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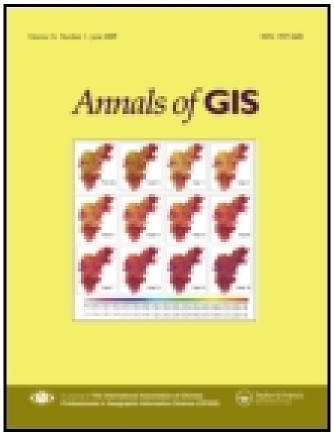

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Because of the difficulty in sharing of modelling conceptions, the complexity of modelling methods, the difficulty of cooperative modelling for experts in different domains and so on, many problems have arisen during the geographic conceptual modelling process. A formalization and visualization method of geographic conceptual modelling is studied in this article for solving these problems. With respect to the traditional entity–relationship model, two issues are studied in this article: one is the establishment of a supporting system, in which the expression methods of geographic concept, the use of geographic conceptual icons as well as the designing methods are illustrated in detail. The other step is using the former to build geographic conceptual models as follows: the concept of geo-entities is represented by geographic conceptual icons and the concept of relationships between geo-entities is represented by directed lines; then geographic conceptual models can be built by dragging those elements into a geographic conceptual scenario in a guided way. Moreover, the geographic conceptual scenarios can be saved as templates for reuse and further modification. Experiments have shown that compared with traditional graphical conceptual modelling methods, apart from enhancing the intelligence of the modelling environment and promoting the visual ability during conceptual modelling process, this approach can also support conceptual model sharing and knowledge reuse.

Keywords: geographic conceptual modelling; visualization; geographic conceptual icons; geographic conceptual scenario

1. Introduction

According to Westervelt (2001), geographic modelling and simulation are the fundamental approaches for geographic research and complex geographic problem solving, and four necessary parts, namely conceptual modelling, computational modelling, model checking and correction, and model application, are involved in geographic modelling processes. Generally, although geographic modelling conception can illustrate the ideas of modelling, introducing the whole process of model building, and high-quality conceptual modelling can facilitate early detection and correction of modelling errors (Wand and Weber 2002), researchers often pay attention to the last three parts but neglect the first step (Hadzilacos and Tryfona 1996, Renolen 1997, Parent *et al.* 2006). Essentially, a conceptual model is the representation of a geographic phenomenon at a certain level of approximation externalized in a semi-formal or formal language (Krogstie and Sùlvberg 2003), and it is necessary to describe geographic phenomena at the conceptual level to acquire and communicate phenomena in the real word (Renolen 2000).

The traditional methods of conceptual modelling are usually performed by experts using sketches (Renolen 1997, 2000), which always gave rise to some problems. First of all, conceptual modelling with sketches is not a formal procedure and has become a serious obstacle to engineering projects. Second, to date, geographic models are built increasingly aiming at solving complex and comprehensive problems, which requires participation of experts from multi-domains (Brail and Klosterman 2001); the traditional methods often fail to express their modelling ideas in a formalized and visualized way, so that modelling conception cannot be shared and reused conveniently. Last but not least, modelling conception usually guides the follow-up computational modelling and data preparation (Renolen 2000); the process of conceptual modelling should comply with geographic rules instead of just employing sketches or diagrams.

With regard to those problems, scholars recently began to explore how to organize geographic conception in a formal way and how to express the modelling conception and process in a visualized way.

For the former, Sùlvberg and Krogstie (1996) summarized that the expression of model conception should follow seven perspectives. According to their argument, several popular languages, which can express the types,

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attributions and relationships expediently and facilitate conception sharing, were employed appropriately, such as XML (e.g. Reeves *et al.* 2006, Franceschet *et al.* 2007), GML (e.g. Tong and Xu 2005, Wadembere and Ogao 2008), RDF/RDFS (e.g. Bishr 2006, Torres *et al.* 2009) and OWL (e.g. Asch *et al.* 2004, Agarwal *et al.* 2005). Among these languages, besides description ability, stronger expression usually requires complex deduction, and those deducing processes should be easy to be understood and manipulated, often considered as criteria when being chosen.

For the latter, Eppler and Burkhard (2004) argued that expression by diagrams or graphs mainly dominates six points; many researches shared the same sentiment and realized that building conceptual models by diagrams and graphs is significant for knowledge sharing. In this case, several modelling environments have recently been built adopting this strategy. Early in 1998, a graph-based modelling system based on structured modelling that supports model formulation, maintenance and solution was established by Chari and Sen (1998). Later, similar conceptual modelling environments such as general modelling environment (Ledeczi *et al.* 2001, Davis 2003), open source problem-solving environment (Taylor *et al.* 2003, Majithia *et al.* 2004), spatial modelling environment (Maxwell and Costanza 1995, 1997, Costanza and Voinov 2004) and GeoVista Studio (Takatsuka and Gahegan 2002, Gahegan *et al.* 2002a, 2002b) were established in different fields. However, although these systems succeeded to some extent, we propose that they should be further improved because building geographic conceptual models with block diagrams and flow charts is still difficult for geographic researchers to understand, and geographic researchers with less computer knowledge may find it hard to participate in those projects.

In this article, based on the entity–relationship model, we want to contribute to a visualized method of geographic conceptual modelling by organizing geographic conception – formally – and expressing the modelling process – visually – so that the geographic conceptual scenario, which is the abstract of the geographic environment and geographic conceptual models, can be built following a guided way. The remainder of this article is organized as follows: the frame of this study is illustrated in Section 2.Section 3 introduces the establishment of the supporting system which prepares for conceptual model building, and Section 4 discusses the detail of the conceptual modelling process. An experiment is addressed in Section 5, and finally Section 6 presents the conclusions and proposals for future work.

2. Framework of the visualized method of geographic conceptual modelling

Essentially, geographic conceptual models are built aiming at (1) studying the composition and structure of geographic entities; (2) exploring both the external and internal factors of geographic entities; (3) exploring the relationships among geographic entities; and (4) providing the basic framework for computational model development and refinement (Wei 2005). In this case, the abstraction of geographic entities and their relationships of a geo-environment are the foundations of geographic conceptual modelling, and the organization method as well as method of expressing geographic conception will directly contribute to the modelling process. Figure 1 shows the framework of our study.

According to the framework, we first illustrate three basic elements of the geographic conceptual scenario:

(1) *Conceptual resources*. Conceptual resources refer to the contents that can be used for organizing geographic conception, such as semantic labels from geo-web. Usually, making good use of those conceptual resources that already exist will greatly reduce the workload of the modelling process and improve the accuracy of the modelling expression.

