

Semantic Driven Geographic Conceptual Modeling Environment Based On Icons

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Abstract: *There are many problems in conceptual modeling process, such as sharing difficulty in modeling conception, complexity of modeling method, difficulty in cooperative modeling by experts from different domains, and so on. To solve those problems, by establishing expression rules of metadata and semantics of geographical models, introductive geographical modeling approaches is put forward here to realize expression and construction of geographical conceptual models interactively. And a semantic driven geographical conceptual modeling environment based on icons is provided. By the experiments, it has shown that our research is a new attempt for geographic conceptual modeling, and it provides a convenient and visualized modeling method for experts in multi-domain of geographic field.*

Keywords: *Semantic driven, conceptual modeling, conceptual modeling environment, Icons*

1. BACKGROUND

Geographic models are one of the most used representation methods for geographical phenomena, geographical mechanism and geographical process. Geographic modeling and simulation are the fundamental approaches for geographical research and complex geographic problem solving^[1]. Conceptual modeling, computational modeling, model checking and correction, and model application are the four necessary parts of modeling during its process. The modeling conception illustrates the ideas of modeling and at the same time can induct and constrain the building of model, only an efficient conceptual modeling can produce a correct geographical model^[2]. The conventional methods of modeling are usually done by experts who build their conceptual models with sketches or diagrams and hide their modeling conception into model conception, and these modeling methods are not convenient for visualizing the modeling process and exchanging the ideas of modeling.

Nowadays, the achievement in graphic modeling in many fields is prominent, such as actively network graph, Petri graph, UML activity graph and State plans. Modeling environment based on icons (GBM/SM)^[3] was designed and developed by Kaushal Chari and so on. This environment can support modeling, syntax editing, automatic matching of model and data in different domains. General Modeling Environment (GME, <http://www.isis.vanderbilt.edu/projects/gme>) was designed and developed by Vanderbilt University and the common concept of system modeling was put forward, and the structure, behavior of model were constructed by a visualization method such as UML. Open Source Problem Solving Environment (TRIANA, <http://www.trianacode.org>) was developed in UK, Cardiff University, which provides modules and tools for data analysis, and it was a problem solving environment based on distributed technique, such as Grid, or network service.

However, the situation of graphical modeling is that: the concept of GIS based on graphical knowledge was put forward by Smith (1987)^[4], representation, management and application of knowledge were first introduced in GIS. Developing research and simulation of geographical cognitive theory based on geographers' logical thinking was proposed by Xuejun Lu et al [1998]^[5,6]. Geographical cognitive research and its thinking mode, meanings and essential in different space image were preliminarily studied. Concept mapping method was introduced into geographic modeling by Wanqin et al [2003]^[7]. They built concept map model of Xiaoqinghe Flood Plain and the flood model of Yongding River. Spatial Modeling Environment (<http://www.uvm.edu/giee/SME3/>) developed by University of Vermont was based on icons, it is a modeling environment that connected supercomputer with object database which was suitable for ecosystem. GeoVista Studio (<http://www.geovistastudio.psu.edu>) developed by University of Pennsylvania using JavaBean was a geographic visualization environment-oriented modeling environment. However, those studies have limitations in modeling from different domain area, spatial and time scale requirements. And the models can only be represented by line connecting, image, intuition. Thus the modeling concepts can't be explicit expressed and shared while multi-users are building the same model.

Meanwhile, because the understanding of geographic conception vary with experts in different domains, which lead to the diversity in semantic information, and hinder the sharing of modeling processes and modeling concepts of different domain experts. In this aspect, in order to solve the problem of cognition diversity in different domains, find a

geographical conception cognition system with the feature of geographical that accord with the habits of geographical cognition, geographic ontology becomes a study focus: Mark and Smith^[8] try to establish geographical object-oriented ontology and its cognitive classification. In September 2000, a meeting called "ontology and methodology of spatial data standard" organized by Winter was hold. Spatial ontology, spatial cognition, spatial knowledge, uncertainty of space, level of space, space generalization, standard and standardization was discussed in this conference. In 2000 and 2002 there had a deeper discussion about geo-ontology in the conference of geographic information science hold in Georgia and Colorado. In September 2002, in the conference of GeoOntology hold in UK, the conception of GeoOntology, the key issues and the key research on the scope of GeoOntology were deeply discussed, and was first put forward. Meanwhile, Ontology-Driven GIS (ODGIS) was also put forward. However, because of the complexity and uncertainty of geographical phenomena and the diversity and difference of geographical cognition, the study about abstract and representation of the semantic issues of geographical domain is still under-development.

