STUDY ON THE MODELLING OF GEOGRAPHIC CONCEPTUAL SCENARIO BASED ON 3D ICONS

Min Chen *, Guonian Lu, Yongning Wen, Hong Tao, Hongjun Su

Key Laboratory of Virtual Geographic Environment (Ministry of Education), Nanjing Normal University, Nanjing, Jiangsu Province, 210046, P.R.China – tianxiaxue99@163.com

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ABSTRACT:

There are many problems in conceptual modelling process, such as difficulties in modelling conception sharing, expressing and simulating the processes via a visual method, and so on. To solve those problems, expression metadata of geographic conceptual scenario is established based on 3D Icons, a visual conceptual modelling approach is put forward to realize expression and construction of geographic conceptual models interactively. By the experiments, it has shown that our research can accelerate practicality of geographic conceptual modelling and deepen its theoretic meanings.

1. INTRODUCTION

Conceptual model, based on the conceptions which derived from observing, abstracting of the research objects, is a model about conceptual entities, relationships between them and the interaction among all entities. The purposes of conceptual modelling are listed as follows: 1) to express the structure and architecture of specific objects; 2) to affirm the external influence factors of specific objects; 3) to specify relationships among inner elements and the relations between the inner elements and the external influence factors; 4) to provide a foundation framework for modelling(Yuchun Wei, 2005). From the view of traditional geographic conceptual modelling, there are no common norms and paradigms for conceptual modelling, and a convenient visual modelling environment is lacked; model builder often uses sketch map or diagram to build conceptual models, but it is arbitrary and will result in difficulty in sharing modelling thoughts. So, a new geographic conceptual modelling method which is used in a formal and visual way based on geographic conceptual scenario is proposed. Geographic conceptual scenario is one of the visual scenes to represent the conception, relationships and geo-data/models based on the representation of geographic conceptual and relationships among them. In this paper, an interactive and expressive geographic conceptual modelling method is provided. The geographic conceptual entities are described by 3D icons, the expression of geographic conceptual entities and relationships among them is studied, and the geographic conceptual scenario can be built as a configured scene.

2. BACKGROUND

There are many ways to describe conceptual models, such as specific method, scientific paper method, conception diagram, object-oriented method and design accommodation method etc. Specific method is designed for specific phenomenon and can't be reused expediently; the source code and a few documents should be analyzed in order to rebuild the conceptual model, and some times should consult with the model developers. A standard structure of scientific report is used in scientific paper method, and the standard numbers and traditional technologies make it effectively and comprehensively. Design accommodation method provides the designing and development for subsequent models, and it uses UML, Rose diagram and some text files to represent conceptual model. To sum up, the researches mainly pay more attention to the domain characteristics, customizing and expanding UML, describing conceptual model combined with the visual knowledge technology (Zhang Qi et al., 2006).

From the view of modelling tools, nowadays, the achievement in graphic modelling in many fields is prominent, such as actively network graph, Petri graph, UML activity graph and State plans. Modelling environment based on icons (GBMS/SM) (Kaushal chari et al., 1998) was designed and developed by Kaushal Chari and so on. This environment can support modelling, syntax editing, automatic matching of model and data in different domains. General Modelling Environment (GME, http://www.isis.vanderbilt.edu/projects/gme) was designed and developed by Vanderbilt University and the common concept of system modelling was put forward, and the structure, behaviour of model were constructed by a visualization method such as UML. Open Source Problem Solving Environment (TRIANA, http://www.trianacode.org) was developed in Cardiff University, UK, which provided 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 researches on conceptual modelling and modelling environments which emphasizing geo-modelling visually are paid little attention to in the earth science fields. The situation of graphical modelling is that: the concept of GIS based on graphical knowledge was put forward by Smith (Smith et al., 1987), and representation, management and application of knowledge were first introduced in GIS. Developing research and simulation of geographic cognitive theory based on

* Corresponding author. Email:tianxiaxue99@163.com,Phone:+86-13951760902

geographers' logical thinking was proposed by Xuejun Lu et al. (Lu Xuejun et al., 1998; Lu Xuejun et al., 1999). Geographic cognitive research and its thinking mode, meanings and essential in different space image were preliminarily studied. Concept mapping method was introduced into geographic modelling by Wanqin et al. (Wan Qing et al., 2003).They built concept map model of Xiaoqinghe Flood Plain and the flood model of Yongding River. Spatial Modelling Environment (http://www.uvm.edu/giee/SME3/) developed by University of Vermont was based on icons; it is a modelling 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 modelling environment. However, those studies have limitations in modelling for different domain areas, spatial and time scale requirements. And the models can only be represented by line connecting, image, intuition. Thus the modelling concepts can't be explicit expressed and shared while multi-users are building the same models.