(2) *Conceptual icons*. Geographic conceptual entities are the key part of geographic conceptual modelling, and they will be expressed by conceptual

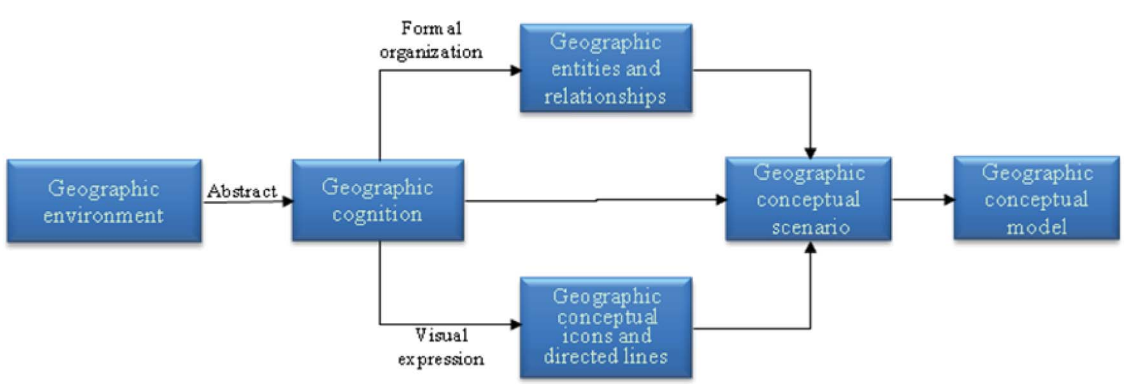

Figure 1. The framework of the visual geographic conceptual modelling method.

icons in a geo-icon library. When a conceptual icon is dragged into the model-viewing window to fill the geographic concept scenario, two aspects of function can be carried out by a modeller. One is that modellers can understand or express the ideas of conceptual modelling by these visual icons; the other is that geographic conception, which is behind these icons and essentially related to the geographic entities, can be acquired for conception sharing and exchanging.

(3) *Directed lines*. Corresponding to conceptual icons, directed lines in the geographic conceptual scenario are designed to represent the relationships between geographic entities, and the directions distinguish the source entities from the target entities.

Using these basic elements, two steps are involved in geographic conceptual modelling: one is the establishment of the supporting system, for which RDF/RDFS was chosen as the organization language so that geographic concepts could be expressed in a formalized manner, and the use of geographic conceptual icons and their design methods are illustrated in detail. The other step is using the former to build geographic conceptual models as follows: the concept of geo-entity is represented by geographic conceptual icons; the concept of relationships between geo-entities is represented by directed lines; and the geographic conceptual models can be built by drawing those elements into a geographic conceptual scenario step by step in an introduction mode. In this case, geographic conceptual models can be built in a formalized and visualized way, which is significant for understanding and sharing of modelling conception by different experts vividly and clearly, and those geographic conceptual models can be saved as templates for reuse and further modification.

3. Establishment of supporting system

The supporting system consists of two parts: one is the development of a geographic conceptual database, and the other is the construction of a conceptual icons database.

3.1. The development of geographic conceptual database

3.1.1. The language chosen for geographic conception expression

It is said that geographic conception can be interpreted by classes and different properties of those classes, and furthermore, the relationships among those classes are of equal importance (Sack 1980). Later, entity–relationship models, which were proposed by Chen (1976), were often adopted to express geographic conception (e.g. Fonseca *et al.* 2003, Costa *et al.* 2006). According to the research mentioned above, geographic conception can be abstracted as a triple like $<C, P, R>$, in which (1) C represents the classes that are the abstraction of geo-objects owning similar attributions; (2) P represents the properties, which refer to the characters of classes, for example, the name of a mountain or the length of a river; and (3) R represents the relationships between classes and can be divided into different kinds, such as interaction relationships (e.g. the sun illuminates the earth, the land is watered by rivers) and hierarchical relationships (e.g. parent–child relationships, part–whole relationships).

To express geographic conception according to the above analysis, we chose RDF/RDFS as the appropriate language. RDF is a suite of World Wide Web Consortium specifications originally designed as a metadata data model, which has come to be used as a general method for conceptual description or modelling of information that is implemented in Web resources, using a variety of syntax formats (Candan *et al.* 2001). RDFS is RDF's vocabulary description language that is similar to an object-oriented language (McBride 2004), but the greatest difference between them is that RDFS often defines the relationships of different classes and separates properties from classes. There are several reasons for adopting RDF/RDFS: (1) RDF's basic expression structure is a triple that contains a subject, an object, and a predicate, which conforms to entity–relationship models and so can represent the classes and their relationships well; (2) the essential syntax of RDF is a kind of XML named RDF-XML, which can be easily understood and utilized; (3) RDF/RDFS supports semantic reasoning; (4) RDF/RDFS is an international standard of Web resource description, which will benefit geographic conception sharing through the Web; and (5) the loose relationship of classes and properties in RDF/RDFS will greatly improve the flexibility of the geographic conceptual database-building process as well as reduce its cost.

3.1.2. The storage method of geographic conception

As mentioned above, it is meaningful to use RDF/RDFS to assist geographic conception expression; but considering there will be a huge number of resources, it is necessary to design a storage method that can manage the geographic conception resources in a database. Traditional methods are mainly of two kinds: one is based on document and the other is based on database. Obviously, to manage a large number of resources, the latter is better than the former, and our proposed approach is based on database. There are still three kinds of methods that need to be considered. The first one is saving the triple of RDF/RDFS as a field. This method can make good use of the database's self-functions for XML operation, but the efficiency of query and update is relatively lower. The second is saving the triple as three fields according to its structure. Although this method is simple and more efficient than the first one, it is still hard to deal with a large number of resources (Tao and Yao 2007). The last method involves breaking down the triple according to mode decomposition, and in this way the resources in the database can be queried and updated according to the field content. We adopted the last one as an acceptable solution, and Figure 2 shows the storage method of geographic conception.

3.1.3. The reasoning method based on the geographic conception database

Generally, the geographic conception description contains the statement of classes, properties and relationships, which have been stored separately in the geographic conception database as Figure 2 shows. Using these three factors, geographic conceptual models can be built in a guided way (Chen *et al.* 2008, 2009). With regard to this idea, we designed the reasoning method based on the geographic conception database. Figure 3 shows the interfaces that are contained in our method.

3.2. Development of geographic conceptual icons database

Geographic conceptual icons, characterized by their graphic factors (e.g. shape, size, direction, colour, contour and label), are designed to express the meanings of geographic conceptual entities in a visual way. After being attached to the geographic conception later, they can be dragged into the model view window to form a geographic conceptual scenario, which is composed of both geographic conceptual entities and their relationships (Do Prado Leite *et al.* 2000), and the latter can be represented by directed segments.

We designed geographic conceptual icons of two types: one is a simple icon, which is used to represent a single geo-entity; and the other is a composite icon, which is designed to represent multiple geo-entities in a single figure. Furthermore, composite icons can also be divided into two types: the first is a combination of multiple simple icons, and the second is essentially a single icon but with different comments in its different regions, so that it can be used to express multiple geo-entities.

Generally, geographic conceptual icons can be made by repainting with tools like Paintbrush, Photoshop, CorelDraw, Illustrator and so on or by reusing existing pictures and figures; and they can be saved in vector format such as SVG and EMF, or picture format such as PNG and GIF, both of which have their own features and should be employed according to actual situations.