In order to solve those problems, semantic representation specification for geographic conception based on geographic metadata was discussed in this paper. The representation and description of the conceptual scenario of geography, the geographic conceptual entity and relationship between entities are also discussed. Farther more, the semantic problem of solving method and data requirement, the building method of geographic conceptual icons library with semantic are also discussed in order to develop a semantic driven geographic conceptual modeling environment based on icons.

2. FRAMEWORK OF SEMANTIC DRIVEN GEOGRAPHIC CONCEPTUAL MODELING ENVIRONMENT BASED ON ICONS

Geographic conceptual model is based on the cognition of geo-problem. The semantic description of geo-problem can be seen as the representation of geographic cognition, and geographic conceptual scenario can also be seen as the product of geo-problem semantic, and the result of virtualized expression. However, because of the diversity of cognition of geo-problem and modeling ideology, we don't try to develop a description criterion that can completely describe the geographic conceptual scenario, but it can offer an extensible way to describe the metadata of conception scenario based on the study of definition and description method of geographic conception scenario. Thus on one hand users can build their model virtually with a common modeling conception, on the other hand users can define metadata description according to their demands.

Based on description of metadata for geographic conception scenario, the elements used in geographic modeling process are categorized into two classes. One is geographic conceptual entities, the other is geographical relationships entities. Metadata specification of these two kinds of elements is put forward, where icons are used to illustrate the geographic conceptual entities and build conceptual scenario visually. Also conception/relationship constrain engine, model/data match engine and graphics/conception constrain engine are developed, it is helpful for the experts in different fields to form a uniform cognition of geographic conception scenario, and make the modeling process easily and visualized. Geographic entity and their interrelationships are represented by geographic icons; those icons contain the meaning of geo-problem, geo-semantic, geo-data, and the match rules between models and data. Expert can choose geographic icons, build relationship among geographic entities, build geographic conception model according to geo-problem, geo-domain, spatial and temporal scale (as shown in figure 1).