Based on the analysis above, it has shown that the representation and building of conceptual model are paid more attention to mainly in all modelling fields. The conceptual modelling using visual method with the domain characteristics is becoming a hot topic especially in military, system simulation and integration circuit fields due to its excellence ability for decreasing the modelling cost and advanced in modelling sharing. Unfortunately, in the geographic field, the geographic conceptual modelling method and software environment with the characteristics of geographic domains are still rare because of the problems about spatiality and scale. And the existing modelling methods can not represent the modelling process visually, even has the disadvantage of interaction, reusing and visualization. In this paper, we try to design a new conceptual modelling method for modelling visually and easily.

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3. GEOGRAPHIC CONCEPTUAL SCENARIO REPRESENTATION

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 modelling ideology, we don't try to develop a description criterion that can completely describe the geographic conceptual scenario, but will offer an extensible way to describe the metadata of conception scenario based on the past study of definition and description method of geographic conception scenario (Xinlin Wang et al., 2007; Yuan Lei et al., 2006; Guoqin Zhao et al., 2005). Thus on one hand, users can build their model virtually with a common modelling conception; on the other hand, users can define metadata description about geo-conceptual entities and relationships according to their demands and store them. It is helpful for reusing and communication of modelling ideas and decreasing the modelling cost.

Based on the study of the description of metadata for geographic conception scenario, the elements used in geographic modelling process are categorized into two classes. One is geographic conceptual entities; the other is geographical relationships among them. Metadata specification of these two kinds of elements is put forward. 3D icons are used to illustrate the geographic conceptual entities, while relationships can be organized by Scene-Graph; those 3D icons contain the meaning of geo-problem, geo-semantic, and the requirement about models and data. Experts 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 Figure1)

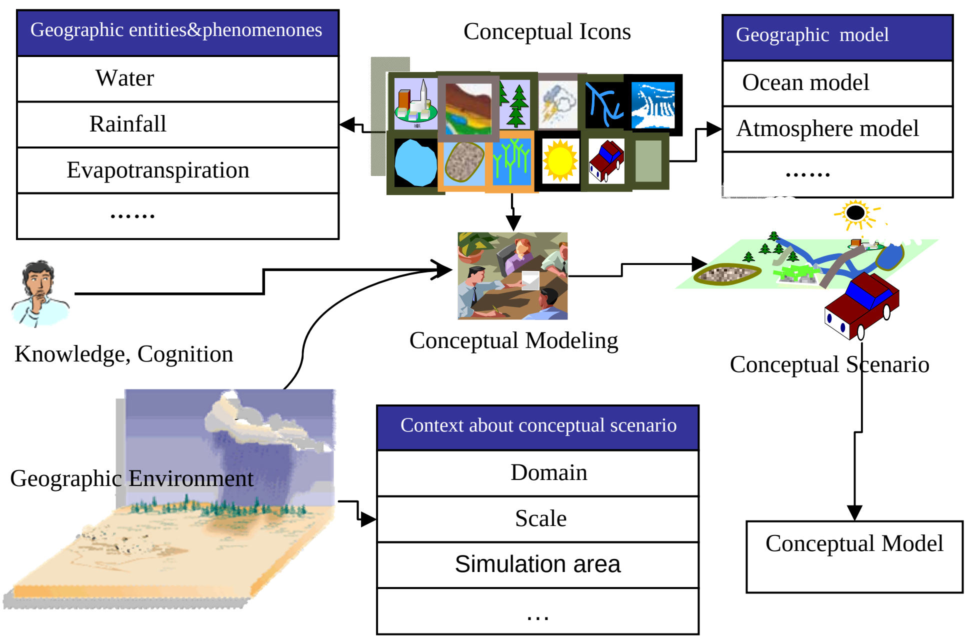

Figure 1. Semantic driven geographic conceptual modelling environment

In the process of geographic conceptual modelling, a nicety express and comprehension have an immediate effect on the sharing of modelling idea. Thus, an abundant conceptual knowledge base which can express geo-conception accurately will contribute to the modelling task (Yufen Zhang et al., 2004). However, it is a huge project to build such knowledge base without cognizance differences; it will cost too much and perhaps wouldn't achieve this objective actually because of the diversity of the world and cognizance differences of people. The key task of this paper is to build geographic conceptual scenario and express geographic conception with a visual method, such knowledge base and rules which used to restrict geo-conception itself haven't been comparative-deeply discussed.

