

# Design and Engineering Practices of National Fundamental Geo-entity Relationship

Yi Zheng<sup>1, a</sup>, Limeng Li<sup>1, a</sup>, Yuanjie Zhang<sup>1, a</sup> and Xuemei Li<sup>1, a</sup>

<sup>1</sup> National Geomatics Center of China, Beijing, China.

<sup>a</sup> 619318155@qq.com

**Abstract.** National fundamental geo-entity construction has been vigorously promoted by the Ministry of Natural Resources of the People's Republic of China. As one of the core contents, national fundamental geo-entity relationship faces new requirements of richer content, more intelligent construction, more flexible association, more intuitive expression, and more efficient application. This paper analyzes the existing entity relationship types, defines the content of national fundamental geo-entity relationship, compiles the geo-entity relationship construction table, establishes a practical and feasible process for geo-entity relationship construction through engineering practices. The first batch of national fundamental geo-entity relationship products show that the production process described in this paper can quickly and effectively achieve the construction of national fundamental geo-entity relationship that are rich in content and convenient to apply. It has certain reference and promotion practical in the construction and integration of multi-scale geo-entity relationship at the national, provincial and municipal levels.

**Keywords:** 3D realistic geospatial scene; fundamental geo-entity; entity relationship; relationship building.

## 1. Introduction

Geo-entities are physical abstractions that humans use to describe and express geographical phenomena with specific spatial ranges, forms, processes, relationships, and related attributes in the geographical world. Their unique data form and the ability to effectively carry other professional information have the potential to integrate, share, and exchange information with various government departments. Fundamental geo-entities refer to the geo-entities described and expressed within the scope of basic surveying and mapping responsibilities, which serve as the positioning framework and carrier of other geo-entities and related information [1].

National fundamental geo-entity construction has been vigorously promoted in China, mainly through the conversion and production of 1:50 000 fundamental geographic information feature data [2]. Feature data traditionally focus on cartographic representation, which is lack of relationship information between geographic entities. And there are problems with inconsistent relationship expression, difficult linkage and association, cumbersome data extraction and customization in cross industry applications [3]. According to the pilot project of new basic surveying and mapping approved by the Ministry of Natural Resources, some regions such as Wuhan, Xi'an, Shanghai, Zhejiang, Jiangsu and Beijing have carried out 3D realistic geospatial scene construction experiments. They have conducted some exploratory research on the expression and construction of geo-entity relationships, preliminarily sorted out the complex relationships between fundamental geo-entities, and explored the construction methods of fundamental geo-entities, but the main source is large-scale feature data [4]. Due to the lack of mature experience, as well as contradictions and conflicts between the results and existing technical specifications, there are significant differences in the understanding of geo-entity relationships, usage scenarios, and data quality among different regions [5]. Therefore, the accuracy and efficiency of geo-entity relationship extraction are low, and the resulting forms are diverse, requiring the use of various complex data structures and specialized software. How to construct and use geo-entity relationships has become a challenge in the construction of geo-entities [6].

This paper conducts the design of national fundamental geo-entity relationships, proposes a feasible method for constructing and expressing national fundamental geo-entity relationships, and

carries out engineering practice, providing a foundation for unified and standardized data linkage updates and comprehensive information mining nationwide.

## 2. Overall Technical Approach and Main Technical Processes

Following the overall approach of "design-build-verify", this paper analyses the relationship types and information of national fundamental geo-entities, defines all entity relationship contents, designs and establishes a relationship structure table and construction rules for national fundamental geo-entity classes [7]. This paper obtains entity relationships through experiments, verifies and analyses the feasibility, correctness, scientific, and operability of the designed geo-entity relationship structure and construction rules, improves and optimizes the relationship structure table and construction rules, and ultimately obtains national fundamental geo-entity relationship results. The main technical processes are shown in Figure 1 [8].