For the storage method of geographic conceptual icons, to contribute to the access mode, we saved those icons

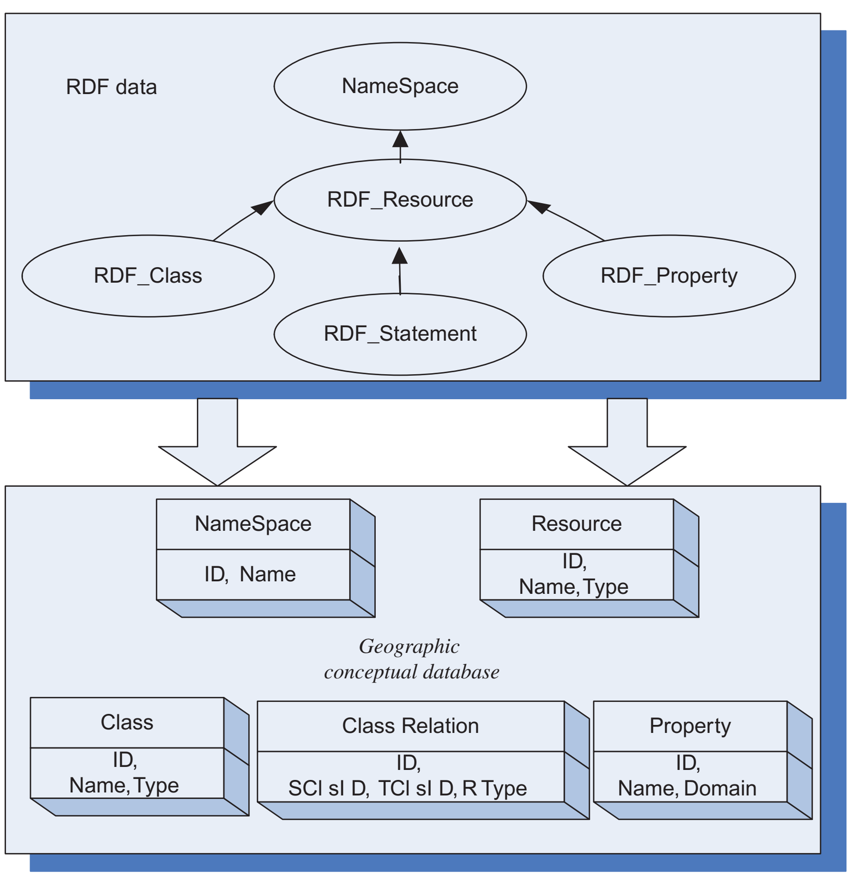

Figure 2. The storage method for geographic conception.

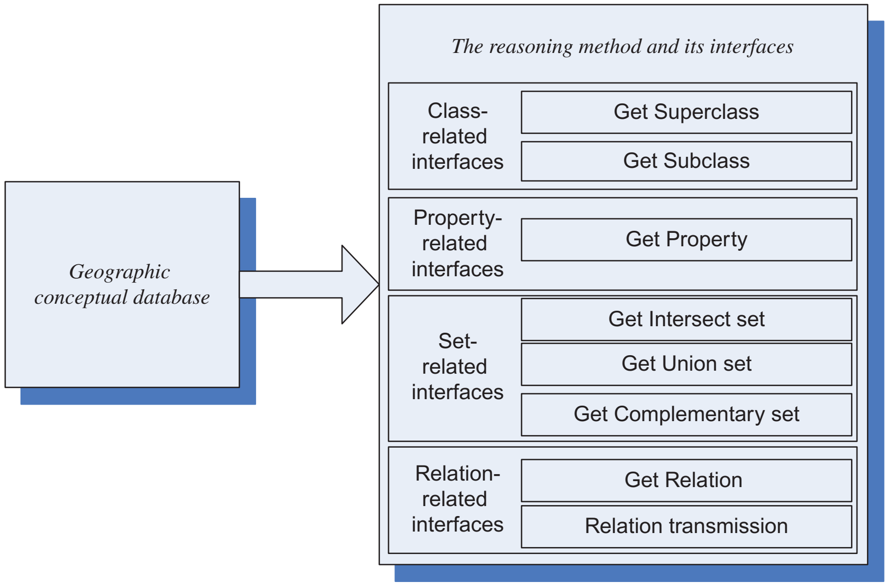

Figure 3. The reasoning method and its interfaces.

as binary streams in the database. At the same time, they were sorted by different keywords, and a keyword index table entitled GCIIK_Table and a keyword table entitled GCIK_Table were built so that an icon can be found expediently from the database.

4. Geographic conceptual models building

Before introducing the whole process of geographic conceptual model building, several key issues should be addressed to assist the modelling process.

4.1. Key issues during the modelling process

4.1.1. Category of geographic conceptual model theme

First of all, it is necessary to give clear descriptions about questions like what kind of geo-problem on which it will focus, where is the research region and so on. The theme of a geographic conceptual model is designed to deal with these problems, and it will illustrate the model's main task combined with the research region, research scale and other related information; for example, trend prediction of groundwater quality in the Yangtze River Delta, flood forecasting of the semi-arid region in China and so on. In this project, based on the analysis of the existing geographic model metadata (Wang and Wu 1999, Liu *et al.* 2000, Su *et al*. 2000, Smith and Mark 2001, Yue 2001), we proposed a draft theme category of geographic conceptual models, and it needs to be further supplemented and modified in future research. Table 1 shows the category as well as some example keywords of geographic conceptual model themes.

Table 1. The category and example keywords of geographic conceptual model themes.

Theme category	Keywords
Geo-Domain	Atmosphere, hydrology, etc.
Geo-Feature	Arid region, semi-arid region, etc.
Geo-Process	Rainfall, infiltration, etc.
Geo-Scale	Large-scale, meso-scale, micro-scale, etc.
Geo-Space	Channel, river channel, catchment, etc.
Geo-Time	10,000 years, etc.
Geo-Boundary condition	Dirichlet Boundary Condition, Neumann Boundary Condition, etc.
Geo-Frequency	Once, many times, etc.
Geo-Value	Extreme value, average value etc.

4.1.2. Building process of geographic conceptual entities and their relationships

The process of building geographic conceptual entities and their relationships can be conducted by first dragging a geographic conceptual icon into the geographic conceptual scenario, then attaching it with geographic conception that is used to express geographic entities, linking this icon to other existing icons with directed segments that represent their relationships and lastly attaching those directed segments with geographic conception that is used to express geographic relationships. It is worth mentioning that constraining rules should be made to develop the constraining engine used to estimate whether the conceptual icons can be attached to suitable geographic conception (e.g. an icon whose keyword is tree cannot be associated with RDF_Class that is used to express a river; an icon whose keyword is mountain cannot be associated with RDF_Property that is used to express the velocity of flow) and whether the directed segments between entities can be attached according to logical specifications (e.g. forests cannot grow on the sea).

In this aspect, we have built some constraining rules and they are saved in the rule library, but in fact, they cannot be self-contained and perfectly owned due to the complexity of geographic phenomenon, so they should be checked, chosen and amended based on experience and common knowledge in future work. Figure 4 shows the whole process of building the geographic conceptual entities and their relationships.

4.1.3. Designing of a multi-level geographic conceptual scenario

As Jones argued in 1991, the physical world should be explored by multi-level models (Jones 1991); in this case, the geographic conceptual models should also be built following different levels.

