FEATURE-BASED SPATIO-TEMPORAL DATA MODEL AND ITS APPLICATION IN LANDUSE MONITORING

LI Xiao-juan *, YIN Lian-wang, GONG Hui-li, ZHAO Wen-ji, SUN Yong-hua

（Key Lab of Resources Environment and GIS of Beijing , Capital Normal University, Beijing 100037）

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ABSTRACT:

Traditional data model takes the geometric object as the modeling target and results directly in decomposing geographic phenomena into a series of objects. Furthermore, the temporal data and spatial data are stored separately. All of those restrict the development of GIS and resources monitoring. Feature-based spatio-temporal data model can support the next generation of GIS effectively. In this paper, based on the landuse monitoring research project of the five year plan of our country, we propose a new spatio-temporal data model based on the states of the changing feature (SCFSTDM) in order to serve for integrating geographic phenomena and geographic information as well as applying object-oriented analysis method to support spatio-temporal analysis, simulation and data sharing.

Finally, we develop a prototype of the temporal landuse information system in which there is a spatio-temporal database based on the feature. With this system, we can query states of the feature instance directly, for example, to query the states and to play the developing process of a feature instance, to make the spatio-temporal reasoning.

1. Introduction

The rapid development of resources monitoring and spatial information technology provide GIS a great opportunity as well as severe challenge. Now how to organize, store, manage and use a large number of spatio-temporal data efficiently is an important problem we are facing. It concerns the development of GIS and resources monitoring in scientific and applied fields directly.

“Accurate description of the problem is the most essential and important step to solve it” [1] [2]. The data model of GIS provides a tool to abstract and depict the objective world, which affects the quality of GIS function. However the GIS function is greatly limited in analyzing and decision-making, because the data model is depicted from computer technology view, but not from geographic view. So the structure of GIS data modal become a seriously problem restricting the development of GIS.

Chrisman points out many times that there are two different ways to code and observe spatial strategies. The first one regards the space as a continuous one interfered by the clear spatial objects. The other one regards the space as the spatial ordinal set composed of clear blocks. Two different observing strategies form two different data models, the vector data model and the raster data model.

Based on conventional GIS data models, many spatio-temporal data models have appeared recently, such as Sequent Snapshots Model, Base State with Amendments Model, Space-Time Composite Model, 3D/4D Model and Three Domains Model. The researches on these models have promoted the development of GIS. With the application of GIS deepening, more problems have emerged.

* LI Xiao-juan，College of Resources, Environment & Tourism, Capital Normal University. Email: xjli2000@sina.com.cn

In this paper, we discuss the feature-based spatio-temporal data model, and develop a prototype of the temporal landuse information system. Compared with the conventional spatio-temporal data model, this data model has some advantages in managing, querying and deducing spatio-temporal land information.

2. The Feature-based Spatio-Temporal Data Model

2.1 The conception

The definition of feature defined by ISO/ TC211 is that the feature exists in two levels: feature type and feature instance. The anterior one is geographical phenomena having same characteristics, and the later is a material phenomenon in feature type.

Feature is the higher abstraction and overall expression for geographical phenomenon, including all information in spatial, temporal and thematic aspects. By using the feature-based method of recognizing and expressing physical world, we can achieve the demand of high abstraction and overall expression of the physical world, and build a uniform frame of expressing the geographical phenomena. It is more important that the overall geographical information can achieve the unification of recognizing and expression physical world on the semantical level and benefits the data sharing and interoperation.

The Feature-based Spatio-Temporal Data Model is a set of interrelated temporal feature. It is also an overall and organic expression of the geographical information, such as feature attribute (which includes thematic attribute, spatial attribute and temporal attribute), feature function and feature relationship. This kind of expression is under the basis of feature classification, feature instances recognization, and the frame of temporal and spatial referenced system. (Figure1)

The differences between the feature-based spatio-temporal data model and conventional spatio-temporal data model are:

(1) The modeled objects are different.

The anterior one models geographical features and the later one models the spatial geometrical objects,

(2) The information carrier is different.

The anterior one makes the feature instances as the carrier integrating the geographical information, which unifies the spatial, temporal and thematic attribute to the feature instances. The carrier of the feature-based spatio-temporal data model has an explicit geographic meaning; the later one uses the spatial or spatial-temporal geometric objects as the carrier. In this way, the geographic meaning of the carrier is not definite and has lower geographic application value.

