

SPATIAL DATA TRANSFER IN THE CASE OF UPDATE

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ABSTRACT

More and more often people exchange geospatial information. This happens when a user gets data from producer. For a transfer of updated data a producer provides a new geographical dataset to users. Nowadays, this update transfer is usually a bulk transfer. Hence, transferred data describes a snapshot of the world. Successive changes undergone by features are not described. To improve the integration process, these modifications should be isolated in the transferred dataset. We study how metadata could be used to represent change in a bulk data transfer. We propose to use information about dating and lineage to detect altered features. Then, only these altered features are integrated in the user information system. For a bulk data transfer, this metadata improve the integration process. Moreover, we extend the use of metadata. It is used during the data transfer and it is not limited to a document role.

1 INTRODUCTION

1.1 Producer - Product - User

Data transfer happens whenever a producer provides a geographical dataset to users. This data provider delivers geographic products with specific characteristics. Therefore, a data transfer is based on a *producer*, a *product* and a *user* as described in figure 1.

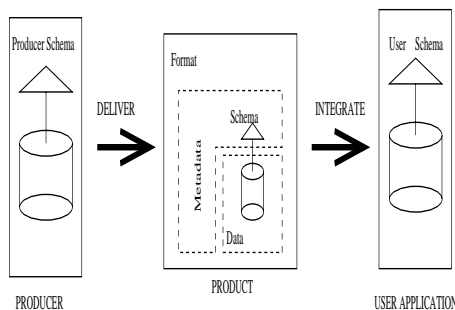


Figure 1: Data transfer

The producer collects data and makes it available to users whose applications depends on it to achieve their specific tasks. Hence, the producer and the user converge either on a customized or a standard product. This product specifies transferred elements and encoding rules (also called format). Thus, feature data specification (Guptill, 1991) contains the transfer schema description, information about data collection, representation and delineation. This information often forms part of the metadata.

For the producer, delivered datasets have to follow specifications fixed by the product. Moreover, users applications mostly have distinct specifications (shown on figure 1 as *user schema*) as those of the product. In order to use these delivered datasets, the user needs to integrate them. This implies the resolution of semantic conflicts (Kuhn, 1994), integration of incompatible database schemata (see (Nyerges, 1989) and (Spaccapietra et al., 1996)) and information conversion. Such an integration process should be left unchanged as long as product and user specifications are not altered.

Meanwhile, geographical features evolve due to human or natural transformations. Therefore, the producer takes into account these evolutions by delivering new datasets.

1.2 Data Evolutions

Land-based features change over time. These transformations may be differently understood. (Claramunt and Thériault, 1995) make a typology of these spatio-temporal processes and define different kinds of evolutions. However, data transfer presented in previous section seldom describes spatio-temporal evolutions. It depicts a state of the world at a given moment. Therefore, between successive datasets, data items are created, deleted or altered.

We believe that each geographic object is structured according to the schema shown in figure 2. Each object has characteristics (called attributes in the figure) which may be spatial or descriptive (e.g. the name of the landowner). Relations are established between these objects. Transferred data follows this generic model.

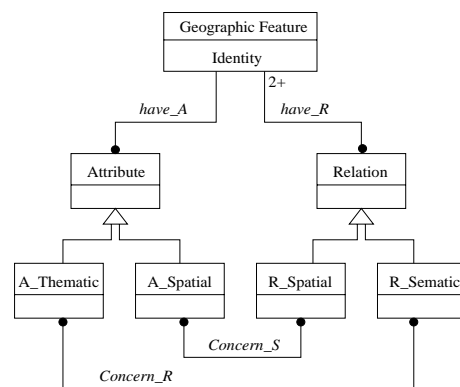


Figure 2: Geographic feature structure

For a given object, changes concern spatial or descriptive attributes. Meanwhile, their effects are not similar. Indeed, some changes alter a particular object instance whereas some other involve deletion of this instance and creation of a new one. This difference is a repercussion of the definition of an object. Each object has

some characteristics that define its identity. For a land parcel, it is an unique cadastral number. This cadastral number may only change when the parcel boundary line is modified. Then a new parcel instance is created. The old parcel is deleted. Here, the identity of the land parcel is linked to spatial characteristics. Object instance remains present (i.e. undeleted) until characteristics relative to identity are unaltered. For each geographic object, feature data specification should explain when a creation or a deletion occurs, and which characteristics are linked to the features identity. Users should be able to interpret real world changes as creation, alteration or deletion of objects.