However, to express related geographic phenomena in a whole geographic environment as well as decreasing the modelling cost, geographic conceptual models in different levels ought to be built in one conceptual scenario. Figure 5 is a schematic diagram showing the moisture evaporation

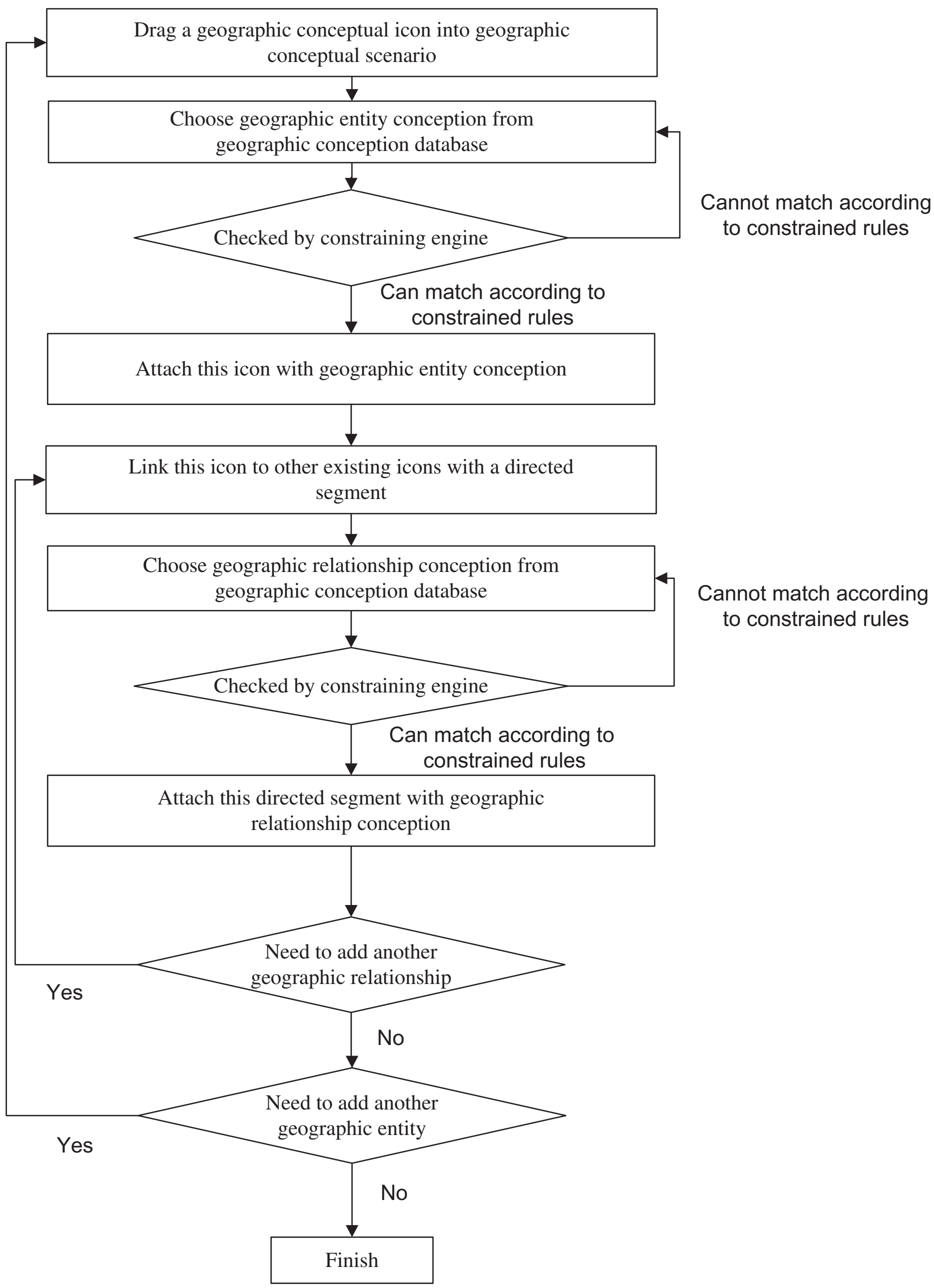

Figure 4. The whole process of building the geographic conceptual entities and their relationships.

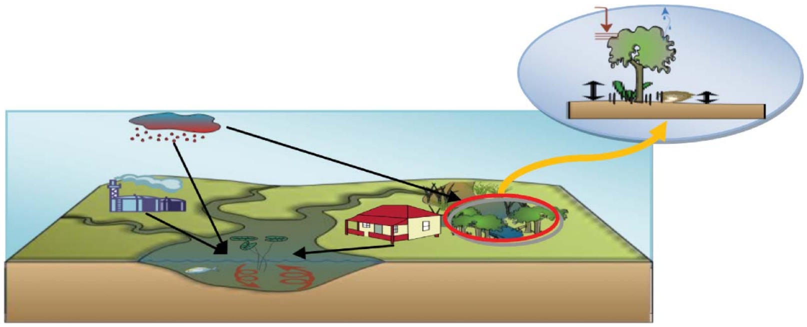

Figure 5. Different levels of water cycles in a multi-level geographic conceptual scenario.

of vegetation and soil, and their moisture absorption composes only a small water cycle within the whole cycle; these different water cycles can be built into one conceptual scenario. It is necessary to discuss how to build the sub-scenes of a whole scenario.

There are three common ways that can be used to create sub-scenes in different levels. (1) Employing geographic conceptual model themes to define the sub-scenes. For example, according to 'Geo-Process', water simulation can be divided into runoff yield and confluence; according to 'Geo-Time', total evaporation in an Alpine Region can be divided into evaporation process in summer and evaporation process in winter (Bao 2006). (2) Using the level of detail of the research to build sub-scenes, as shown in Figure 6. (3) Creating sub-scenes according to different importance levels. A modeller can classify the geographic conceptual entities and their relationships into different levels of importance, and sub-scenes can be built according to these levels. In this way, geographic conceptual models at different scales can also be illustrated by geographic conceptual scenario designed at different levels.

To realize the idea mentioned above, several classes are designed, which can be seen in Figure 6, where 'MultiLayerScene' is a subclass of 'GeoScene' and can be used to obtain 'SubSceneEntry'. 'SubSceneEntry' is a class that is used to describe decomposed types, decomposed objects and all pointers of sub-scenes, and every sub-scene should be accessed by this class. Sub-scene is represented by 'SubScene' class, which owns the properties entitled 'ParentScene', 'InRelations' and 'OutRelations'.

4.1.4. Documenting the conceptual model

The existing geographic conceptual models are the foundation of new models. An efficient multiplexing method of conceptual modelling will provide outstanding support for a conceptual model's construction and reuse. For the purpose of reusing the existing conceptual models and improving management, after a new conceptual model has been constructed in the modelling environment, its image–text can be stored directly, or the graphs exported within conceptual models in PPT format, images or other simple graphs for a researcher's communication. The conceptual models can also be exported as structured and formalized models, like models described by XML, to be queried and verified automatically at the computing level, as shown in Figure 7.

