



## Research on Geographic Information Perception Fusion Technology in Urban Planning and Mapping

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**SUMMARY:** *The effect of urban planning is related to the happiness of the people's life, and it is necessary to carefully process and effectively integrate the geographic information involved in it, and endeavor to improve the integration degree of each region of the city. In this paper, the relative coordinate positions of geographic images before and after geometric correction are calculated to find suitable corrective control points and improve the accuracy of mapping information. The identification framework and multi-class function of D-S evidence information fusion theory are utilized to effectively identify different geographic images and complete the classification of urban elements. Introducing the spatio-temporal data model for urban geographic element objects to complete the perceptual fusion of geographic information and optimize urban planning. The D-S evidence information fusion theory model achieves the highest classification accuracy of 97.61% for the seven functional areas, and the time required is no more than 1.2 s. The spatio-temporal data model fusion of geographic information reduces the degree of overlap of the planning of various areas of the city to less than 0.4%, and enhances the rationality of urban planning.*

**KEYWORDS:** *urban planning; geographic information; geometric correction; D-S evidence information fusion; spatio-temporal data modeling*

### 1 Introduction

In China's economic construction and social development, urban planning has made significant contributions, but it has also triggered the competition for spatial resources and planning discourse [1]. In response, China has issued relevant documents that require the integration of traditional spatial planning into national spatial planning, the establishment of a nationally unified and hierarchically managed national spatial planning system, the comprehensive enhancement of the level of national spatial planning and governance, and the focus on the scientific, intelligent, informatized, and public participatory nature of the planning, implementation, and regulatory processes [2-5]. Geographic information perception fusion technology is the technical support to realize this change, which can provide scientific decision support for urban planning.

Geographic information perception fusion technology is a combination of geographic information systems (GIS) and a variety of perceptual data such as satellite remote sensing technology, remote sensing imagery, etc., so as to realize the comprehensive and intelligent analysis of the geospatial environment technology [6, 7]. In urban planning and mapping, GIS provides many basic functions such as map production, spatial data management, spatial analysis, and geographic modeling, and utilizes a variety of tools and techniques to process the

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data [8, 9]. These tools allow designers to perform complex queries and analyses, such as calculating the shortest path from a public service facility to a residential area, or analyzing the land use patterns of different parcels [10]. Regarding the use of GIS in urban planning, literature [11] examines the role of GIS in urban planning development, which will firstly elaborate on the information needs, emphasizing that GIS plays an important role in urban planning practice, using the UK and the Netherlands as examples. Literature [12] explored the development of an intelligent management information system for urban planning based on GIS and tested the effectiveness of the system, which has a good needs assessment, stable system operation, and plays a facilitating role in urban planning. Literature [13] points out the complexity of urban land use planning, which triggers problems such as power imbalance, and introduces the limitations of previous urban planning methods, and proposes a participatory geographic information system, which helps to develop comprehensive urban planning and can meet the needs of different population groups. Literature [14] examined the different applications of GIS in urban planning and urban development plans, and the results of the study showed that with the continuous development of modern technology, the application of GIS in urban planning is increasing and meets the needs of urban development planning in the context of digital analysis. Literature [15] points out that traditional land surveying tools cannot meet the needs of urban planning and describes the application of GIS in the field of urban planning and management and its key role, which provides a new perspective for better realization of urban planning that meets people's needs. Literature [16] based on GIS spatial analysis of the landscape of suitable construction areas for urban development in the city of Ann Arbor and used spatial analysis methods to assess this suitability, considering factors such as accessibility as well as potential environmental impacts.

And a variety of sensing data, satellite remote sensing technology, for example, it is with the help of satellite remote sensing measurements of the earth's surface, to obtain a large area of geographic information data, with a wide coverage, real-time characteristics, can quickly obtain a large area of topography, geomorphology, land use and other information [17, 18]. Regarding the role of remote sensing technology in urban planning, literature [19] points out that urban planning requires a large amount of data in the planning and implementation stages to determine the status of existing facilities, and remote sensing technology can provide accurate, organized and reliable information for urban planning and management in this process. Literature [20] identifies the current challenges facing urban planning and initiates a study of various techniques for categorizing residential areas using satellite imagery, discusses the advantages and disadvantages of these methods, and identifies the image metrics used to generate the information needed to meet the requirements of sustainable urban planning. Combining the two techniques, the geographic information perception fusion technology has the functions of information collection, environmental monitoring, transmission, storage, expression and analysis. It can describe the spatial attributes, morphology and relationship characteristics of geographic objects in detail, improve the planning information acquisition, analysis and processing capabilities, and apply it to urban planning and mapping to effectively obtain accurate digital images, provide scientific planning and mapping solutions, and further promote the informatization and intelligent transformation of urban planning and mapping [21-24].

Currently, academic research in this field has achieved good results, literature [25] shows that there are challenges in urban planning, emphasizes the necessity of using GIS as the main tool for planning operations, and combines satellite data, GIS and satellite imagery can support urban planning by storing, processing, and analyzing data applicable to planning and decision-making. Literature [26] argues that the expansion of urban construction land destroys the

natural ecological areas, based on which it discusses urban green space planning combining remote sensing and GIS, and establishes an assessment system for urban green space construction, aiming to alleviate the contradiction of urban land use and realize sustainable urban development. Literature [27] discusses the important role of remote sensing and GIS in understanding and managing urban ecosystems, emphasizing that the combination of the two can help in urban eco-regional planning, which leads to monitoring and assessment of urban biodiversity, and protection and restoration of ecological habitats. Literature [28] conducted a simulation study of urban development scenarios based on remote sensing and GIS and discussed the advantages and disadvantages of urban scenario analysis based on the literature review, suggesting that global planning and design, urban planners and politicians should develop appropriate frameworks to implement sustainable urban development policies.