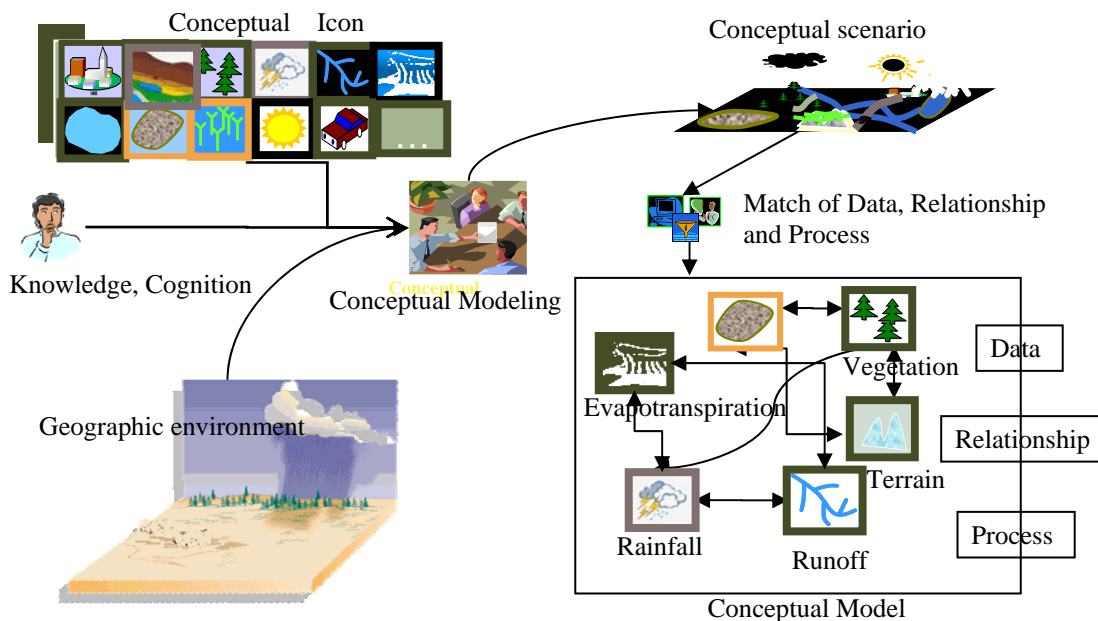


Figure.1 Framework of Semantic driven geographic conceptual modeling environment

Geographical conceptual entities are the key part of geographic conceptual modeling, and they are expressed by icons in geo-icon library. Every icon illustrates the meanings of geographic data or geographic phenomena and it is associates

with the metadata description information of geographic conceptual entity. When an icon is dragged into the model viewing window to form the geographic concept scenario, two aspects of function can be carried out by a modeler. One is that the modeler can understand or express the ideas of conceptual modeling by semantic metadata hidden behind an icon, the other is he or she can find out and select corresponding data and model types based on the understanding of metadata description information for geographic conceptual entity which associates with the icon. And these selections will be constrained by geographical relationships and rules such as applied domains, scale matching, and requirement of coupling and so on. Geographical relationships and rules have their own semantic description metadata, and they are managed by building a rule library and it can provide induction and rule verify function for conceptual entity matching when building conceptual scenario. Also, the model builder can add his own geographical relationships and rules in order to enrich the rule library and make the rebuilding of conceptual scenario conveniently. After a complete set up of conceptual modeling, the geographical concept scenario can be saved as a template. Every scenario template corresponds to one of the run of the conceptual model. These templates are convenient for model rebuilding and modification. And at the same time, it is convenient for visualization and analyzing of the similar model (fig 2).