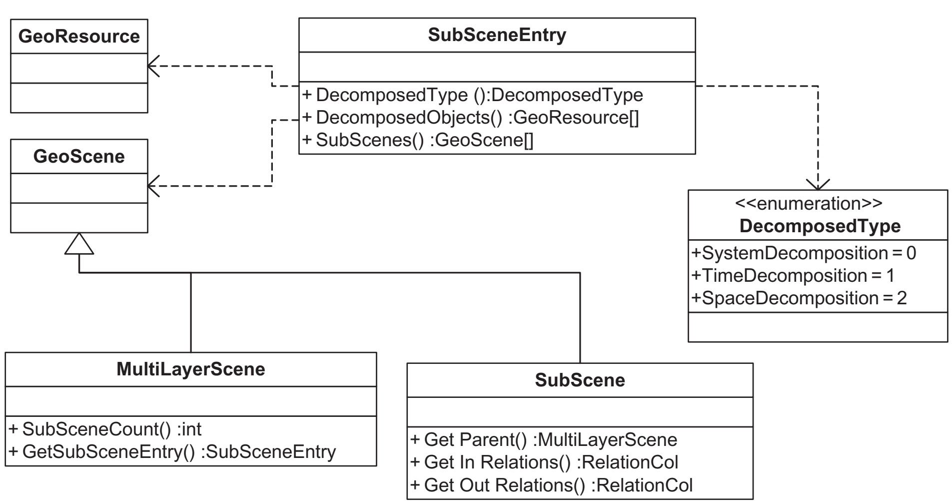

Figure 6. Classes designed for realizing a multi-level geographic conceptual scenario.

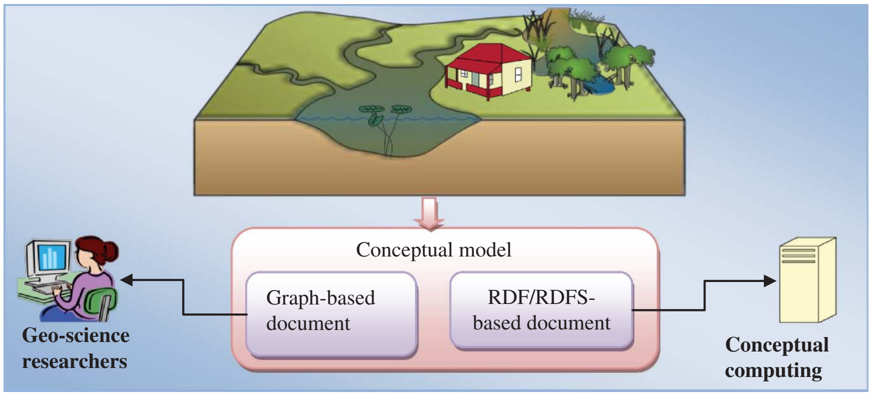

Figure 7. Conceptual model document.

Therefore, to store the information of conceptual models, graph-based and literal document-based storing strategies were designed. The former can be produced as .jpg, .gif and so on. The latter can be produced according to the RDF/RDFS contents which were illustrated in Sections 3.1.2 and 3.1.3, including theme, entities, relations and some other sub-conceptual graphs. To facilitate the application, an index of significant objects (entity/relation) and additional information such as the creator and version was designed. The basic structure of a literal document is as follows:

```
GeoConceptualModel
{
  Theme: {Geofeature, Geolocation, . . . . . . }
  Scenes:
  {
  Scene1
  {
  ID:
  Name:
   Entities: {Entity (ID, Desc, . . . . . .), Entity (ID,
     Desc, . . . . . .), . . . . . .}
   Relations: {Relation(ID, Desc, . . . . . .), Relation
     (ID, Desc, . . . . . .), . . . . . .
   Importants: {ID1,ID2, . . . . . . }
   SubScenes:{{EntryEntity,ID },{Entry Entity,ID },
    . . . . . .}
   Additions:{Creator,Datetime,Version . . . . . .}
   }
   {
   Scene2 { . . . . . .}
   }
   . . . . . .
  }
}
```

4.2. *The processes of geographic conceptual scenario building*

The visualized geographic conceptual modelling method, which is based on scene, consists of three steps. The first step is data preparation, including basic conceptual knowledge preparation, icon acquirement and construction, and associating concepts and icons, thereby achieving the geographic conceptual database and geographic conceptual icons database. After that, specific geographic conceptual models need to be built. By using the achievements of the first step and combining the themes of conceptual models with the constraining engine, geographic conceptual models based on scenes can be built with the support of the modelling environment. Finally, geographic conceptual models need to be applied. By exporting conceptual models into documents of different format, model sharing, model reusing and further modelling will be supported.

The procedure of specific geographic conceptual modelling is as follows:

(1) Loading the geographic conceptual database and geographic conceptual icons database.

The geographic conceptual database and geographic conceptual icons database are necessary for building conceptual models as the significant support library that provides support for conceptual corpus and knowledge of the conceptual model. The support library, which can be local and may also be distributed and network-based, will be loaded based on various modelling requirements, so as to save the operating cost and improve modelling flexibility.

(2) Setting the geographic conceptual model theme.

The geographic conceptual model themes of each conceptual model require to be described clearly, which is not only the basic element of conceptual models but also the fundamental criteria for model checking; moreover, they play a significant role in storing and querying conceptual models.

(3) Dragging geographic conceptual icons and setting geographic entity conception corresponding to geographic conceptual entities.

After the geographic conceptual icons database has been loaded, it is possible to select the corresponding icons and drag them to conceptual scenes. The suitable geographic entity conception will then be selected from the geographic conceptual database and attached to geographic conceptual entities by means of the constraining engine's verification.

(4) Establishing the relations between geographic conceptual entities, setting attributes of conceptual relations.

After establishing the relations by drawing directed segments between geographic conceptual entities, the suitable geographic entity relation conception will then be selected from the geographic conceptual database and attached to geographic conceptual relationships by means of the constraining engine's verification.

(5) Comparing and verifying conceptual models.

After conceptual models have been established, the rationality of missing conceptual entities and entity relations can be checked and verified in terms of the geographic conceptual database. In addition, these conceptual models can be compared with other conceptual models of the same theme, which will help to verify the conceptual models.

(6) Exporting the documents of geographic conceptual models.

Geographic conceptual models established previously can be exported as graphs, RDF/RDFS documents or proprietary documents integrating graphs and concepts of the conceptual modelling system. In addition, new conceptual models need to be stored in the geographic conceptual database for further reuse and modelling.

5. Case study

To verify the validity of the method advanced in this article, a prototype system was developed using .Net 2005 as the development platform. The visual representation of geographic conception modelling has facilitated the process of geographic conception modelling.

Aiming at verifying the holistic function of this system, we designed the geographic conceptual class and its attribute data. The graphs were collected from MS Office and partially from the Internet, mostly in EMF, WMF and PNG formats.

