CHANGE-ONLY MODELING IN NAVIGATION GEO-DATABASES

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ABSTRACT:

Navigation geo-database is the foundation and vital component of vehicle navigation system. Now almost geo-database is stored in hardware, such as CD, DVD. But, with the development of urban construction, road networks often change, as well as traffic rules. In order to reflect the changes of reality, direct the uses correctly and timely, it's necessary to update geographic database on time. The common method about map updating is to replace the old database with new one periodically by hardware or internet, and it always takes more than half a year. Actually, many navigation map providers have their own system of data collection and updating. The problem is that they couldn't deliver the updating data to clients because of lack of map updating model and format. They must process all the changed map data and transform them into certain traditional format, and deliver them to users by DVD or other medias. It's a hot problem to develop novel methods to support change-only map updating in navigation, and it's the efficient way to resolve the bottle problem of development with navigation industry.

The paper will study on the data model of navigation system to support change-only updating. We develop the change-only concept mode based core GDF road network models with UML schema, analyze the types of changes of road features. Also we discuss the approach of determination of change-only data, define the representation of increment map data in spatial object, property, operation aspects. As such, this model for change-only road data model is allowed to add definitions specifically concerned with change-only road data. The key techniques include:

- how to identify a feature(mainly road) between different version
- how to clarify the definition what is change-only data and to give a set of operators responsible for realizing the updating
- data model for such a data set which can be easily updated by the change-only data
- data structure for change-only data

1. INTRODUCTION

With the development of GIS, electronics, WEB, vehicle techniques, intelligent transportation system (ITS), as an integration application of above techniques, plays a more and more important role in social industry and our lives. Vehicle navigation system is an aspect of ITS, which make our travels and drives convenient. Nowadays US, Japan and Europe have the advanced techniques about ITS and utilize them prevalently.

There are some navigation data models provided in recent years. American delivered the details national cooperative highway research program (NCHRP) in 1997, and provided a spatial-temporal model of multi-dimensional location reference system (MDLRS) in 2002. Also ESRI provides an unified network for transportation system (UNETRANS) in his software ARCGIS with a package. Also there are different map format to store spatial navigation dada. Geographic Data File (GDF) is an ASCII format with logical model, and accepted by Central European Normalization (CEN)[1]. GDF describes the topological relation among geographic features and gives exchange file to users. Japanese KIWI-W consortium develops a physical storage format--- KIWI. KIWI file uses large storage space to deal with rapid query speed. NavTech also presents shared data access library (SDAL) to store navigation data. Although these data formats have many advantages in navigation system, it's difficult to update the data in time. Now GDF 5.0 has promoted its structure to support update information.

But there are still some challenges in navigation system. The first is the currency of spatial data. There is a long time between data release and data user, and geographic data updating is still a hard problem. Second, how to integrate many techniques efficiently in navigation system is a time-pursuiting problem. Also the cost of investment and practicability of navigation must be taken into account.

Map updating is a traditional problem in cartography, but things change in digital environment. Map updating and upgrade become more and more important because of application of spatial data. And large amount spatial data need a long to update the whole database. In 1999, ICA and ISPRS set up a group of "incremental updating and versioning of spatial databases". In 2004, ISPRS deliver the two initiatives: "Change detection and updating for geo - databases" and "Revision and maintenance of core geo-database". The contents with updating and upgrade include three aspects: a) map data updating mechanism, b) data collection with RS, c) historical data management.

In navigation fields, Japan present a new generation telematics system—I-format[2]. I-format is an innovative systematized server technology. It provides telematics navigation services for vehicle navigation systems, PDAs, and mobile phones.

ERTICO developed Actual and Dynamic Map for Transport Telematic Applications (ActMAP) group to study updating techniques. Both these groups deliver the incremental update concepts[3]. ActMAP further provide the details of data model and data format with map updating.