4. GEOGRAPHIC CONCEPTUAL SCENARIO BUILDING BASED ON 3D ICONS

4.1 Geographic conceptual scenario description and representation

4.1.1 Geographic conceptual scenario description

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, the problem domain description, geographic characteristics of objects, time scales, spatial scales, boundary conditions and other supplement information can be defined by XML Schema. Using this method, users can add new definitions according to existing conceptual scenario description method. The visible definition of metadata of geo-conceptual scenario provides the primary framework of definition of geographic conceptual model, benefits the category of geo-conceptual model patterns, and advances the sharing of ideas of geographic modelling finally. Figure 2 illustrates a part of conceptual scenario without conceptual entities, where GeoModelMatch and GeoDataMatch implicate some simple requirements of data and model in geographic conceptual scenario.

```
<GeoConcept>
    <uuid>
      14F75F95-B513-41a9-A3AF-5A1BC1EA48AF
    </uuid>
    <description>
      This domain is to research  on drainage area model in large-scale.
    </description>
    <spatialScale>
     large
    </spatialScale>
    <timeScale>
     medium
    </timeScale>
    <keyword>
      drainage area,large-scale
    </keyword>
    <GeoModelMatch>
        <Node>
            <Node type="match" name="model requirement" keyword="drainage area"
            text="large-scale model" description="large-scale simulation"/>
        </Node>
    </GeoModelMatch>
    <GeoDataMatch>
        <Node>
            <Node type="match" name="data requirement" text="large-scale data"
            description="data for large-scale"/>
        </Node>
    </GeoDataMatch>
</GeoConcept>
```

Figure 2. metadata descriptions for geographic conceptual scenario

4.1.2 Geographic conceptual entity representation

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, which appeared as 3D icons attached with assigned metadata, can be dragged into the scenario.

The difficulties of study on geographic conceptual scenario modelling are the organization and the presentation of the geographic conceptual entities. DIAS (Dynamic Information Architecture System) (Simunich et al., 2002) developed by Argonne National Laboratory, USA, provides a framework with the object-oriented library which can support complex modelling 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.

Referring to the design of DIAS, we take the geographic conceptual entity as a geo-object with many aspects, and each aspect is attached to a special application with its parameters, actions and events alone. The parameters describe the demand of data and the actions describe 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. Complex geographic conceptual entities can be constituted of simple entities, and the description of entity contains its parent and children entities. Figure 3 shows geographic conceptual entities represented by icons, and Figure 4 has shown a description of geographic conceptual entity.

4.1.3 Geographic conceptual entity relationship representation

The other element used in modelling process is geographic entities relationships namely the simple mapping relationship and complex interaction relationship among geographic entities. It is should note out that the relationship not only existing in bio-entities, but existing in multiple entities. During the integrated process of conceptual modelling, the interaction among entities is administered by rule relationship library which restricting the interactions among all entities in conceptual scenario. Only the rules tally with the common understanding about the real world, a geographic conceptual model can be built ideally. Because of the uncertainty and complexity of the real world, the library can't be completeness and without error, and it should be maintained manually, and this work must be done through another prefect system. So, the purpose of this paper is to provide a new conceptual representation method for building the relationships among geographic conceptual entities in geographic field.

