Event-based Specification for Managing Change History of Geographic Information

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Summary

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.

Key words:

GIS, Data model,Event

1. Introduction

Recently, geographic information systems (GISs) are used in various fields such as economics and city administration, etc., and take important roles as the social information infrastructure systems. In these fields, a GIS is used to obtain statistics of application domains quantitatively. Traditional researches on GIS only focus on the 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 changes are caused by real world phenomena such as typhoons, earthquakes and so on. Therefore, if a GIS can manage logical relation between local changes as global changes, it may become more useful in various application domains.

There are researches focusing on representation of events. Peuquet et al. proposed an event-based spatio-temporal data model (ESTDM)[4]. In ESTDM, a set of geographic changes at grid-based location for one geographic theme (event) is organized according to temporal axis. With this time-based organization, sequential changes of property values in a location associated with the event are explicitly stored in a GIS database. Chen et al. defined events as decision-making actions of human beings, and proposed another event-based spatio-temporal database model in which three relations are represented: deterministic relation between events, relation between an event and a state of space, and causal relation between states of space [2]. Their model is capable to represent events hierarchically. In these researches, the event is associated to the point on time axis. However, there are some mismatches between human recognition and representations in these researches. We usually can recognize simultaneous events. However, above two researches cannot represent plural events caused at the same time and space, because geographic information is expressed by snapshot model. In [5], an event is defined as an external factor of changing spatial objects. Their objective is to reconstruct the geographic data set by using event information and observation data. However, a reference to relations between events is not deeply mentioned.

In this paper, we propose a data model for representing events in generic geographic information from various aspects. In our approach, it is possible to represent and utilize an event dynamically corresponding to various viewpoints. This paper is organized as follows. In Section 2, we show a framework of our data model. In Section 3, we present a prototype system based on our model. Then we discuss characteristics and mechanisms of our system. Finally in Section 4, we describe conclusions 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 [8]. 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
- event driven relations on events.

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An is-a relation represents different aspects of a single event. For example, a “typhoon” event can be treated as not only a “storm wind” event, but also a “disaster” event. A part-of relation represents a composite structure. For example, a “typhoon” event consists of a “downpour” event. An event driven relation represents a causal affection among events. For instance, a “downpour” event may cause a “flooding” event. 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 object such as destruction of premises, consolidation of municipalities and so on. Firstly we introduce spatio-temporal objects, which are primitive unites 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.

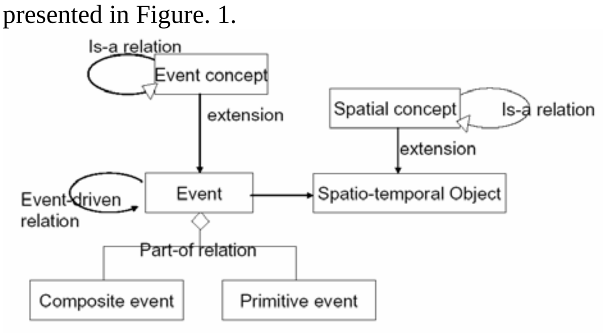

Fig.1 Framework

2.1 Spatial Concept and Spatiotemporal Object

A spatial concept is an object that can be identified on the geographic space. A spatial concept may change its properties during its lifespan. An invariable state of a spatial concept is represented as 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 $AT = (at_1, \ldots, at_n)$. 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.

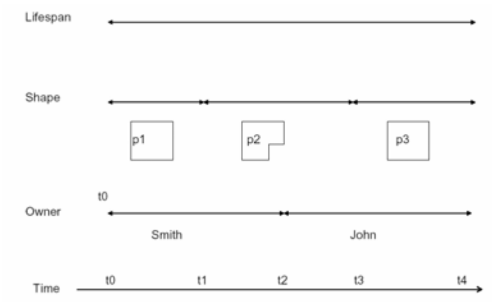

Fig 2. State transitions of spatial concept

Table 1: Margin specifications

***id**ST*	***ids***	ot	et	shape	owner
#1ST	#1S	t0	t1	p1	Smith
#2ST	#1S	t1	t2	p2	Smith
#3ST	#1S	t2	t3	p3	John
#4ST	#1S	t3	t4	p4	John

2.2 Primitive Event

In our approach, the minutest 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.

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

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

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, a “typhoon” event can be treated as a “disaster” event and a “storm wind” event. It is assumed that all the event instances have corresponding event concepts. That is,

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

EVC is a set of event concepts and EVI is a set of event instances. Ext is a mapping function from EVC to EVI, and returns instances of the event concept $c \in EVC$. We define a binary relation $\leq_E$ for $c_1, c_2 \in EVC$.

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

This relation represents is-a relation between c_1 and c_2. This binary relation is an order relation. $(EVC, \leq_E)$ has a 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 such as Figure 3.

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 event instances. This inclusion relation is defined as the part-of relation. A composite event is represented as follows.