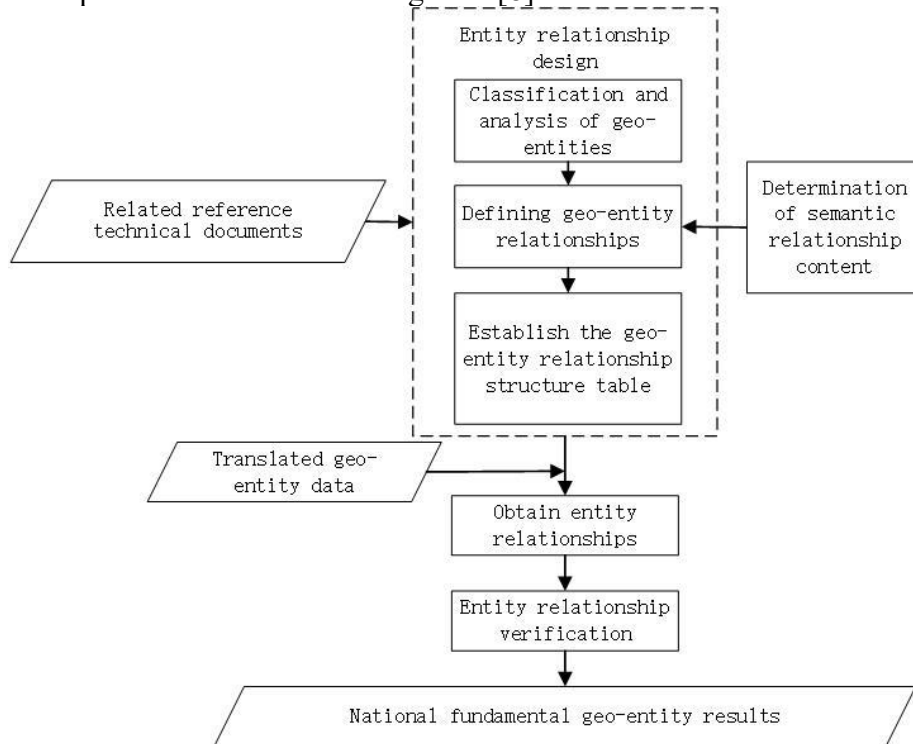


Fig. 1 Process diagram for building fundamental geo-entity relationships

### 2.1 Entity Relationship Design

#### 2.1.1 National fundamental geo-entity relationship classification and analysis

National fundamental geo-entities can be divided into three categories: natural geo-entities, artificial geo-entities, and management geo-entities [9]. By sorting and analysing the various levels of classification, it is necessary to determine the relationship structure that requires pairwise construction of entity relationships, forming a framework system for constructing geo-entity relationships (shown in Figure 2) [10].