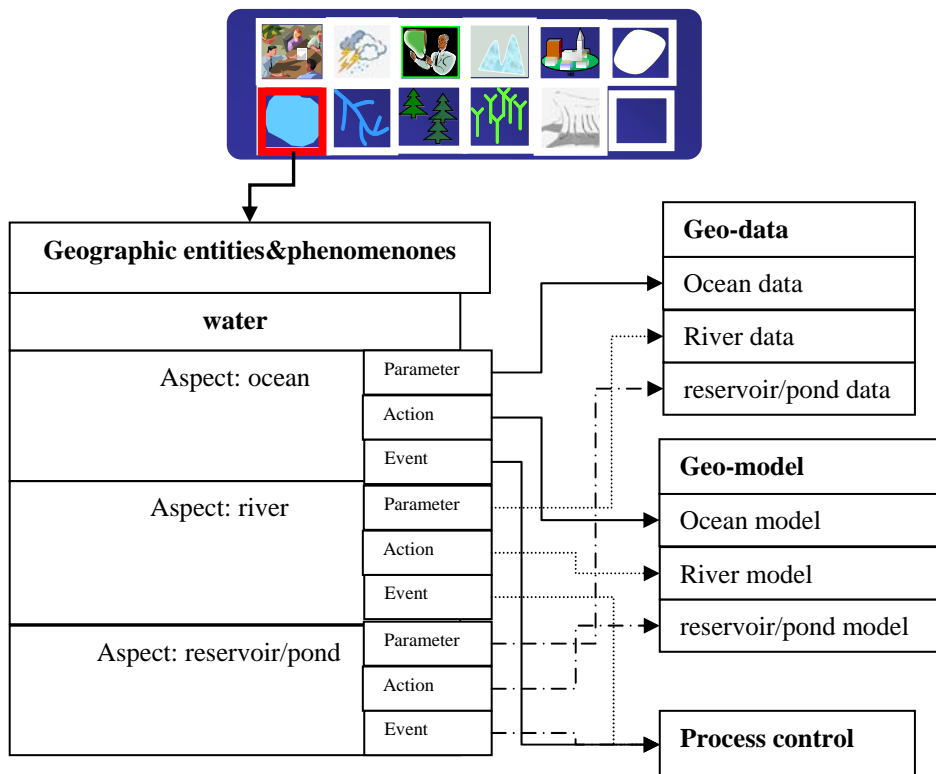


Figure.2 Geographical conceptual entities

3. IMPLEMENTATION

3.1 Descriptions for geographic conceptual scenario

3.1.1 Metadata description for geographic conceptual scenario

The metadata of geographic conceptual scenario describes the semantic of geo-problem stimulated by geographic model, which defines the problem domain, location, spatial-temporal scale and so on. It could also contain the information of data and model in preliminary requirement. This paper defines an extensible metadata description methodology of geo-conceptual scenario based on XML, with which user can add new definitions according to existing conceptual scenario description method. The visible definition of metadata of geo-conceptual scenario provide the primary framework of definition of geographic conceptual model, benefit the category of geo-conceptual model patterns, and advance the sharing of ideas of geographic modeling finally. Figure 3 illustrates a part of conceptual scenario without conceptual entity.

```

<GeoConcept>
  <uuid>
    14F75F95-B513-41a9-A3AF-5A1BC1EA48AF
  </uuid>
  <description>
    This domain is to research on drainage area model in bigsize.
  </description>
  <size>
    bigsize
  </size>
  <timeScale>
    mediumsize
  </timeScale>
  <keyword>
    drainage area, bigsize
  </keyword>
  <GeoModelMatch>
    <Node>
      <Node type="match" name="bigsize" keyword="drainage area" text="bigSize model" description="bigSize model"/>
    </Node>
  </GeoModelMatch>
  <GeoDataMatch>
    <Node>
      <Node type="match" name="bigsize" text="bigSize model" description="bigSize model"/>
    </Node>
  </GeoDataMatch>
</GeoConcept>
  
```

Figure.3 Metadata descriptions for geographic conceptual scenario

3.1.2 Metadata description for geographic conceptual entity

When the primary definition of geo-problem is finished, the geographic conceptual scenario can be constructed by adding new necessary geographic conceptual entities into the scenario. The geographic conceptual entities, whose appearance as icon types and moving by dragging is attached with assigned metadata.

The difficulties of study on geographic conceptual scenario modeling are the organization and the presentation of the conceptual entity. DIAS (Dynamic Information Architecture System)^[9], developed by Argonne National Laboratory, provide a framework with the object oriented library which can support complex modeling and simulation. This library contains large amount of entities which can represent features in the real world, and these entities can be reused. The framework of DIAS consists of two parts, one is entity that can represent the complex entity in the real world, the other is the model which can represent the activity of entity, and thus models of different domains can do collaborative work in this framework. Using this framework, complex simulation scenario can be set up and manipulated in an easy way. And all the entities in this framework can interact with each other by concurrent processes.