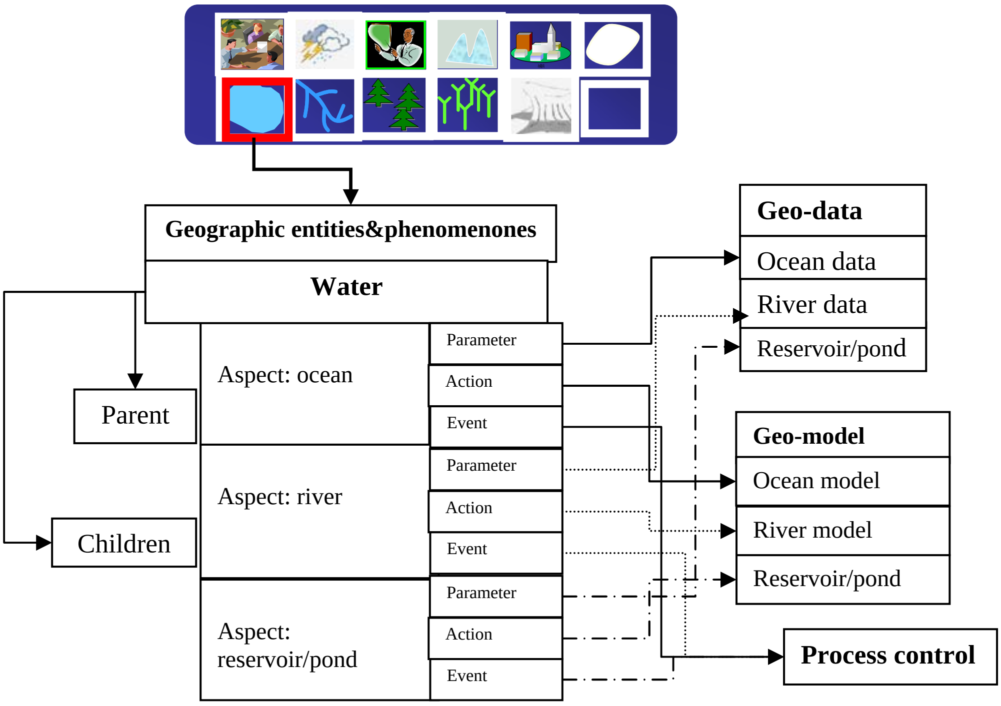

Figure 3. Geographic conceptual entities


```xml
<GeoEntity uuid="A2C94147-54E8-4616-AA60-52BC51C23E86" name="underground aquifer" description="underground aquifer" keyword="
groundwater,watershed,evaportranspiration,runoff yield and confluence, infiltration" image="underground aquifer.wmf">
    <aspect>
        <feature description="underground aquifer in sunshine"/>
        <parameter>
            <Data description="illumination intensity" size="medium" timeScale="micro"/>
            <Data description="aquifer water reservoir" size="medium" timeScale="micro"/>
        </parameter>
        <action description="water evaporation of the underground aquifers induced by illumination">
            <modelMatch>
                <Node type="match" name="model requirement" text="small and medium-scale model" description="small and medium-scale model">
                    <GeoMtExpression type="and">
                        <GeoMtExpression type="atom" operator="equal" value1="model.size" value2="value:string(medium)"/>
                        <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>
        </action>
        <event>
            <Node description="when the illumination reaching a certain intensity arise the aquifer water evaporation, arise action"/>
            <Node description="when the illumination is less than a certain value, aquifer water will not evaporate, close action"/>
        </event>
    </aspect>
    <aspect>
        <feature description="lake underground aquifer"/>
        <parameter>
            <Data description="vertical water infiltration" size="medium" timeScale="micro"/>
            <Data description="lateral water infiltration" size="medium" timeScale="micro"/>
            <Data description="aquifer water reservoir" size="medium" timeScale="micro"/>
        </parameter>
        <action description="Infiltration of water reslut in the aquifer increase">
            <modelMatch>
                <Node type="match" name="model requirement" text="small and medium-scale model" description="small and medium-scale model">
                    <GeoMtExpression type="and">
                        <GeoMtExpression type="atom" operator="equal" value1="model.size" value2="value:string(medium)"/>
                        <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>
        <event>
            <Node description="when lake water pressure is greater than the aquifer water pressure, the water begins infiltrating"/>
            <Node description="when lake water pressure is less than the aquifer water pressure,the water stops infiltrating"/>
        </event>
    </aspect>
</GeoEntity>
```


Figure 4. Metadata description of geographic conceptual entity

All those relationships contain function relations, direction relations, subordination relations, and they can be divided into unilateral and bidirectional. According to the concrete condition of geographic model, relationships also can be divided into engine flow, material flow and other types of relationship. In detail, the relationship can be describing by: *Relationship (ID, Description, Type :{normal|flow}, SourceFeature, TargetFeature, IsBidirectional, Attributes).*

In 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.

