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Modeling temporal cadastre for land information management

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ABSTRACT

Time is regarded as an essential feature of land information enabling to track historical landmarks of land uses, ownerships, and taxations based on cadastral maps. Object-oriented temporal modeling helps to simulate and imitate time-varying cadastral data in a chronological and persistent manner. The aim of study is to analyze the role of temporal cadastre tracing footprints of foregoing events in response to various needs and demands associated with historical information of cadastral transactions. In this paper, temporal cadastral object model (TCOM) is proposed to delineate object version history. As an evidence of a new approach and conceptual idea for the importance of temporal cadastre, a part of spatio-temporal processes is illustrated to explain major changes of cadastral map. The feasibility and application of the approach is confirmed by proof-of-concept of temporal cadastre in land information management.

Keywords:*Temporal cadastre, Land information management, TCOM*

1. Introduction

A sense of time involves some feeling or awareness of duration, but it depends upon our interests and the way in which we focus our attention. As long as our attention is concentrated on the present of cadastral data, we tend to be unaware of time. Recording the temporal evolution of land information allows users to better model the dynamics of the real world. If land transactions occur frequently, then cadastral time seems short, but if more attention for cadastral information is necessary, then cadastral time seems extended. Clearly, our sense of duration is affected not only by the degree to which we concentrate our attention on what we are doing in land information, but also by the general physical circumstances of database management.

An archive is considered as a historical record or a collection of documents preserved in historical databases. Cadastral informations make it possible to produce a variety of derivative maps and outputs that smoothly maintain the consistency of

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historical landscapes and heritages. Using object version state diagrams, it illustrates the extended object version model for temporal cadastre. The object version view plays an important role in visualizing versioning control of the object version manager in charge of detection and maintenance of versions. The object history view enables us to understand how the DB history manager can manage historical object of cadastre.

Although many models approach to Temporal GIS (TGIS) have been examined (Faria et al., 1998; Erwig et al., 1998; Parent et al., 1999), there are few manifest models for temporal LIS that is significantly concerned with persistent cadastral history clarifying comparisons and disparities between cadastral objects. Thus, the focus of this study is not only on temporal roles for land information, but also on temporal object version mechanisms of cadastral map databases. An ideal design of temporal object version and two major temporal operations are proposed to not only identify the majority of cadastral activities and events, but also illustrate temporal cadastre object model (TCOM) that effectively manages historical version of cadastral maps and their attributes. A feasible way of implementations for time-varying cadastral histories is examined.

2. Related works and challenges

Time is regarded as a discrete object and loses the intrinsically continuous aspects of temporal variability. It represents phenomenon variability that ranges from stationary data like a boundary of land parcel to highly variable data through the boundary representation delineating time values in spatial-temporal domains. To represent the whole evolution in a continuous way is equivalent to retaining all the shapes and localization of the object through time. In order to depict such variable data, the space-time cube data model in CAD/CAM and engineering areas is used. Langran (1993) and many other geo-scientists describe the processes of two dimensional spaces along a third temporal dimension. This data model is similar to the boundary representation mode in a GIS.

A common model of spatio-temporality is a snapshot sequence of time slices. The nature of each time slice for spatial changes is described by Peuquet and Wentz (1994) describing maps as sequential snapshots in the form of vector and raster. To overcome the drawbacks of the snapshot model, the vector update model is best implemented using current GIS software technology. Feature updates are added to the base state layer, with the old versions of any modified features moved into an archive layer. This model has been used for a cadastral database developed by Hunter and Williamson (1990). Peuquet and Duan (1995) propose a new raster-based event-oriented approach called the Event-oriented Spatio-Temporal Data Model (ESTDM) based upon GRASS GIS and suggest the Tempest model.