The paper defines change-only model of navigation geographic database, mainly road network for core GDF road data. Navigation geo-database is the foundation of car navigation system. There are many map providers and client users, the exchange of map data become the key component between the providers and users, especially map updating. Due to no common structure and description of change-only map data, it is difficult to understand updating with change-only map. The paper is organized as following. First we give states of art, then describe the analysis of types of road features change in section 2. The key technologies in map data updating in navigation system will be illustrated in section 3. We develop the general design about map updating framework in section 4, and give some examples section 5. Lastly a conclusion is presented.

2. ANALYSIS OF ROAD FEATURES CHANGES

Here we first define some concepts in updating description. **Change** is used to describe objective geographical entities change, such as reshaping and drying up of river, building or abandon of residence buildings. Different spatial entities have different changes. Concept of Event aims at objects in database of geographical features, and it is the abstract description of **Change**. We use disappearance to describe drying up of a river or abandon of a residence. There are nine kinds of Event: appearance, disappearance, displacement, amending, reappearance, expansion, contraction, rotation, deformation. Conception of **Operator** aims at operations about geographical data in geo-database. Such as: disappearance Event is corresponding to Deletion operator in the database. There are 3 kinds of operations: addition, deletion, modification.
An event usually corresponds to a real-world change that has a dynamic behavior. Changes to point road features including new building, abandoning, renaming and displacing .For linear road features, these four changes are also exist. But the changes can be analyzed in two aspects: semantic change and shape change.

- From semantic aspect, the changes include reclassifying and properties changes of road element. reclassifying or changing natural properties (e.g. lane, material) of road element is regarded as the essential changes to road features, and often happened with the change of identifier. However, changing properties of road segments (not whole road) usually correspond with road split change.

- From shape-change aspect, the changes include new building road, abandoning/ extending/ shortening an old road, reshaping road. The former two changes relate to road objects with identifier, and the others refer to only partly adjustment of properties.

The description of change has restricted to simple features (also for GDF) because of the limitation of human cognition and analysis. Thus, we only consider the ROAD ELEMENT and JUNCTION of simple feature. The attributes of JUNCTION are simple, that's Junction Type. GDF describe ROAD ELEMENT as following: Individual *Road Elements* must be independent of one another. A change in the status of one *Road Element* must not affect a change in another. *Road Elements* may also have a distinguishing set of *Attributes*. For the strictness of standard of road element in GDF, especially the characters of ROAD ELEMENT we believe that the most modification to ROAD ELEMENT will change the road identifiers. These essential changes include natural properties (e.g. material, width, lane, capability) andsocial properties (restriction, grade, form of way, Functional Road Class). The non-essential change modification including: renaming, displacement, etc. Table 1 shows the types of change, event and operator about road network in navigation database.

Dimension	Change	Event	Operator
0	Build a new object (e.g. bus stop)	Appearance	Addition
	Remove an old object (e.g. station)	Disappearance	Deletion
	Change object's name, location, etc.	Amend properties	Modification
1	Build a new road	Appearance	Addition
	Disuse an old road	Disappearance	Deletion
	Rename, reclassify an old road.	Amend properties	Modification
	Extend /shorten the shape of an old road	Expansion/contract	Modification
Changing grade or natural properties is regarded as the essential changes to transportation elements. Thus, we usually consider them as **Disappearance of the old objects** and **Appearance of new objects**.		Disappearance	Deletion
		Appearance	Addition
Changing natural properties of road segments (but not the whole road) is corresponding with **road split** into several new parts.		Split	Deletion/ Modification

Table 1. Types of change, event, operator about road features

3. KEY TECHNOLOGIES

The key technologies in change-only update system include three aspects.

- **Rapid locating and matching of road data based on different versions.**

  At present, the navigation data have different versions and source with different format, therefore, to locate and match them rapidly is a time-consuming process. Several effective index methods should be used to find out the relative road data between different versions, so that the proposed system can be applied to massive datasets.

- **Modeling and representation of Change-only information.**

  How to define the features change and incremental information is the core of the problem. As a result, modeling, representing, storing and distributing Change-only information should be on the basis of establishment of its proper, prefect data structure.