This paper utilizes geographic information obtained from mapping and fusion technology to improve the accuracy of urban planning. The relative positions of remote sensing images before and after coordinate transformation are established and calculated, and the geometrically corrected control point and the brightness value of the point are determined to reduce the error of geographic mapping information. For complex and diverse geographic remote sensing image data, use D-S evidence information fusion theory to convert the image classification and identification problem into probabilistic operations and discriminations of hypothetical propositions and subsets, and improve the effect of geographic image classification and perceptual fusion. Construct a spatio-temporal data model for urban planning element objects, comprehensively consider the temporal and spatial characteristics of diverse urban geographic mapping information elements, and improve the level of urban integration planning.

## 2 Geographic information correction fusion and planning optimization model construction

### 2.1 Image Geometry Correction

In urban planning and mapping, the original satellite remote sensing image is affected by the satellite position and motion status, terrain undulation, the curvature of the earth's surface, atmospheric refraction and the earth's rotation and other factors, so that the remote sensing image is geometrically distorted. The distorted images cause difficulties in quantitative analysis and positional alignment. Therefore, after the receipt of remote sensing data, the first receiving department to carry out correction, this correction is often based on the remote sensing platform, the earth, the sensor's various parameters for general processing. After the staff related to urban planning and mapping get such products, they still need to make further geometric corrections due to the different purposes of use or projection and scale.

#### 2.1.1 Basic idea

Figure 1 shows the image geometric correction process. Before correction, the image in Fig. 1(a) appears to be composed of neatly aligned equally spaced pixel points, but in fact, due to some geometric distortion, the ground distances corresponding to the pixel points in the image are not equal. The corrected image of Fig. 1(b) is also composed of equally spaced grid points, and is based on the ground, which conforms to some kind of uniform distribution of projections, and the intersection point of the grid in the image can be regarded as the center of the pixel. The final goal of the calibration is to determine the row and column values of the corrected image, and then to find the luminance value of each pixel in the new image.

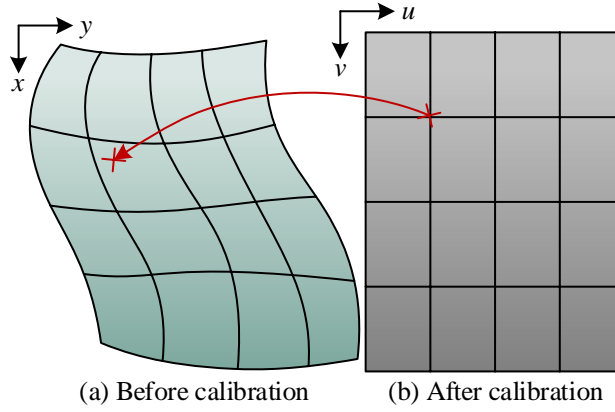


Figure 1: Image Geometric Correction Case Study

### 2.1.2 Geometric correction steps

1) Find a mathematical relationship to establish the relationship between the pre-transformation image coordinates  $(x, y)$  and the post-transformation image coordinates  $(u, v)$ , and calculate the corresponding pre-transformation image coordinates  $(x, y)$  by the center position of each post-transformation image pixel ( $u$  stands for the number of rows, and  $v$  stands for the number of columns, which are all integers). It is analyzed that the image element point of integer  $(u, v)$  is generally not in the integer  $(x, y)$  point in the original image coordinate system, i.e., it is not in the center of the original image element.

Calculate the position  $(x, y)$  in the original image corresponding to each point in the corrected image. Calculate point by point by line, after the end of each line into the next line of calculation, until the end of the whole picture.

2) Calculate the luminance value of each point. Since most of the calculated  $(x, y)$  are not at the center of the original image, the luminance value of the new position must be recalculated. Generally speaking, the luminance value of the new point is between the luminance values of the neighboring points, so it is commonly used to calculate the interpolation method.

### 2.1.3 Calculation methods

1) The correspondence between the points of the image elements of the cubic image is denoted as:

$$\begin{cases} x = f_x(u, v) \\ y = f_y(u, v) \end{cases} \quad (1)$$

Usually the mathematical relation  $f$  denotes a binary  $n$ th degree polynomial:

$$\begin{cases} x = \sum_{i=0}^n \sum_{j=0}^{n-i} a_{ij} u^i v^j \\ y = \sum_{i=0}^n \sum_{j=0}^{n-i} b_{ij} u^i v^j \end{cases} \quad (n = 1, 2, 3, \dots) \quad (2)$$

Practical calculations are often performed using binary quadratic polynomials with the expansion:

$$\begin{cases} x = a_{00} + a_{10}u + a_{01}v + a_{11}uv + a_{20}u^2 + a_{02}v^2 \\ y = b_{00} + b_{10}u + b_{01}v + b_{11}uv + b_{20}u^2 + b_{02}v^2 \end{cases} \quad (3)$$

In order to find the corresponding  $(x, y)$  by  $(u, v)$ , the full coefficients in equation (3) must first be calculated. From the linear theory, we know that to find all the coefficients must at least list all the equations, that is, to find half of the known corresponding points, that is, one and a half points corresponding to  $(u, v)$  and  $(x, y)$  are known. Therefore, these corresponding points with known coordinates are called control points. Then through these control points, solve the system of equations to find all  $a$  and  $b$  coefficient values.