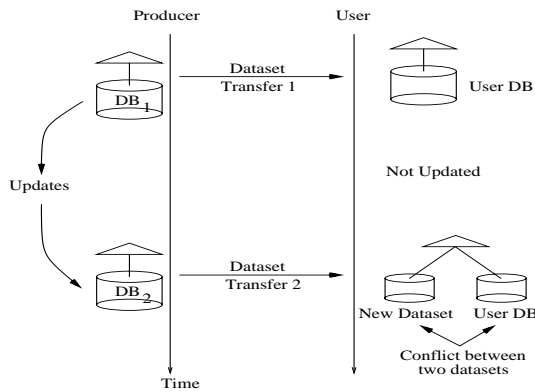


Figure 3: Successive update transfer

After the first dataset transfer, the producer updates his geographical database. Therefore, the new delivered dataset underwent some modifications unknown of the user. The user has a new dataset, different from which he already integrated. This implies that the user is not informed of updates when they occur. So, after the transfer, the user gets two distinct datasets for the same area. If the old dataset can not be deleted, the user has to detect the differences between them. Each dataset contains data relative to the area under consideration. In regard to the amount of transferred information, few geographic object instances are actually modified. In order to improve the integration process, the user should be able to identify changes easily (described as creation, alteration or deletions of objects) that take place between successive data transfers. Therefore, our main problem is to identify and to pick out this data.

In section 2, we present different kinds of data transfer. Section 3 concerns metadata. We analyze how metadata about lineage and up-to-dateness may represent evolutions. Then, the French standard EDIGÉO and the European pre-standard CEN TC 287 are studied in section 4 in order to see how this metadata is implemented. An application case with the transfer of French cadastral data is described in section 5.

2 DIFFERENT KINDS OF DATA TRANSFER

Geographical data transfer plays an increasingly significant role. The user often purchase geographical products. Therefore data is transferred from a producer to the user. Here, if real world evolutions are delivered to the user, the transfer becomes an update data transfer. For update transfer, we distinguish a typology of basic transfer processes:

- bulk data transfer: the dataset is a snapshot of the world. Transferred data depicts a state of the world at transfer time.
- incremental data transfer: only features that were altered are transferred. The description of evolutions undergone by these features may also be given.

- snapshot with incremental data: a state of the world and information about features that were altered are transferred.

Various solutions may be adopted to implement these three transfer processes.

For *bulk transfer*, modifications are not indicated. Users must detect changes that have occurred between their geographical database and transferred data. This operation is often difficult. Evolutions relative to the existence of real world features are represented by creation or deletion of geographic features. Such geographic objects have a unique identifier surrogate. This identifier plays the same role as a key in a relational database. Therefore, as long as this geographic object remains present this identifier is unchanged. This is true for any transformation undergone by this object. If such an identifier exists, it is possible to use it to determine whenever an object is created or deleted. For each geographic feature, a list of feature identifiers is built up. This list exists for the transferred dataset (called L_{TD}) and for the user database (called L_{UDB}). They are compared. Feature identifiers may be present in one or in both lists. Table 1 shows the result of this comparison.

		<i>Old Dataset</i>	
		Present	Missing
<i>New Dataset</i>	Present	Unaltered	Created
	Missing	Deleted	-

Table 1: Result of the comparison of two datasets based on identifiers

- Creation or deletion of geographic object happens whenever characteristics that define the object identity change. Such evolutions affect spatial relations between this object and its neighborhood. The detection of an object creation or deletion does not explain these spatial evolutions. Such a mechanism does not establish a link between altered objects and new ones which may replace them.
- The detection of no evolutions means that there is no change of characteristics related to identity. However, some other characteristics may change. Such evolutions are not detected with this mechanism.

However, so that such a mechanism is usable, identifiers must exist and must be preserved. Hence, the user should not alter them. We believe that such a mechanism is easily usable to detect evolutions which undergo administrative spatial units like cadastral parcels.

