode, and parallel-line mode; then, using the four modes singly or in combination, the complex map symbols of the topographic map are directly derived from the geographic entity data based on programming, and the topographic map cartographic result is obtained automatically. Finally, some topographic maps for Shanxi Province, China, is used for the validation of the creation of map symbols. The experimental results show that the proposed method can automatically derive the complex map symbols of the topographic map, greatly improving production efficiency and obtaining a good visualization effect. The proposed method is a new approach for a new situation and realizes the transformation and upgrading of fundamental surveying and mapping achievements.

Keywords: topographic map; complex map symbols; automatic derivation; new fundamental surveying and mapping; map cartography

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1. Introduction

Topographic maps play a significant role in a country's economic construction [1], and a great deal of surveying and mapping work is done based on these maps [2,3]; thus, the readability of topographic maps is crucial. To make topographic maps visually readable, topographic map symbols are used to express the location and type of spatial elements in the cartographic process [4]. Topographic map symbols provide a map language means for the transmission of spatial information [5,6]. By employing signs and symbols, maps communicate about near as well as distant geo-spatial phenomena, events, objects, or ideas [7]. In China, the creation of map symbols and usage of topographic maps are unified according to the legal norms and diagrams [8]. The specifications specify the symbols, notes, and map margin decorations of various kinds of land cover and land forms represented on the topographic map, as well as the methods and basic requirements for using these symbols. They are significant references for preparing a geographical base map or cartography of similar scales in topographic mapping, but there are many complex types of symbols, such as line symbols of steep slopes and power lines, which are more challenging to symbolize. Ensuring that the styles of symbols of topographic maps adhere to norms is a problem worth studying.

Many scholars have researched how to make topographic map symbols. In the study based on AutoCAD [9], the main principle is to define point symbols by attribute blocks and create line files and areal hatch files based on the built-in syntax—this process is time-consuming, labor-intensive, and requires command interaction. In the study based on ArcGIS [10,11], the main principle is to use the symbolization function provided by the platform and finish the combination of some symbols that look like symbols in the national standard, similar to a jigsaw puzzle [12]. There are other similar studies into drawing custom symbols using existing software's symbol editing functions, including MicroStation [13], Tsinghua Shanwei [14], etc. However, the drawing efficiency using the symbol editing function provided by the platform mentioned above is low, especially for complex map symbols. Therefore, the creation of map symbols must be completed with the help of other methods.

There is another way to draw topographic map symbols based on programming [15–17], which interacts with the platform interface mentioned above to extend the symbolization function. The programming approach is usually to split the symbols, analyze the composition of the elements, interact with the platform interface through VBA or other programming languages, and combine different elements to complete the drawing of complex map symbols. The degree of automation has been improved to a certain extent but is limited by the platform interface used for the interaction, and the ability to draw certain complex map symbols will still have limitations. For instance, if in the drawing of a shed, the program cannot find the location of the corner line, the programming approach will not be able to draw the shed corner line.

From a comprehensive view, the current method based on using a software platform for symbol editing is inefficient; although the secondary development method's automation degree has been improved, it is not possible to fully complete the drawing of complex map symbols in certain topographic maps. Therefore, an automatic derivation method for complex map symbols in a topographic map was proposed in this study.

The paper is organized as follows. Section 2 presents the definitions of four derivation modes. Section 3 introduces an automatic derivation method for the four derivation modes. Section 4 provides an experiment to validate the superiority of the proposed method. The discussion and conclusions are presented in Section 5 and Section 6, respectively.

2. Definition of Four Derivation Modes

By analyzing the structural characteristics of different complex map symbols, the following four modes are summarized to disintegrate the complex map symbols of a topographic map.

2.1. Feature-Point Mode

Feature points mainly refer to the nodes on the line entity or the boundary of the area entity. These nodes often show noticeable angle changes relative to other nodes, such as the six numbered nodes(1, 2, 3, 4, 5, 6) with angle change features in Figure 1. For line entities, their endpoints are generally feature points.

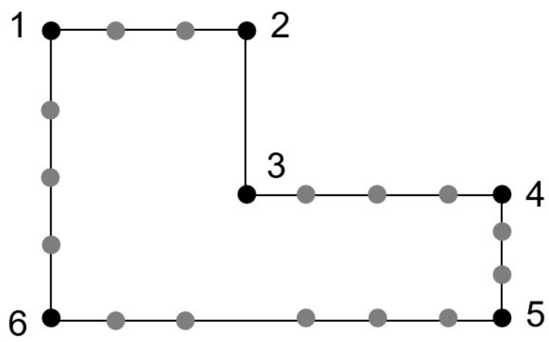


Figure 1. This is an example of feature-point mode.

2.2. Centroid Mode

The centroid mode is used to locate the position of some symbols by obtaining the shape center point of the area entity. This position includes the position relative to other symbols and the absolute position of the symbol itself. As shown in Figure 2, the point P is the centroid of the area entity.

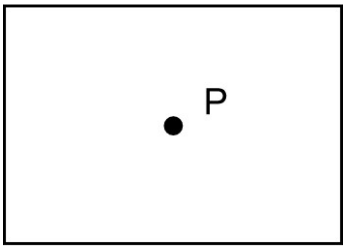


Figure 2. This is an example of the centroid mode.

2.3. Feature-Line Mode

The feature-line mode is mainly used to obtain lines with obvious or implicit features on or inside the area entity, such as the four explicitly represented boundaries of the entity in Figure 3 (feature lines:1, 2, 3, 4) and the implicitly expressed main skeleton line (feature line 5).

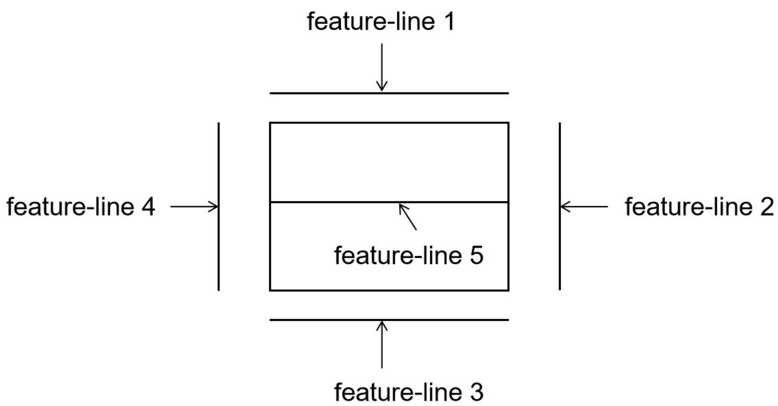


Figure 3. This is an example of the feature-line mode.

2.4. Parallel-Line Mode

The parallel-line mode is mainly used for the scenario in which an area entity with only four feature points is filled with multiple parallel or nearly parallel lines after the feature-point mode analysis. The parallel lines and four feature points(a, b, c, d) are shown in Figure 4. The parallel-line mode differs from the feature-line mode in that the parallel lines are not part of the original features of the entity and are therefore described in sub-modes.