In practice, it is found that half of the control points are just the theoretical minimum required to solve the system of linear equations, and such a small number of control points makes the corrected image very poor, so it is also necessary to greatly increase the number of control points to improve the accuracy of the correction. After the control points are increased, the calculation method is also changed, and the least squares method needs to be used to find the coefficients by fitting the surface to the control point data. At this point, the system of equations (3) becomes:

$$\begin{cases} a_{00} \sum u_i + a_{10} \sum u_i + a_{01} \sum v_i + a_{11} u_i v_i \\ + a_{20} u_i^2 + a_{02} \sum v_i^2 = \sum x_i \\ a_{00} \sum u_i + a_{10} \sum u_i^2 + a_{01} \sum u_i v_i + a_{11} u_i^2 v_i \\ + a_{20} u_i^3 + a_{02} \sum u_i v_i^2 = \sum x_i u_i \\ a_{00} \sum v_i + a_{10} \sum u_i v_i + a_{01} \sum u_i^2 + a_{11} u_i v_i^2 \\ + a_{20} u_i^2 v_i + a_{02} \sum v_i^3 = \sum x_i v_i \\ a_{00} \sum u_i v_i + a_{10} \sum u_i^2 v_i + a_{01} \sum u_i v_i^2 + a_{11} u_i^2 v_i^2 \\ + a_{20} u_i^3 + a_{02} \sum u_i v_i^3 = \sum x_i u_i v_i \\ a_{00} \sum u_i^2 + a_{10} \sum u_i^3 + a_{01} \sum u_i^2 v_i + a_{11} u_i^3 v_i \\ + a_{20} u_i^4 + a_{02} \sum u_i^2 v_i^2 = \sum x_i u_i^2 \\ a_{00} \sum v_i^2 + a_{10} \sum u_i v_i^3 + a_{01} \sum v_i^3 + a_{11} u_i v_i^3 \\ + a_{20} u_i^2 v_i^2 + a_{02} \sum v_i^4 = \sum x_i v_i^2 \end{cases} \quad (4)$$

Here  $\Sigma$  stands for  $\sum_{i=1}^L$  and  $L$  is the number of control points, notating Eq. (4) in matrix form:

$$AU_1 = B_1 \quad (5)$$

Similarly, matrix forms dominated by  $y$  can be listed:

$$AU_2 = B_2 \quad (6)$$

Here:

$$A = \begin{bmatrix} \sum 1 & \sum u_i & \sum v_i & \sum u_i v_i & \sum u_i^2 & \sum v_i^2 \\ \sum u_i & \sum u_i^2 & \sum u_i v_i & \sum u_i^2 v_i & \sum u_i^3 & \sum u_i^2 v_i \\ \sum v_i^2 & \sum u_i v_i & \sum v_i^2 & \sum u_i^2 v_i^2 & \sum u_i^2 v_i & \sum v_i^3 \\ \sum u_i v_i & \sum u_i^2 v_i & \sum u_i v_i^2 & \sum u_i^2 v_i^2 & \sum u_i^3 v_i & \sum u_i v_i^3 \\ \sum u_i^2 & \sum u_i^3 & \sum u_i^2 v_i & \sum u_i^3 v_i & \sum u_i^4 & \sum u_i^2 v_i^2 \\ \sum v_i^2 & \sum u_i v_i^3 & \sum v_i^3 & \sum u_i v_i^3 & \sum u_i^2 v_i^2 & \sum v_i^4 \end{bmatrix} \quad (7)$$

$$U_1 = \begin{bmatrix} a_{00} \\ a_{10} \\ a_{01} \\ a_{11} \\ a_{20} \\ a_{02} \end{bmatrix}, U_2 = \begin{bmatrix} b_{00} \\ b_{10} \\ b_{01} \\ b_{11} \\ b_{20} \\ b_{02} \end{bmatrix}, B_1 = \begin{bmatrix} \sum x_i \\ \sum x_i u_i \\ \sum x_i v_i \\ \sum x_i u_i v_i \\ \sum x_i u_i^2 \\ \sum x_i v_i^2 \end{bmatrix}, B_2 = \begin{bmatrix} \sum y_i \\ \sum y_i u_i \\ \sum y_i v_i \\ \sum y_i u_i v_i \\ \sum y_i u_i^2 \\ \sum y_i v_i^2 \end{bmatrix} \quad (8)$$

Solving the system of equations (5) and (6) yields  $U_1$  and  $U_2$ , and thus all the coefficients of the binary quadratic polynomial. Once the coefficients are determined, using equation (4), the corresponding  $(x, y)$  position of the corresponding original image can be found based on the rank value  $(u, v)$  of each image element point.

2) In order to determine the brightness value of each point on the corrected image, only the brightness of the point  $(x, y)$  corresponding to its original image is required. Usually there are three methods: Nearest Neighbor Method, Bidirectional Linear Interpolation and Cubic Convolutional Interpolation. In this paper, we use three times convolutional interpolation method to correct remote sensing images.

### 3) Selection of control points

The first step of geometric correction is the position calculation, the first step is to find the coefficients of the selected binary polynomial. In this case, a set of control point coordinates must be known. Quadratic polynomials (e.g., (3)) with all coefficients require all equations, i.e., at least half of the control points are needed. Practical work has shown that correcting the image with the minimum number of control points needed to solve the equation is often ineffective. At the edge of the image, in areas with large changes in ground features, such as river bends, etc., the image will be distorted due to the absence of control points and the introduction of corresponding points by calculation. Therefore, the number of control points needs to be increased.

## 2.2 D-S Evidence Information Fusion Theory

The D-S evidence information fusion theory is utilized to classify a large number of remote sensing images to provide suitable classification data for the subsequent urban geographic information perception fusion. The theory is a reasoning theory that effectively solves the problem of uncertainty, which is superior to the traditional probabilistic approach in grasping the uncertainty and unknown nature of things. In addition, the theory of evidence introduces the method of synthesizing evidence, which enables the fusion of evidence from multiple sources of evidence. Therefore, evidence theory has been successfully applied to the field of geographic information perception fusion. The basic concepts of  $D-S$  evidence theory are systematically introduced below:

1) Discriminative framework

The discursive framework underlies the various functions and concepts in the theory of evidence.  $\Theta$  denotes the set of all hypotheses one can recognize about a judgment problem, and any proposition in question is a subset of  $\Theta$ . A proposition is said to be recognized by the framework if it corresponds to a subset of the recognition framework.

For example, the recognition framework contains three basic assumptions:  $\Theta = (A, B, C)$ , then  $D-S$  theory will consider all possible combinations of  $[A],[B],[C],[A,B],[A,C],[B,C],[A,B,C]$ , and  $\phi$ , and denote the set by  $2^\Theta$ . Figure 2 shows the recognition framework for the basic hypothesis  $[A,B,C]$ . That is, for an identification framework with  $N$  basic assumptions, then the total number of evidences corresponding to the  $D-S$  theory is  $2^N$ . The first three in this example are said to be independent hypotheses because they contain only one most basic element, and the rest are called composite hypotheses.