Refer to the design of DIAS, we take the geographic conceptual entity as a geo-object with many aspects, and each aspect is attached a special application with its parameters, actions and events alone. The parameters described the demand of data and the actions described constrain of conceptual-entity which would be used to decide the install and uninstall of exterior model modules, and the events control the flow of actions. Then, we can put the isolated model into many applications. There are three methods to implement the design of geographic conceptual-entity according to constrains of geo-conceptual scenario: 1) add the new metadata to the aspect of existing geographic conceptual entity; 2) revise the existing metadata; 3) create a new entity based on the design. Figure 4 shows a description of geographic conceptual entity.

```

<GeoEntity uuid="A2C94147-54B8-4616-AA60-52BC51C23B86" name="地下水含水层" description="地下水含水层" keyword="地下水,流域,蒸散发,产汇流,入渗" image="地下水土层.wmf">
  <aspect>
    <feature description="日照地下水层"/>
    <parameter>
      <Data description="日照光强度" size="mediumsize" timeScale="microsize"/>
      <Data description="含水层储水量" size="mediumsize" timeScale="microsize"/>
    </parameter>
    <action description="光照引起地下水含水层水蒸发"/>
    <modelMatch>
      <Node type="match" name="mediumsize" text="中小尺度模型" description="中小尺度模型">
        <GeoMtExpression type="and">
          <GeoMtExpression type="atom" operator="equal" value1="model.size" value2="value:string(mediumsize)"/>
          <GeoMtExpression type="atom" operator="equal" value1="model.field" value2="value:string(groundwater)"/>
          <GeoMtExpression type="atom" operator="equal" value1="model.function" value2="value:string(evaporation)"/>
        </GeoMtExpression>
      </Node>
    </modelMatch>
    <event>
      <Node description="当光照达到一定强度引起含水层水蒸发,引发action"/>
      <Node description="当光照小于一定的值不再蒸发,关闭action"/>
    </event>
  </aspect>
  <aspect>
    <feature description="湖泊地下水层"/>
    <parameter>
      <Data description="垂向入渗水量" size="mediumsize" timeScale="microsize"/>
      <Data description="湖向入渗水量" size="mediumsize" timeScale="microsize"/>
      <Data description="含水层储水量" size="mediumsize" timeScale="microsize"/>
    </parameter>
    <action description="入渗引起含水层水量增加"/>
    <modelMatch>
      <Node type="match" name="mediumsize" text="中小尺度模型" description="中小尺度模型">
        <GeoMtExpression type="and">
          <GeoMtExpression type="atom" operator="equal" value1="model.size" value2="value:string(mediumsize)"/>
          <GeoMtExpression type="atom" operator="equal" value1="model.field" value2="value:string(groundwater)"/>
          <GeoMtExpression type="atom" operator="equal" value1="model.function" value2="value:string(inleakage)"/>
        </GeoMtExpression>
      </Node>
    </modelMatch>
    <action>
      <Node description="湖泊水量压力大于含水层水压力,开始入渗"/>
      <Node description="湖泊水量压力小于含水层水压力,停止入渗"/>
    </action>
  </aspect>
</GeoEntity>
  
```

Figure. 4 Metadata description of geographic conceptual entity

3.1.3 Metadata description for geographical relationship entity

The other element used in the process of modeling is geographical relationship entities. All those relationships contain function relation, direction relation, subordination relation, and they can be divided into unilateral and bidirectional. Unilateral relationship can be described in the way of triples like relationship (feature1, feature2, relation), while bidirectional relationship must be described using two triples in the form of relationship (feature1, feature2, relation1), Relationship(feature2, feature1, relation2). Relationship can be chosen from rule and relationship library or added by user, and they are restricted by conception/relationship constrain engine. Because of the uncertainty and complexity of the real world, the library can't be completeness and with error, and it should be maintained manually, and this work must be done through another perfect system.

As a summary, a full description of geographic conceptual scenario contains the description of research purpose, research domain, research scale, the description and representation of geographic entities and relationships among them.

3.2 Introductory construction of geographic conceptual model

After the geographic conceptual scenario is set up, matching and associating rules can work by three engines mentioned above. The key technique of transforming geographic conceptual scenario which is visible to geographic conceptual scenario is using model matching rules and data matching rules to guide how to choose models data and their configure. In this way, geo-problem oriented geographic conception model can be built (fig 5).