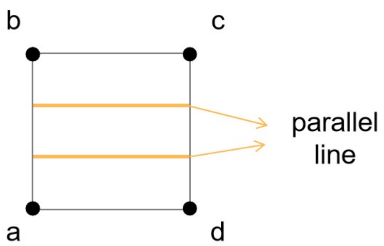


Figure 4. This is an example of the parallel-line mode. The points (a, b, c, d) are the feature points.

3. Derivation Methodology

3.1. Technology Route

Firstly, by analyzing the structural characteristics of complex map symbols, a mode layer is established, which includes four modes: feature-point mode, centroid mode, feature-line mode, and parallel-line mode. Then, according to the type of complex map symbols, various modes are used singly or in combination to derive complex map symbols, which is the logical layer. Finally, in the actual production of topographic maps, complex map symbols are automatically derived based on the mode layer and logical layer. The technology route is shown in Figure 5.

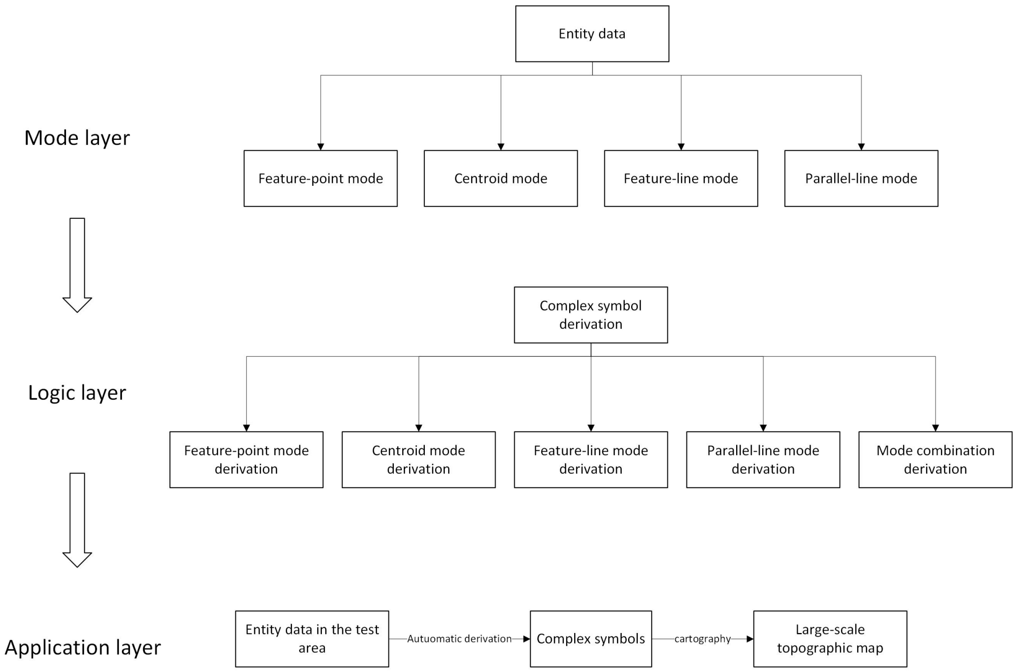


Figure 5. Technology route of the proposed method.

For a more detailed technology route, the workflow for the creation of map symbols involves the following steps:

Step 1: Save information about attributes of map symbols, including name, feature code, mode, color, etc;

Step 2: Add an entity to the candidate set to be processed;

Step 3: Identify the unique attribute of the entity and recognize the type of map symbol;

Step 4: Use the four modes mentioned in the mode layer to disintegrate the entity into some figures;

Step 5: Derive each disintegrated figure and combine these figures;

Step 6: Put the entity into the derivation result set;

Step 7: Repeat stepss 2–6 until all entities in the original set have been processed.

The flowchart is shown in Figure 6.

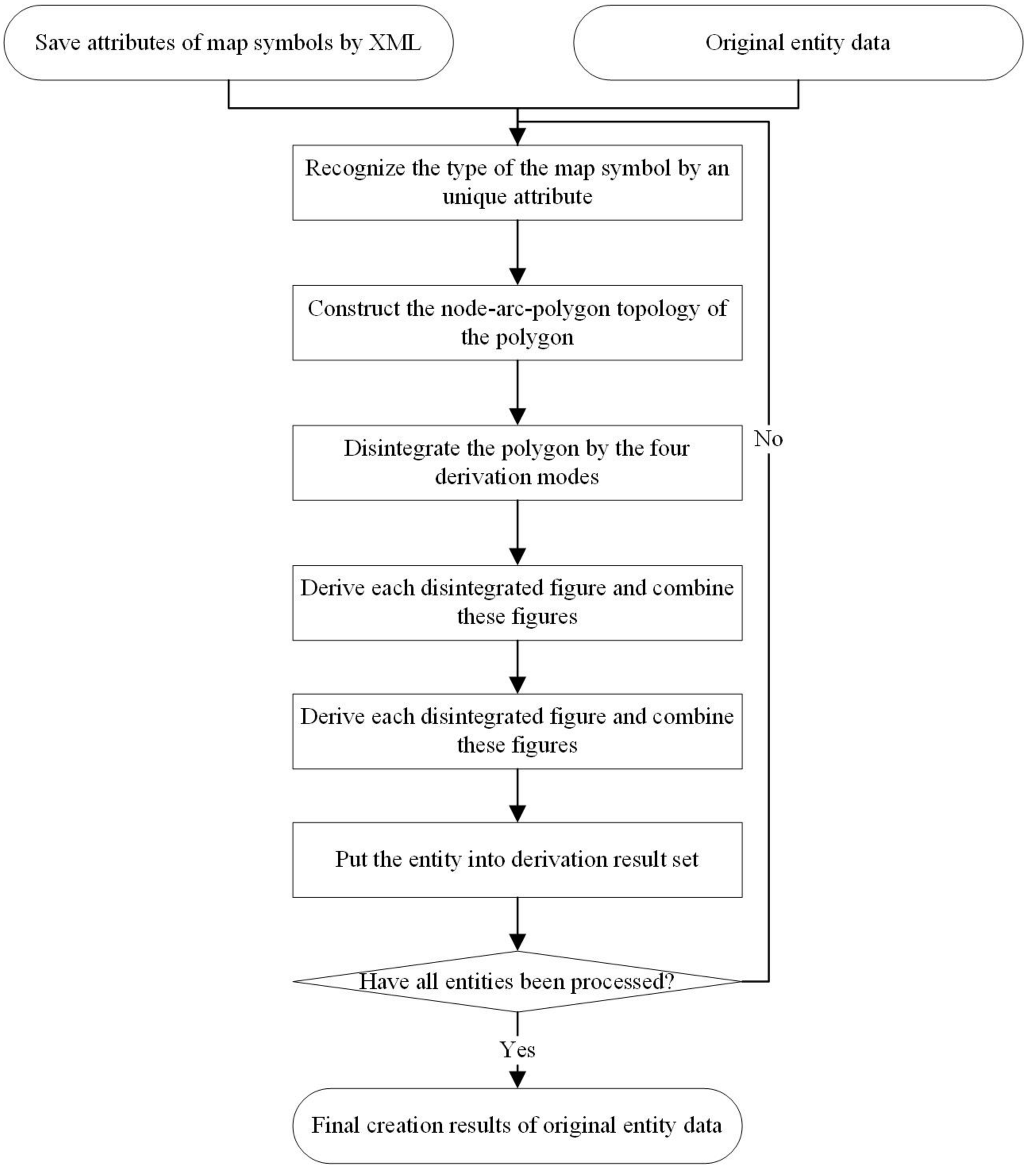


Figure 6. Flowchart of the proposed method.

