Conceptual Model Based on *Change Relation* (*CR*)

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Abstract. This work is focused on modeling of geographic environment, particularly considering changes with respect to the existence of objects in time intervals. Modeling dynamic aspects provide additional semantic that is not considerate from approaches that only are focused in static objects. For example, in a traditional approach for modeling a rain, only are recorded results in each moment that are registered. While in own approach, floods in streets caused by rains and their effects are considered, providing additional semantic that can help to explain variations that exists in successive records. The aim is to develop a model based in "Changes" to describe the object's behavior in a dynamic geographic environment. We introduce *Change Relation* (*CR*) concept as a series of changes, which specify when a change occur by the existence of an event. In this paper, we explain necessary concepts to define the *Change Relations*.

1 Introduction

In the world there are not static objects, but all are dynamic in a certain degree. For decades, the scientific community on geographical information has a great interest in capturing these dynamic objects [14]. Recently, developed approaches have been based in events, where the events become the main component of modeling [22]. The events are abstractions of interconnected phenomena and activities in the real world. These abstractions, however not represent actions and behaviors isolated [2].

The happening of events depends on the fulfillment of certain conditions and involves some consequences in the modeling of world. This independence among events with the complex nature of geographical phenomena imposes additional requirements for the conceptualization of a temporary data model. This model requires more elaborate temporary structures that capture the complexity of geographic happenings as well as a formal representation of relations among such happenings. The inclusion of events in the data model provides a foundation to distinguishing particular semantic of movement based on patterns of events, providing the support to different types of events as well as providing a fundament to developing notification event systems.

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Traditionally, changes in geographic phenomena have been derived from a temporary reference frame. Temporal aspects of GIS have been researched from cartography perspective [14][19], data models [10][17][21], and spatial databases [20][1]. Although to date, no model has been adopted to include time in a GIS.

A more specific approach about changes has considered the associated semantic with the change, as typically founded as part of many spatiotemporal processes including the appearance o disappearance of entities and production or transmission of entities [5][6].

Areas where a model that manage events can be useful in epidemiology, where provide response to changes in distribution of diseases and search for clues in pattern of disease occurrence who can aid in preventing spread of disease. This is an example that describes continuous changes.

The motivation of this work consists of recognizing the phenomena in geographic environment are dynamics, and require models that deal explicitly with the elements of these environments, which mainly are events. In this paper, we research if the dynamic component is performed trough their properties, relations, and involved events.

2 Backgrounds

A common method to capturing changes has been to rely with the sequence of snapshots or discrete samples in sequential moments in time [14][17]. The snapshots approach is a procedure used by cartographers based on animated sequences of maps [7]. Several techniques can be applied, such as playing with sequences of discrete samples at different speeds as pictures in a film, changing the length of a scene to affect the pace of an animation, or alter the order in the scenes presented. Researchers are interested in capturing the complexity of underlying processes, however, are often dissatisfied with the snapshots approach, because this approach ignore the events, each of which occurs separately [4]. Indeed, the changes that occur among snapshots are not explicitly stored; these must be determined by comparing spatial pattern of two successive statements. Another disadvantage is the storage of redundant information [14][18] that occur since the representation of localizations where not occur changes.

Recent works deal the evens as without duration, but not as continuous happenings, which seeks to deal with this problem.

This paper develops an approach based on "*Changes*" to modeling object movement in dynamic geographic domains, such as cars, aircraft, ships, etc. We consider, the "*Change*" as a set of related events, and an event as a unique happening.

3 Methodology

The main question that is done in GIS is Where is it?, then the main aspect is register the movement as a sequence of changes that capture the semantic of dynamism of such entities, such that a domain handler can infer the type of movements and movement patterns that occur. To provide support, such as timely intervention in dynamic domains to generate automatic system to notify warning events.

Dynamic aspects not only involve position change of objects, but also change in other properties. For this reason the *Change* concept is added to the conceptualization to represent if something happening in a time interval. This is a general concept, which is specified according to type of change occurred.

3.1 Spatial Relations in *Change* Concept

To define the changing spatial relations, firstly is needed to define which spatial relations are affected by some change. This variety of spatial relations can be grouped into three different categories:

- Topological relations, which are invariant under geometric transformations [8][9]; for instance, "the street *cross* the railroads" (see Fig. 1).