The following is RDF-XML of the geographic conceptual class employed in this article. Attributes of the class are not displayed.


```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF xmlns:rdf=http://www.w3.org/1999/02/
    22-rdf-syntax-ns#
      xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
      xml:base="http://127.0.0.1/geography#">
      <rdfs:Class rdf:ID=" Geosciences "/>
    <rdfs:Class rdf:ID=" Rainfall ">
      <rdfs:subClassOf rdf:resource="# Geosciences "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Runshine ">
      <rdfs:subClassOf rdf:resource="# Geosciences "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" River ">
      <rdfs:subClassOf rdf:resource="# Water body "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Lake ">
      <rdfs:subClassOf rdf:resource="# Water body "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Water body ">
      <rdfs:subClassOf rdf:resource="# Geosciences "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Underground
      water carrier">
      <rdfs:subClassOf rdf:resource="# Geosciences "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Underground water carrier near
      surface ">
      <rdfs:subClassOf rdf:resource="# Underground
          water carrier"/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Seconded confined aquifer ">
      <rdfs:subClassOf rdf:resource="# Underground
          water carrier"/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Fresh water lake ">
      <rdfs:subClassOf rdf:resource="# Lake "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Salt water lake ">
      <rdfs:subClassOf rdf:resource="# Lake "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Pool ">
      <rdfs:subClassOf rdf:resource="# Water body "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Vegetation ">
      <rdfs:subClassOf rdf:resource="# Geosciences "/>
    </rdfs:Class>
    <rdfs:Class rdf:ID=" Human activity ">
      <rdfs:subClassOf rdf:resource="# Geosciences "/>
    </rdfs:Class>
</rdf:RDF>
```


The conceptual resource management system is shown in Figure 8. The major functions include loading RDF/OWL files into the present conceptual database and displaying the name of each namespace on the listing of the conceptual database. When clicking on namespace, the corresponding conceptual structure tree or graph will appear in the graph box, where the conceptual class is displayed in the shape of round nodes and the directed line segment between nodes indicates their paternity relationship. When clicking the conceptual class marked by the

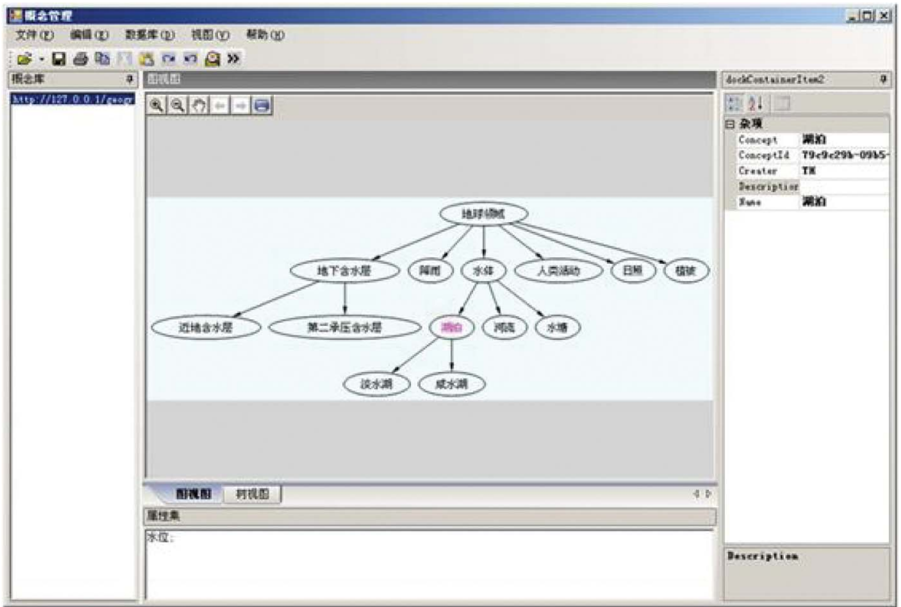

Figure 8. Conceptual resource management.

corresponding node, its attributes will appear in the textbox below, as well as its concept name, ID, description and so on, on the property dialogue on the right side.

The experimental data employed in this article is shown in Figure 9. Classes are in ellipses and their attributes in rectangle boxes. RDF files can be imported into the database, and the class with its attribute will be read through the management system, as well as being displayed by the Visual Component Library.

The management interface of conceptual icons is shown in Figure 10. Conceptual icons in the icons database can be produced by binding the external icons with concepts in the conceptual database. Icons currently loaded are displayed on the left of the listing, whereas conceptual resources are in the graph box below, and current icons are in the middle. By selecting the existing icons on the left of the listing, the icons can be edited. Conceptual icons can be made and stored in the database by clicking one concept on the concept tree and using the command on the toolbar.

After the conceptual icons are edited, the datasheet view can be used to attach geo-conception with conceptual icons by invoking the conception preview function (see Figure 11).

Figure 12 shows the establishment of the interface of conceptual models in the prototype system, including a listing of geographic concept icons and concept tree, geographic relations and a major workspace for scene drawing. This modelling environment can support basic graphic operations and a modelling guide. The former includes graph dragging, zoom in and zoom out, layer location setting, graph combination and so on. The latter indicates querying the attributes of conceptual classes and conceptual classes' generalization and specialization and so on. The modelling guide works when the right click menu is dynamically loaded. During conceptual modelling, conceptual class icons or attribute icons on the icon listing can be dragged into the scene-drawing workspace, and icon size and layer location can be adjusted. Although

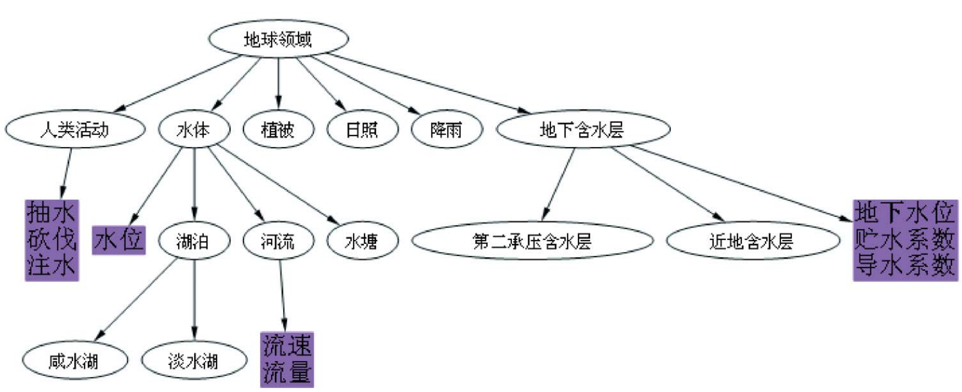

Figure 9. Conceptual resources.