- **Change-only information extraction algorithms.**

  Because the changes have both quantitative and qualitative differences, the coordinates–based change identifying method is not enough. We should also consider semantic changes and spatial neighbor area to confirm the changes happened to the road features, and that is the difficulty of the project.

4. GENERAL DESIGN

We design the updating system based on GDF. First we compare the two GDF section file to locate and match the corresponding objects, and use some methods to detect and represent change-only data. Figure 1 shows the technical workflow in updating framework, and figure 2 describe the rapid location and match of spatial objects.

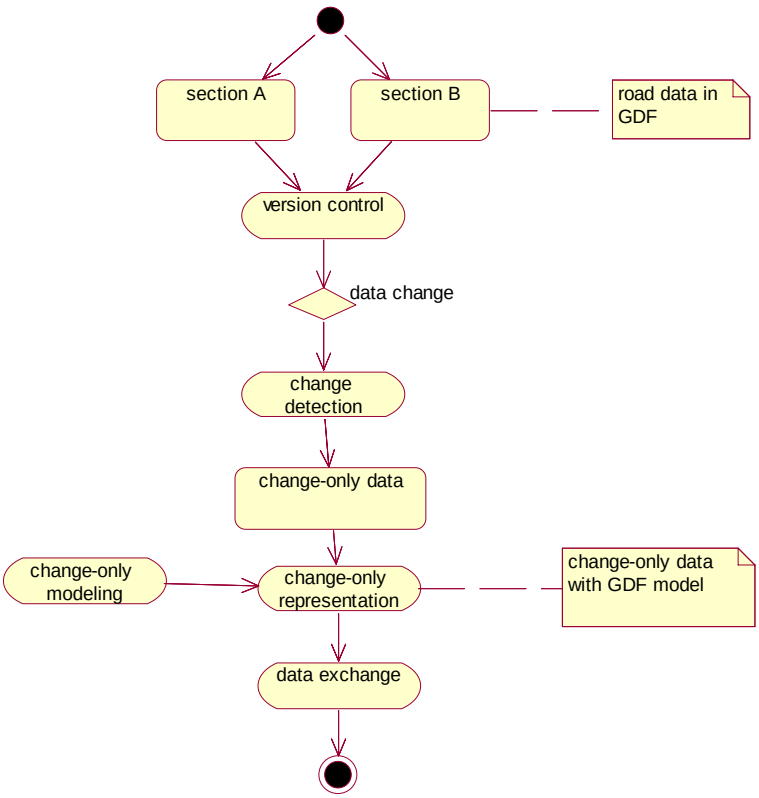

Figure 1. Technical workflow in change-only updating framework

With the GDF logical model we develop the conceptual model for map updating showed in figure 3. A section corresponds to a geographic area that can be updated separately. Every section has a data dictionary that data elements are present in the section. Every section is split in one or more layers. An update collection corresponds to an on-line incremental update. An update transaction consists of update operations that are related to each other. Multiple update transactions can be associated with one event, where the first update transaction describes the changes with respect to the normal situation, and subsequent update transactions describe the changes with respect to the previous situation.

According to the requirements the update format shall be based on the GDF model. This requires choosing a model that allows a sequential processing of updates. The consequence of this requirement is to use a flat model of GDF for change-only updates. We use ActMAP for reference to design the framework. Figure 4 shows the data model for updates in UML notation. A change-only update contains first metadata that identify the map database for which the update applies. Those are defined in an own data entity metadata that contains the information about provider, version, section, layers. A change-only update includes one or more Update Collections. An Update Collection contains all individual Update transactions for one section, therefore the corresponding section ID is mentioned.