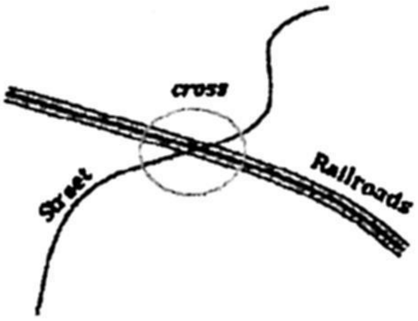

Fig. 1. The street *cross* the railroads.

- Metric relations in terms of distance and directions [16]; for instance, "the hill is just *north*" (see Fig. 2).

Fig. 2. The hill is just *north*.

- Relation concerning to partial or total order of spatial objects [13], as described by prepositions such as *in front of*, *behind of*, *over of*, *before of* [11][3][12]; for instance, "the car is *in front of* the house" (see Fig. 3).

Fig. 3. The car is *in front of* the house.

3.2 Change Relations (*CR*)

A Change Relation (*CR*) is the description of the change to the relations and properties of a geographic object in a state e. This *CR* represents the minimum part in the model. We can collect a set of *CR* to form a history of happenings. This is a chain of *CR*, where the first *CR* is the start point and the last *CR* is the end point in the history of a happening. In Fig. 4, we show the conceptualization of *Change* concept used to represent the *CR*.

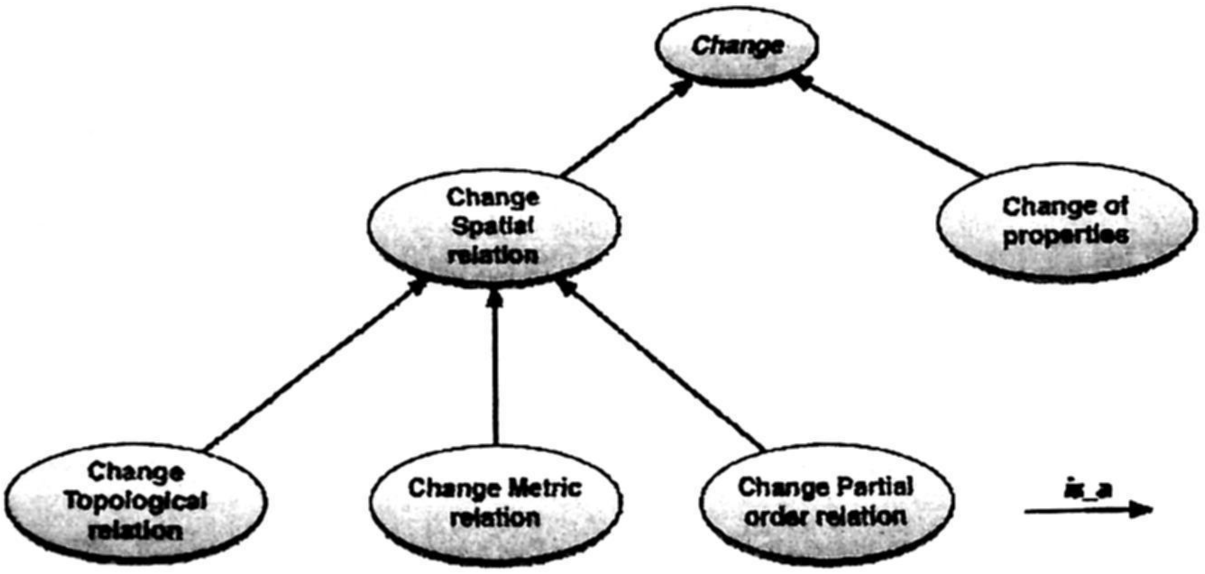

Fig. 4. Conceptualization of *Change* concept.

For instance, Fig. 5 represent the change from one state e_1 to a state e_2, where the object X is inside of object Y. Later in e_2, the object X crosses by the border of object Y. To represent this through chains of CR are as follows:

CR(Obj_X,Obj_Y, e_1)={*Change_CRelSpatial_CRelTopological_Inside => cross by*}

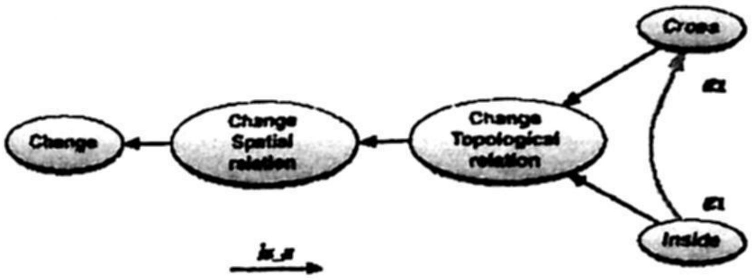

Fig. 5. Change of topological relation.