3.2. Derivation of Map Symbols Based on the Four Modes

3.2.1. Feature-Point Mode Derivation

Feature-point mode derivation consists of two parts. First is feature point extraction; second, complex map symbols are derived based on feature points.

(1) The workflow for feature points extraction involves the following steps.

Step 1: Calculate the angle of each node in the line or area entity according to Equation (1);

$$\mathrm{A}_i = |\mathrm{A}_{ie} - \mathrm{A}_{si}| \\ \begin{cases} \mathrm{A}_i, \frac{\mathrm{A}_i}{180^\circ} \leq 1 \\ \mathrm{A}_i - 180^\circ, \frac{\mathrm{A}_i}{180^\circ} > 1 \end{cases} \quad (1)$$

where A_{ie} and A_{si} are the azimuths of node i with reference to the two nodes e and s before and after, respectively. If angle A_i is greater than 180°, subtract 180°;

Step 2: Select feature points according to angle filtering conditions. The conditions include two types:

(1) Neighborhood selection. The selection range is $R \in [A_o - A_\delta, A_o + A_\delta]$, A_o is the upper range limit of the candidate angle, andA_δ is the upper and lower floatable

range value of the upper range limit; for example, the angle threshold is set to 90°, A_δ is preset to 20°, then the node corresponding to angle A_i in the range $[70°, 90°]$ is selected as the feature point.

(2) Neighborhood inversion. The selection range is $R \notin [180° - A_\delta, 180°]$; for example, A_δ is preset to 20°, then the nodes corresponding to the angle A_i in the range $[160°, 180°]$ cannot be selected as feature points.

Either one or a combination of the two angle filter conditions are used depending on the situation.

(2) Feature points processing and complex symbol derivation.

The feature points have two problems: a large number, which interferes with the mapping of certain complex map symbols; and a small number, which makes the mapping of certain complex map symbols less readable. Thus, the processing scenario of the feature points is divided into two kinds:

(1) Secondary filtering of feature points.

When the feature point set selected from the feature point mode requires secondary filtering, the specific method is as follows: according to Formula (2), using the inner corner IA_i or outer corner OA_i of the node for further filtering. The outer and inner corners here depend on the direction. When calculating clockwise, the right angle in the forward direction is the inner corner, and the left angle in the forward direction is the outer corner. Conversely, when finding counterclockwise, the left angle in the forward direction is the inner corner and the right angle in the forward direction is the outer corner. If the outer angle is negative, the outer angle has 360° added to it.

$$
\begin{aligned}
OA_i &= A_{ie} - A_{si} \\
IA_i &= 360° - OA_i
\end{aligned}
\tag{2}
$$

For example, Figure 7 shows the automatic derivation process of a shed. According to the norm of the shed's angular line derivation, the angle of the shed with an inner angle greater than 180° does not need to derive the angular line, while the inner angle of the feature point "3" in Figure 7a is greater than 180°. Consequently, the feature point "3" is discarded and the shed's angular line is derived according to the retained feature points in Figure 7b, where the length of the angle line is determined according to the norm of a Chinese fundamental scale topographic map.

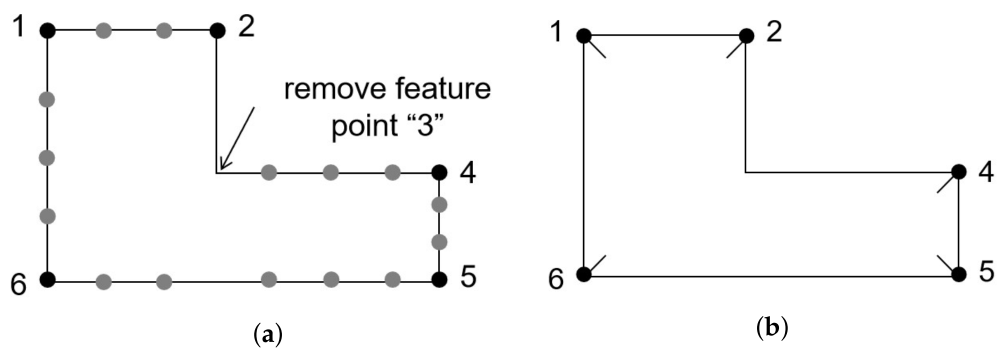


Figure 7. Deriving a shed automatically. (**a**) Secondary filtering of feature points and (**b**) derivation of the shed's corner lines.

(2) Feature points densification.

Some complex map symbols' feature points obtained from the feature-point mode need to be supplemented. For example, a power line symbol consists of a point representing a "power pole" and an arrow extending outward based on the point. After the feature points are extracted by the feature-point mode, it is usually necessary to discern whether the feature points are too far apart for uniform symbolization of the power lines.

As shown in Figure 8, the set of feature points $P = \{P_{i=1...n}\}$ has the endpoints s, e and two other feature points P_j and P_k. It can be seen that the distance between P_j and P_k is long. Besides, the distance is calculated using the Euclidean distance from Formula (3), where (x_1, y_1), (x_2, y_2) are the coordinates of the feature points P_j and P_k, respectively. If the distance D between the two points is greater than a certain distance D_ξ and there are no other feature points between the two points, feature points densification between P_j and P_k is required, where D_ξ is determined according to the general distance d between two power poles in the real world, which can be set to $2d$. Accordingly, the densification principle is as follows: if the distance D is greater than $2d$, the original nodes of the line entity are judged within each d distance, and if so, the node or group of nodes is added to the feature points set.

$$D = \sqrt{(x_1 - x_2)^2 - (y_1 - y_2)^2} \quad (3)$$

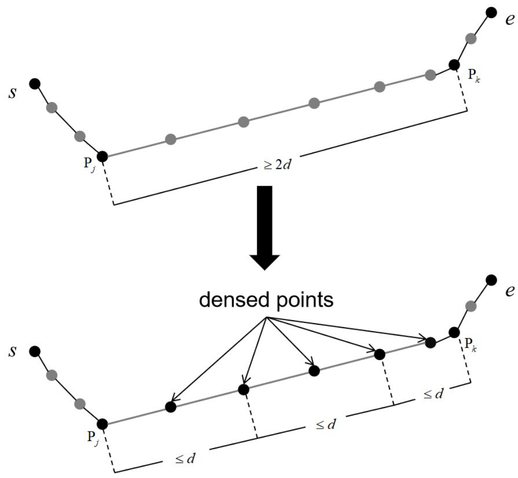


Figure 8. This is an example of feature points densification.