For *incremental transfer*, several solutions are suggested to describe evolutions applied to the old dataset. They should bring this old dataset to the current state of the world. Solutions suggested to manage history in temporal in GIS are usable here. Differences between both datasets are described differently. We consider that:

- New features are linked to those that they replace: an history record holds all previous states in the form of a linked chain as described by (Kemp and Kowalczyk, 1994). This history record stores successive states for each geographic feature.
- Delta between new and old features is represented: to each transferred data item is associated a set of valid properties denoted P_V and a set of no more valid properties denoted P_I . These properties are spatial and descriptive. Deletion of P_I and addition of P_V makes an item evolve from the old to the new state. P_V and P_I correspond to the difference (delta) between two successive states. (Bédard et al., 1997) introduce this kind of data transfer.

Both suggestions rely on a data model that describes successive states. Therefore, they refer to a single feature. To be used for data transfer, these models must be applied on each feature defined in the transfer schema.

Incremental data transfer seems to be an interesting opportunity. Nevertheless, the producer has to know the state of the user geographical database. Indeed, delivered datasets reflect only the difference between the producer database (which is constantly updated) and the user database. (van Oosterom, 1997) describes a similar case. After an initial full delivery, users get updates files which contains the differences with respect to the previous delivery. The update file consists in old objects that have to be deleted and new objects to add. According to the user needs, these update files contains distinct information (e.g. only the difference between producer and user database or all undergone changes for each altered feature). So, the producer delivers a specific dataset to meet user needs. Moreover, the producer needs to store object history to be able to extract previous states and to build this customized datafile.

If the producer dataset does not fit the user requirements, an incremental data transfer is hardly usable. Synchronization problems appears. The dataset reference (i.e. the old dataset) upon which differences are applied may be distinct for the producer and the user. Here, some evolutions may not be stored, or they may be applied on non existing objects. To avoid these problems, a snapshot of the producer database should be included in the data transfer. To update the user geographical database, changes identified in the transfer are applied. The outcome of these modifications is a new state of the user database. This state should be equal to the transferred snapshot. This kind of update transfer is similar to "base map with overlay" defined by (Langran, 1992). The base map is the new snapshot of the ground (i.e. the new dataset). The overlay is the state of the altered feature in the old dataset.

Other update mechanisms are conceivable. However, to take advantage of this information, users should have high technical skills and developed tools should be able to make use of this information. Solutions which use incremental data are difficult to bring into play. Producer have to take each user situation into account. Nevertheless, update integration is easier. Each user knows, for his database, modifications that should be applied. Today, bulk update remains largely used. Therefore, we try to improve user integration process in the case of bulk data transfer. We believe metadata should help users during this process.

3 HOW METADATA REPRESENTS CHANGES

Metadata is usually described as "data about data". This metadata is about content, quality, condition and other characteristics of data (Federal Geospatial Data Committee, 1994). One of metadata major issues is to provide information needed to process and interpret data to be received through a transfer from an external source. Usually, this issue is related to data integration for a dataset. Data transfer may be usual between producer and user. Changes that occur due to real world evolutions between these successive datasets may also be described by some metadata. Thus this metadata may be used to identify which data item changed.

The producer tries to detect evolutions that affected data the in order to incorporate them in delivered products. Hence, information relative to observations carried out by this producer are included in transferred dataset. Such information may concern data capture or update process undergone by this data. This information forms part of the metadata. Indeed, such metadata is linked to lineage. They may therefore be used to identify altered data. Furthermore, metadata about temporal extent may be useful to identify the altered data.

Next sections present how metadata relative to lineage and temporal extent is able to represent changes that occurred.

3.1 Lineage

(Clarke and Clark, 1995) define lineage as "information that describes the source observations or materials, data acquisition and compilation methods, conversions, transformations, analyses, and derivations that the data has been subjected to, and the assumptions and criteria applied at any stage of its life". Therefore, we believe lineage is divided into two kinds of metadata:

- Metadata relative to the production process which applies to transferred datasets. For a given product, this information is valid for all datasets. It is usually about production specifications such as data capture, data portrayal.
- Metadata made of information relative to data items. This metadata is linked to observations made by the producer. Thus, this metadata is distinct from production process and product.