Where Obj_X is the object which is being compared with respect to Obj_Y. e_2 is the state that caused that the relation between the objects changing.

Changes can occur between a single object or between two or more objects. For the case where change an object property (see Fig. 6), we have:

$$CR\,(\text{Obj\_X,Val\_1}, e_1) = \{\mathit{Change\_CProperty.Prop\text{-}a} \Rightarrow \mathit{Val\_2}\}$$

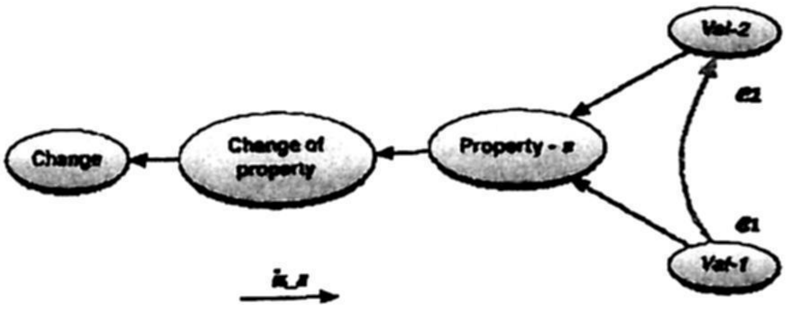

Fig. 6. Change of property value.

Where Obj_X is the object which one more of his properties change in value, and e_1 is the state in which the value changes.

Let's call as e_0 to the start state, for which every geographic object has a position, spatial relation with other geographic objects, and the value of their properties. Then, we can define this with chains of change.

$$CR\,(\text{Obj\_X, Val\_1}, e_0) = \mathit{Prop\text{-}a} \Rightarrow \mathit{Val\_1} \div$$

The CR to state e_0, is used to specify the properties values of the objects and the relation that exist among other geographical objects.

So, for instance, the change of value in a property for the object OBJ_X can be described with CR as:

$$\text{CR}\,(\text{Obj\_X, Val\_1}, e_0) = \mathit{Prop\text{-}a} \Rightarrow \mathit{Val\_1};$$

$$\text{CR}\,(\text{Obj\_X, Val\_1}, e_1) = \mathit{Change\_CProperty.Prop\text{-}a} \Rightarrow \mathit{Val\_2};$$

We can read these CR as: "the property a of the Obj_X *change* from Val_1 to Val_2".

3.3 Intervals

To define an event is necessary to define the moment in this occur, we call this moment as ***interval***. An interval is defined as an element that which are composed by elements that are called ***instants***. An interval has two instants: start instant and final instant, and if the case a set of instants between the start and final instants. This set of instants form the interior of the interval.

An instant is the moment whose dimension is almost zero, therefore it is considered as instant, i.e., has no interior point. An instant is denoted by *i*. Basically, exists two types of intervals.

- Intervals with interior, i.e., there at least an instant between start and final instants. Which are called *continuous intervals* and is denoted as I_c.
- Intervals without interior, i.e., there is no instant between start and final instants. Which are called *instantaneous intervals* and is denoted as I_i.

A continuous interval is defined by instants the i_1 and i_2, where i_1 occur before that i_2, besides that there an instant such that is between both instants:

$$I_c = \{i_1, i_2 \exists i_x \mid i_1 < i_x < i_2\}$$

An instantaneous interval is defined by instants the i_1 and i_2, where both occur at same time, this is, there no other instant between i_1 and i_2.

$$I_i = \{i_1, i_2 \mid i_1 = i_2\}$$

Given these two types of intervals, it is possible to define relations between intervals. First, we define relations between continuous intervals, then, between instantaneous intervals and, finally, between two types of intervals.

