An Event-based Spatiotemporal Approach

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ABSTRACT

With the development of temporal GIS (TGIS), users are not satisfied with the traditional static 2-dimensioinal maps any more, for the real-world entities are evolving in both space and time. Many papers have been brought to propose data models and query languages for TGIS applications. However they are not really adapted for the representation of dynamic geographical phenomena. The current concept of version is not suitable for storing continuous entity evolving information. To fulfil this work, this paper discusses the extended concept of version, called dynamic version, for modelling spatiotemporal entity evolution. The new definition of events and processes this paper presented allows for comprehensive decomposition and representation of complex spatiotemporal phenomena. Two application examples of our approach are brought out to discuss how we express temporal relationships among geographical entities and links describing their joint evolution.

Keywords: Dynamic version, Event, Process, Entity evolution

1. INTRODUCTION

Time is an important dimension in the study of TGIS. A TGIS must be able to monitor and analyze successive states of spatial entities, and also be equipped to study dependencies between linked entities [2]. Version is mainly used to represent different entity evolving states, however researchers usually deal version as a static representation. Obviously the evolving information between each two adjacent versions is missed. The problem is how we can find an approach to store enough spatiotemporal information and represent the evolving geographical phenomena. This paper will introduce our basic work. A data schema and its query will be mainly talked in another paper.

This paper is organized as follows. In Section 2, we propose the extended concept of versions. The new definition of events and processes will be discussed in Section 3 and in Section 4 we introduce the basic spatiotemporal processes. Two application examples of our approach are mentioned In Section 5. Section 6 summarizes our work and presents conclusions.

2. THE CONCEPT OF VERSIONS

2.1 The Current Concept of Versions

Understanding temporal behaviour is one of the most fundamental issues in spatiotemporal systems [1]. Version is mainly used to represent different entity evolving states. However most of the researches have been focused on the treatment of discrete changes in spatial entities. Entity changes and events are regarded as at time points. As we know, many changes and events have duration in the real world. With the current concept of version, researchers have to model the nature phenomena discretely and analyze geographical patterns with incomplete information.

According to Cole and King [13], there are tree types of objects in the real world:
1. Objects that are always static need only one version.
2. Objects that are basically static but changed by events need relatively fewer versions which are evolving with duration.
3. Objects that are continuously changing such as moving cars also exist. It is impossible to provide a version at each time point for this kind of objects for the amount of time points is infinite.

As for the latter two types of objects, obviously the current concept of version is not compatible any more. The good understanding of version is the key to remove the stone in our way. As usual we still defined an entity as a real-world abstraction of an existing feature, while 'object' means its database representation. Object versions correspond to successive states of a specific entity. Then what is version? Version must be able to describe the entity evolution. Version means a period of changing or stable state as an instance of a specific entity. A version represents a period of entity evolution. A new version will be created as long as its current state is destroyed, no matter the entity is stable or not during that period. That is our understanding of version. To differentiate this concept between the former one, we call it dynamic version for it cannot only represent timestamps or static state, but also be used to describe entity evolution as well.

The example in figure 1 explains what dynamic version is explicitly. Even though we can describe a

04PSI18: Manuscript received on December 24, 2004 ; revised on June 3, 2005.
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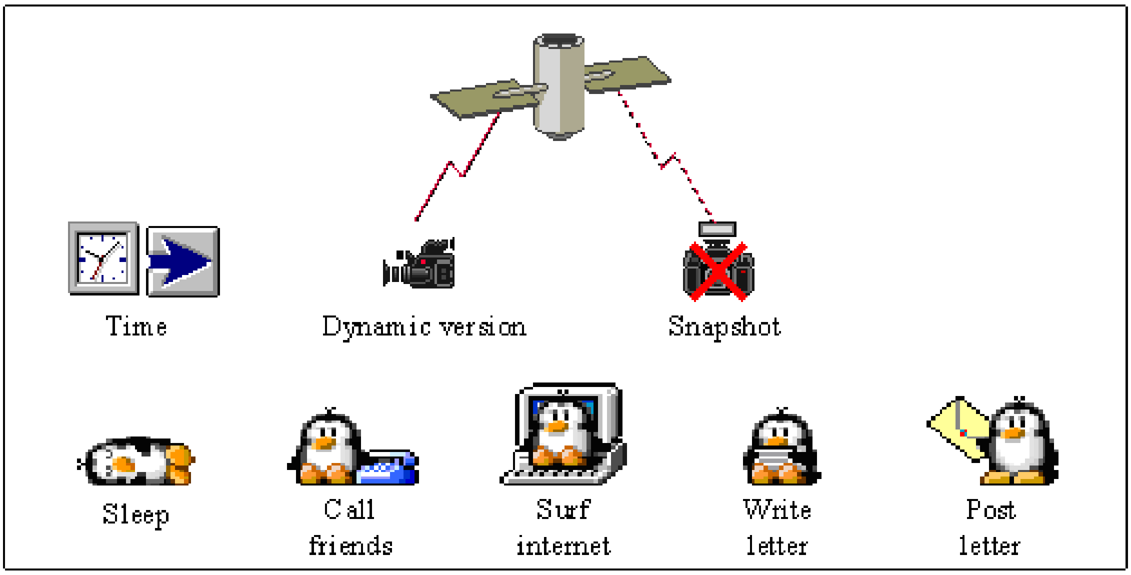