Worboys (1995), Claramunt and Theriault (1995), and Yuan (1996) examine TGIS and spatio-temporal DBMS based on object-oriented approach. Harme (1995) argues the associations of on object-oriented spatio-temporal datasets dealing with integrations of locational, temporal and thematic attribute. Wachowicz (1999) proposes an object-oriented data model for TGIS using Smallworld GIS and develops the spatio-temporal data model based on time geography and object-orientation. Hunter and Williamson (1990) clearly indicate the importance of preserving historical data in GISs. Al-Taha (1992) describes temporal issues for cadastral systems based on an Entity-Relationship model to explain temporal reasoning and formalism in deed recording system. Arcieri et al. (1999) present a nation-wide of the Web-based cadastral information system operating on spatio-temporal DBMS. Highlighting the importance of historical cadastral mapping, mapping agency and concerned governments traditionally need to know who occupies lands, and what and where historical changes to cadastral data are occurred through time. However, there might be few efforts to delineate the essences of temporal cadastre connecting with land management or ownership management that are often focusing on legal and institutional barriers and problems.

3. Temporal wisdoms for land Information

A review of past cadastral records and historical resources allows us to understand the spatio-temporal history of maps. Cadastral maps include the temporal (or historical) attributes in terms of the history of geometric, topographic and legal change. Historical information can be conceived as temporal data of spatial changes in the context of historical states and events. Vrana (1989) examine land information's issues requiring historical and spatial information. Temporal data are transformed into historical information in the process of identifying the status of a parcel in a longer cycle of development. Information on changing land boundaries, land ownerships, natural resources and physical characteristics of a geographic area allow temporal information to support decision making of land use.

On the basis of LIS history, cadastral maps provide a concise and accurate method of both fairly assessing and permanently recording charges on a particular piece of land as a form of fiscal cadastre. The historical analysis of land values and uses enables to forecast spatial and temporal balance of land revenues and equilibrium of land taxation. A fiscal system of cadastre becomes a register that includes a wide list of all land value determinants for every tax parcel, together with maps delineating tax parcel boundaries.

Historical information pertains to the nominal attribute of land ownership and transitional cadastral extent. Historical changes of property (or real estates) ownership may stem from the legal actions of property transfer. Public agencies are often required by law to maintain historical records of land dealings. Even in land surveying and mapping, it is very laborious to constantly update original cadastral map when lacking a permanent over-all record of property boundaries at any given time, except the present. Land records are also kept for a long time and are never deleted or destroyed.

Other systems may periodically destroy old records with guidelines and rules for deleting old versions when cadastral data values are completely fade away along the timelines.However, cadastral systems should keep records no matter how old land records are. Therefore, there are update requirements for existing cadastral map's information that contains temporality coupling to land registers and others (Fig. 1). From the perspective of spatio-temporal processes, it is obvious that geometric changes can be illustrated very clearly with time-stamps in terms of changes of land size and shape, events of land subdivisions and merges, evolution of land boundaries, and underground changes of utilities. Some studies require more details of object's behaviors (or actions) and spatial changes in cadastral systems because changes of ownership and land boundaries including time-related activities and events are major issues in temporal history.

The more complex cadastral map database require the entry of a new geometry for parcel boundaries after lot line adjustments or subdivisions because cadastral events are the smallest spatio-temporal processes, not easily detected until a buyer or seller register's action through the public land registry. In modern times, effective management of publicly owned lands requires a complete and accurate historical inventory of all such estates pertaining to boundaries, areas, land uses, soil types, vegetation types and other parameters. Moreover, modern multi-purpose land information systems including temporal functions are needed to assist in tracing underground natural resources and utilities that should take into