The identification framework is the basis of the theory of evidence, and in order to be able to achieve the purpose of transforming more abstract logical concepts into more intuitive set-theoretic concepts, the identification framework is applied to unite the corresponding propositions and subsets, and to transform logical operations between propositions into set-theoretic operations. For example, the disjunction, conjunction, and implication of two propositions correspond to the union, intersection, and inclusion of sets, respectively, and the negation of a proposition corresponds to the complement of a set.

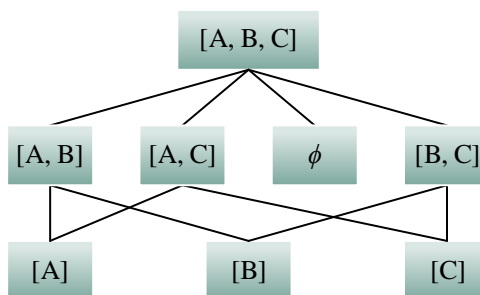


Figure 2: The identification framework of basic assumptions  $[A, B, C]$

2) Basic Probability Assignment Function

Basic Probability Assignment Function: a piece of evidence can support one or more propositions, and this support can be expressed as a function in terms of BPA. The BPA function falls between  $[0.0,1.0]$ . The basic probability assignment function  $m$  on the power set  $2^\Theta$  is defined as  $m: 2^\Theta \rightarrow [0.0,1.0]$  and satisfies

$$\begin{cases} m(\phi) = 0 \\ \sum_{A \subseteq \Theta} m(A) = 1 \end{cases} \tag{9}$$

where:  $m(A)$  means the degree to which the evidence supports the occurrence of proposition  $A$ .  $\phi$  denotes the empty set, and  $m(A)$  is known as the basic probability number or basic credibility of  $A$ . The first equation indicates that the evidence produces no confidence level for the empty set  $\phi$  (empty propositions), and the second equation indicates that the sum of the confidence values for all propositions is equal to 1.0, i.e., the total confidence level is 1.0.

By definition, the BPA of evidence  $[A, B]$  represents the degree of support for  $[A, B]$  rather than the sum of the BPAs of  $[A]$  and  $[B]$ , i.e.,  $m[A, B] = BPA([A, B])$ . The BPA sum of all combinations equals 1.0.

In general, the BPA of a given hypothesis is a probability derived from objective or empirical data.

### 3) Trust Function

Trust function: for any  $A \subseteq \Theta$ , there are

$$Bel(A) = \sum_{B \subseteq A} m(B) \quad (10)$$

$Bel(A)$  denotes the sum of the underlying probability functions of all the evidence for a proposition, indicating the degree of support for that proposition.

Also, the trust function has the principle of semi-additivity:

$$Bel(A) + Bel(\bar{A}) \leq 1 \quad (11)$$

### 4) Likelihood function

Likelihood function: for any  $A \subseteq \Theta$ , there are

$$Pl(A) = \sum_{A \cap B \neq \emptyset} m(B) = 1 - Bel(\bar{A}) \quad (12)$$

denotes the maximum value of the total basic probability number of elements that may be distributed in  $A$  (without opposing proposition  $A$ ). It is known from the above equation:

$$Bel(A) \leq Pl(A) \quad (13)$$

The confidence function  $bel(A)$  denotes the degree to which the evidence supports the proposition  $A$ ; the likelihood function  $pl(A)$  denotes the degree to which the evidence does not cast doubt on the proposition  $A$ ; and the interval  $[bel(A), pl(A)]$  constitutes the interval of uncertainty of the evidence, which denotes the degree of uncertainty of the proposition. Reduce the uncertainty interval is one of the purposes of evidence theory.

### (5) Combination function

Combination function: multiple evidence or hypothesis synthesized by the quality of the function, expressed in terms of orthogonal sums, defined as follows:

$$m = m_1 \oplus m_2 \oplus \dots \oplus m_r \quad (14)$$

When the intersection of different hypotheses is null, that is, when  $A = X \cap Y = \emptyset$ , this indicates that the hypotheses conflict with each other. The synthesis function is expressed as:

$$m(A) = 0(X \cap Y = \emptyset) \quad (15)$$

When the assumed intersection is not empty, the combinatorial function expression is:

$$m(A) = m_1 \oplus m_2 \oplus \dots \oplus m_n = \frac{\sum_{\cap A_i = A} \prod_{i=1}^n m_i(A_i)}{1 - \sum_{\cap A_i = \emptyset} \prod_{i=1}^n m_i(A_i)} (X \cap Y \neq \phi) \quad (16)$$

Let  $K = \sum_{\cap A_i = \emptyset} \prod_{1 \leq i \leq n} m_i(A_i)$ , let  $K$  be the normalization constant,  $K \neq 1$ , and  $k$  denote the conflict of the evidence, reflecting the conflict situation among the evidences, and the greater the  $K$  indicates that the greater the conflict among the evidences.

### 2.3 Spatio-temporal data model

The geographic information after geometric correction and D-S evidence information fusion processing is spatially static, while urban planning often needs to consider the overall change characteristics of geographic information in time and space, so the introduction of spatio-temporal data model highlights the importance of temporal features in urban change and improves the rationality of urban planning.

The primary problem in the establishment of spatio-temporal data model is the division of time periods and moments, which is equivalent to the division of points and arc segments in spatial data model. It is generally believed that the time period is continuous and the moment is discrete, the time period is associated with the state of things that exist, while the moment is associated with the event that causes the occurrence of change, and the starting point and the end point of the moment make up the time period.