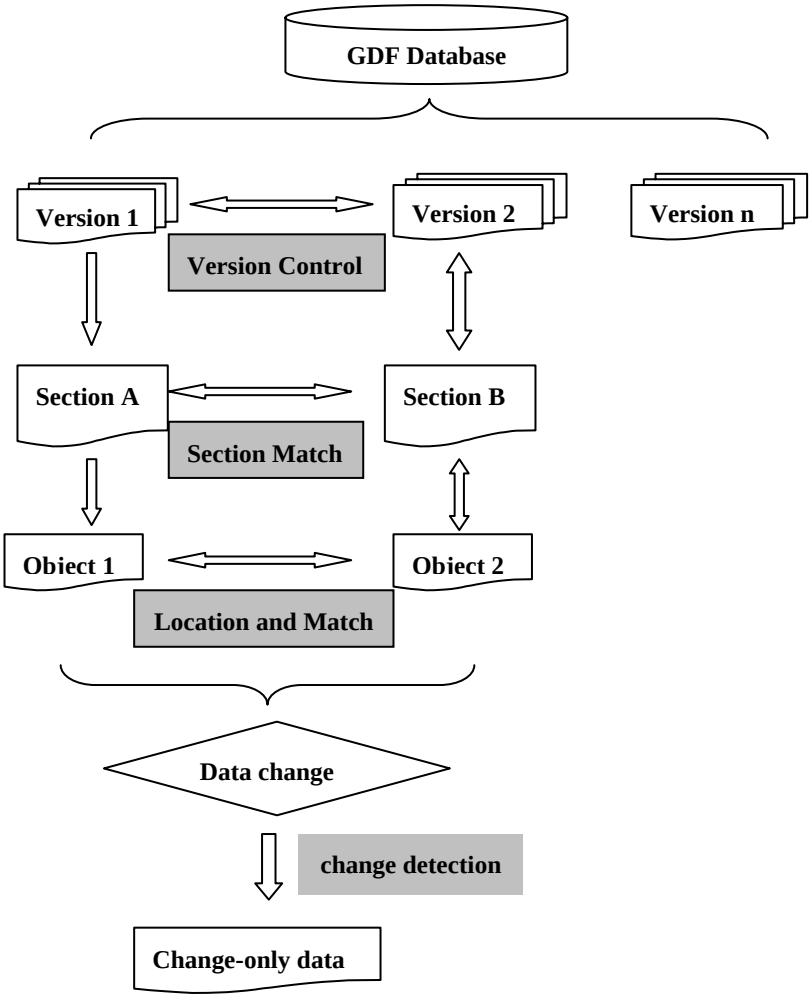

Figure 2 Determination of change-only data

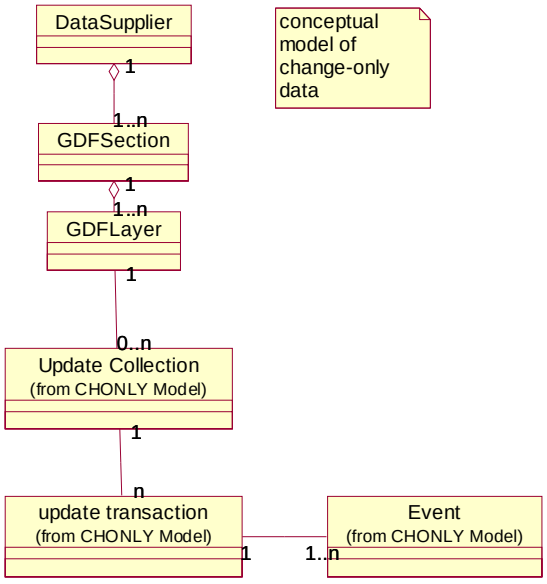

Figure 3. UML notation of conceptual model for map updating based on GDF

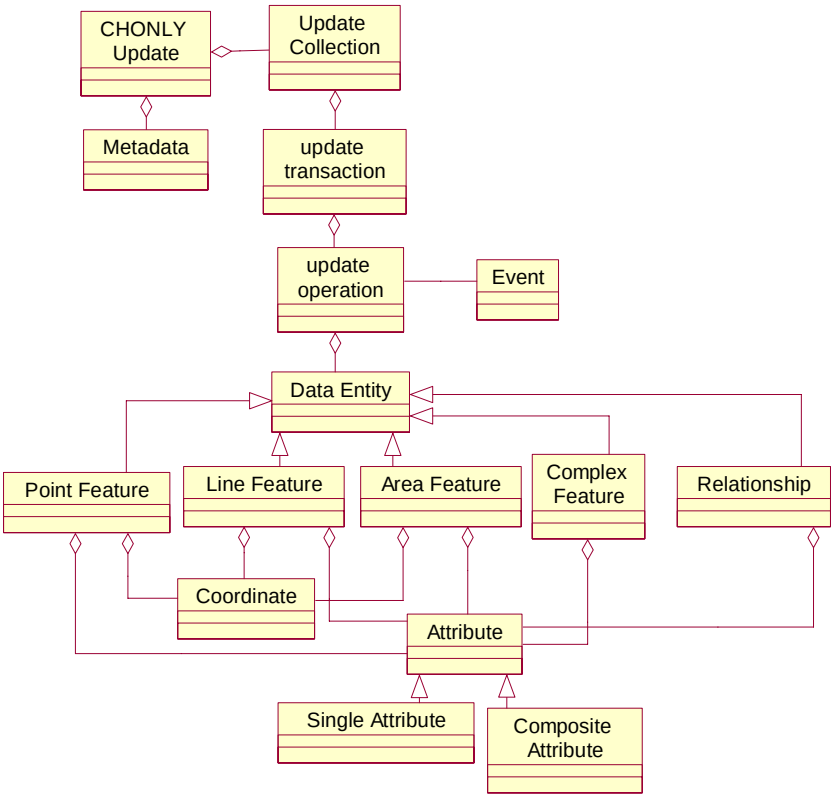

Figure 4. UML notation of change-only model

Change-only inforamtion is the difference between two database, but how to define it is a problem. The difference happens in many aspects: geometric morpholoy, theme attributes, semantics, spatial relationships, and the expression of change-only information must take them into accounts. Change-only information must provide semantics to inquire for users, especially information about events of changes with geographic features. Change-only information aims to update and upgrade geographic database, so it must support operators of database. With the analysis of events, snapshot of graphics, attribute, semantics and relationship, the definition of change-only information includes five components: identifier, defference of graphics, semantics and attribute, events .

$$\Delta I=\{ID,\ \Delta semantic,\ \Delta graphics,\ \bigcup_{i=1}^{n}\Delta Attribute,\ event\}$$

Because of the speciality of identifier, we list it in change-only information. But we don't request the uniform of identifiers in two database, and it can be deal as one common item of object. "Δsemantic" represents the difference of semantics between two spatial objects, which mainly invovles classification information. "Δgraphics" delivers the difference of geometric shape of two objects. Event includes not only the change information of reality entities, like reshaping, abandoning of road, but also the operators with database to update.

There are simple update operations on one database feature (addition, modification, deletion) and there are complex operations that involve multiple features (mergence, split). The chosen model is flexible enough to support both types of operations. In the case of complex operations it is required to flag the status of the involved features with old or new. Figure 5 shows the updating implementation with GDF features and attributes.