4.2 Geographic conceptual scenario building based on 3D icons

4.2.1 Building of 3D icon lib

As the representation of geo-conceptual-entity, 3D icons with the characteristics of visualization, strong interaction, can express the spatiality of geo-entity more clearly. The environment research department of Maryland University has made lots of icons about zoology including vegetation, insect, daily life and so on. However, those icons are in 2D styles with the PNG format, and they can't be used directly .Thus, using 3d-max as the tool of modelling, we made some 3D geo-conceptual icons classified by conception to validate the feasibility of our research. When model builder build their geo-conceptual scenario, they can drag the icons into the scenario and link the geographic entities and relationships with metadata which used to describe and express them mentioned above.

4.2.2 Building of Geo-conceptual Scenario

Using Scene-Graph as its organization mode, which featured with multi-level organization and spatiality, Geo-conceptual Scenario can express spatial characteristics more clearly. When dragging an icon into the scenario, it can be put in a right place, and the metadata of geo-entities and relationships among them should be defined and saved.

As the research field of geography refers to space scales according to different requirements, the function of geo-entities and the relationships for the scenario are mapped with Scene-Graph levels. For example, when a 3D icon is dragged into the scenario, the metadata which used to describe the geo-entities and relationships relatively can be defined by multi-levels as:

{level,aspect{parameter ,action ,event ,parent ,children},relationship{ID ,Description ,Type:{normal flow},Source Feature, Target Feature, IsBidirectional, Attributes}}

And all those fields have been defined and mentioned above. Each level has its corresponding definitions---aspect and relationship just for this level, and that is to say just for this scale of the conceptual scenario. With the support of this method, the feature of multi-scale and multi-level of spatiality is embodied, and model builder can organize and express their modelling conception clearer and more expediently .Also, model viewer can grasp the cognition from top to down as a whole, and discriminate the details with its help.

After the conceptual scenario is built, it can be stored as XML document. The storage maybe partially stored or wholly stored. It is helpful for the model rebuilt and modification expediently, and can provide an easy way to compare the same conceptual scenario.

4.2.3 Scenario rendering and 3D icon editing

Using VC++.net2005 as the developing platform, an engine supporting both OpenGL and D3D is developed. There are three windows: the first is for 3D icons chosen, the second is for conceptual scenario view, and the last is for the metadata view and edit. Model builder can choose a 3D icon just like choose a single 3d model in the conceptual scenario view window, and edit its metadata in the metadata view window, that's more excellent than traditional method.

5. VALIDATION

Take the conception model of evaporation, infiltration in the hydrology process as an example, some experiments have been done. The results show that the prototype system is flexible for the process of geographic modelling, and it provides a convenient and visualized modelling method for experts in multi-domain of geographic field (Figure 5).

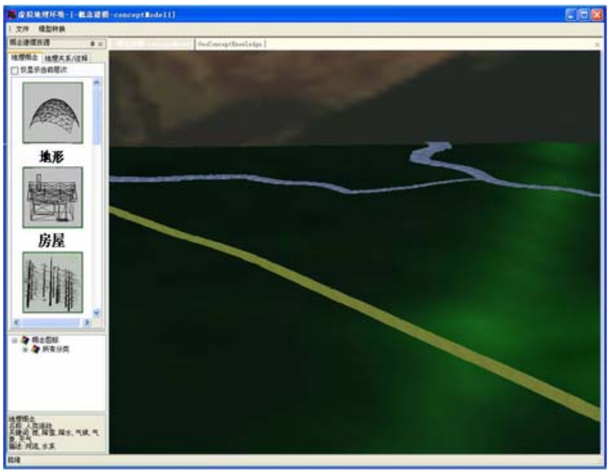

Figure 5. The result of geographic conception modelling

6. CONSIDERING AND FURTHER PERSPECTIVES

However, the research of this paper has some disadvantages and should be improved in the future. The paper just tries to express the conceptual modelling processes in a visual method, and makes the thinking of the conception clearer by this process. Thus, some aspects such as rule base which used to build rules among entities relationships are neglected. It will spend a lot of times and money to build such lib, for example the diversity of the world would proved that the ground is higher than the clouds because of the height above sea level of this area, while the rule in rule base perhaps prescribes that the cloud must fly above ground according to general knowledge . In this instance, the conceptual model building based on those special areas may be restricted. It is an objectivity problem we can't solve completely, the real world is too complex to be described by priori experience and conventional theory, thus the rule base must be built and modified by manual intervention which may also induce checking problem. The problem is so intricate and hasn't been settled.

Another problem is the description and expression of the conceptual scenario because the specifications we defined are only the resolution for some specific domain; the applicability of it should be further validated and extended.

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