Fig.1: *Example to explain what dynamic version is.*

version by a single action, it does not mean the entity is static during this period. It is a period of entity evolution that the version represents. That is why we call it dynamic version.

Version succession is some like that the acceleration of a moving object is changed. No matter the car is running or not, if only the acceleration is changed, the velocity will change, which means that the current state is destroyed, the car comes into another state, the current version is finished and a new version is produced.

This version succession will no longer be identified completely by events (of course the changes are still caused by events) but directly by the action of objects themselves, which will be explained in detail later.

Version can be represented in database as follows:

Version:

[
VersionID: Long; {Identify each version}
ObjectID: Long; {Ref. to the appropriate object}
ProcessID: Long; {Link to corresponded process}
EventID: Long; {Link to corresponded event}
SpatialInfoID: Long; {Link to spatial information of version}
ThematicInfoID: Long; {Link to thematic information of version}
ValidTime: Date; {Starttime, Endtime}
TransactionTime: Date; {Starttime, Endtime}
]

The advantage of this definition is obvious because:
1. We resolve the former problem that represents entities only in terms of static representations, or as we mentioned that we make it dynamic. It is our first step because our goal is to modelling dynamic geographical world.
2. Notice that it is almost impossible to store all the data at anytime to keep time continuity, we find another way to do that work. Look back to the example in figure 1, since we can describe a singe action with a single word, can not we describe a period of complicated entity evolution with some complicated methods? One version will be born as soon as the former version die, there will be no information lost during this version succession. On the other hand, we abstract the regular information during the period of one singe version to keep time continuity while at the same time we omit some data at anytime to reduce data storage. Philosophers note that there is no absolute best way to do anything, we make this side better at the same time we cost more on the other side. Systematists note that local maximum cannot guarantee the system maximum. Come down to earth, what we want to say is that it is a wise way to keep the maximum information with the minimum data storage, or in a word to keep the equilibrium between them.

Now we have found a container to store consistent data, the next problem in front of us is how to describe entity evolution during the period of this dynamic version.

3. EVENTS AND PROCESSES

3.1 Why to Study on Events and Processes

The GIS application designers defined data model for the efficient storage of spatiotemporal data in a database [5]. Many papers have been brought to propose spatiotemporal data models and query languages, such as the entity relationship (ER) data