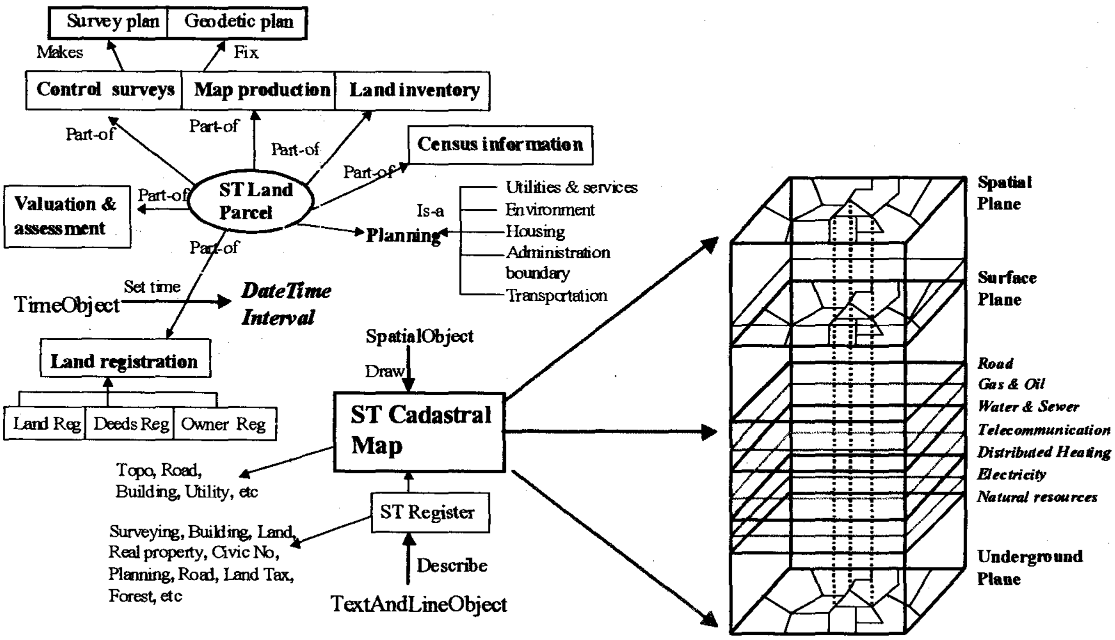


Fig. 1. Application of spatio-temporal land parcel

consideration geographical history of residential areas and historical sites for preservation.

3.1 Modeling temporal cadastre in cadastral map's evolution

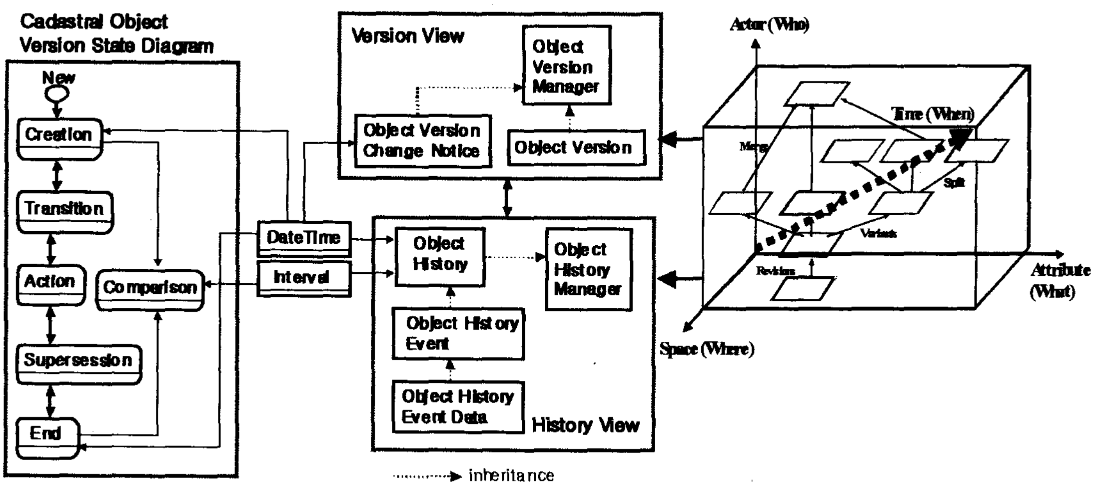
The temporal history of an object is an order between the different versions of that object reflecting the creation time order of the versions. This evolution leads to historical object versions along time dimensions that do have timestamps, allowing the building of a linear temporal history. Persistent object version allows users to update, insert and delete an object at the same logical time, to create a new object version. Although version control might not be considered to be a mandatory feature of object-oriented cadastral databases, it has often been associated with the problems of cadastral changes through time. Multi-version timestamp orderings within databases (Medeiros and Jomier, 1994) are also very significant aspects in history management system. Object version appears as a useful tool to implement temporal dimensions in databases (Doucet et al., 1996) and is considered to be an essential mechanism for design (e.g. planning and engineering) and database application.