Assuming that  $S$  is a set of states on the set of integers  $Z$ , the spacetime relation at time  $t$  and the subsequent time  $(t+q)$  is, from a set-theoretic point of view, as follows:

$$F: S_t^z \leftrightarrow S_{t+q}^z \quad \text{and} \quad \frac{dS_t}{dt} = f(\text{Process1}, \text{Process2}, \text{Process3}) \quad (17)$$

It can also be interpreted in terms of the metacellular automaton model: assuming that  $C$  is a state at a certain moment in time, that its state at the moment  $(t+1)$  consists of a series of states of its different constituent parts, and that  $f$  is a mapping from one state to another at a certain time, the mathematical model is:

$$F(C_{t+1}^n) = f(C_t^{i-r}, \dots, C_t^i, \dots, C_t^{i+r}) \quad (18)$$

Based on the above principles, people have studied a series of modeling methods by adding timestamps to the spatial attributes and thematic attributes of spatial objects, such as spatio-temporal snapshot model, basis state correction model, spatio-temporal cube model, spatio-temporal composite model, spatio-temporal object model, and graph theoretic model. According to the actual needs of urban planning, here we focus on the spatio-temporal cube model, base state correction model and spatio-temporal object model.

#### 2.3.1 Space-time cube modeling

Figure 3 shows the structure of the space-time cube model. The space-time cube model is built on the basis of the Cartesian coordinate system with the addition of the time dimension, with the structure:  $Geo-Object = f(Space(x, y), Time)$ . The process of development and change

of two-dimensional graphics along the third dimension of time expresses the evolution of the real world plane position over time, and given a time position value, the state of the corresponding cross-section can be obtained from the three-dimensional cube, which can also be extended to express the process of change in three-dimensional space along time. The disadvantage is that as the amount of data increases, backtracking and prediction of the cube becomes more and more complex and the amount of data becomes so large that it eventually becomes unmanageable. In strategic urban planning, this model can be considered appropriately because there are few overall macro factors involved in the changes and the time granularity is relatively large, but in implementation urban planning, where different changing factors are superimposed, the cube is extremely prone to collapse.

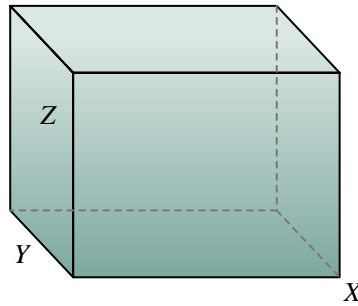


Figure 3: The model of the space-time cube

### 2.3.2 Base state correction model

The purpose is to first determine the initial state of the change, that is, the base state, generally in the time axis to choose the appropriate sampling interval to record the region where the change occurs, through the superposition of the content of each change, to get the state of each change, correct the amount of change relative to the base state, let the state set  $Y$  is the state to be backtracked, the set of states  $V$  is the definition of the base state,  $\varepsilon$  is the logical difference from the state  $Y$  to the logical difference of state  $V$ , then:

$$Y_{it} = V_{it} + \varepsilon_{it} \quad (19)$$

Since only the part of geographic element changes are stored instead of all geographic elements of each state, it effectively reduces the amount of data and saves storage space, and it is a model that is easier to realize at present, but a series of logical operations have to be carried out when restoring the previous state, and when there are more changes in the elements, the arithmetic is relatively large, and it is difficult to manage the index changes, and meanwhile, in the practical application, there will be a kind of “pseudo-change”, topological relationships are prone to rupture, this model is modified to construct multiple base states, such as double or triple base states. In order to support the variability of time granularity, we propose a correction model with multiple base states and multiple level differences, which can also construct multiple base states on the time axis of elemental changes as needed to reduce the complexity of backtracking. This model is more suitable for raster data in urban planning, such as in modeling city contours or the process of urban land change.

### 2.3.3 Object-oriented spatio-temporal data models

Object-oriented spatio-temporal data model adopts object-oriented ideas, geographic elements are one in time, space and attributes, there are integrated carriers and mechanisms, provides a rich modeling structure, such as support for types and classes, aggregation, propagation,

generalization, operation, nesting, polymorphism, etc., time, space and attributes are abstracted as classes, but temporal classes can not exist independently and are dependent on spatial classes and attribute classes. Object-based spatio-temporal data model that is to use computer and mathematical language to describe the spatio-temporal change process and behavior of each spatial object in a specified spatial region at a specified time region, and then aggregate the spatio-temporal change process of each object during this time into a spatio-temporal data collection. The general structure of the spatio-temporal object is: <T-Object, ID, T-Attribute, T-Rule, T-space, Operation>, In urban planning, the use of object-oriented technology can make the different historical versions of the city elements to be concentrated in the record of the entity object, but in the specific system implementation, it should also take into account the causes that cause the changes of the planning object the determination of non-essential and essential attributes, the organization of attribute changes, and so on.

### 3 Analysis and comparison of the effects of geometric correction of geographic images

#### 3.1 Comparison of the effect of grayscale correction of image data

Establish and calculate the relative coordinate position of the image before and after correction, determine the correction control point and the brightness value of the point, carry out the grayscale correction of the obtained remote sensing image, and lay a good foundation for the subsequent image recognition classification and information fusion. An example of the gray scale correction process of a remote sensing image of area S of city A is given to show the effect of the method selected in this paper in image gray scale correction.

Figure 4 compares the gray level distribution of this remote sensing image before and after correction. The gray scale distribution of this image before correction shows a sudden high and low trend, and at the horizontal coordinates 25-57 and 158-210, the gray scale of the image is higher, while the gray scale of the rest of the positions is lower, and there is overexposure in most of the positions. After the correction, the gray scale distribution of the image shows the change rule of gradient increase and decrease, which is more in line with the change of brightness of the actual geographic remote sensing image on the whole.