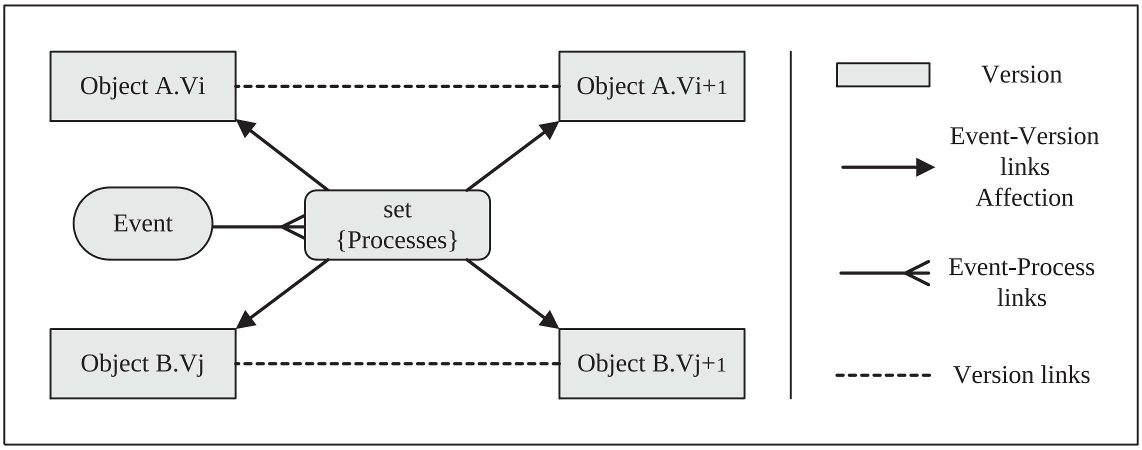

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Fig.2: *How Claramunt describes spatiotemporal phenomena.*

model [29], the object-oriented (OO) data model [26], and spatiotemporal data models with moving objects [19]. All of them can support the complex analysis about entity changes. However, without the storage of events, which affect the real-world entities, it is difficult for them to answer questions like "why" and "how", that is the questions about reasons and evolving processes. Equipping with the events information into a TGIS will improve its power of describing dynamic geographical phenomena. Langran first described an approach to represent the events explicitly in 1992 [9]. Peuquer and Duan extended the idea and implemented the Event Oriented Spatiotemporal Data Model (ESTDM) in 1995 [7]. In addition, Claramunt defined events and processes in 1995 [3]. He also summarized complex spatiotemporal processes based on the Event Pattern Language (Gehani, 1992 [28]) and explained the knowledge that lead to facts, processes and events. Facts reflect the apparent phenomena. Processes go further and model dynamics behind changes in order to understand evolving mechanism and, ultimately discover how changes happen and how entities are related into spatiotemporal interaction networks for they are the bridge to correspond events and entities [3]. As he mentioned, our GIS researchers are not to explain why events happen but to identify significant properties about the transformation mechanisms and to explicitly record relationships among entities involved in real-world processes.

3.2 Claramunt's Approach

Claramunt notes that events are things that happen, they are conditions, and they can be modelled as a set of processes that transform entities. That is:

$$\textit{Event}=\{P1, P2, \ldots, Pi, \ldots, Pn\}$$

Processes are used to describe events and they are parts of events. Claramunt uses the EPL (Event Pattern Language) to describe dynamic geographical phenomena centred by events, while not spatiotemporal entities. Since our research field is GIS, one of the most important works that we should do is to describe entity evolution, but not how events go on. Otherwise we become a history researcher. Claramunt describes spatiotemporal phenomena like this (figure 2).

In the case of figure 3, volcano eruption caused the forest fire, which burned out the forest and resulted in the appearance of the desert. Although the same event happened, to different object, the process was different. With Claramunt's theory, we can get:

Forest fire=
{P1=Disappearance(Forest),
P2=Appearance(Desert)}

The problem is that since the two processes P1 and P2 describe different entities evolution, why to put them together forcibly to describe event? And if we want to know how the entities were going on during that period, shall we have to come back to the study of event? However do not forget that it is the entity evolution that we should concentrate on.

Evidently separating processes from events is better to describe entity evolution. Moreover we will not have to consider the sequence of processes as Claramunt mentioned.

Another problem is that if processes are used to describe events, how shall we identify the version succession? Can events be suitable for that work? Now let us look at another example.

In figure 4 the earthquake happened from t1 and finished at t2, while the building completely collapsed at t3. The new version started at t1 and finished at t3. Obviously it is not the events that identify the version succession. Then what is that?