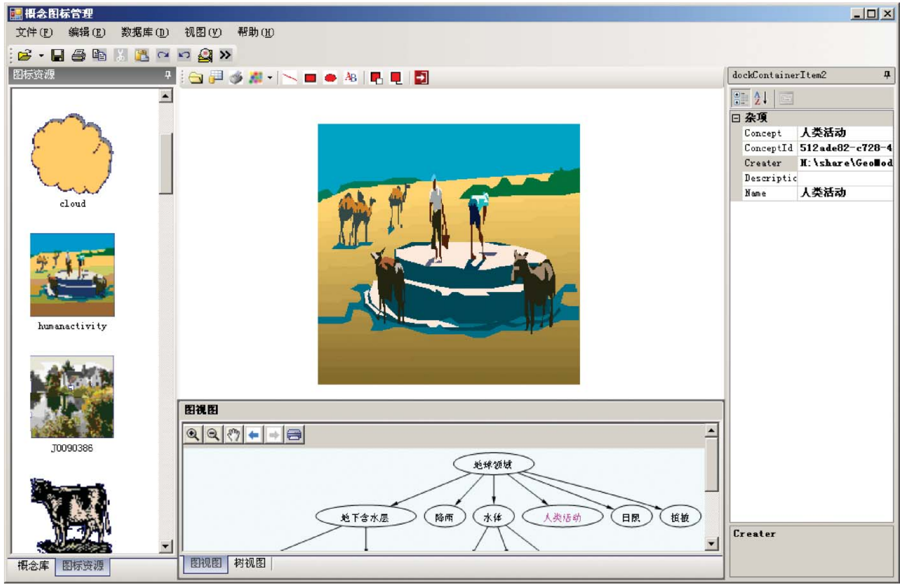

Figure 10. Editing conceptual icons.

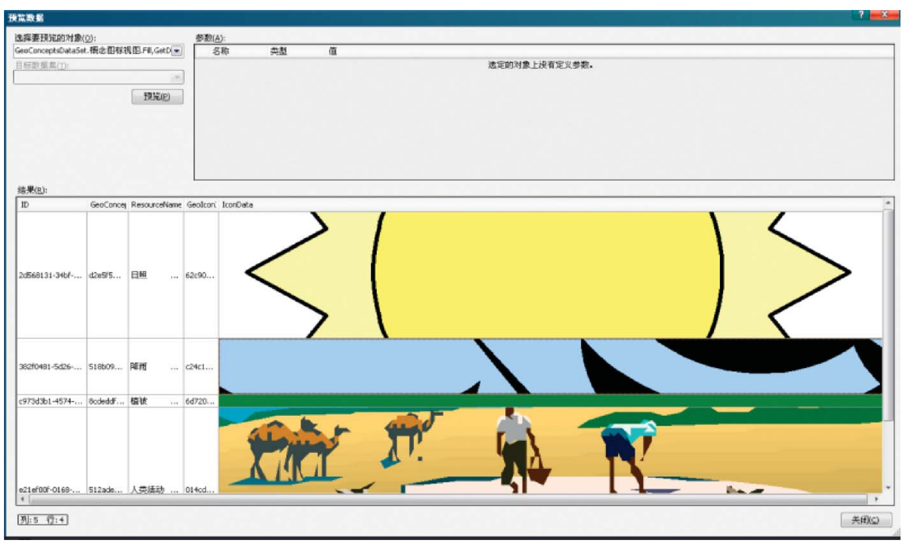

Figure 11. Attaching geo-conception with conceptual icons.

concepts were given to corresponding icons before, the concept of 'vegetation' may still be represented by the concept of 'tree'. Therefore, the system supports querying the set membership; when right clicking one conceptual class, the corresponding menu item of set membership appears, and current icons can be bonded with a given conceptual class. In addition, the attributes of one conceptual class can be selected in the right click menu by being queried first.

When right clicking different objects, the corresponding guide menu appears as shown in Figure 13. Picture A shows right clicking river; as two attributes, namely water level and flow velocity, are chosen in the present modelling, they can be seen on the attribute items. No subclass item is on the river menu due to no subclass of river being in the conceptual database. Picture B displays a guide to setting superclass when right clicking lake and rebinding the current lake icon with water. Picture C displays a guide to setting relations, but now it is still simple and needs to be further extended. Picture D demonstrates how to query missing brother classes of the present conceptual entities. For example, the conceptual entity of lake is contained in the present model without river and pond, which can be verified for suitability by querying missing brother classes. Picture E displays prompts and a guide to overall arrangements for the location of conceptual icons.

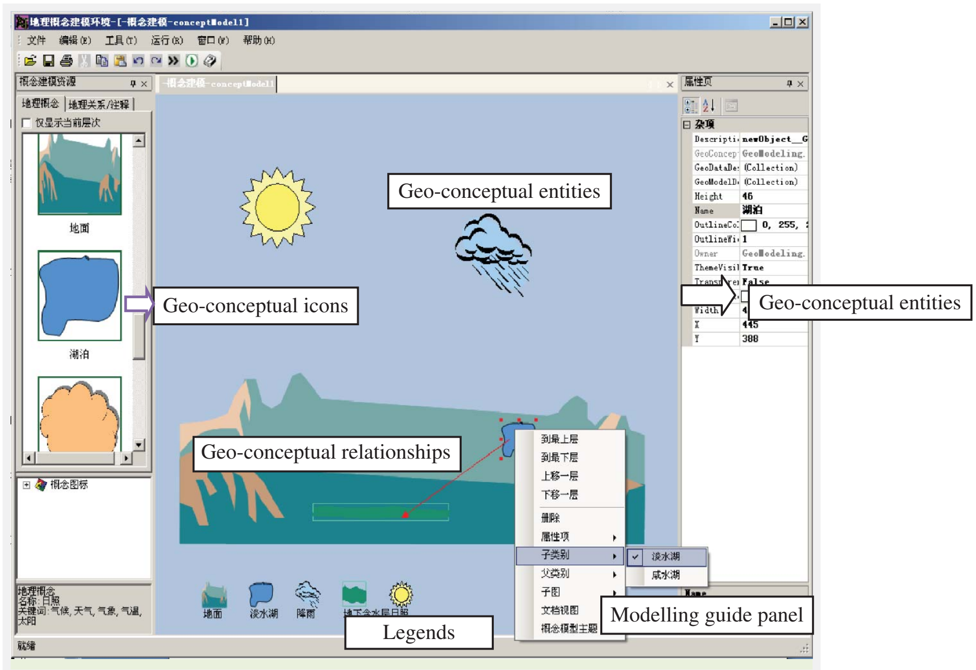

Figure 12. Conceptual modelling environment.

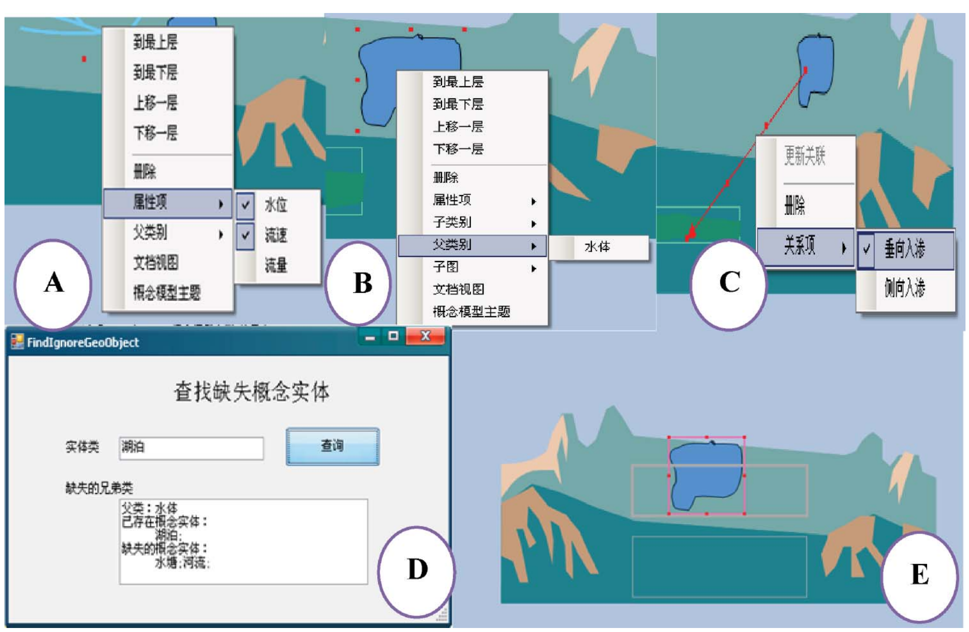

Figure 13. Modelling guide.