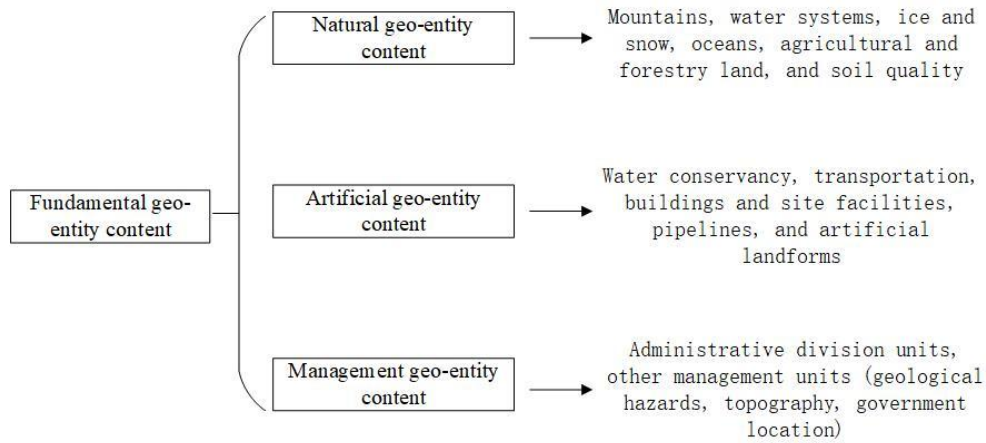


Fig. 2 Classification structure of fundamental geo-entity content

### 2.1.2 Determination of entity relationship content

There are many types of relationships present in actual geo-entity data. The national fundamental geo-entity will be oriented towards the integration and linkage of national, provincial, municipal, and county levels in the future [11]. It requires the designed entity relationships to have certain commonalities, to meet the needs of different departments for maximum common divisor entity relationships horizontally, to maintain consistency of entity data at different levels vertically, and to be as simple and feasible as possible in relationship construction and use. Entity relationships should focus on supplementing the basic and strongly correlated relationships that are missing from the original feature data, rather than duplicating GIS spatial relationships [12]. GIS spatial relationships should be a means of obtaining entity relationships. At the same time, entity relationships need to consider discrimination, which reduces the intersection of fuzzy intervals for different types of relationships and facilitates the clear and accurate construction of relationships [13]. Based on the above principles, this paper uses case analysis and induction method through preliminary experiments and theoretical research to classify the national fundamental geo-entity relationships into two categories: the combination relationship of combined entities and the correlation relationship between entities [14]. Correlation relationships mainly include seven basic relationships: belonging, affiliation, connection, inflow, adjacency, route, and flow (shown in Figure 3).

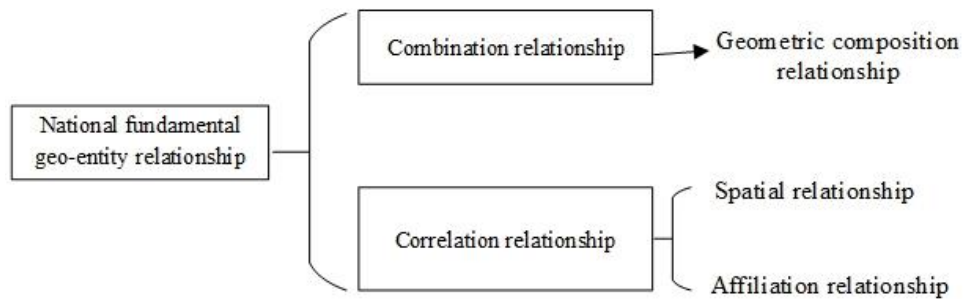


Fig. 3 Classification of national fundamental geo-entity relationship

### 2.1.3 Establish the geo-entity relationship structure table

Based on the content of fundamental geo-entity relationships, record the relationship content that needs to be established pairwise between each secondary class of fundamental geo-entities in the form of charts, that is, establish a geo-entity relationship structure table.

## 2.2 Obtaining Geo-entity Relationships

Geo-entity relationships are obtained mainly by using human-computer interaction. Firstly, by writing algorithms and utilizing software, the composition and association relationships of combined entities are calculated based on the topological relationships between geo-entities [15].

Part of the relationship descriptions are relatively complex, such as the affiliation, ownership, and connection of water bodies and transportation, which cannot be fully automated by software. Operators need to manually input data based on standard specifications, expert definitions, and experience summaries while editing data.

### **2.3 Verification of Geo-entity Relationships**

The final result of entity relationships is in the form of a table, and the reading subject is a computer. When humans act as the main body to read entity relationship tables, it is too abstract and difficult to understand. For the convenience of manual verification of entity relationships, it is necessary to visualize the relationship table data, that is, extract the fundamental geo-entities recorded in the entity relationship table, form inspection vector data, and facilitate inspectors to verify the results of entity relationships [16]. After the entity relationship verification is completed, the geo-entity relationship is modified to form the final results based on the verification conclusion and modification suggestions.

## **3. Key Technologies**

The most crucial part is the construction of relationships between geo-entities. It mainly includes two parts: the definition of geo-entity relationships and the construction of geo-entity relationship structure tables.

### **3.1 Definition of Geo-entity Relationships**

The national fundamental geo-entity relationship includes two types: the combination relationship and the correlation relationship.

The combination relationship refers to the relationship between a stored combined entity and the entities that make up that combined entity.

The correlation relationship refers to various relationships between entities, including belonging, affiliation, adjacency, connection, route, flow, and inflow.