3.4 Relations Between Continuous Intervals

The possible relations between continuous intervals are:

- *Equal*
- *EndEqual*
- *BegEqual*
- *Inside*
- *Cover*
- *Disjoint*
- *EndBegin*
- *Overlap*

All these relations are binaries, so it requires two intervals. The first relation is *Equal*. This relation defines the situation that given two intervals; both start and finish at same time. Given the intervals I_{c1} and I_{c2}, defined by i_1, i_2, i_3, i_4 intervals as follow:

$$I_{c1} = \{i_1, i_2 \mid i_1 < i_2\}$$
$$I_{c2} = \{i_3, i_4 \mid i_3 < i_4\}$$

then, we say that these intervals are equals if:

$$i_1 = i_3 \text{ and } i_2 = i_4$$

and we denote this relation as I_{c1} *Equal* I_{c2}, and show them in Fig. 7.

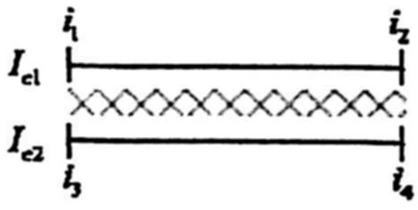

Fig. 7. I_{c1} *Equal* I_{c2}.

The relation *EndEqual* define the situation when two intervals finish at same time, but not at starting. Given the intervals I_{c1} and I_{c2}, we say that both finish at same time if:

$$i_1 < i_3 \text{ and } i_2 = i_4$$

and we denote this relation as I_{c1} *EndEqual* I_{c2}, and show them in Fig. 8.

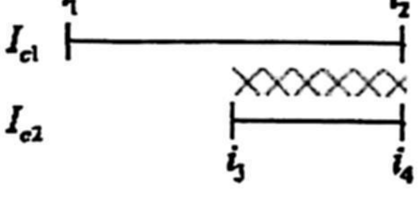

Fig. 8. I_{c1} *EndEqual* I_{c2}.

BegEqual is similar to the above, but in this case, both intervals start at same time and finish at different time. Given the intervals I_{c1} and I_{c2}, we say that both start at same time if:

$$i_1 = i_3 \text{ and } i_2 > i_4$$

and we denote this relation as I_{c1} *BegEqual* I_{c2}, and show them in Fig. 9.

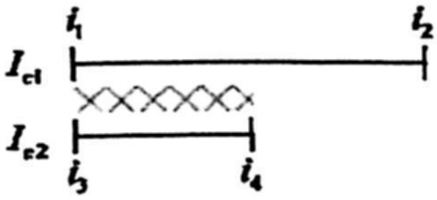

Fig. 9. I_{c1} *BegEqual* I_{c2}.

Next relation is named *Inside* and denote when an interval occur inside while another interval occur. Given the intervals I_{c1} and I_{c2}, we say that both start at same time if:

$$i_1 > i_3 \text{ and } i_2 > i_4$$

and we denote this relation as I_{c1} *Inside* I_{c2}, and show them in Fig. 10.

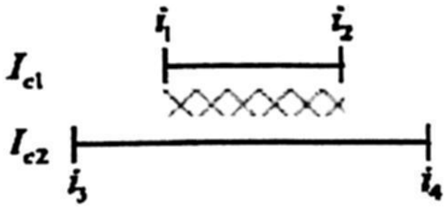

Fig. 10. I_{c1} *Inside* I_{c2}.

Cover relations is dual to the above, i.e. , this relation describe the inverse situation of *Inside*. Given the intervals I_{c1} and I_{c2}, we say that both start at same time if:

$$i_1 < i_3 \text{ and } i_2 > i_4$$

and we denote this relation as I_{c1} *Inside* I_{c2}, and show them in Fig. 10.

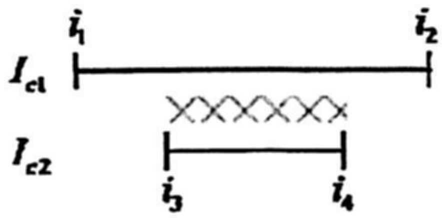

Fig. 11. I_{c1} *Inside* I_{c2}.

Next relation describes the situation where both intervals not have common parts. Given the intervals I_{c1} and I_{c2}, we say that both start at same time if:

$$i_1 < i_2,\ i_3 < i_4 \text{ and } i_2 < i_3$$

and we denote this relation as I_{c1} *Disjoint* I_{c2}, and show them in Fig. 12.