3.2.2. Centroid Mode Derivation

The derivation of the centroid mode consists of two parts: first, the determination of the centroid, which is mentioned in the research [18]; second, the drawing of complex map symbols based on the centroid. Depending on the area entity's concave and convex features, there are two treatments:

(1) Convex area entity derived from centroid mode.

The centroid of the convex area entity is the geometric center, as shown in Figure 9. Taking the overhanging passageway as an example, the intersection line can be obtained by directly connecting the corner points based on the geometric center.

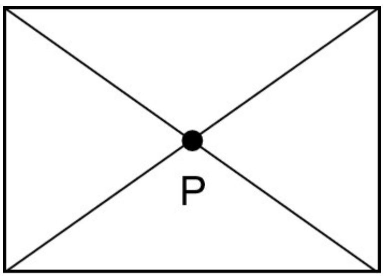


Figure 9. An example of a convex area entity symbol derived from the centroid mode.

(1) Concave area entity derived from centroid mode.

The details steps in this derivation mode are given as follows:

Step 1: As shown in Figure 10a, we obtain the centroid P_0 of the concave area entity A, the minimum boundary rectangle(MBR) R, and the MBR's centroid R_0. In order to distinguish R from A, dashed lines are used to represent R and solid lines to represent A;

Step 2: As shown in Figure 10b, the diagonal of the MBR R is made from R_0;

Step 3: As shown in Figure 10c, according to the position of P_0 and R_0, the whole diagonal is translated to the position of P_0;

Step 4: The intersection line that is outside the A is cut and discarded; in addition, if the endpoint of the cut diagonal line is not on A, it is extended to the boundary of it. The final result is illustrated in Figure 10d.

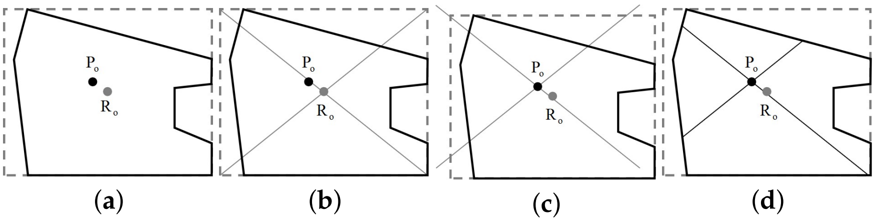


Figure 10. An example of the concave area entity symbol derived from the centroid mode: (**a**) obtaining centroids; (**b**) generating diagonal; (**c**) translating diagonal; and (**d**) post-translation processing.

3.2.3. Feature-Line Mode Derivation

The derivation process of the feature-line mode consists of two parts: feature lines identification and drawing complex map symbols.

(1) Feature-line identification.

Taking the feature line identification of the top and bottom edges of an area entity as an example, the steps of how to identify the feature lines are given with the example diagram:

Step 1: As shown in Figure 11a, we construct the area entity's constrained Delaunay triangulation and obtain the main skeleton line;

Step 2: As shown in Figure 11b, we construct the point-line topology of the main skeleton line and the area entity and use the endpoints s, e, and the main skeleton line to split the area entity data into two parts;

Step 3: As shown in Figure 11c, we use the feature-point mode, and then four feature points are obtained;

Step 4: We delete the arcs between the feature points and endpoints of the main skeleton line; then, the top and bottom edge lines of the area entity are obtained. The final result is illustrated in Figure 11d.

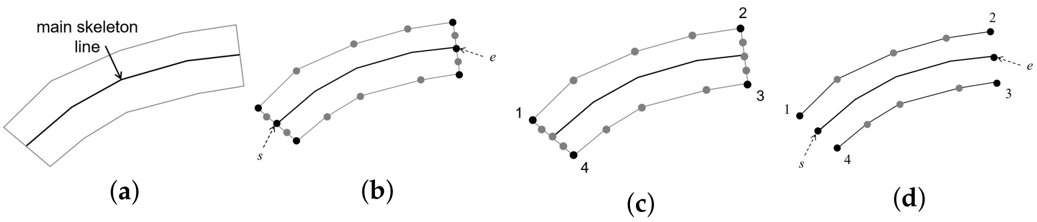


Figure 11. An example of a concave area entity derived from the feature-line mode. (**a**) The extraction of the main skeleton line; (**b**) constructing point and line topology; (**c**) obtaining feature points; and (**d**) the derivation of top and bottom lines.

(2) Symbol derivation based on feature lines.

Based on the identification result of the top and bottom feature line, taking the symbol derivation of the "unreinforced slope" as an example, the derivation steps are given as follows:

Step 1: Reserve only the top or bottom line as needed and calculate the reserved line's length L;

Step 2: The number of sampled feature points on the reserved line is calculated as N_S, where $N_S = \frac{L}{D_S}$, D_S is the sampling spacing according to the graphical norm. Insert N_S feature points on the reserved line by D_S distance;

Step 3: Taking the top edge line as an example, extend each feature point inward to make a line perpendicular to the top edge line. These vertical lines are called long-tooth lines. The length of vertical lines is determined according to the distance between the top and bottom edge lines, and the spacing between the vertical lines refers to the national standard. Multiple unreinforced slope tooth lines are derived as shown in Figure 12a;

Step 4: Take a midpoint between two feature points on the edge line and extend it inward to make a line perpendicular to the bottom edge line at the respective midpoints, where the vertical distance refers to the norm. Consequently, multiple short teeth lines of unreinforced slope are derived, and the final result is shown in Figure 12b.

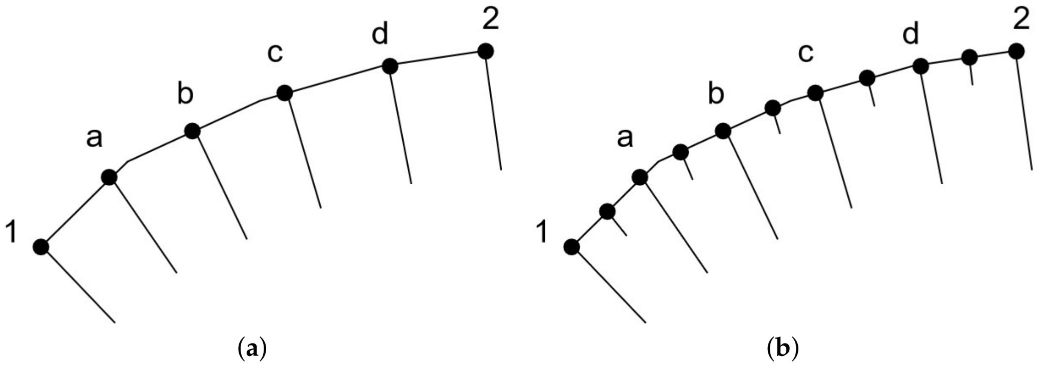


Figure 12. Symbol derivation of "unreinforced slope". (**a**) Deriving long tooth lines; and (**b**) deriving short tooth lines.