3.3 Redefinition of Events and Processes

Considering events and processes separately is indispensable. The key is how we shall define events

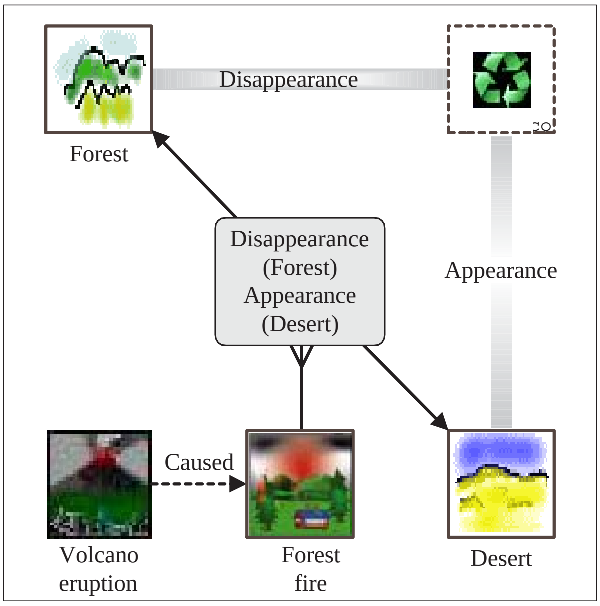

Fig.3: *Forest fire.*

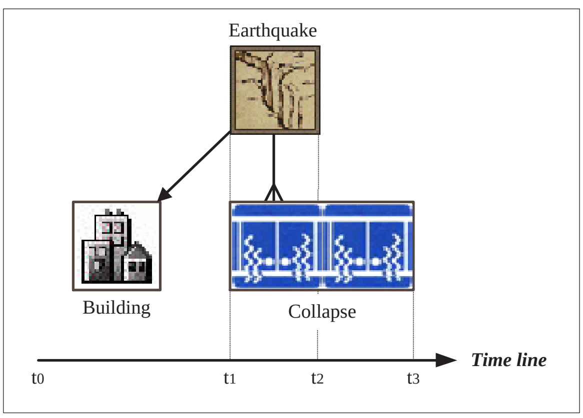

Fig.4: *Earthquake.*

and processes. In this paper we also consider events as things that happen to entities. They are reasons that cause the changes. While processes are the actions of entities during (after) events happen to them, which describe how entities evolve.

Events and processes can be represented in database as follows:

Event:

[

EventID : Long; {Identify each event}

ObjectID : Long; {Ref. to object(s) which is (are) affected by event}

EventInfo : Varchar; {Description about event}

Time : Date; {Starttime, Endtime}

]

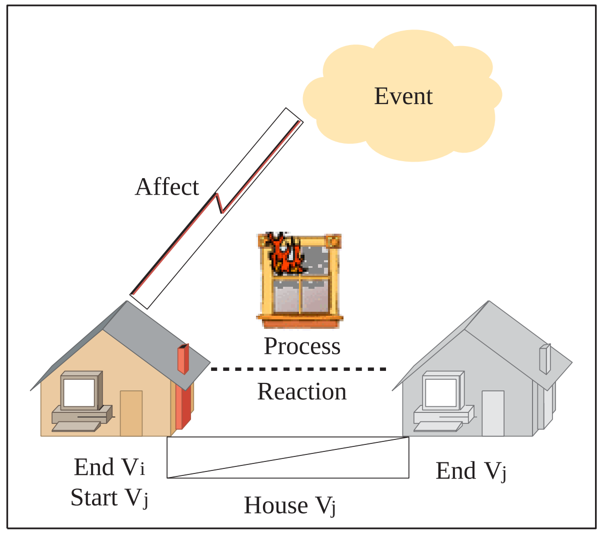

Fig.5: *Relationship among events, processes and entities.*

Process: [

ProcessID : Long; {Identify each process}

ObjectID : Long; {Ref. to the appropriate object}

VersionID : Long; {Ref. to the appropriate version}

ProcessInfo; Varchar; {Description about the process}

Time : Date; {Starttime, Endtime}

]

The relationships among events, processes and entities are given in the following figure 5.

Events affect object version(s), and as the reaction, each version links one or several processes. These processes describe how this specific object evolves during the period of the version. Of course the events information will also be stored for they are the reasons and can answer us why changes happen. The history researchers will be more interested in the details of them.

4. BASCI SPATIOTEMPROAL PROCESSES

Claramunt summarized the complex spatiotemporal processes and also proposed the rules to define new types of processes. He and his members distinguish between evolving and mutating entities to define three main classes of basic spatiotemporal processes [3]:

1. Evolution of a single entity represents basic changes (appearance, disappearance, etc) transformations and movements of that entity.