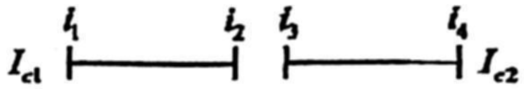

Fig. 12. I_{c1} *Disjoint* I_{c2}.

The situation where an interval start immediately when finishes other interval is names as *EndBeg*. Given the intervals I_{c1} and I_{c2}, we say that both start at same time if:

$$i_1 < i_2,\ i_3 < i_4 \text{ and } i_2 = i_3$$

Finally, last relations describe the situation where both intervals have common parts, but not are equals and no finish or start at same time. Given the intervals I_{c1} and I_{c2}, we say that both start at same time if:

$$i_1 < i_2,\ i_3 < i_4 \text{ and } i_2 > i_3$$

and we denote this relation as I_{c1} *EndBeg* I_{c2}, and show them in Fig. 13.

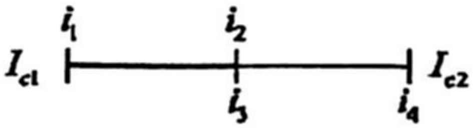

Fig. 13. I_{c1} *EndBeg* I_{c2}.

3.4 Relations Between Instantaneous Intervals

The possible relations between instantaneous intervals are just two. The first relations describe the situation where both intervals occur at same time. Then, Given the intervals I_{i1} and I_{i2}, we say that both start at same time if:

$$i_1 = i_2 = i_3 = i_4$$

and we denote this relation as I_{i1} *Equal* I_{i2}, and show them in Fig. 14.

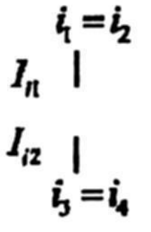

Fig. 14. I_{i1} *Equal* I_{i2}.

The second relation is the opposite of the above. This relation describes the situation when both intervals occur at different time. Given the intervals I_{t1} and I_{t2}, we say that both start at same time if:

$$i_1 = i_2 \, , \; i_3 = i_4 \text{ and } i_2 < i_3$$

and we denote this relation as I_{t1} *Disjoint* I_{t2}, and show them in Fig. 15.

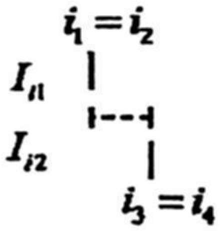

Fig. 15. I_{t1} *Disjoint* I_{t2}.

The next tables show the relations between different types of intervals. Table 1 shows relations between continuous intervals, Table 2 resume relations between instantaneous intervals and, finally, in Table 3 we resume relations that we believe could exists between continuous and instantaneous intervals.

Table 1. Relations between continuous intervals.

Relation	**Meaning**
Equal	Indicate given two intervals start and finish at same time.
EndEqual	Given two intervals, both finish at same time.
BegEqual	Given two intervals, both start at same time.
Inside/Cover	One interval is into other interval it is covered.
Disjoint	The intervals related have not common elements.
EndBegin	This relation indicates when the instant of an interval finishes, another starts immediately.
Overlap	Given two intervals, both share parts, but one finishes before other.

Table 2. Relations between instantaneous intervals.

Relation	**Meaning**
Equal	Indicate when both intervals occur at same time.
Disjoint	Indicate that both intervals occur at different time.

Table 3. Relations between continuous and instantaneous intervals.

Relation	Meaning
EndEqual	Indicate that an instantaneous interval occurs when finishes one continuous interval.
BegEqual	Indicate that an instantaneous interval occurs when starts one continuous interval.
Inside	One instantaneous interval occurs during the occurrence of one continuous interval.
Cover	One interval is into other interval it is covered.
Disjoint	The related intervals ~~related~~ ~~have not~~ does not have common elements.

4 Conclusions

It has worked to identify the elements that should be having the model to describe explicitly the changes that happening within a dynamic geographic environment. As part of these elements is to define the changes that occur on intervals, which can be of two sorts: continuous and instantaneous, resulting on relations between them. The next step is to define the relations that may exist between *Changes* and *CR*.

We believe that with these descriptions through of *CR*, we can make operations among *CR*s like union, intersection, and overlap. This can give us additional information about what happened in different descriptions at different times. As well as to make comparisons with patterns of set of *CR*'s and can detect differences among these to develop alert systems, for example.

As future work, is necessary to go up a conceptual level to define relations between events similarly to the relation between intervals. Also define granularities in temporal and conceptual terms.

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