3.2.4. Parallel-Line Mode Derivation

The process of parallel-line mode derivation consists of two parts: first, the base edge of the parallel line is determined, and second, multiple parallel lines parallel to the base edge are copied and inserted at equal intervals to derive a complex symbol.

(1) Determining base edge.

As shown in Figure 13, if the starting node of the entity is "a", then define the edge E_{bc} as the base edge in a clockwise direction, and all parallel lines are derived relative to the base edge.

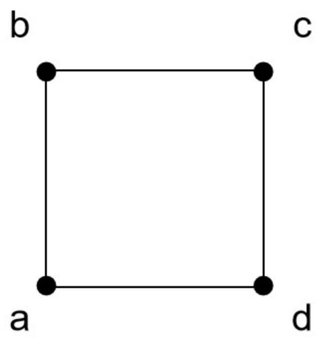


Figure 13. Determining base edge. The nodes(a, b, c,d) are the feature points.

(2) Deriving parallel lines

Depending on whether the bending of the base edge is greater than the bending rate κ, there are two parallel line treatments:

(1) Less than bending rate.

Step 1: The lengths of E_{ab} and E_{cd} are calculated separately, with the longer edge denoted as L_1 and the shorter edge denoted as L_2. Take the former (E_{ab}) when the length is equal;

Step 2: Calculate the number (N_2) of sample points on the shorter edge, where $N_2 = \frac{L_2}{D_2}$, D_2 is the sample spacing on the shorter edge, and then calculate the sample spacing on the longer edge D_1, $D_1 = \frac{L_1}{N_2}$;

Step 3: As shown in Figure 14, the sample points are connected sequentially to obtain multiple parallel lines relative to the base edge.

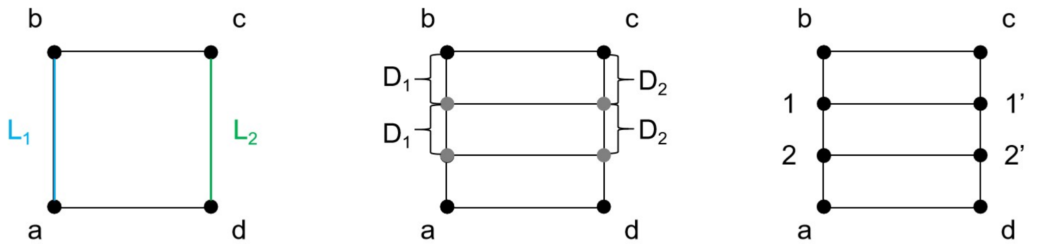


Figure 14. The first scenario of deriving parallel lines. L_1 and L_2 are the lengths of E_{ab} and E_{cd}, respectively. D is denoted as the sample spacing.

(2) Greater than bending rate.

Step 1: The lengths of E_{ab} and E_{cd} are calculated separately, with the longer edge denoted as L. Take the former(E_{ab}) when the length is equal;

Step 2: Copy $\frac{L}{D}$ base edges and insert them equally spaced and parallel to the base edge, where D is the spacing between the copied lines;

Step 3: As shown in Figure 15c, discard the copied lines that are outside the area entity. Use the entity entity to trim all copied parallel lines. If one or both ends of the copied parallel lines are inside the area entity, extend the endpoints until they are on the area entity boundary. The final result is illustrated in Figure 15d.

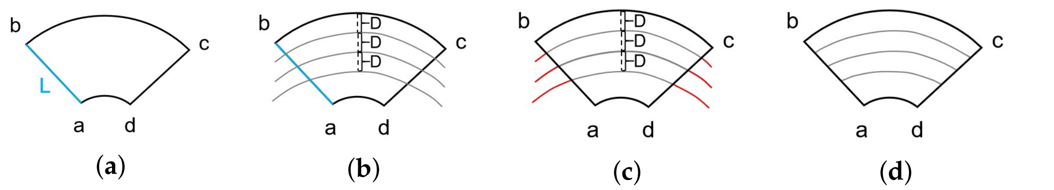


Figure 15. The second scenario of deriving parallel lines. (**a**) choosing the longer edge; (**b**) copying base edges; (**c**) discarding the copied lines; and (**d**) the derivation of parallel lines.

3.2.5. Combination Mode Derivation

Figure 16 shows the "Gantry Crane" symbol in the topographic map "Crane" scheme. The following disintegrates the structure of this symbol and derives it by combination using the four modes.

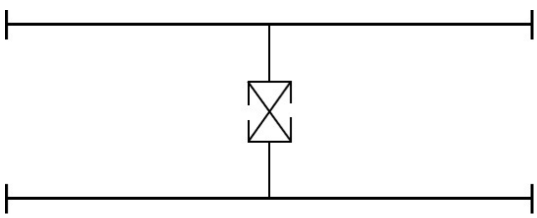


Figure 16. "Gantry Crane" map symbol.

(1) Disintegration idea.

In the "Gantry Crane", the graph is disintegrated with two edge lines above and below, four vertical lines at their endpoints, a detailed graphic in the center, and two vertical lines connecting the top and bottom. The mode disintegration idea of deriving the "Gantry Crane" is illustrated in Figure 17—there are three deriving modes, including the feature-line mode, feature-point mode, and centroid mode.

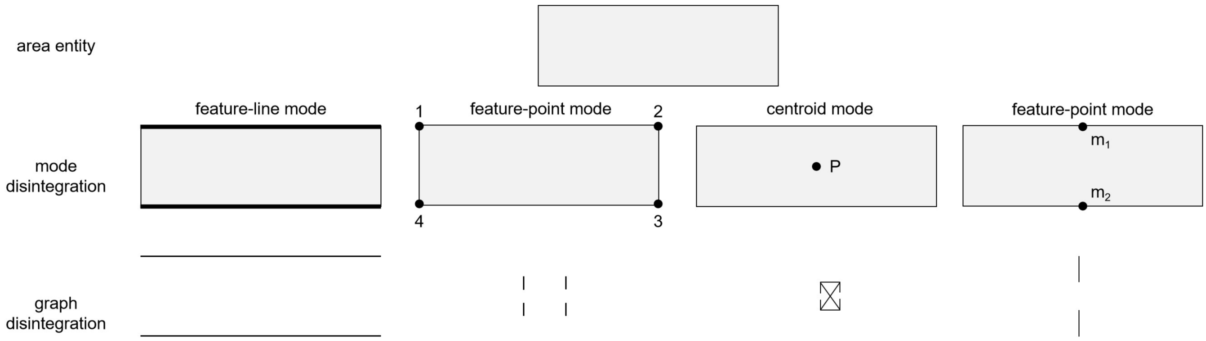


Figure 17. Disintegration idea.

(2) Derivation steps.