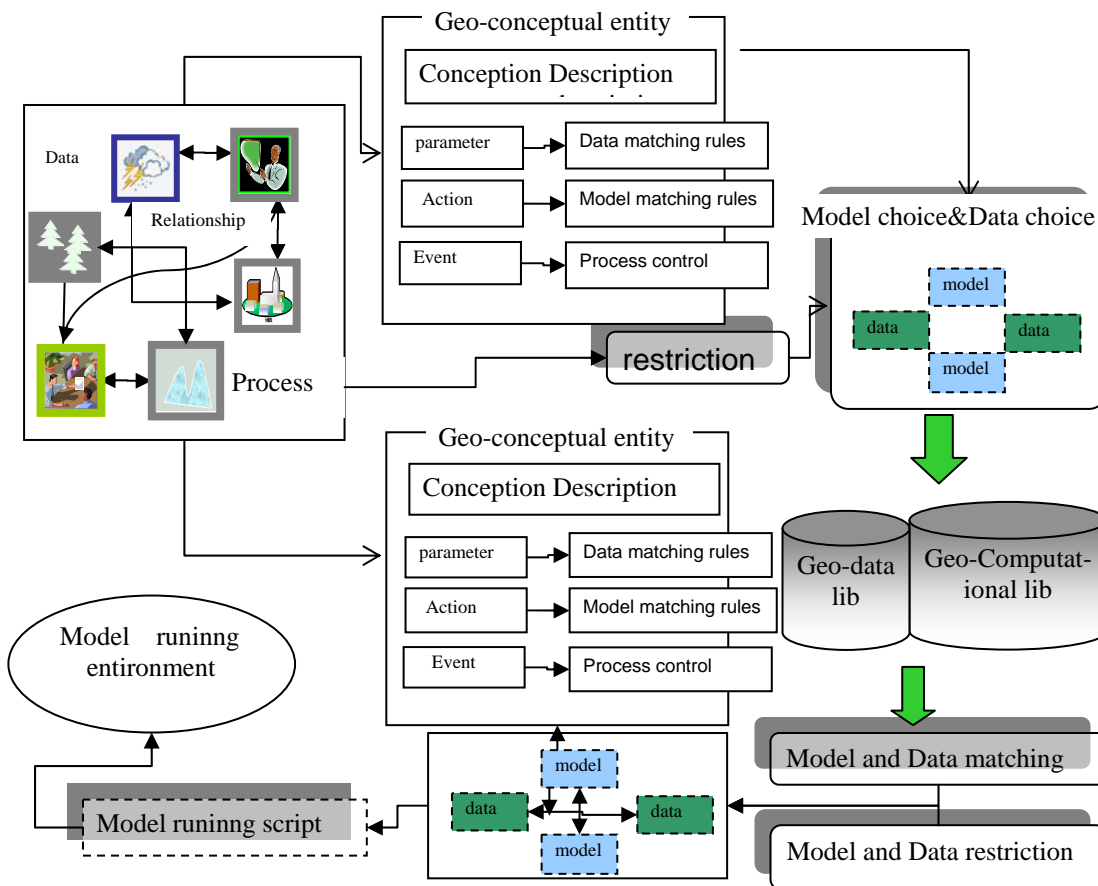


Figure.5 Induct to build geographic conceptual model

3.2.1 Conception /relationship constraining engine

The conception/relationship constraining engine is used to estimate whether the relationship and constraining among geographic conception icons come into existence and whether the relationships among entities are associated with the logical specifications. For example, the forests can not grow on the sea. But in fact, the relationship description in the relationship rule library can not be self-contained and perfectly own to the complex of geographic phenomenon and the opening, extensible of rules library, so it should be checked, chosen and amend based on experience and common sense.

3.2.2 Model/data matching engine

(1) Geographic model metadata and semantic representation

Because of the characteristics of geographic models such as diverse domains, larger volume, semantics discrepancy, distributed and so on, which result in the scarcity on the classification system, scope of application, spatial-temporal scales, model quality, model performance, parameter types, running conditions, modeling theory, solution, integration mode of a geographic model, it is difficult for the model/data matching engine to match model expediently owing to lack of metadata specifications of geographic models.