2.2 Predominance of feature-based spatio-temporal data model

(1) The feature-based spatio-temporal data model is favorable to integrate spatio-temporal thematic information and develop object-oriented analysis methods.

Feature has two aspects of meaning: geographical phenomena and its digital expression. Feature moves and develops, and it has the characteristic of producing, developing, shrinking, moving, vanishing and regenerating. So feature itself is an object integrating of time, space and themes. Accurate comprehension and overall expression of feature is the way to solve the problems of keeping integrity of geographical phenomena and integrating spatio-temporal thematic information.

In feature-based GIS, feature instances are the fundamental units expressing information. No matter it is survival or perished each feature instance has a unique ID. The feature's ID is encapsulated with the attribute, function and relation, which are used to describe the features. In this way, we can describe the characteristic of feature‘s occurrence and development

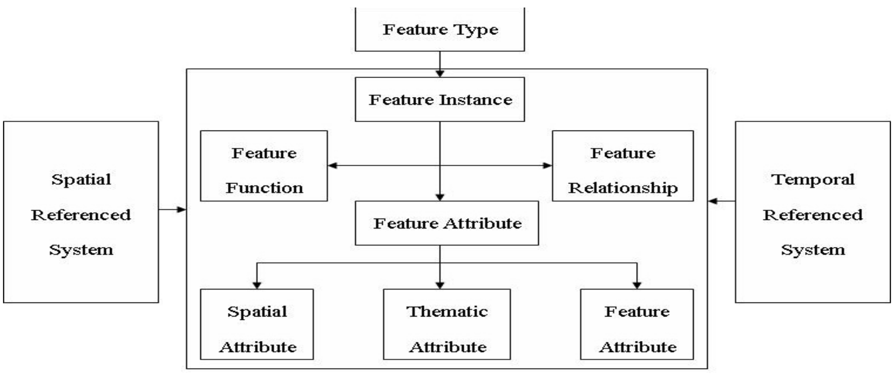

Fig1。The conceptual frame of feature-based spatio-temporal data model completely. With the feature's ID, a series of states or events of features are associated or organized organically, which is favorable to manage and query the spatio-temporal data, and provides the foundation for the application of the target-oriented analysis method.

(2) GIS function develops farther.

In feature-based GIS, features can become more complicated by using the method of aggregation or association .For example, A city is a complicated feature composed of roads, mines, residential areas, parks and other infrastructures. The complicated features can be composed of many simple features by using the method of aggregation or association.

Feature can be regarded as the only key word to obtain various data collections including the spatial data collection of vector and raster. The operations related to features can realize all functions and actions of features, such as producing, expanding, shrinking, vanishing, moving and regenerating features.

(3) The feature-based data model can be supported by the spatial data structure

The feature-based modeling technique not only makes the data model ameliorated radically and improves the system capability, but also provides an effective implement mechanism. The feature-based data model can be supported by the technique of OODB and programming.

The feature-based modeling technique not only provides a kind of standard and effective method of establishing the data model directly which is fit for people to realize the realism world mode, but also offers a effective realization mechanism .This method can generalize our integrated cognitions of geographical phenomena and construct a complete high - level data model This method can also solve the problems such as spatio-temporal information integration and spatio-temporal analysis and establish a foundation of geographical data sharing at the data model level by the integrated meaning of features.

3. Design of feature-based spatio-temporal data models for landuse monitoring

3.1 Basis of designing feature-based spatio-temporal data models

3.1.1 Contents of landuse monitoring in China and meanings in feature-based GIS: Landuse dynamic monitoring is divided into many sorts by its meaning and task, such as economic effect monitoring, landuse type monitoring, landuse level monitoring, land quality monitoring, land tenure monitoring, and so on. At present, the major task of landuse dynamic monitoring in China is to monitor the change of landuse type, that is ,to monitor all kinds of spatial changes of landuse type, and solve the problems, such as" where lands has changed?" and" which kind have them changed into?", etc.

The work mentioned above is considered as monitoring the changes of spatial attribute of feature instance. Based on the feature-based GIS, we can solve more problems of temporal and spatial changes. For example, did the feature instance change? How did it change? Which feature instances will change caused by another feature instance's spatial changes and how they will change?

We divide the changes of feature instances 'spatial attribute into five forms:

(1) Expanding: It means the spatial extent of the feature instances expands (area increases) such as the expansion of the city and the settlement.