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

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

Table 2: Example of events concepts

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 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 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

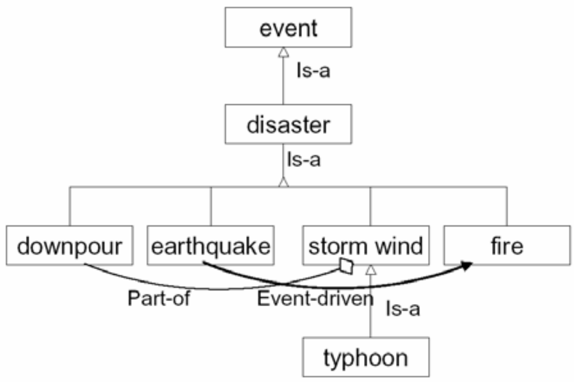

Fig. 3 Example of event concept hierarchy

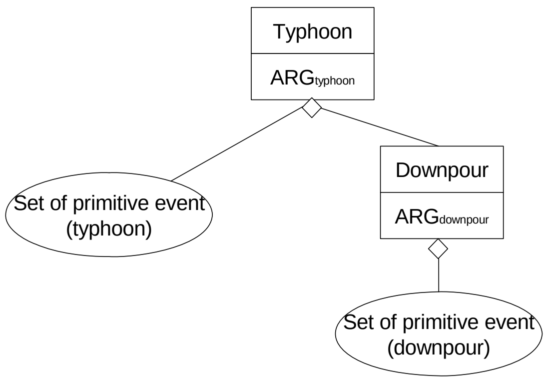

Fig.4 Hierarchical structure of event instance

2.5 Event Driven Relation: Causal Relation

An event driven relation represents a causal relation between event instances. 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.

$$cr = (ev_1, ev_2) \quad (6)$$

ev_1 is a causative event, and ev_2 is a caused event. For example, if an event "earthquake" causes an 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 events that is described in 2.3. 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. 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 interesting event concepts and event instances provides more accuracy representation of changes of geographic information in interesting regions corresponding to the viewpoints of GIS users.

Figure 7 shows an example of a map view of spatial information. In this example, 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.

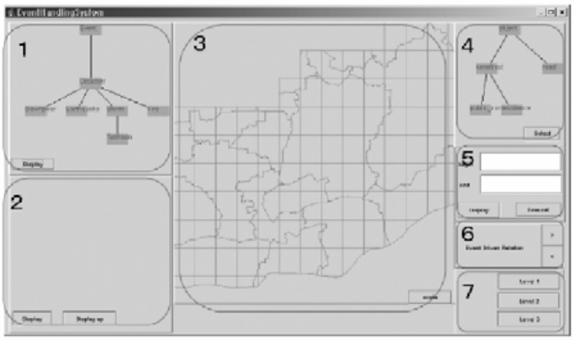

Fig.5 Interface of prototype system

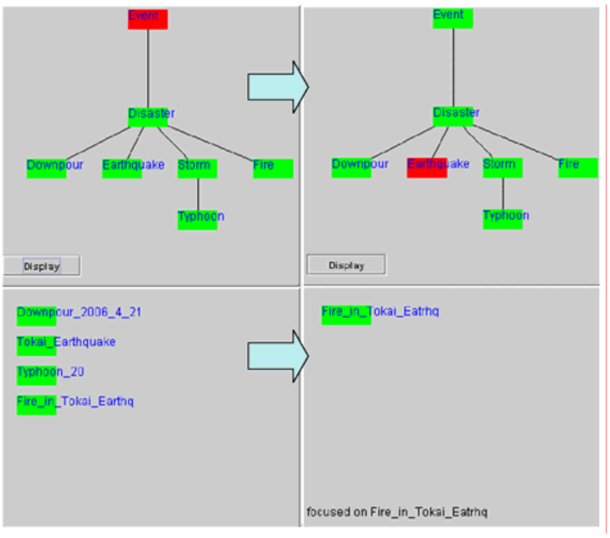

Fig.6 Conceptual hierarchy and event instances of disaster events

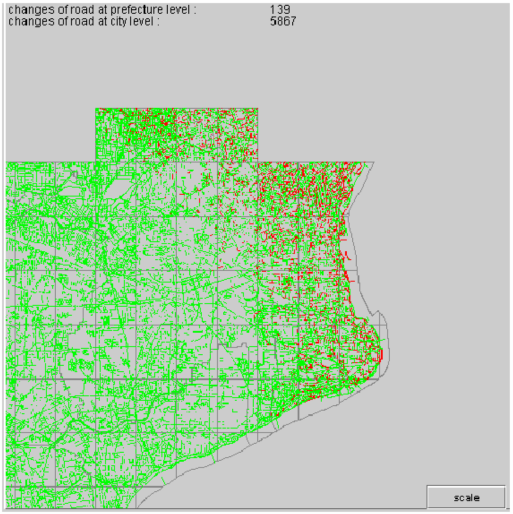

Fig.7 Display spatial concept changed by the event

4. Conclusions

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 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.

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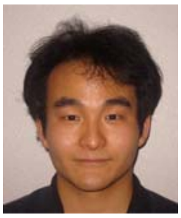

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