The simplest kind of object versioning is to preserve object state histories based on retaining information on all past states of objects. An object-oriented model is able to encapsulate the notion of time in class. An object-oriented database system supports the creation and manipulation of objects with versions. Temporal persistent object helps to maintain current objects and historical objects that are generically referred to as version sets (Suzuki and Kitagawa, 1996). Although several temporal models based on object and schema versioning approaches have been discussed and compared, and a few universal standards for data exchange (SAIF, 1994; ISO/TC211, 1996) show how time is semantically incorporated into a geographic data model, there still might need more efforts to tightly fuse spatial version histories into temporal models. Particularly, there are few dominant models to apply their concepts to historical informations on cadastre and cadastral map that pertains to enormous spatio-temporal processes and their attributes. In terms of temporal history, the significance of temporal validity of cadastre is associated with individual property that an object has its own characteristics as temporal attributes (or data values) related to the temporal behavior of cadastral objects. Temporal dimensions can be defined at the object level or at the attribute level or at both levels. Most of them would choose a discrete model of time. Span (or durations), intervals and instants are the basic data types that can be manipulated through temporal operations (Fauvet et al., 1997). In engineering aspects of version model, there are several object version models that would only deal with the issues of version object. Being different from temporal object version, spatio-temporal processes consist of many activities and events associated with each object's evolution and the values of each spatial, thematic and temporal attribute. A generic change of spatial object version model might not be yet developed (Claramunt et al., 1997).

Here, we propose the temporal cadastral object model (TCOM) that enables to trace the footpaths of historical version at the cadastral object level (Fig. 2).

By identifying the historical evolution's process of cadastral version, the mutation of cadastral object version can be described by object version state diagram. When users start to split, merge, delete and insert an object version, comparison step enables to identify interval difference of object version between the creation and end, and then the dead object version is sent to historical database. The version manager is in charge of the creation and maintenance of the version and end of object version through object version change notice. It also receives some message about temporal disparities of object version from valid time (VT) and transaction time (TT) time-stamps. In the process of evolution of object version, the version manager does not determine the termination of object version's validity until the history manager gets a message from the Interval. The version manager provides object version with version-stamp and identifier and keeps it in database.

From the perspective of an object history, it keeps the occurrence of an event in time. An object history event provides an occurrence of an event in time. An object history event data is the data generated during a specific history event. The object history manager interacts with the object version manager when temporal value of each object version is terminated. Each object version may have its temporal value associated with historical event data. With the help of the version manager, the history manager puts a dead object version into



	OID	Name	VT (start, end)	TT (start, end)	Version-stamp	Actorname	Rolename	Historical index
Process Activity Event								

Fig. 2. Temporal cadastral object history in state diagram

historical storage index. However, it may be difficult to make a clear difference between the role of history view and the task of version view. The history manager receives object version from the version manager and provides them with the transaction time. We postulate that the history index manages the spatio-temporal relationship between current object and historical objects. The majority of history index stores a record of format concerned with current ID of object and historical ID of object, and start time and end time in the form of the snapshot. Although Langran (1993) describes spatio-temporal data in a three-dimensional phase space (2D and time) and focuses on time-related versioning and a selection of spatio-temporal query, there might be, however, few indications how spatial object version can be developed over time.

Like many spatio-temporal data models, our conceptual idea might have shortcomings of data duplication between two spatio-temporal versions. To overcome existing drawbacks of data model, object version model may enable to keep spatio-temporal consistency without any replication. More details of version managements might be beyond the scope of this study. Cadastral mapping processes range from existing survey laws and regulations to productions of cadastral maps. In this process, it is often recognized that temporal requirements should be considered when a significant change of projects occurs at departmental level or central level of mapping agencies. Hence, negligence in the historical recording of land related activities on the grounds of emphasizing current information, may give rise to the absence of need for temporal LIS. Cadastral data management that is concerned with land transfers, split and merge of land parcel, and new creation of cadastre, etc is a major concern of temporal cadastre and its application under the umbrella of land information management.