2. Functional relationships involve spatiotemporal processes between several entities (replacement , diffusion, etc)

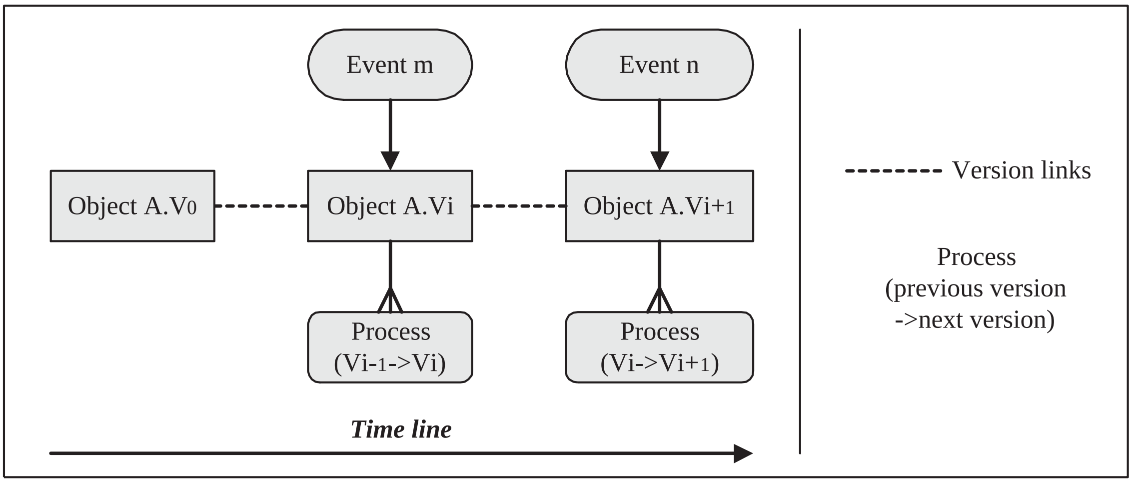

Fig.6: *Syntactic graph of single entity evolution process.*

3. Evolution of spatial structures describes spatiotemporal processes involving several land-based entities (union, split, etc).

However, according to our new definition of events and processes, I have to make some essential alternation.

First, considering the process like union (involves a mix of simultaneous transformation, appearance and disappearance of interrelated entities) of type 3, the process is not limited to land-based study. In the case of object-based study, for example, there were two adjacent buildings A and B. Building A belongs to Corporation A and Building B belongs to Corporation B. Fives year later two corporations became bankrupt for some reasons and the two buildings were bought buy Corporation C, the two buildings were united to one called Building C.

The process union is also suitable in this object-based study example. Then we united the latter two types of processes into one kind of processes, which describe the functional relationships among objects.

Figure 6 and Figure 7 show the syntactic graph of spatiotemporal processes. The main difference between them and Claramunt' figures are that they are centred by object versions, while Claramunt's figures are centred by processes (since processes are parts of events as Claramunt mentioned, we can also say that the figures are centred by events).

Second, because the object temporal relationships must be reflected into the data storage, the parameters of processes have to be changed. The parameters must store the VersionId of one or several object(s) to represent version succession explicitly. With that, process can not only describe a period of entity evolution but also represent the adjacent version relationships of one single object or object relationships among several interrelated objects.

At last, as we have mentioned, processes are linked to object versions. Although event is the same, different objects may act differently and their versions will have different processes. In the above example two object Building A and Building B disappeared, while Building C appeared. Two buildings were united and one building united them. Three objects were involved in this event. They acted differently according to their different position.

An example of spatiotemporal processes is given in Figure 8.

5. APPLICATION EXAMPLES

We have discussed versions, events and processes for so long in order to propose a new approach to represent dynamic geographical phenomena. We wonder how we can apply the approach. Now let us see some application examples.

5.1 Example I

Figure 9 shows the case that one event affected several objects.

The earthquake happened to Object A and Object B at the same time, which caused the splice of Object A and the appearance of Object B. Although the event was the same one, the affected objects acted differently. During the period of one specific object version, we use one or several different processes to describe entity evolution. In addition, the temporal object relationship will also be stored through corresponding processes. For example, if we want to know the father of Object B.V1, we can get the answer easily by the simple description as the processes described, Split(A.V0− >A.V1, B.V1). The father is Object A.V0. Of course we can also know the children of Object A.V0, evidently they are Object A.V1 and Object B.V0.