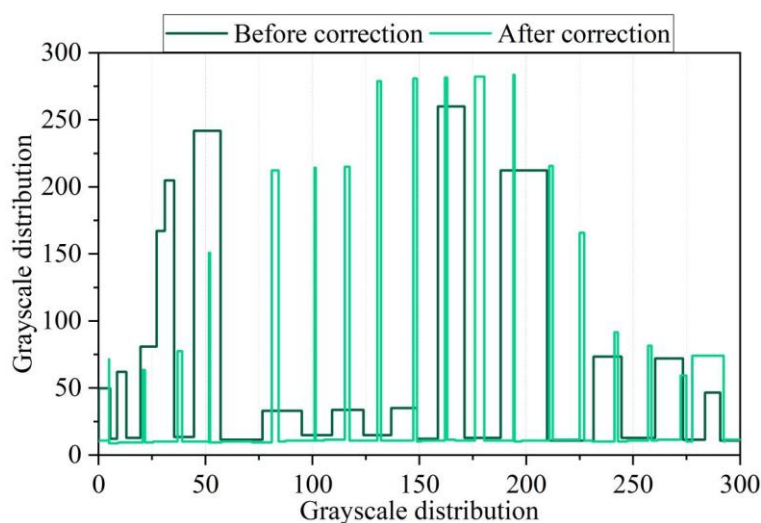


Figure 4: gray-scale distribution before and after image correction

### 3.2 Comparison of orthodontic effects of different orthodontic methods

The uncorrected remote sensing images of each area of city A acquired are utilized to establish the dataset. The comparison methods SIFT algorithm and SURF algorithm are introduced to compare the image correction effect with the geometric correction method of this paper in three datasets to analyze the correction advantages of the selected methods.

#### 3.2.1 Comparison of anti-rotation properties

Figure 5 shows the comparison of the anti-rotation ability of the images after correction by the three methods. The number of control points of the reference image are 450, respectively, according to the image rotation of  $5^\circ$ ,  $50^\circ$ ,  $100^\circ$ , the geometric correction method can calculate the number of control points to be corrected for 432, 420, 405, respectively; while the SIFT algorithm can calculate the number of control points is only 358, 326, 308; SURF algorithm is slightly better than the SIFT algorithm, respectively, are 405, 364 and 313. The geometric correction methods are better able to determine the location of the corrected control points regardless of the change in image rotation angle.

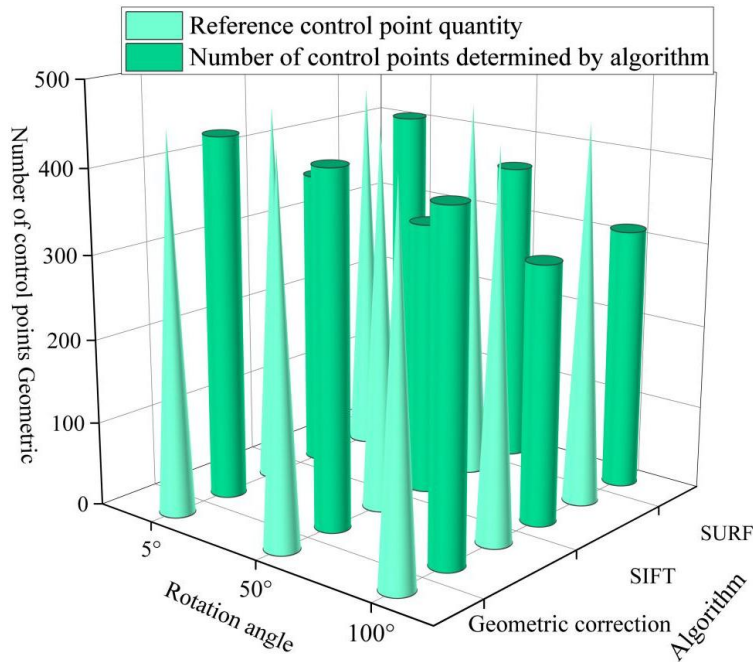
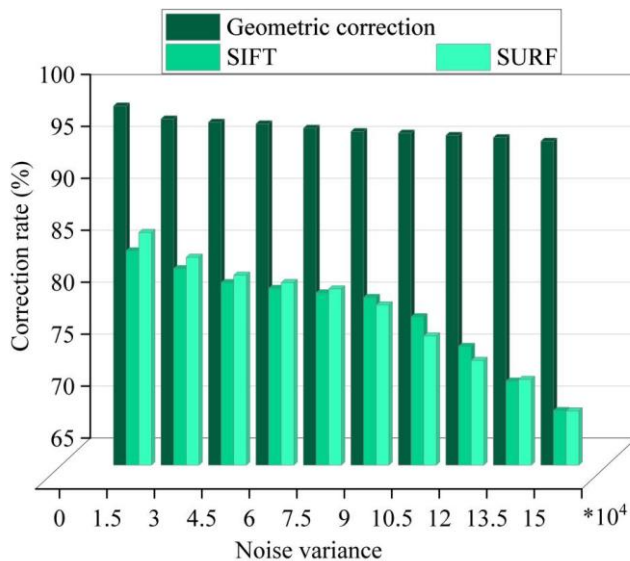


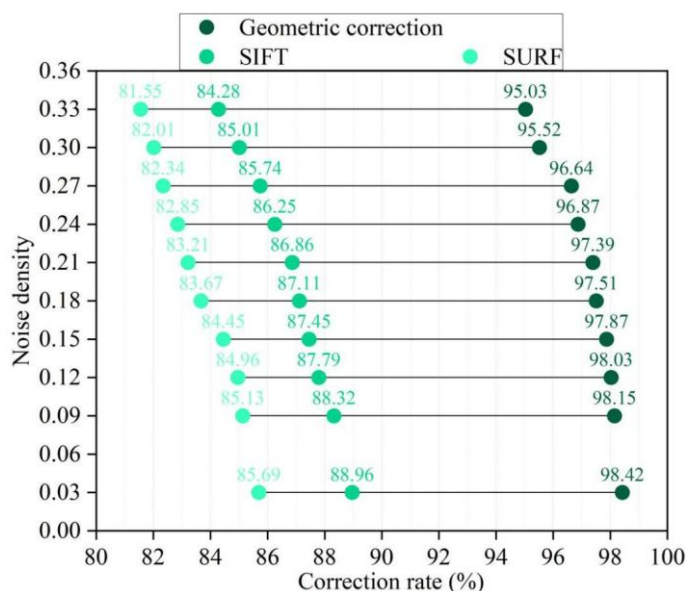
Figure 5: Comparison of anti-rotation capabilities of images after correction

#### 3.2.2 Comparison of noise resistance

Gaussian noise and pretzel noise are added to the images of the dataset respectively, and the image correction task is accomplished using the 3 methods. Figure 6 shows the comparison of the anti-noise performance of the 3 methods. Although the Gaussian noise variance/pepper noise density is increasing, the image correction rate of the geometric correction method always stays within the range of 99.57% to 96.18% (Gaussian noise) and 98.42% to 95.03% (pepper noise density), and the correction rate of greater than 95% indicates that the method is more noise-resistant and is able to successfully information correction even when the image error is large.



