Event-based Specification for Controlling Spatio-temporal Changes of Geographic situation

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Abstract

In this paper, we propose a data model to manage dynamic aspects of geographic information. In our model, a geographic change is represented as an event. Three relations are defined on events: they are is-a relation, part-of relation, and event-driven relation. We implemented a prototype system, and confirmed that our model is adaptable to searching dynamic aspects of geographic information based on real world phenomena.

1 Introduction

Recently, geographic information systems (GISs) are used in various fields such as economics and city administration, etc., and takes an important role for our lives. In these fields, a GIS is used to obtain statistics of an application domain quantitatively. Traditional researches on GIS only focus on version history of spatial objects [1],[3],[7],[6]. In other words, they manage only local changes of geographic information. However, many occurrences of local change are caused by real world phenomena such as typhoons, earthquakes and so on. Therefore, if a GIS can manage semantic relation between local changes as global changes, it may become more useful in various application domains.

There are a few researches on management of global changes of geographic information. In [4], Peuquet et.al proposed an event-based spatio-temporal data model (ESTDM). In ESTDM, an event represents a point on time-axis where changes of spatial object are occurred. Chen et.al defined an event as decision-making action of human, and proposed event-based spatio-temporal database model which represent three relations: deterministic relation between events, relation between an event and a state of space, and causal relation between states of space [2]. In addition, their model can represent hierarchical structures as aggregation links between events and sub-events. However, above two researches cannot represent plural events occurring at same space-time, because targeted geographic information is expressed based on snapshot model. In [5], an event is defined as an external factor of changing spatial objects. Their objective is to reconstruct dynamic changes of spatial objects by using events and observation data. However, it was not mentioned clearly that how events should be managed and have relations mutually.

In this paper, we propose a data model for spatial changes in generic geographic information. This paper is organized as follows. In Section 2, we shows a framework of our data model. In Section 3, we present a prototype system based on our model. Then we discuss characteristics and mechanism of our system. Finally in Section 4, we describe conclusion of this paper and future works.

2 Data Model

In our model, an event is defined as a thing that causes one or many changes of geographic information. All events are related to changes of spatial object. In addition, in order to represent phenomena in the real world, we introduce three relations as follows.

- Is-a relations on event concepts,
- Part-of relations on events, and
- causal relations on events.

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The Is-a relation represents different aspects of a single event. For example, an event "*typhoon*" can be treated as not only a "*storm wind*", but also a "*disaster*". The Part-of relation represents an composite structure. For example, an event "*typhoon*" is consists of a event "*downpour*". The causal relation represents a causal affection among events. For instance, an event "*downpour*" may cause "*flooding*". In our model, all of various phenomena in the real world can be represented by using above three relations.

An event causes changes of spatial objects such as destruction of premises, consolidation of municipalities and so on. Firstly we introduce a spatio-temporal object, which is primitive unite for modeling dynamic aspects of a spatial object. Then we introduce events and their relations. An overview of structure of our model is presented in Figure. 1.

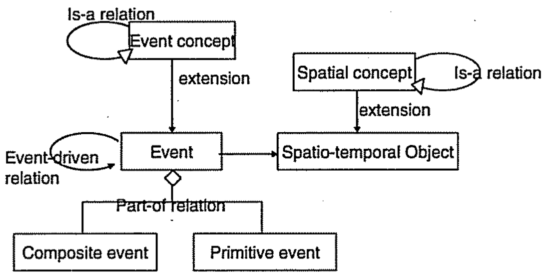

Figure 1. Framework of the model.

2.1 Spatial Concept and Spatio-temporal Object

A spatial concept is an object that can be identified on a geographic space. A spatial concept may change its properties during its lifespan. An invariable state of a spatial concept is represented as a spatio-temporal object. A spatio-temporal object is described as follows.

$$o_{ST} = (id_{ST}, id_S, ot, et, AT) \quad (1)$$

Here, id_{ST} is the identifier of O_{ST}. id_S is the identifier of the spatial concept that o_{ST} represents. ot and et represent the onset time and the termination time respectively. AT is a set of attributes. If there are n attributes, AT is formalized as $AT = (at_i | i = 1, \ldots, n)$, and if each at_i has m records, at_i is formalized as $at_i = \{at_{ij} | j = 1, \ldots, m\}$. Figure 2 shows an example of state transitions of a building. The lifespan of this building is from t_0 to t_4. Its state changes at t_1, t_2 and t_3. Table 1 shows specification of the spatio-temporal objects that represents the states of the building.