To represent evolutions undergone by geographic objects, lineage should consist in:

- Information on documents which made it possible to note this evolutions. This information should be classified in accordance with the time period for which the source dataset corresponds to the ground. On this source document is observed the current state for a given feature. Hence, this information consists of: data source used, data source identification, edition date / source date and the list of features for which a modification is observed on this source.

Example : data source: air photography, edition date / source date: time of photography, list of features. If the source is a map, edition date/source date should record the date for the last occurred update.

To detect modifications that appeared between two data transfers, the source document and the feature list that is associated to it are compared. This comparison exhibits:

- Appearance of a source document: features linked to this new document underwent modifications. Their new state is observed on this document.
- Disappearance of a source document: feature characteristics (spatial and descriptive) linked to this source are obsolete.
- Modification of feature list related to a source document: features that are no more referenced have new characteristics (spatial and descriptive). These features should be associated with a new source document.

Thus altered features are identified when the source to which they are associated. However, it is not possible to associate the old and the new state of altered features.

- Information on observation made on each document. This information describes what kind of modification is observed: no change observed, spatial changes (e.g. building a side extension onto a house), non spatial changes (e.g. new owner for a house), creation or deletion of the geographic object. This information makes it possible to establish relations between altered features.

This mechanism is usable for every transferred data. However, the producer has to document each undertaken update. So that metadata about lineage is used to represent changes that occurred.

3.2 Temporal Informations

Metadata contains information relative to the date of transferred geographic data. Usually, this information is relative to the time at which data is captured and to the time at which it is added to the producer database. As (Jensen et al., 1994), we call them respectively *valid time* and *transaction time*. However, as (Guptill, 1995) noticed, valid time is usually the time at which the evolution is observed. It is seldom the time at which the event really occurred.

Temporal information may be connected with geographic features. Then, it is about the feature life. Therefore, such temporal information is relative to the creation and deletion of features. For a given object instance, only identity changes are then represented. But this temporal information may also represent successive transactions that happened. To each modification corresponds a transaction that is recorded. For a transaction, both valid and transactional time are stored. This allows the identification of successive transformations (creation, deletion but also update) undergone by geographic features. Represented changes are then related to the meaning associated with temporal information.

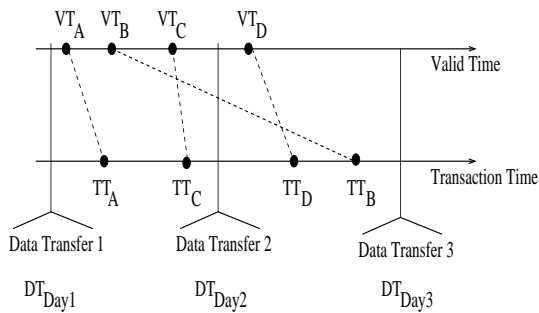


Figure 4: Data transfer and temporal information

The example shown on figure 4 makes it possible to describe how temporal metadata is used to detect change. The data producer detects changes for A, B, C, and D. For A, the observation is made at valid time VT_A . This evolution is recorded at transaction time TT_A . This is true for all observations made by the producer. Data transfer between a producer and a user happens at DT_{Day2} . Only evolutions which affect A and C are known by this user after this data transfer. Modifications that affect B and D are described in the next data transfer (DT_{Day3}). Here, we do not consider that the producer anticipates updates. To isolate changes that occurred, the user has then to compare the update date (transactional time) with the date at which the previous data transfer occurred. If, for an object, the update date is more recent than the transfer date, then an evolution occurred (e.g. for data transfer 2, $TT_C > DT_{Day2}$).

To find changes that occurred following an update transfer, transactional time is used in the previous mechanism. Transactional time relates the recording in the producer database of changes that occurred. However, users are mostly interested in valid time. Indeed, valid time makes it possible to describe the ground at a given moment. After data transfer 2 (see figure 4), evolutions that affect B are not known. They are known after data transfer 3. Or B is prior to C. Therefore, evolutions relative to B must be recorded before those relative to C.

Changes that occur in updates datasets may be identified by means of metadata relative to lineage and temporal information. Metadata does not describe successive evolutions undergone by features. It is about the current state of these features. Consequently modifications are observed in an indirect way. For an updated object, the old state is stored in the user database. It is possible to isolate its new state in the update transfer. Then, the user has to correlate both objects and to update his database with the new object. However, transfer format must include this metadata to allow the use

of such mechanism. Moreover, features that underwent alterations must be related to this metadata. Otherwise, changes that occur are known but it is not possible to identify features which undergo them. Next section presents how some transfer standards meet this requirement.