The flood affected three Object A B C. Object A disappeared before the end of the flood. It is not the events that identify the version succession. Events

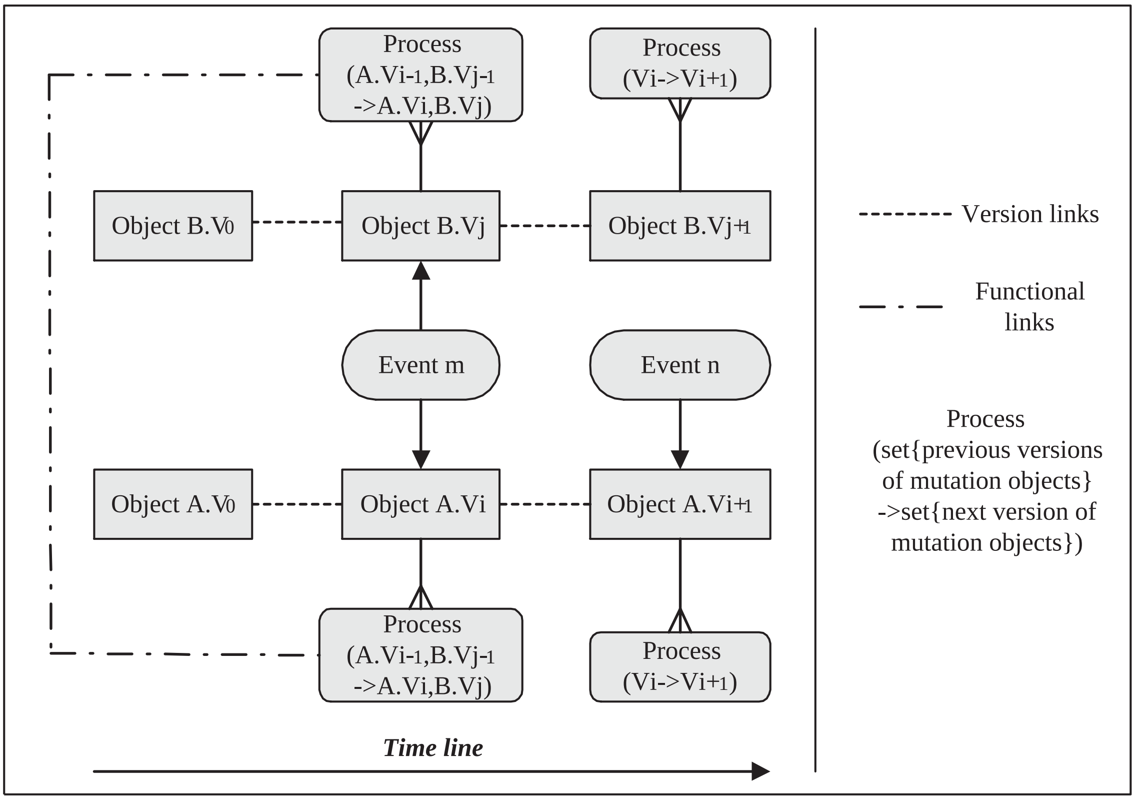

Fig.7: *Syntactic graph of functional process.*

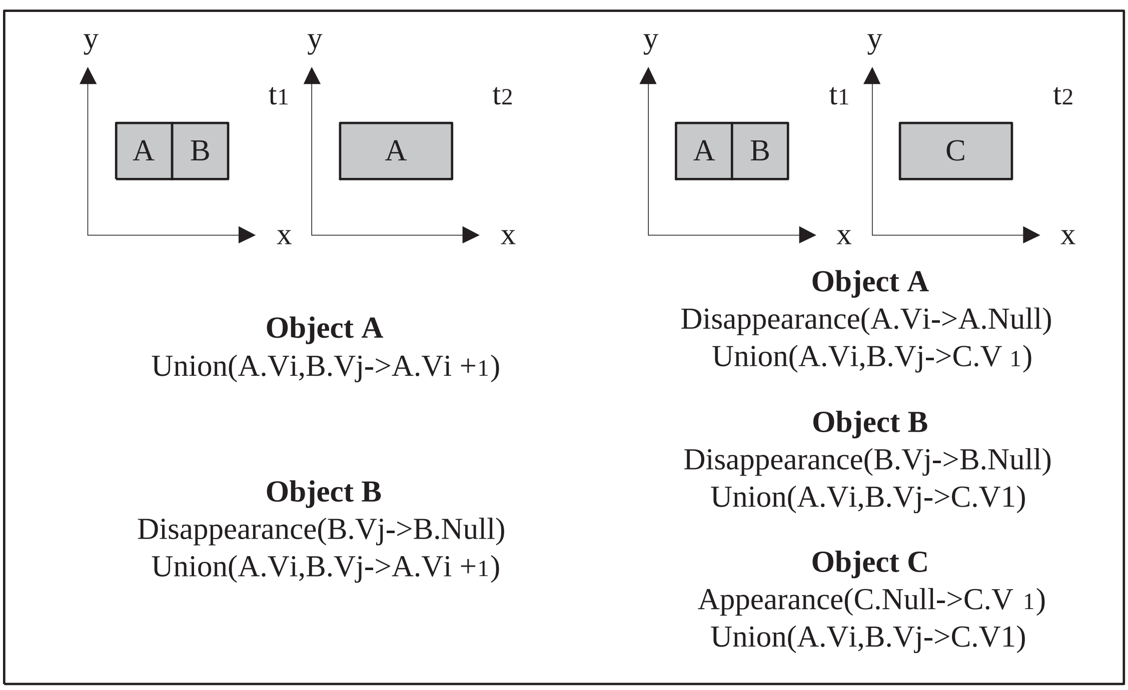

Fig.8: *An example of spatiotemporal processes.*

are the reasons but it is the entities themselves decide their version succession.

Version succession happens at a single time point because as long as the current state is destroyed, a new version will be born to replace the former one. To explain easily, once the acceleration is changed, the velocity will be changed. We never mind whether it is moving or not.