(a) Comparison of image correction performance in presence of Gaussian noise



(b) Comparison of correction performance in presence of salt-and-pepper noise

Figure 6: Comparison of Anti-Noise Performance of Three Methods

### 3.2.3 Comparison of Brightness Resistance Performance

Table 1 shows the comparison of the three methods in terms of their ability to resist luminance variations. In 25%, 50%, 75%, and 100% brightness, the image correction rate of geometric correction is always the highest among the three methods, reaching 99.00%, 94.64%, 94.03%, and 98.10%. By calculating the relative coordinate position of the image to determine the position of the image correction control point, the geometric correction of the image can be accurately achieved, which prepares geographic mapping information with less error for the subsequent optimization of urban planning using the D-S evidence information fusion theoretical model to classify the image and the spatio-temporal data model.

Table 1: Comparison of the resistance to brightness changes of the three methods

Image brightness	Method	Reference control point count	Calculate the number of control points	Correction rate (%)
25%	Geometric correction	500	495	<b>99.00</b>
	SIFT	500	416	83.20
	SURF	500	452	90.40
50%	Geometric correction	634	600	<b>94.64</b>
	SIFT	634	541	85.33
	SURF	634	502	79.18
75%	Geometric correction	385	362	<b>94.03</b>
	SIFT	385	300	77.92
	SURF	385	325	84.42
100%	Geometric correction	420	412	<b>98.10</b>
	SIFT	420	386	91.90
	SURF	420	340	80.95

## 4 Urban planning practices based on D-S evidence and spatio-temporal data

### 4.1 Regional division of urban functional types

Combining the geometrically corrected geographic remote sensing imagery and the original planning map of City A, the functional types of areas in the city are divided. Figure 7 shows the results after the delineation. As can be seen from the area division map, the seven functional type areas have a large number of overlapping locations, and it is necessary to utilize the D-S evidence information fusion theoretical model to classify the geographic remote sensing images in a more detailed way and to clarify the classification boundaries of the areas in the city planning.

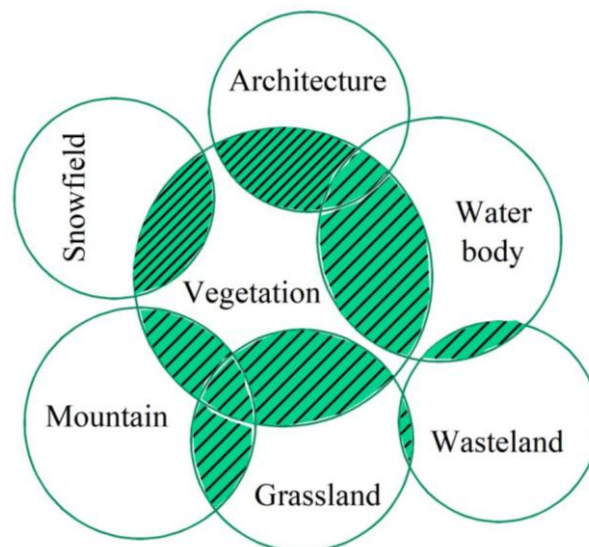


Figure 7: Urban functional type area division

## 4.2 Comparison of Classification Effectiveness of D-S Evidence Information Fusion

### 4.2.1 Comparison of classification accuracy of remote sensing images by different models

Five models, small sample remote sensing image classification (SSR), hyperspectral remote sensing image classification (HRS), support vector machine remote sensing image classification (SVM), random forest remote sensing image classification (RF), and K-neighborhood remote sensing image classification (KNN), are selected as the comparative models to classify remote sensing images of overlapping areas together with the D-S Evidence Information Fusion Theory model. Figure 8 compares the remote sensing image classification accuracies of the six classification models. The classification accuracy of the D-S evidence information fusion theory model for remote sensing images of seven types of functional areas reaches 95.09%~97.61%, which is much higher than that of the five models in comparison, and the classification effect is more stable in different types.