4. Proof-of-concept implementations

As the proof-of-concept for temporal cadastre, we conceptually depict the TCOM model in the context of temporal GIS. Principally, it describes feasibility of spatio-temporal operations for concerned queries of cadastral transactions in land information system. A full-scale expansion of spatio-temporal processes to an integrated TGIS could be a large-scale project when considering a wide range of different functions of GIS softwares towards 2D/3D with time. In fact, a spatio-temporal class is designed to include spatial data, temporal data, attribute data and their behaviors. There are two ways to links temporal data to cadastral data. One is a combination of attribute between time and cadastre at the attribute level. The other couples temporal object and cadastral object. In the case of attributive coupling (left), it provides valid and transaction time for cadastral attribute of transaction. At the object level, cadastral object inherits from temporal object or class (right) (Lee et al., 1999).

Although this expression of coupling could not fully describe overall spatio-temporal changes, it illustrates a major principle of

```
Structure Valid Time_Owner
{
    String Name;
    Valid_time vt;
    Transaction_time tt;
};

Class Cadastre
{
    String land surveyor;
    VT_Owner owner;
    String cadastral address;
};
```

```
Cadastre
-----------------------------
Cadastral object id: object
Owner name: string
Parcel address: string
Parcel number: int
Parcel land use; string
-----------------------------
Get owner(): string
Getarea(): real
```

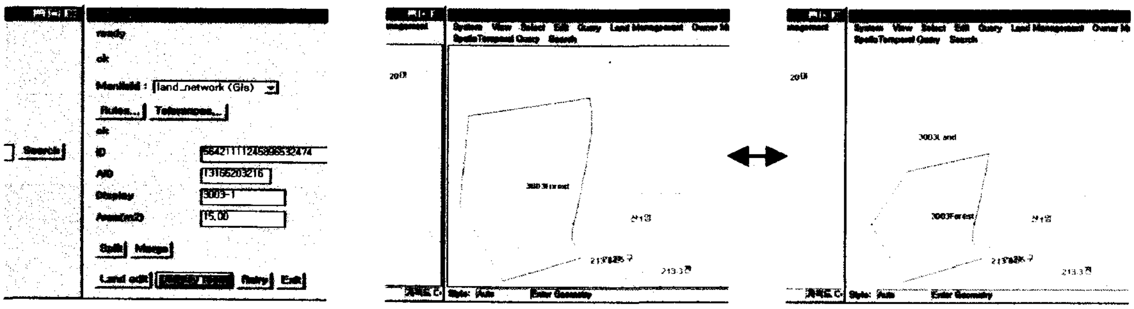
←

```
Bitemporal
-----------------------------
VT: interval
TT: interval
Predecessor: Set<t>
Successor:Set<t>
-----------------------------
Get_valid(): interval
Get_transaction(): interval
```

combinations of two different way applied to cadastral object history management. It also requires various spatio-temporal operators, but needs a lot of algorithms to support spatio-temporal changes. Much focus on description of algorithms of spatio-temporal changes is beyond the scope of our aims of research. Many spatio-temporal operators should be used for available to land transfer and history management. But this section only shows operation of parcel split and merge in the context of land transfers. To explain a conceptual idea of temporal cadastral object model, we take a look at a simplified evolution of cadastral object. A special Editor (Fig. 3A) is used to directly describe some changes of spatial attributes.