4 TRANSFER FORMAT

A transfer format defines the logical file structure for the transfer of the data. To make data transfer across heterogeneous environments easier, such spatial transfer formats are standardized. We study in the following section how metadata we are interested in is implemented in standards like EDIGéO and CEN TC 287.

4.1 Contents of a Dataset Transfer

EDIGéO : (AFNOR, 1992) defines an experimental standard transfer format resulting from DIGEST. This standard is promoted in France to improve digital geographic data transfer. Transferred data may be raster or vector.

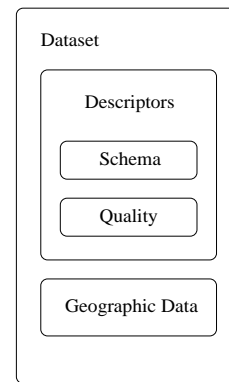


Figure 5: EDIGéO structure

EDIGéO does not explicitly allow metadata. But, in addition to data, the transfer dataset contains descriptors (see figure 5). Quality and schema may be seen as metadata. Among quality descriptors, source and up-to-dateness information are usable.

- **Source**: describes the origin of a dataset. Useful information is relative to the producer, source documents, data history. However, the transfer standard does not specify how such metadata is entered. Consequently, this metadata is hardly usable.
Example: Producer and source document identity: Carte IGN numéro 2125E. History: Last general update November 1990
- **Up-to-dateness**: this information is about the date at which data is observed and the date at which the same data is recorded (called "update time") in the database. These dates refer to the valid and transaction time. Update type may also be explained. This updates breaks down into creation, alteration or deletion of an entity. We believe that this metadata is the most easily usable to represent changes.
Example: Observation time: 19890502. Update type: Data creation. Update time: 19930101.

CEN TC 287 : Technical Committee 287 introduces a set of draft European Standards about digital geographic data. Their use is not mandatory until now. Therefore, national standards have not to include them. Works undertaken by TC 287 concerns the standardization of quality, metadata, data transfer, position, geographical identifiers. Each proposed standard is structured by a conceptual schema.

Usable information is found in the quality schema described in (Comité Européen de Normalisation, 1996). This schema contains elements relative to lineage and temporal accuracy. This temporal accuracy is defined as a primary quality parameter considered as relevant to all geographic information.

- **Lineage:** Lineage information indicate for (Comité Européen de Normalisation, 1996) who was responsible for the original production and technical description of its source sufficient to show how it came to be in its current state. Among this information, we can use:
 - the date or time period at which this data is produced. This information is given by “date_of_production” and is linked to the data producer.
 - the process history which explain transformations that transferred data underwent since their capture. The date at which a transformation is applied is recorded. Then, it is possible to identify when data was captured on a source.

This information identifies source documents that allow to update the dataset. Then, it is possible to use this data about lineage to pick altered geographic features out.

- **Temporal accuracy:** The quality model includes quality parameters such as temporal accuracy. CEN TC 287 does not specify the contents of each quality parameter. It only defines the schema that structures this parameter. For instance, the quality parameter updateness shall rely on the date of the latest update.

These transfer standards enable usage of metadata about lineage and temporal accuracy to describe datasets. However, there is no production specifications for this metadata. Moreover, this metadata is often optional. Hence, its usage is bound to the product specifications. If the producer includes it, users may use them to detect evolutions.

4.2 How to connect metadata and data

Metadata described in section 4.1 and data are exchanged during a data transfer. Now our problem is to connect data to its related metadata so as to implement a mechanism that enables change detection. To answer this question, existing links between data and metadata should be studied for these standards.

EDIGéO: Between transferred data and metadata about quality, two type of links may be established (see figure 6). Quality descriptors may be linked to each object described in the schema. Here, quality information is valid for every instance of this object. Moreover, each object instance may be directly linked to a quality descriptor. Then quality information is only relative to this instance.