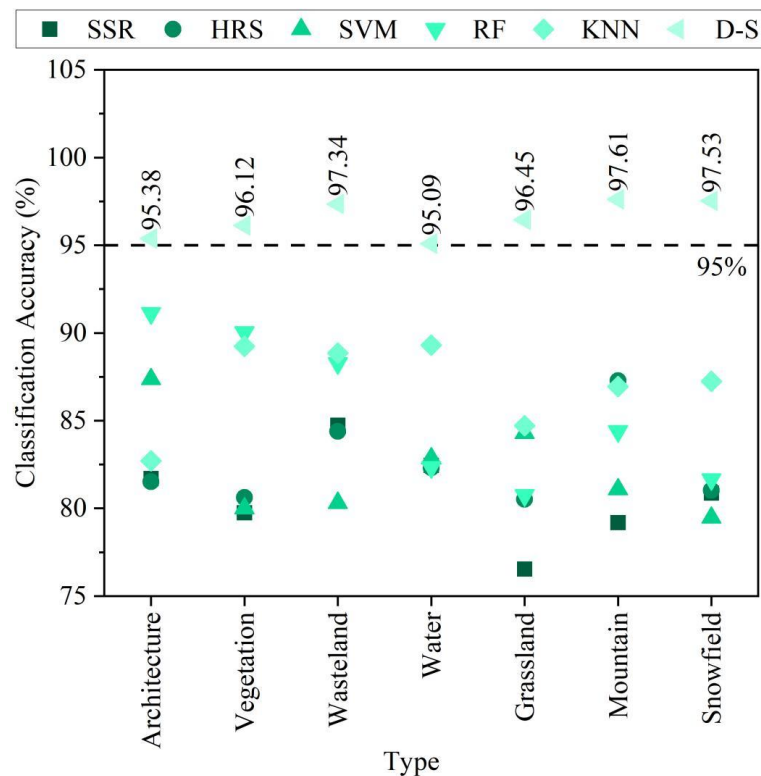


Figure 8: Classification accuracy of 6 model's remote sensing images

### 4.2.2 Comparison of Classification Speed of Remote Sensing Images by Different Models

Figure 9 shows a comparison of the classification speed of remote sensing images with six classification models. The D-S evidence information fusion theory model takes only 0.49s~1.14s to classify the remote sensing images of seven types of functional areas. The classification speed is the fastest among the six models, which is able to accurately and efficiently complete the classification of different remote sensing images.

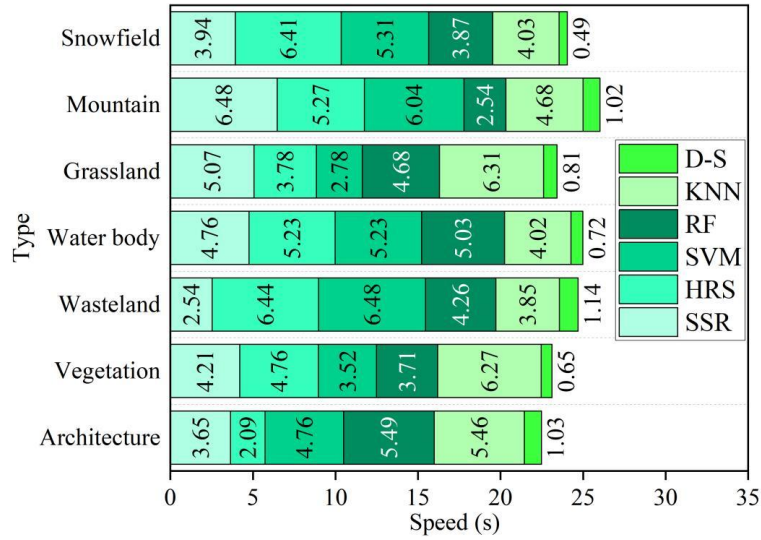


Figure 9: Classification speed of remote sensing images for 6 models

### 4.3 Comparison of urban planning effects supported by spatio-temporal data models

After geometrically correcting the geographic image information and accurately classifying the remote sensing images of different functional types of regions, the spatio-temporal data model is used to optimize the planning of each type of region in the city by comprehensively considering the temporal and spatial characteristics of urban planning. Figure 10 shows the planning overlap of each area of city A supported by the spatio-temporal data model. The error between the optimized planning overlap of each area of city A and the ideal planning overlap is only 0.03%~0.08%, and the actual overlap of each area does not exceed 0.4%. The city planning combined with the spatio-temporal data model makes City A closer to the ideal livable city.

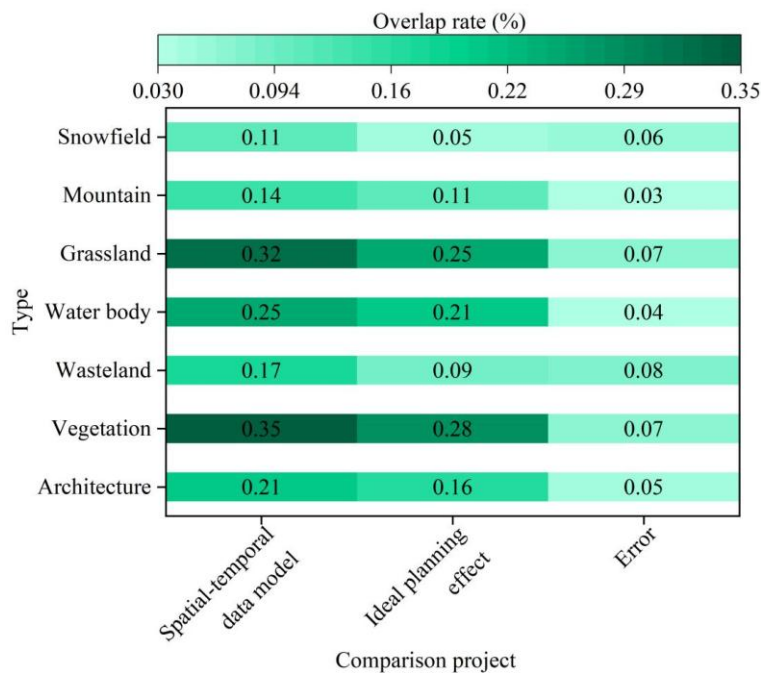


Figure 10: The degree of overlap in the regional planning of City A

## 5 Conclusion

This paper synthesizes the geometric correction technique, D-S evidence information fusion theoretical model and spatio-temporal data model to reduce the error of urban geographic remote sensing image data and improve the quality of urban planning. The geometrically corrected remote sensing images have strong advantages in three dimensions: anti-rotation, anti-noise, and anti-brightness. And the theoretical model of D-S evidence information fusion has an image classification accuracy in the range of [95.09,97.61]% and classification time in the range of [0.49,1.14]s for overlapping areas, which is characterized by high accuracy and speed. Using the spatio-temporal data model to optimize urban planning, the error between the overlap of the seven regions and the ideal city is only 0.03% to 0.08%.

The use of geographic information perception fusion technology to improve the rationality of urban planning has a certain value for promoting the economic development of the city, humanistic care optimization and so on. In the future development of data diversification and information diversification will be organically combined with geographic information to create a more advanced urban spatio-temporal data model. Combined with the theory and method of artificial intelligence, it realizes the rapid establishment and updating of the information data model.

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