Based on the conceptual modelling scene, products in .jpg format can be exported from the modelling environment as shown in Figure 14.

The corresponding XML document of a conceptual model in the modelling scene above is shown in Figure 15, which displays conceptual entities, attributes of conceptual entities and relations between entities.

6. Conclusion

Geographic conceptual modelling is an important step in constructing geographic models concerning model sharing. This article focuses on visual geographic conceptual modelling methods and modelling environment construction, which provide us an intuitive and iconic geographic conceptual modelling environment, and introduces the

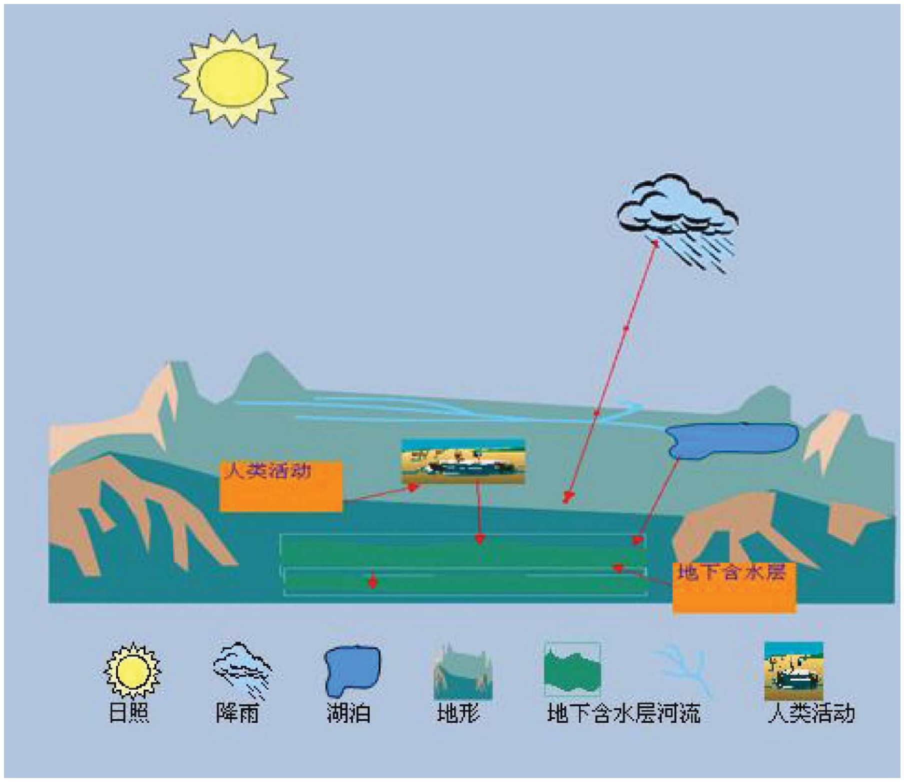

Figure 14. Image-based document of conceptual model.

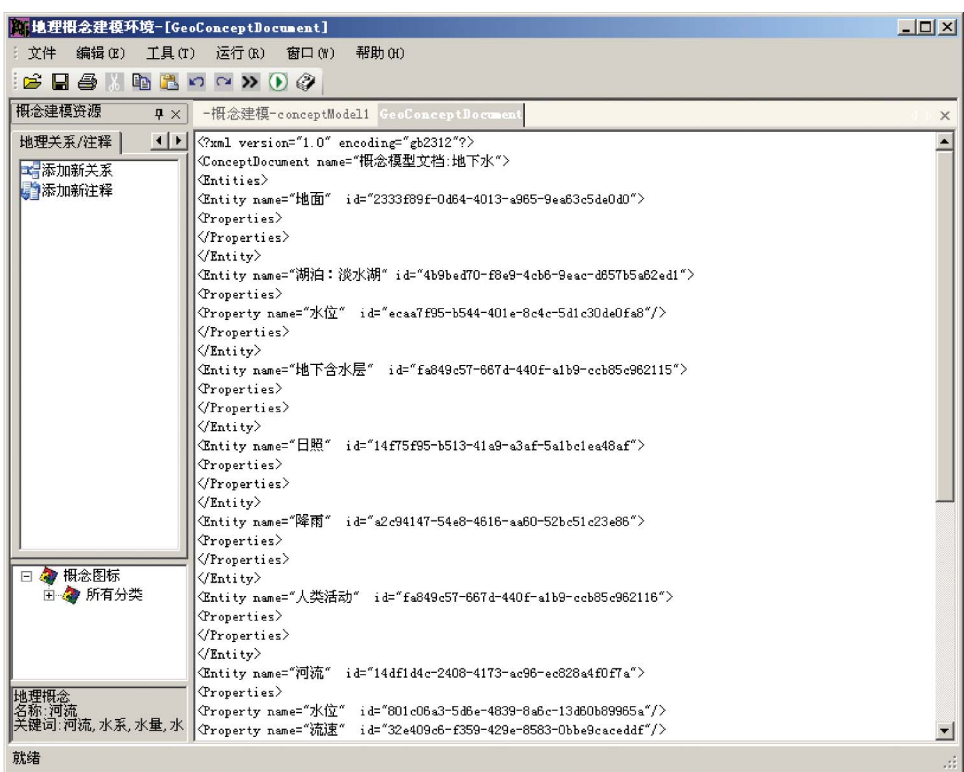

Figure 15. XML document of conceptual model.

organizing and simple reasoning of conceptual knowledge, the design of the conceptual icons database and function, the designing of the conceptual scene and so on. However, further research must be explored as follows:

(1) Strengthening the organizing and reasoning of conceptual knowledge based on achievements of semantic network and ontology: studying the method of expressing generic geographic knowledge rules and their application in geographic conceptual modelling.
(2) Expanding the expression of the skill of conceptual models. This article established conceptual models in terms of static entities relations. In addition, the expressing of entity status, behaviour and interactive processes also requires consideration, especially spatio-temporal aspects revealing more relations between elements by way of dynamic graphs.
(3) Enhancing the character analysis of geographic conceptual modelling: establishing a useful and valuable conceptual modelling environment by studying specific geographic modelling fields.
(4) Studying case analyses of geographic conceptual model databases and knowledge mining.
(5) Studying how to transform conceptual models based on scene into computation models.
(6) Developing the scene-based method, building an integrated environment for geographic models and data with scene as the link.

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