Based on the analysis on the existing geographic model metadata [10-16], a specification of geographic model metadata (<http://www.vgelab.com>) was established by Key Lab of Virtual Geographic Environments (Ministry of Education) Nanjing Normal University referring to the geo-spatial metadata standard of OGC、ISO/TC211、FGDC and national fundamental geographic information metadata standards of China. Figure 6 shows a part of specification of geographic model metadata for 2D finite element model for underwater.

```

<metaData>
  <mBMMXX>
    <MXZWQC>二维地下水流有限元模拟模型</MXZWQC>
    <MXZWJC>二维水流模拟模型</MXZWJC>
    <MXYWQC>2-D groundwater flow finite element model</MXYWQC>
    <MXYWJC>2-D FEM Model</MXYWJC>
    <MXEB>FEM-1.0</MXEB>
    <MXXLN>1-1-1</MXXLN>
    <MXFBRQ>2003-5-2T</MXFBRQ>
  </mBMMXX>
  <mBMSXX>
    <XMMC>String</XMMC>
    <XMLX>国家自然科学基金项目</XMLX>
  </mBMSXX>
  <mJHESXX>
    <DWMC>南京师范大学</DWMC>
    <KPFZM>String</KPFZM>
    <KPFZY>自主研发</KPFZY>
    <mLXFS>
      <GJ>中国</GJ>
      <XZQ>江苏</XZQ>
      <CS>南京</CS>
      <DZ>南京师范大学</DZ>
      <YZBM>String</YZBM>
      <WZ>String</WZ>
      <DZYJDZ>String</DZYJDZ>
      <DHHM>String</DHHM>
      <CZHM>String</CZHM>
    </mLXFS>
  </mJHESXX>
  <mAFZDXX>
    <mMXNRXX>
      <MXKJCD>区域尺度或中小尺度地下水模拟</MXKJCD>
      <MXSJCD>层序层序同步</MXSJCD>
      <SJFWLX>分步长时间段模拟</SJFWLX>
      <MXKPHY>FORTRAN</MXKPHY>
      <ZY>运用有限元方法对饱和含水层地下水进行二维模拟；边界条件包括一类、二类边界；含越流补给项</ZY>
      <MD>二维饱和含水层地下水数值模拟</MD>
      <JZ>完成</JZ>
      <ZTFLMC>
        <GJC>二维地下水流、有限元方法</GJC>
        <SYZX>String</SYZX>
        <FWXZ>String</FWXZ>
        <SYXDXZ>String</SYXDXZ>
        <SJZSM>String</SJZSM>
        <MXJDSM>精度主要含含水层概念建模(概念)方法限定</MXJDSM>
        <MXJMVL>(错别字:建模)数学方法(有限元方法)</MXJMVL>
        <KJCZTLX>平面坐标</KJCZTLX>
        <MXKCSM>指空间离散数据、时间离散数据、含水层空间分布参数、含水层属性参数(导水系数、贮水系数)、含水层边界条件参数</MXKCSM>
        <MXKJFF>有限元模拟</MXKJFF>
        <SJL>3.14159EO</SJL>
        <DJ>3.14159EO</DJ>
      </mMXNRXX>
    </mAFZDXX>
  </mJHESXX>
</metaData>

```

Figure.6 Geographic model metadata and semantic representation

(2) Model matching engine

The geographic model with the metadata can be categorized into different classes by keywords such as fields and scales. During the process of conception entities construction, some requirement of constrains and matching are provided for conception entities, and the computation model can be selected by adding the matched models (fig 5).

type	name	text	description
1 match	bigsize	大尺度模型	大尺度模型
2 match	mediumsize	中小尺度模型	中小尺度模型

Figure.7 XML for Model matching engine

(3) Data matching engine

Data matching engine provide the function of filtrating data which matched with the geographic conception entities data from geo-database. It should be pointed out that matching only refers to conception levels and do not includes the heterogeneity of multi-source geo-data. So the data should contain the metadata of keywords like the models. In addition, in order to interpret the data in semantic layers and structure layers, we have developed a data model representation which likes SEDRIES (<http://www.sedris.org/>). The Figure.8 gives out a small example of the data matching.

```

<GeoDataMatch>
  <Node>
    <type>group</type>
    <name>root</name>
    <text>root</text>
    <description>降水量</description>
    <Node (2)>
      <type>match</type>
      <name>bigsize</name>
      <text>大尺度数据</text>
      <description>适合大尺度模型数据</description>
      <GeoMtExpression>
        <type>and</type>
        <GeoMtExpression (2)>
          <type>atom</type>
          <operator>equal</operator>
          <value1>Data.size</value1>
          <value2>value:string(mix)</value2>
          <type>atom</type>
          <operator>equal</operator>
          <value1>Data.field</value1>
          <value2>value:string(rainfall)</value2>
        </GeoMtExpression (2)>
      </GeoMtExpression>
    </Node (2)>
  </Node>
  <Node (2)>
    <type>match</type>
    <name>mediumsize</name>
    <text>中小尺度数据</text>
    <description>适合中小尺度模型数据</description>
    <GeoMtExpression>
      <type>and</type>
      <GeoMtExpression (2)>
    </GeoMtExpression (2)>
  </Node (2)>
</GeoDataMatch>
  
```

Figure.8 XML for Data matching engine

In fact, the matching under the same system of model metadata representation specifications and data representation specifications is simple, while the matching of multi-sourced heterogeneous data integration is difficult.