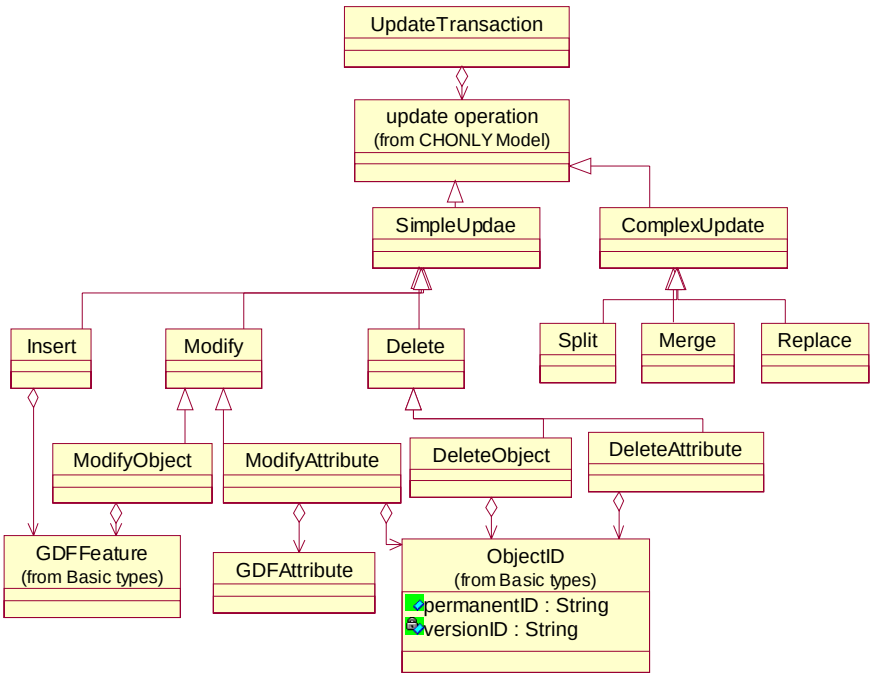

Figure 5. UML notation of updating with GDF features and attributes.

5. IMPLEMENTATION AND DATA EXCHANGE

Based on the above framework of change-only updating, we make a program to implement the system. We select two temporal GDF file about the same section to extract the change-only information about geographic objects, and figure 6 shows the query of change information.

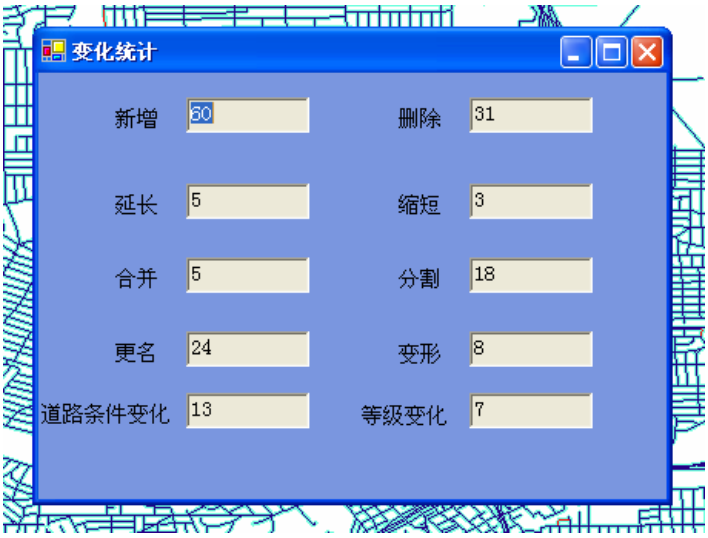

Figure 6. Query of change information

Figure 7. Query of change-only information about addition (left) and split (right).

We know almost every system provider uses an own proprietary physical storage format (PSF) for storing the digital map database, and there is currently no standard format available now. Now GDF v5.0 supports update information. This situation forms a very important constraint for the update strategies. Here we choose XML to describe exchange file. Figure 8 gives the example of modification and deletion of one road element.

```
- <UpdateOperatrion Operation="Modify">
  - <PolylineFeature FeatID="301384329">
      <ID>301968909</ID>
      <net2class>6</net2class>
      <RoadCondit>2</RoadCondit>
      <Coordinates>-836535010,429986330 -836531440,429985920 -
        836526480,429984470 -836522630,429984430 -
        836520530,429984540 -836519330,429984540 -
        836516030,429984620</Coordinates>
    </PolylineFeature>
  </UpdateOperatrion>

- <UpdateOperatrion Operation="Delete">
    <PolylineFeature FeatID="301340367" />
  </UpdateOperatrion>
```

Figure 8. Exchange file of XML

6. CONCLUSION

With the universal application of geographic information, data updating become more and more important in digital environment. Change-only updating of spatial data is an efficient solution. The paper gives the analysis the change of road network based on GDF, describe the change-only update framework, and the details with every section need the further study.

REFERENCES

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