(1) belonging: refers to the complete location of a geo-entity within or as a component of another geo-entity.

(2) affiliation: refers to a geo-entity serving as a facility to another geo-entity.

(3) adjacency: refers to the spatial adjacency between two geo-entities.

(4) connection: refers to the spatial connection between a geo-entity with a linear shape and another geo-entity with a linear shape in space.

(5) route: refers to the geo-entities such as railway lines and highways passing through administrative units.

(6) flow: refers to the geo-entity of rivers and ditches passing through administrative units.

(7) inflow: refers to the flow of water from rivers and other geo-entities into planar water system geo-entities (such as lakes, oceans, etc.)

### **3.2 Construction of Geo-entity Relationship Structure Table**

Geo-entity relationship structure tables are organized and constructed based on natural geo-entities, artificial geo-entities, and management geo-entities.

#### **3.2.1 Natural geo-entities**

Taking water bodies and water conservancy as examples, the relationship structure table of natural geo-entities is shown in Figure 4, 5, 6, 7, 8.

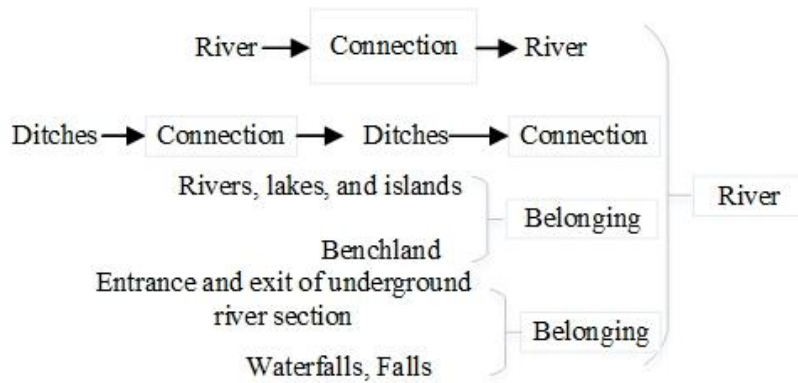


Fig. 4 Design of relationships between various entities in water systems and water conservancy

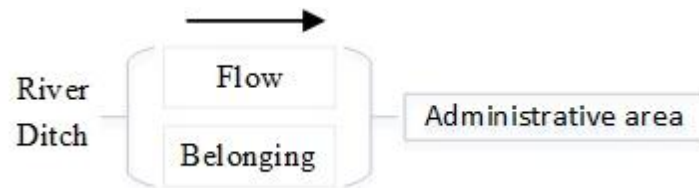


Fig. 5 Design of relationships between various entities and administrative regions in water systems and water conservancy

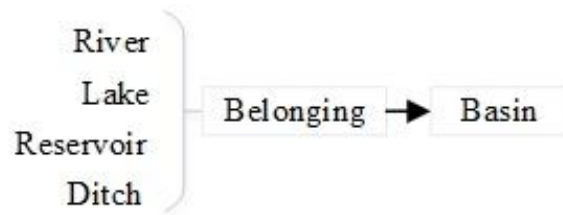


Fig. 6 Design of relationships between various entities in water systems and water conservancy

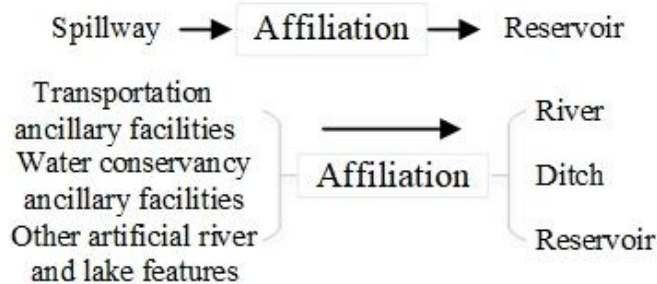


Fig. 7 Design of relationships between various entities and ancillary facilities in water systems and water conservancy

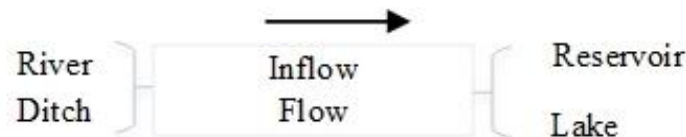


Fig. 8 Design of the relationship between rivers, canal bodies, reservoirs, and lakes

### 3.2.2 Artificial geo-entities

Taking transportation as an example, the relationship structure table of artificial geo-entities is shown in the Figure 9, 10, 11.