3.2.3 Image/conception interaction engine

The image/conception interaction engine provides a friendly image interaction environment and can induce the peoples to model conceptual model visually. In order to construct conceptual scenario based on the content of conception scenario visually, the constrain rules and matching rules were added into entities and relationships. The role of image conception interaction engine is facilitate reorganization and construction of conception scenario by adding label, metadata and drag icons.

3.2.4 Restoring and sharing of conception model template

Based on the conceptual scenario and rules matching by matching engine, the conceptual model can be stored after it was construction. The storage of conception model can be categorized as conception scenario storing and conception model storing, and the storage maybe partially stored or wholly stored. When stored partially, the selected constraining rules are partially stored, and the whole constraining rules unselected would be lost.

4. EXPERIMENTS AND DISCUSSIONS

4.1 Experiments

To verify the validity of the method advanced in this paper, a prototype system of semantic driven geographic conceptual modeling environment based on icons was developed using VC++.net2005 as the developing platform. The visual representation of geographic conception modeling has facilitated the process of geographic conception modeling for geographers in different fields.

Take the conception model of evaporation, infiltration in the hydrology process as an example, some experiments were done. The result shows that the prototype system is flexible for the process of geographic modeling, and it provides a convenient and visualized modeling method for experts in multi-domain of geographic subjects (fig.9).

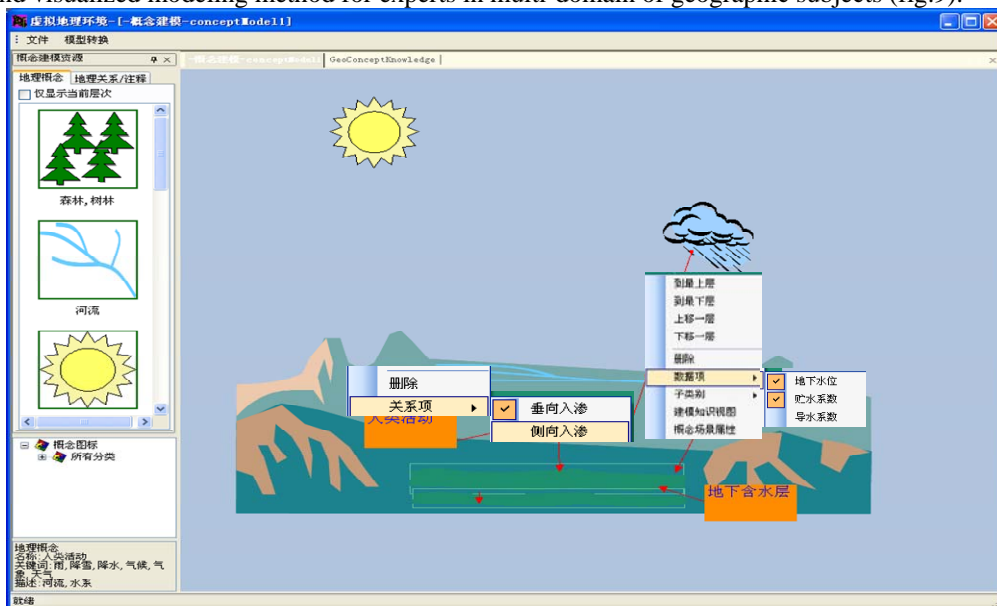


Figure.9 the results of conception modeling

4.2 Discussions

Although some key problems has been solved in this paper, there are still something should be improved. Firstly, some rules libraries still remain unconstructed, take entity relationship rules library for example, if we suppose that the height of cloud must higher than that of land, but in fact there are really some hills may be higher than clouds which surrounding them. If we take this area as the research area, the rule library would be incorrect! Therefore, manual intervention should be considered and added into the process of the experiment. Another problem is the description of the specifications, because the specifications we defined are only the resolution for some specific domain, the applicability of it should be further extended.

5. ACKNOWLEDGEMENT

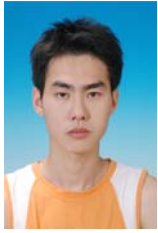
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