Step 1: Obtain the top and bottom edge lines of the area entity through the feature-line mode, and then the first disintegrated graphic is obtained;

Step 2: Locate the endpoints of the top and bottom edge lines and make four vertical lines over the endpoints. The length of each vertical line is two times the width of a single edge line, and then extend one times the distance inversely to get the second disintegrated graphic;

Step 3: Obtain the centroid of the area entity by the centroid mode;

Step 4: The Chinese topographic map style norms have specified the length and width attributes of the detailed graphic. Based on the location of the centroid of the shape, we can draw the peripheral lines and then connect the corner points to get the third graphic;

Step 5: Calculate the distance between the top and bottom edge lines. The length and relative position of the fourth graphic can be obtained after calculating with the length and width attributes of the detail graphic. In the direction of the centroid and the edge lines' midpoints, the final derivation result is completed by inserting the graphics.

4. Experiments and Analyses

4.1. Experimental Environment

The proposed method in this paper is embedded into the Intelligent Geographic Entity Objection Platform (IGEO) developed by the Chinese Academy of Surveying and Mapping. The operating environment used to run the platform is an Intel Core I7-4790 CPU with the Windows 7 64-bit operating system with a main frequency of 3.6 GHz, 8 GB of memory, and a 1 TB solid-state hard disk. The programming language for symbol derivation is C++. Before the creation of map symbols, XML [19] is used to save information about attributes of map symbols (line type, line weight, areal fill-pattern name, color, etc.). XML is an excellent support for storing, manipulating, and querying temporal data, due to its hierarchical structure.

In the following, we carry out the adaptation cartographic test in the platform according to the results derived from the proposed method, and their relationship is shown in Figure 18 below.

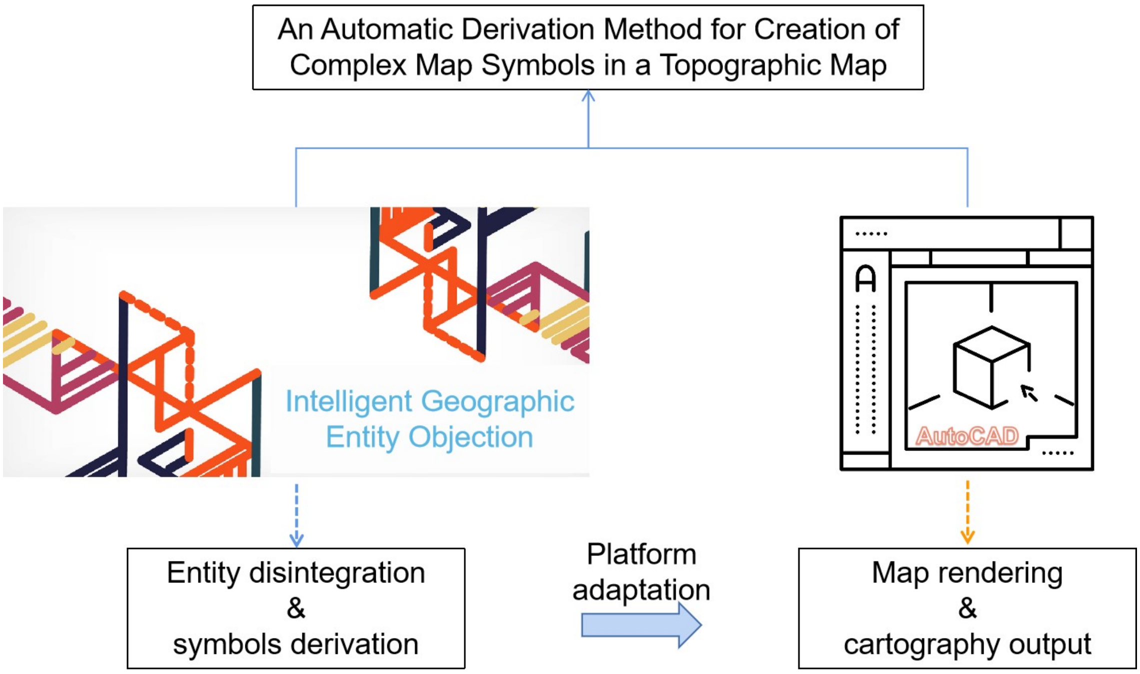


Figure 18. Relationship between IGEO and cartography platform.

4.2. Automatic Cartography

The range of the test area is 8.26 km^2 $\times$ 9.31 km^2, and the algorithm automatically derives the map symbols of the test area, which takes nearly three hours. Figure 19 shows some cartography results of a topographic map of a test area in Shanxi Province in China. Because these are national standard topographic maps, all symbols strictly conform to national standards and do not need additional design or artistic editing. Thus, this paper only considers the symbol's implementation mechanism and an efficient way to achieve national standards for each symbol.

Taking the common topographic map business platform AutoCAD as an example, the principle of adapting and deriving topographic maps is to use the C# programming language to communicate with it for the symbol editing function based on the interface provided by AutoCAD. In the CAD software, point symbols are generally implemented by different defined block references or shape files, linear symbols are generally expressed by different line types, and area symbols are usually filled by different hatches. The method operates directly on the geographic entity data without the participation and collaboration of cartographers, and the cartographic interpretation are well visualized. Figure 20 lists the complex map symbols that exist in this area. These symbols are effectively displayed on the map. Approximately 40% of map symbols are these symbols, and 99% of these symbols are well-visualized on the map. The remaining 1% of the results are mainly due to the layer problems of the entity location, resulting in the illusion of symbol interpretation. After the actual investigation of the local topographic map production work, this method has vastly improved the topographic map production efficiency compared with the symbol editing function or the secondarily developed plug-in provided by the platform. According to statistics, with manual interactive mapping, one person can complete 1 to 2 topographic maps daily; in contrast, one person can complete 20 topographic maps after the automated derivation of the proposed method. The production efficiency has been improved by more than 10 times.