(2) Shrinking: It means the spatial extent of the feature instances shrinks. For example, the cultivated land shrink because of the expanding of settlement .Roads traverse the settlement and split them into some spatial object.

(3) Vanishing: It means the original feature instances disappear because of some reasons, for example, the changes of instructed thematic attribute of the feature instances or other feature instances expanding.

(4) Newborn: It means a birth of a new feature instance, which will lead to the contiguous feature instances' shrinking and vanishing.

(5) Regenerating: It means the feature instances which has already been extinct appear again after some time.

With the method of ISO/ TC211 which divided the changes of spatial feature into other types such as division, fusion and substitution, the method mentioned above is able to reflect the characteristic of the spatial change of feature instances more comprehensively.

3.1.2 Fundamental characteristics of landuse change in China: According to the landuse changes surveyed on the suburb of Baotou (from 1992 to 1998), we find that most of them didn't change. For example, the detailed landuse survey map of the whole suburb in 1992 has 26,510 map polygons, and we surveyed 703 map polygons on the spot. The landuse change of Qianming countryside, which is near to the urban districts of Baotou, is more explicit than other towns. There are

923 map polygons in the detailed landuse survey map of Qianming countryside in 1992 and 106 map polygons have changed. Similar situations occurred in other research districts, such as PanZhihua in Sichuan province and Dehui in Jilin province.

In fact, landuse is a kind of relatively constant human-land relationship which came from human’s long - term productive practices and based on the natural, economic and social factors of land. So it's reasonable to say the change of the annual landuse has a characteristic of finites. This characteristic is an important basis for us to establish the feasible data model of landuse monitoring information systems.

3.1.3 Landuse monitoring and acquisition of feature instances: Applying “3S” technique into Landuse dynamic monitoring, we have to find the target areas which maybe changed in RS images firstly. Generally speaking, we can find the expanding, newborn and regenerating feature instances in RS images, and then measure them by GPS after confirmed them on the spot in the fields.

For the newborn instances, we usually survey their boundary. In addition, the spatial data we obtained is spatial attribute data of the feature instances. For the expanding instances, we can survey both their expanding aspects (named spatial events) and the whole spatial boundary of the new state (named spatial states). Supported by the function of spatial overlapping analysis, we can calculate the spatial states from the spatial events. For the shrinking instances, we generally get their new spatial states by using spatial overlapping analysis.

3.2 State of Changing Feature Based Spatial-temporal Data Model (SCFSTDM)

3.2.1 Description of SCFSTDM :(1) The feature instances are the modeling objects of SCFSTDM and the units of information organizing. SCFSTDM records the feature instance’ integrated states all the time. First of all, it records the feature instance’s initial state. Then, when feature instance’s state changes; it will record the new state.

(2) In landuse dynamic change, changes of a feature instance on the space must cause changes of other feature instances. So the changed feature instances are not only the extended or newborn feature instances but also the reduced or extinct feature instances.

(3) In SCFSTDM, we define a feature instance ID for each feature instance. This ID is corresponding to only one feature instance; even this feature instance is perished. Similarly, the different state of feature instance is corresponding to a unique mark, called edition ID. The developing and changing of feature instances is organically connected by feature ID, edition ID and the relations between feature instance editions. The feature instance developing the process of the development of feature instance is composed of a series of ordered editions. The feature instances’ events can be calculated from feature instances’ states.

Figure 2 is a sketch of landuse changes. There are five instances in the chart: A, B, C, D, and E. C vanished at T3 and regenerate at T4. D is always in the initial state. E is a newborn instance at T4.

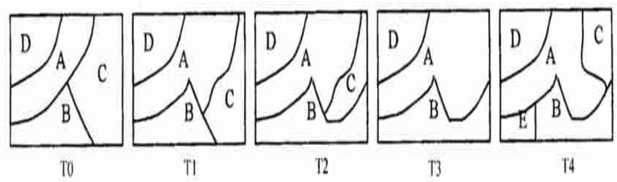

Fig.2　Landuse changing

The description of the way of feature instance changes is shown in Table 1. “—”means no changing and “null”means none. Figure 3 is the abstraction and expression of feature instances dynamic changes in Figure 1 by using SCFSTDM. S means state; 1, 2, 3, 4, 5 are edition ID. For example, As1 represents the first state of A or is called A’s first edition. As2 represents the second edition of A. Others can be explained in the same way.