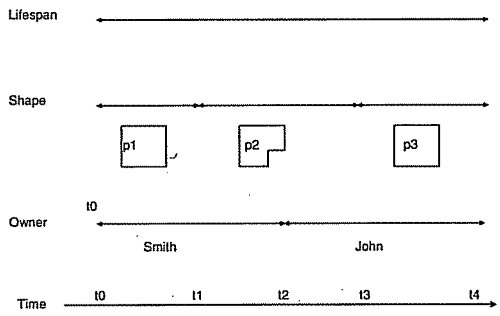

Figure 2. Example of state transitions of a spatial object

Table 1. Example of spatio-temporal object.

id_{ST}	id_S	ot	et	$polygon$	$owner$
$\#1_{ST}$	$\#1_S$	t_0	t_1	$p1$	$Smith$
$\#2_{ST}$	$\#1_S$	t_1	t_2	$p2$	$Smith$
$\#3_{ST}$	$\#1_S$	t_2	t_3	$p2$	$John$
$\#4_{ST}$	$\#1_S$	t_3	t_4	$p3$	$John$

2.2 Primitive Event

The most minute geographic change is a generation of spatio-temporal object. This is an atomic component of the event, and defined as a primitive event. The primitive event shows that which spatio-temporal object is generated. The primitive event pe is represented as follows.

$$pe = (id_{pe}, id_{ST}) \quad (2)$$

pe is the identifier of the primitive event. id_{ST} is the identifier of the generated spatio-temporal object. For example, when a spatial concept $\#1_S$ managed as table1 transits from $\#1_{ST}$ to $\#2_{ST}$, the primitive event is described as $(\#1_{pe}, \#2_{ST})$.

2.3 Concept Hierarchy of Event: Is-a Relation

A concept hierarchy is introduced in order to treat an event from varied viewpoints. An event can be treated from diverse viewpoints. For instance, an event "*typhoon*" can be treated as not only "*disaster*" but also "*storm wind*". It is assumed that all the event instances have corresponding event concepts. That is,

$$(\forall ev)(\exists c)[ev \in EVI \wedge c \in EVC \wedge ev \in Ext(c)]. \quad (3)$$

Here, EVC is a set of event concepts and EVI is a set of event instances. EXT is a mapping function from EVC to

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EVI. We define a binary relation $\leq_E$ for $c_1, c_2 \in EVC$.

$$if\ Ext(c_1) \subseteq Ext(c_2)\ then\ c_1 \leq_E c_2 \quad (4)$$

This relation represent Is-a relation between concept c_1 and concept c_2. This binary relation is order relation. $(EVC, \leq_E)$ has hierarchical structure. This structure is named as a concept hierarchy. For example of disaster events, a set of disaster concepts such as table 2 constructs the concept hierarchy in Figure 3.

Table 2. Example of events concept

event concept	intension	extension
event	a phenomenon which changes spatial information	all the event instances
disaster	a phenomenon which is a natural or man-made event that negatively affects life, property, livelihood or industry	the Chuetsu Earthquake the first typhoon in 2004 the Great Hanshin Earthquake the Nada fire disaster in the Great Hanshin Earthquake the downpour in Ikenuma, Hokuriku the downpour in Kochi
fire disaster	a disaster caused by fire.	the Nada fire disaster in the Great Hanshin Earthquake
downpour	a disaster caused by excessive rainfall	the downpour in Ikenuma, Hokuriku the downpour in Kochi
storm wind	a disaster caused by high wind	the first typhoon in 2004
typhoon	a disaster which is a kind of tropical depression without the front	the first typhoon in 2004
earthquake	a disaster caused by trembling or a shaking movement of the Earth's surface.	the Great Hanshin Earthquake the Chuetsu Earthquake

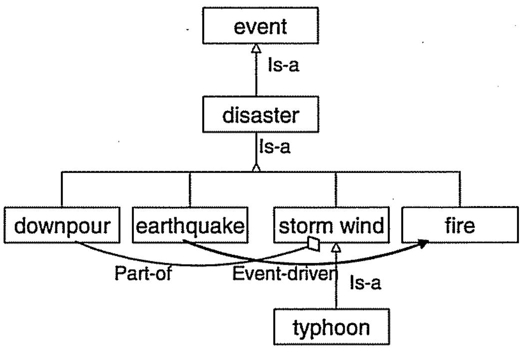

Figure 3. Example of event concept hierarchy

2.4 Composite Event: Part-of Relation

A composite event has attributes and its components(sub-events). Sub-events of a composite event are structured hierarchically. Therefore, the event instance represents not only contents but also inclusion relation between events. This inclusion relation is defined as Part-of relation. An composite event is represented as follows.

$$ev = (ARG, EV)$$
$$EV = \{ev_1, \ldots, ev_n\} \quad (5)$$

ARG is a set of attributes of ev. EV is a components of the event. An element of the components ev_i is a primitive event or another composite event. Figure 4 shows the part-of hierarchy of event "*typhoon*". Attributes of the event "*typhoon*" is described as $ARG_{typhoon}$, and its components are a set of primitive event and the event "*downpour*". In addition, event "*downpour*" has a set of attribute $ARG_{downpour}$ and its components.