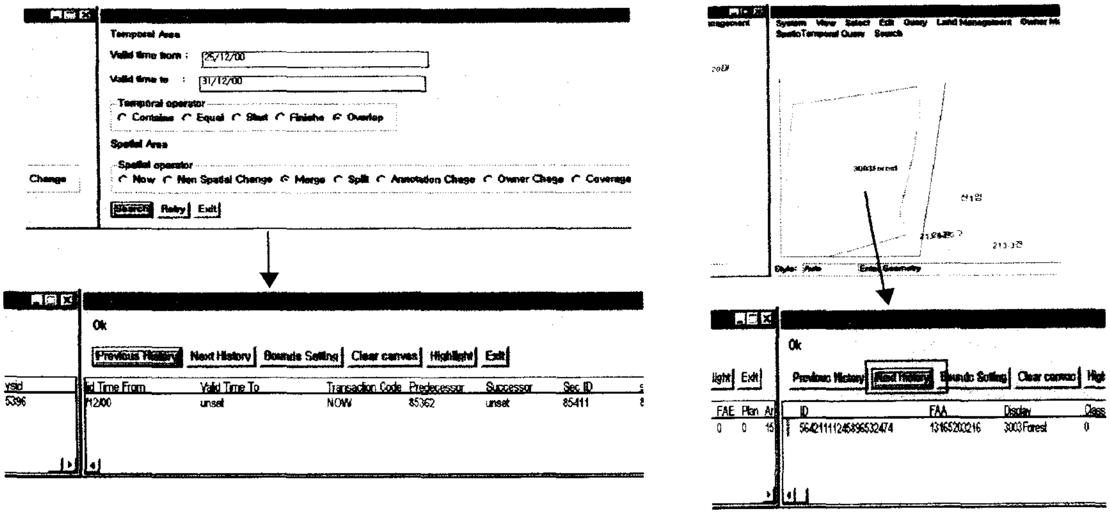
Fig. 3B illustrates presentation of cadastral parcel's split and shows split (before) and split (after) in a given time. A cadastral parcel (forest) is divided into two small parcels of versioned object as a land and forest. Through the Editor, it also illustrates a case of parcel's merge (before, after). Up to this point, temporal operations ascertain that the boundary of cadastral object is precisely separated. They are also closely related with spatial operations (e.g. disjoint, union, etc) extensively proposed by the OpenGIS (1999). Therefore, it definitely requires the best choice of spatio-temporal operators to search for enormous versions of cadastral object when the resolutions of geometric attributes and temporalities are very incremental.

In terms of spatio-temporal query for



A) Split/Merge Editor B) Cadastral evolution

Fig. 3. Execution of the evolution of cadastral object



A)Main menu for query and result B) Query of cadastral history

Fig. 4. Execution of spatio-temporal query for cadastral history

historical object of cadastre, temporal query languages have been developed as users interface through manipulating and querying temporal databases. Interval-based representations of objects with regard to spatial and/or temporal aspects are employed by many geo-scientists. Fig. 4A explains the results of spatio-temporal query for cadastral merge between 25/12/2000 and 31/12/2000 based on the concept of predecessor and successor. Fig. 4B shows how spatio-temporal operators can trace cadastral history. With the help of the function of prehistory and next history, it depicts image of cadastral split (or merge) with attributes of cadastral object between two versions. Obviously, there are several efforts to obtain this image, but we only explicate a major task and result of spatio-temporal operations. Considering many cases of geo-processing applications, well-defined spatio-temporal operators are required to explicate the diverse changes of spatial data and its attributes.

5. Conclusions

Conventional cadastral data can be viewed as snapshot map's information representing the state of transactions with the history of object of cadastral time. Although many different domains of land information system put an emphasis on the importance of historical information in a database or information system environment, outdated information representing past states might not be persistent. In cadastral systems, historical changes of land parcel may stem from legal actions of property or real estate's transfers through transactions based on conveying rights from one legal person to another leading to geometric changes to cadastral objects. Physical changes of land size and shape, events of land subdivisions and merges, and evolutions of land boundaries are major issues in a temporal cadastre. On the basis of temporal object version in the context of a cadastral map's information, it provides version models and mechanisms for change management of different cadastral versions of object. Even though many spatio-temporal data models have articulated the essences of spatial change over time, there are very few manifest approaches as to what cadastral model of temporal object version looks like. One major accomplishment of this research is that the TCOM provides an important framework for change histories of cadastral evolutions with an extended version mechanism that is composed of the version view and the historical view with change management of version tables. This research also proposes a solution for the management of time-varying data evolution in LIS in terms of spatio-temporal operations for query of cadastral history. As a feasible outcome of spatiao-temporal application in LIS, it could pave the way for the history management that is required for cadastral administration and efficient services for keeping tracks of cadastral pasts.

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