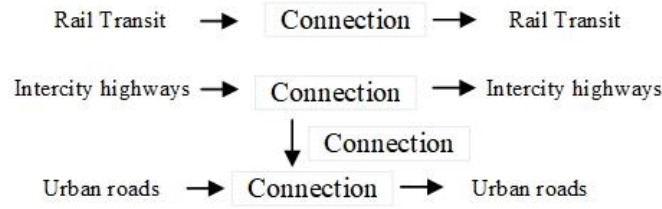


Fig. 9 Design of connection relationships between various transportation entities



Fig. 10 Design of affiliated relationships for various transportation

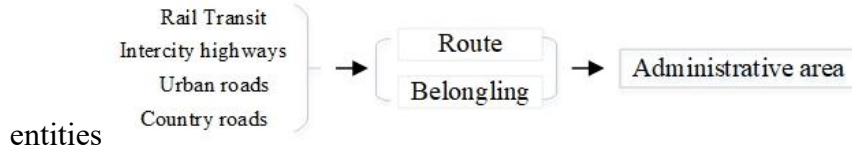


Fig. 11 Design of relationships between various transportation entities and administrative regions

### 3.2.3 Management geo-entities

Taking administrative division units as an example, the relationship structure table for managing geo-entities is shown in Figure 12.

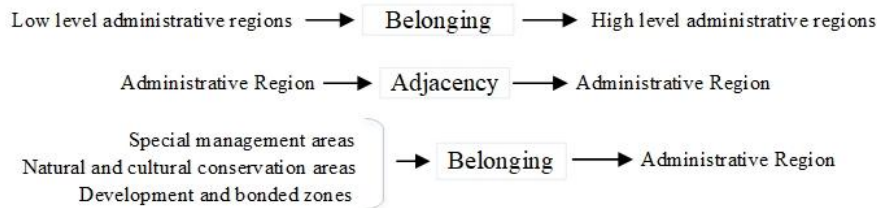


Fig. 12 Design of entity relationships in administrative regions at all levels

## 4. Engineering Implementation

From 2022 to 2023, the Ministry of Natural Resources organized the National Geomatics Center of China, Shaanxi Bureau of Surveying, Mapping and Geoinformation, Heilongjiang Bureau of Surveying, Mapping and Geoinformation, Sichuan Bureau of Surveying, Mapping and Geoinformation to carry out national fundamental geo-entity data trial production. The data covers parts of Qinghai, Gansu, Shaanxi, and Sichuan provinces in the Yellow River Basin, totalling approximately 400000 square kilometres.

The achievements of national fundamental geo-entity relationships mainly include the combination relationship of combined entities and the correlation relationship between entities, such as belonging, affiliation, connection, inflow, adjacency, route, and flow, covering about 200 specific entity relationships between dozens of third level categories.

## 5. Conclusion

No geographical entity exists in isolation in the world, that is, there is a relationship between any two geo-entities. The design principle of national fundamental geo-entity relationships is to record the most basic, framework based, and general common sense entity relationships, focusing on building a basic framework for understanding and describing the world.

The national fundamental geo-entity relationship construction method proposed in this paper is based on China's 1:50000 basic geographic information features as the main data source, producing basic geo-entity relationship results with unified national standards and specifications. It has good

demonstrative and reference value, and is an innovative utilization of existing national level basic geographic information data. It is an important practice to achieve the transformation and upgrading of surveying and mapping products from traditional feature data to entity data, and provides an important foundation for future multi-scale geo-entity integration work at the national, provincial, and municipal levels.

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