	A	B	C	D	E
T0	initial	initial	initial	initial	null
T1	expanding	—	shrinking	—	null
T2	—	expanding	shrinking	—	null
T3	expanding	—	vanishing	—	null
T4	shrinking	shrinking	regenerating	—	newborn

Table 1　The changing type of feature instance

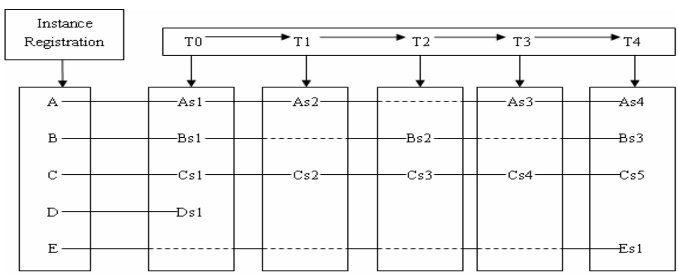

Fig.3　Feature-based spatio-temporal data model

3.2.2 Characteristics of SCFSTDM: CFSTDM uses the predominance of sequent snapshots model and feature-based spatio-temporal data model for reference and overcomes their shortcomings. The anterior model records the states of all objects at different time, but the latter one only records the changes. Compared these two models, SCFSTDM has three characteristics:

(1) Compared to sequent snapshots model, SCFSTDM saves a lot of storage space. Because SCFSTDM stores the initial state of all feature instances and the new state of the changing ones, but it doesn't record the state of the unaltered ones.

(2) Compared to feature-based spatio-temporal data model, SCFSTDM records the new state of feature instances instead of the events, and keeps the integrality and unification of geographical phenomena.

(3) The feature-based modeling and expression have explicit geographical meanings. It can opposite- process, query and dynamically play the process of development based on the feature. And it also can query the state and deduce the events because various relationships between different feature instances or instances and their editions. Finally, it can support spatial-temporal analysis and deduction. In essential, it meets the demands of user.

4 Experiment and Discussion

Based on the research of feature-based spatial-temporal data model, we designed and developed a temporal landuse information system based on SCFSTDM by using Visual Basic and Mapobjects. Table 2 provides the function of the system in its temporal aspect.

First Class Menu	Second Class Menu		Description Of Menu' Function
Active Performance And Play	Active Play		Play the developing processing of all feature instances dynamically
	Instance Development		Play the developing processing of the appointed feature instances dynamically
	Instance Tracing		Play the opposite developing processing of the appointed feature instances dynamically
Spatial-Temporal query	Overall Time Snapshot		Query the status of the land feature instance for a certain year with given time
	Spatial-Temporal Distribution Of Changes		It means the distribution of the changing feature instances on the time and space. By dragging the time slider, the system automatically flashes the changing feature instances of the year, and the users can realize the distribution of the changing feature instances on the time and space clearly.
	Spatial Distribution Of Changes		Query the distribution of any periods which accords with thematic property qualification on the space.
	Compound Spatial-Temporal Query		Make more complex spatial-temporal query by the composition of the time, space and thematic property. For example, query the feature instances of given periods, given districts, accordant given changing qualifications.
	Reasoning Of Spatial-Temporal Relationship	Shrink	Query the shrinking feature instances caused by other ones.
		Vanish	Query the vanishing feature instances caused by other ones.
		Change	Query the feature instances related to other ones on the time and space, including the shrinking and vanishing ones.

Table 2 Description of menu in spatio-temporal landuse information system

We tested the detailed survey data in 1992 and dynamic change data from 1992 to 1998 of the suburb of Baotou, Inner Mongolia. The result is that the model is useful and valuable in the application. We can extend the field of application in land cadastre information system and traffic information system, which take feature instances as monitoring objects.

The feature-based data model radically aims at solving the problems of conventional GIS in data organizing, spatial temporal querying, analyzing and reasoning. It also seeks after a solution to the problems on data sharing and GIS interoperating. Now it becomes the core of the next generation of GIS, in tune which fits the international latest developing trend of GIS. On the whole, the research on feature-based GIS is on an underway stage. More comprehensive research on data modeling, feature cataloging, feature instance identification, geographical information expression, data structure, feature-based spatial-temporal querying, reasoning, analyzing, simulating and forecasting, etc.

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