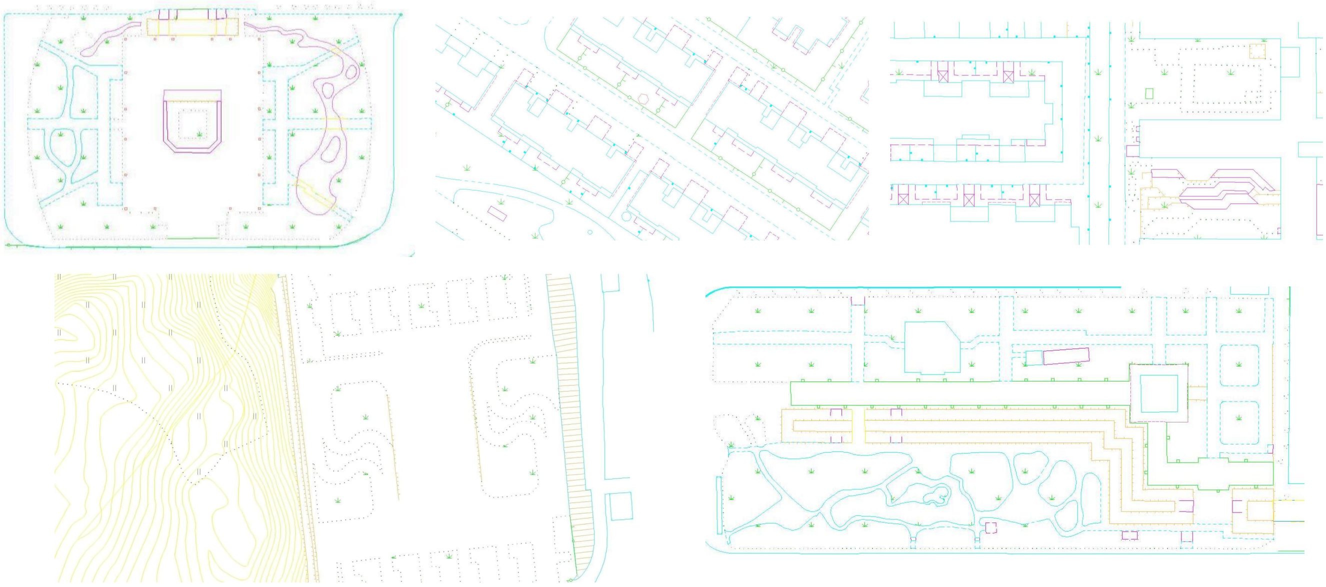


Figure 19. Creation results of map symbols in the test area.

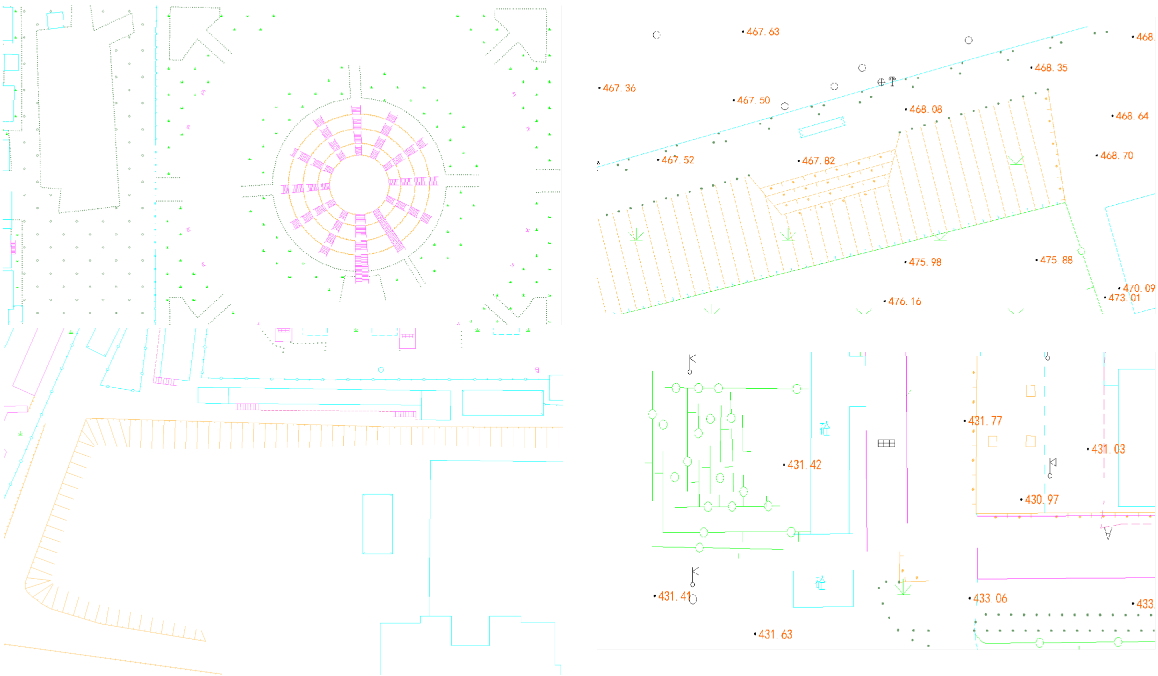
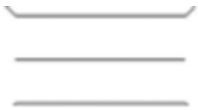
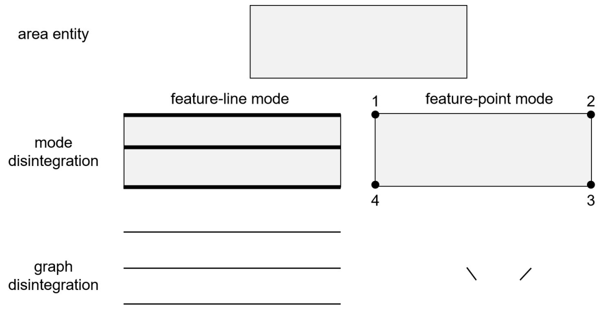
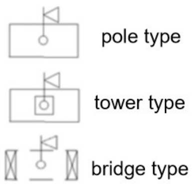
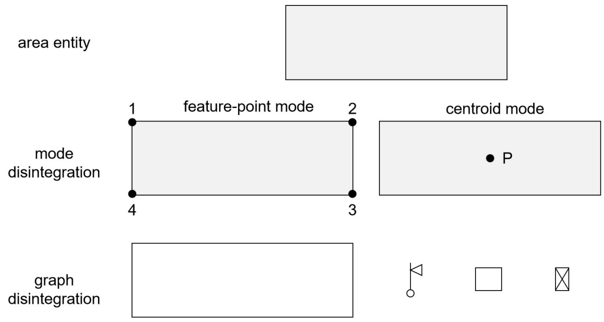
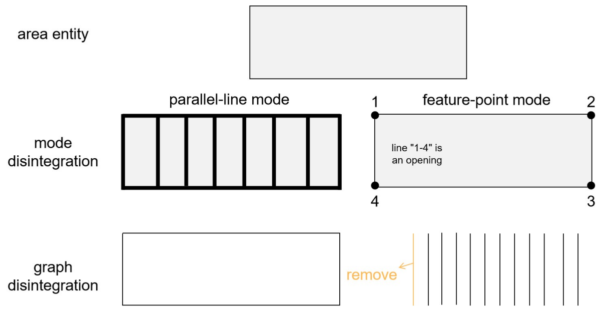


Figure 20. Some complex map symbols of the test area.

In addition, some examples of symbolic expressions of other geographic entity data are listed in Table 1. By disintegrating the composition of complex map symbols, the complex map symbols of topographic maps are automatically derived by using the four modes, singly or in combination.

Table 1. Examples of derivation of other complex map symbols.