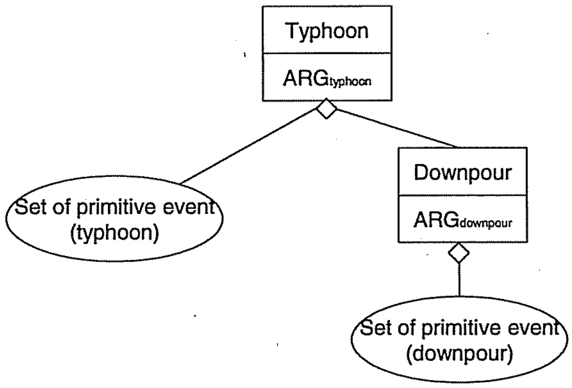

Figure 4. Hierarchical structure of event instance

2.5 Event Driven Relation: Causal relation

An event-driven relation represents causal relation between events. If event ev_1 causes event ev_2, event-driven relation is specified between ev_1 and ev_2. This relation is binary relation, and described as follows.

$$cr = (ev, ev') \quad (6)$$

ev is a causative event, and ev' is a caused event. For example, if event "*earthquake*" causes event "*tsunami*" disaster, it is described as cr = ("*earthquake*", "*tsunami*").

3 Prototype System

We developed a prototype system based on our model. This system maintains the concept hierarchy of disaster event that is described in 2.3.

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A screen snapshot of the interface is presented in Figure 5. Figure 6 depicts the concept hierarchy of disaster events. When a user clicks an event concept, the instances of the selected event concept are displayed. A sub-events of an event instance can be displayed. In addition, by tracing event driven relation, resulting events can be observed. The function for selecting both interesting event concepts and event instances provides more accuracy representation on the interesting region for GIS users.

Figure 7 shows an example of map view of spatial information. In this figure, changed spatial concepts are shown in the map, and its total number is displayed in upper left according to the selected events. This screen provides spatial aspects and quantitative aspects of geographic changes to a user. This presentation method helps a user to understand the interesting changes in geographic information.

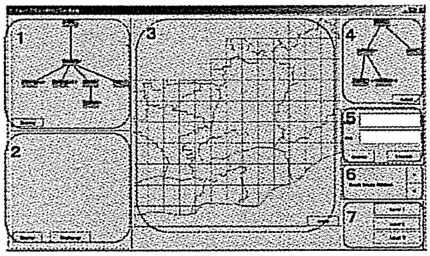

Figure 5. Interface

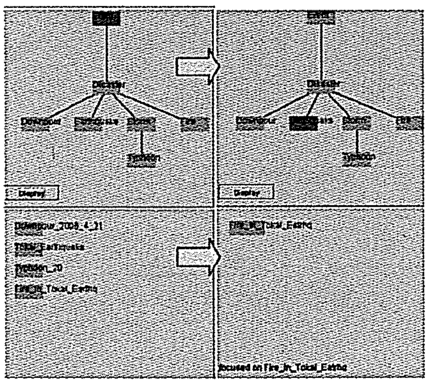

Figure 6. Concept hierarchy and event instances of disaster events

4 Conclusion

In this paper, we proposed a data model to manage change history of geographic information. In our model, conceptual level, inclusion relation, and causal relation

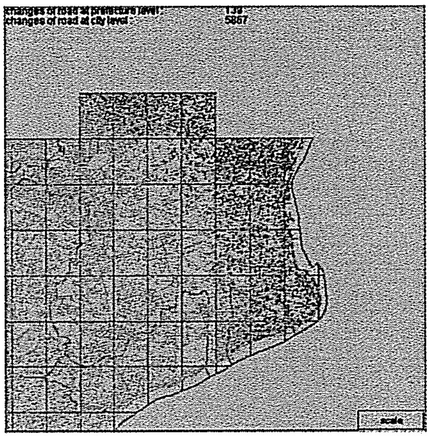

Figure 7. Display changes of spatial concept

among events could be represented. We implemented a prototype system based on our model, and confirmed that our model helped a user to understand change history of geographic information. In future works, we should how and where our model can be useful. Therefore, we plan to implement a practical GIS application.

References

[1] M. Hatayama, H. Matsuno, S. Kakumoto, and H. Kameda. Development of spatial temporal information system dimsis. *Theory and Applications of GIS*, 7(2):25–33, 1999.

[2] J. JIANG and J. CHEN. Event-based spatio-temporal database design. In *International Journal of Geographical Information Systems*, volume 32/4, pages 105–109, Germany, 1998.

[3] Y. Negishi and Y. Osawa. A spatio-temporal geographic information system based on implicit topology description: Stims. In *DMGIS2001*, 2001.

[4] D. Peuquet and N. Duan. An event-based spatiotemporal data model (estdm) for temporal analysis of geographical data. *International Journal of Geographical Information Systems*, 9(1):7–24, 1995.

[5] Y. Sekimoto and R. Sibasaki. Conceptual data modeling for dynamic updating of spatio-temporal database. *Theory and Application of GIS*, 8(1):63–73, 2000.

[6] Y. Tao and D. Papadias. Efficient historical r-trees. In *Proceedings of the 13th International Conference on Scientific and Statistical Database Management*, pages 223–232. IEEE Computer Society, 2001.

[7] Y. Tao and D. Papadias. Mv3r-tree: A spatio-temporal access method for timestamp and interval queries. In *The VLDB Journal*, pages 431–440, 2001.

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