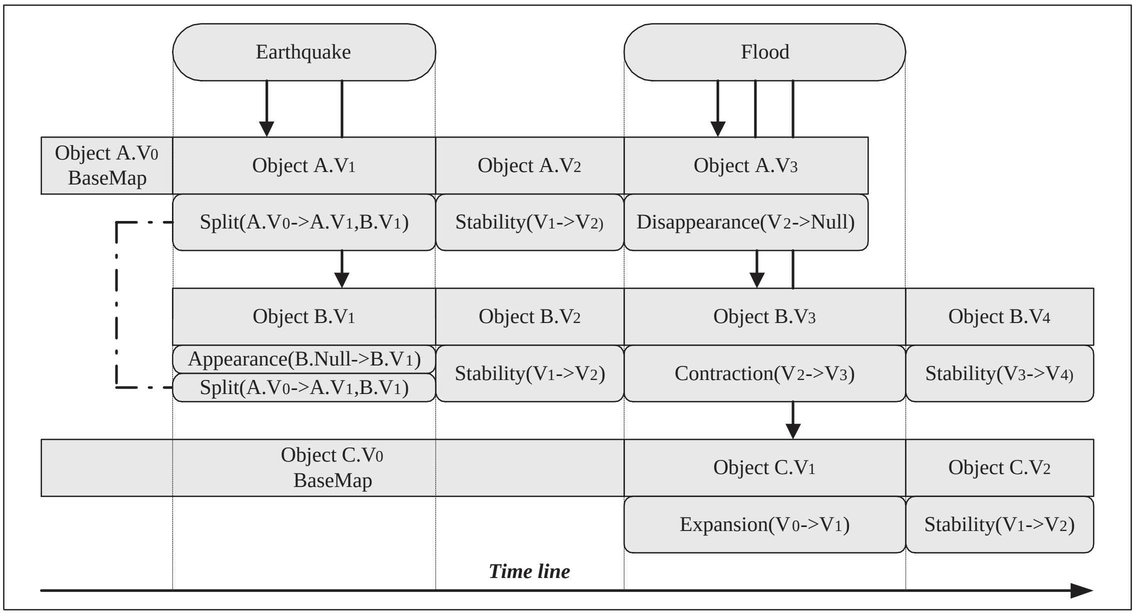

Fig.9: *Events happened to Objects A B C.*

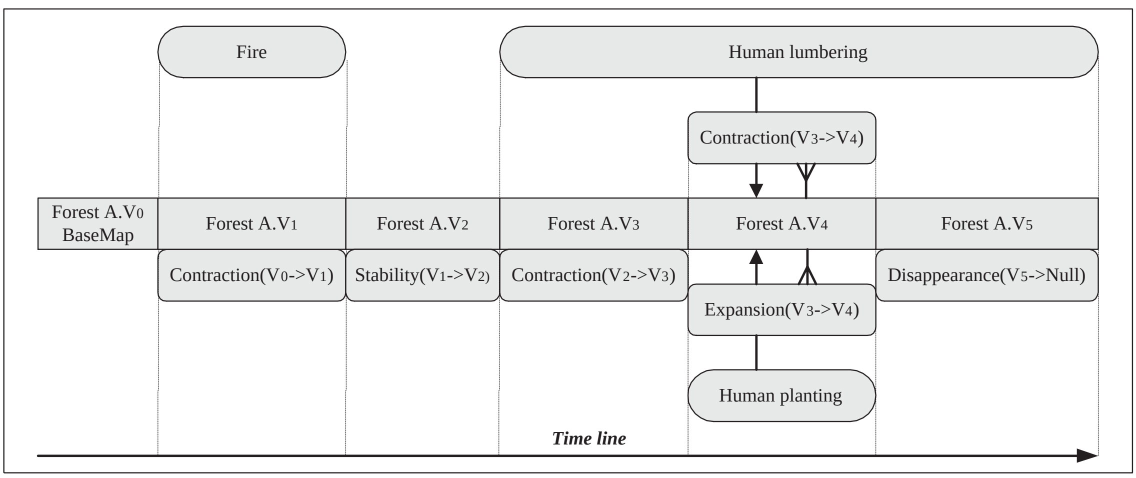

Fig.10: *Events happened to forest A.*

One more word we want to mention here is that version succession is not limited to single object. Most time in the real world, one object may die or be replaced by another object. We also consider these kinds of situation as version succession. It is true we give no definition of version succession, after all, do not forget our rule is that as long as the current state is destroyed. Null can also be regarded as a version for it represents one kind of state.

5.2 Example II

Figure 10 shows the case that several events affected many versions of a single object.

There may be many events and many changes during a period, only essential information will be observed according to different application. For example, a light earthquake happened, which collapsed the cabin in the forest but almost did nothing to the forest. At the same time a forest fire happened at the same area. Foresters would pay attention to the forest destroying while fireman would be more concerned about the fire and human safety. It is not the time to talk about humanism here. One application only cares about or one kind of thing, one layout only represents on theme. It is a common rule of GIS and has almost been accepted by all the GIS researchers.

When several events affect one object, it is essential to identify the different actions of the object caused by the different events. Since the entity evolution is complicated, why not to decompose it into single and independent processes? We mix flour, egg, sugar, butter and milk to make bread. We