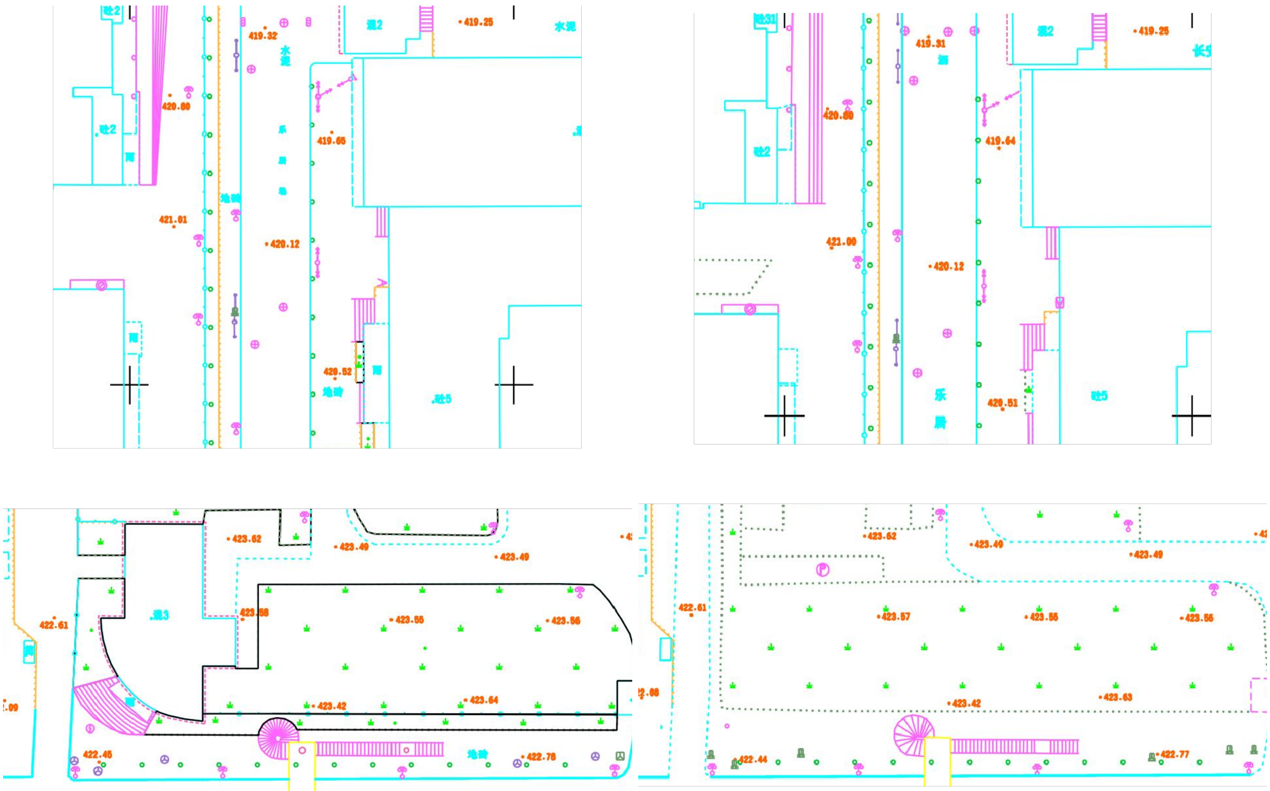
Serial Number	Entity Name	Symbolic Expression	Disintegration Idea
1	Parallel Bridge		
2	Illumination Light		
3	Crossing Bridge		

5. Discussion

There are some books on map design and compilation [20,21] summarizing cartography's theory, technology, and method, providing many application cases and providing significant reference value for cartographers. Many studies based on the norms of map design standardization have designed a vast amount of well-visualized maps. However, with the rapid development of computer technology, cartography has transformed from manual work into automatic work. In our country, realizing the transformation, upgrading, and high-level application of fundamental surveying and mapping achievements is an important goal of new fundamental surveying and mapping. This paper mainly describes the application of a new type of data, namely entity data, in topographic maps for the new situation in China. The proposed method summarizes four derivation modes by analyzing different symbol forms on the map. Based on these four modes, topographic map data are automatically generated under the Chinese standard and adapted to different map business platforms to achieve the effect of automatic cartography.

Table 2 shows the qualitative description and comparison of the advantages and disadvantages of map symbol creation methods as mentioned in Section 1. Creating map symbols based on the software symbol editing function is more flexible than the other two methods, but it requires more labor; the secondary development based on the software interface is used to draw the map. Although the degree of automation is improved compared with the former, it still needs manual participation in the creation process. The method in this paper realizes automatic map symbol derivation through programming, which significantly reduces the amount of labor and improves the rendering efficiency.

To verify the reliability and effectiveness of the proposed method, two fragments of a paper map were used for comparative analysis. The creation results of the traditional manual annotation method (annotation is a design term, meaning a painting work for the topographic map) and our method are demonstrated in Figure 21a,b, respectively. It is evident that most map symbols created by the proposed method match the result created by manual annotation. However, with the city's development, the data are upgraded. The inconsistent map symbols in the Figure 21b are created by the latest data.



(a) (b)

Figure 21. The comparison between the creation result of the proposed method and the paper map. (**a**) Two fragments of the paper map; and (**b**) creation result of the proposed method.

Table 2. Qualitative comparison of methods.

Method	Advantage	Disadvantage
Software editing	The drawing process is highly controllable and flexible	A large amount of manual creations
Secondary development	Semi-automatic	Specified manually yet
Proposed method	Fully automatic derivation	cartographers cannot intervene in the drawing process

6. Conclusions

The traditional platform-based symbolization method is a common, time-consuming map symbol creation method in which the map symbols are combined from the symbol library or drawn manually. However, for a map with complex map symbols, the it is difficult to draw a map with the traditional method in a specified time or with a task deadline. Therefore, as an improvement to the platform-based symbolization method, in this paper, based on the structural characteristics of complex map symbols of topographic maps, the four derivation modes of feature-point, centroid, feature-line, and parallel-line are summarized in conjunction with the Chinese topographic map norm. Fully automatic derivation from geographic entity data to topographic map data is realized by using one or a combination of the four modes. The map symbols produced in this way not only meet the norm but also are easy to use and have sound visualization effects, verified by actual production to meet the needs of topographic map operations and vastly improve production efficiency. The following conclusions were drawn from the experimental validation and analysis using actual data.

(1) The experimental data include 171 map symbols; approximately 40% of the symbols are complex map symbols that are difficult to derive during creation, while the proposed method can create them easily and quickly. Correspondingly, the remaining 60% of map symbols are easy to create. Approximately 65% of the map area can be reasonably drawn by the line type, and these map symbols mainly are buildings and roads;
(2) Through the comparison of the traditional methods, the speed of creating map symbols is more efficient, at approximately 10 times faster.

The four derivation modes in our method provide an approach that simplifies complex map symbols and facilitates programming, avoiding the excessive manual participation that occurs with the traditional method, and is conducive to improving cartographic efficiency. However, our method has two limitations. First, different map symbols may have different disintegration plans. Allowing the computer to automatically recognize a disintegration plan of map symbols and perform symbol derivation is a problem. Second, the selection threshold is a known value in the experimental area. If this value can be adaptively calculated according to the symbol shape characteristics of the local area, the cartographic result will be more reasonable. Hence, future research should focus on two topics. First, derivation processing should be systematically summarized and classified because the fine division of derivation modes is conducive to recognizing the spatial shape characteristics of map symbols. Second, the threshold plays a vital role in map symbol creation, and the setting of an appropriate threshold in map symbol creation for multi-type map symbols requires further study.

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