can make all kinds of bread because we know it is ingredient. Also, we will be able to do all kinds of analysis if we know the basic processes of entity evolution. However we just propose this method, it is beyond our ability to decompose all the spatiotemporal phenomena.

Now let us come back to the example in figure 7. During the period of V4, two events, human lumbering and human planting happened and they all affected the forest. Obviously, human lumbering caused the contraction of the forest while human planting expanded it on the contrary. We present two processes to describe this period of evolution. I think we have finished our work now for researchers to analyze the evolution of the forest, after all it is a piece of cake for a ten years old child to make a simple subtraction if he or she wants to know the acreage of the forest.

6. CONCLUSION

To represent dynamic geographical phenomena is one of the most important goals in the research field of TGIS. The current concept of versions is incapable of efficiently storing information and keeping the time continuity. We extend the concept of version to make it dynamic for the description of entity evolution. Processes link entities and events, and events cause the changes. They are used to describe how entities evolve. Another paper will mainly talk about a data schema and its query based on the approach this paper proposed. Further research perspectives include simulating entity evolution by artificial intelligence, describing spatiotemporal relationships and network analysis.

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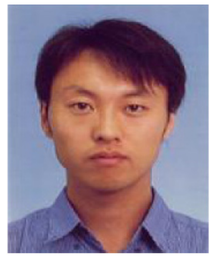

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