CEN TC 287: According to CEN TC 287, datasets may be made of “subsets”. The dataset is partitioned in a hierarchy of subparts as presented in figure 7. Each subpart shall contain some “quality elements” which are part of metadata. At each node of this hierarchy, we find:

- only metadata and information about quality
Example: Metadata relative to the extent, spatial reference system, schema, ... concern the full dataset description.
- metadata, information about quality and data
Example: Information (that is also metadata) relative to quality elements such as lineage, usage, temporal accuracy ... may be applied to smallest subsets.

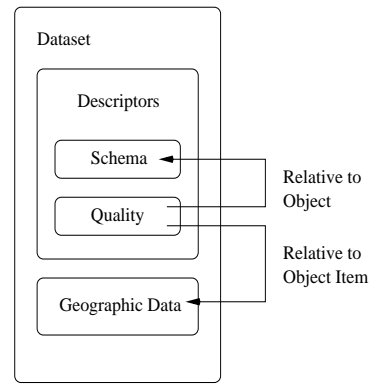


Figure 6: Existing links between data and metadata for EDIGéO

The relevance of information stored at each node is refined as in a hierarchy of inheritance.

Therefore, as presented in figure 7, general information about the dataset such as the producer name, an expected positional accuracy may be given at the higher level of this hierarchical structure. This information is valid for each data item in the dataset. Each subpart of this dataset contains more precise information such as the specific positional accuracy available for an object type (e.g. buildings). A subpart may even be limited to a particular object item.

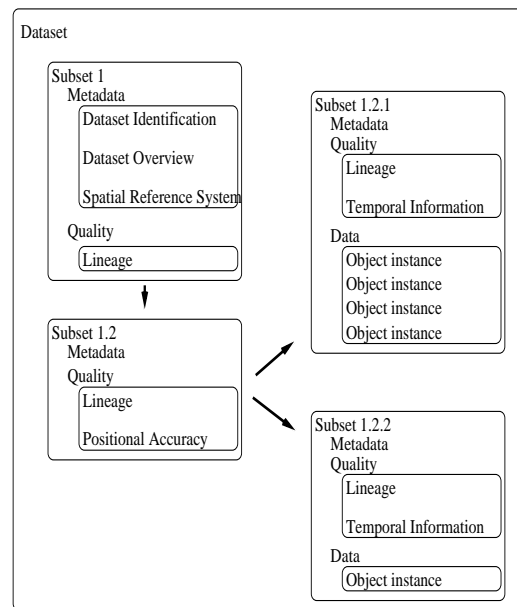


Figure 7: Data and metadata organization for CEN TC 287

Both presented transfer standards allow to link information (mostly relative to quality) to data items. However, for these standards, subparts are defined differently. For EDIGéO, information may only be relative to an object type (e.g all data relative to the type building) or a specific object (e.g. parcel 1247). For CEN TC 287, many subsets may be included in the same dataset. These subsets should be defined by some common constraint within the data (e.g. data located in a specific area).

4.3 Change and metadata

To use metadata in order to represent geographic object evolutions, additional constraints should be introduced. Changes that occur between successive dataset transfers alter some data items. To use this metadata in order to detect change, it is necessary to associate them only with objects that evolved. Hence we believe that these data items should form a new subpart of the dataset.

In the EDIGéO standard, there is only one way to create such subpart. As changes affect object instances, information relative to lineage and up-to-dateness may be associated with each object instance. Otherwise, it is not possible to distinguish various objects of a specific object type. Change detection can not be done while being based on metadata.

Example: If the update time is linked to the object type "house", we do not know if all instances of this object type underwent changes or if only some houses did.

To create a subpart within a dataset transfer following CEN TC 287, a constraint within data should be defined. We are interested in subsets that gather data which underwent modifications. Therefore the constraint may be related to temporal metadata such as the date at which the alteration was noticed or is valid. It is also possible to make subparts with individual data items.

5 CASE STUDY: A FRENCH DIGITAL CADASTRAL MAP TRANSFER

In France, the Direction Générale des Impôts (DGI) manages the cadastral map for tax purposes. This cadastral plan is updated by the cadaster. These updates concern:

- Legal modifications (e.g. division of a land parcel). Any undergone modification is added in the cadastral map as soon as the Conservation des Hypothèques (which is equivalent to a land registry) validates this operation.
- Modifications that do not have any legal repercussion (e.g. construction of a house). One or two years may be necessary to take these changes into account.

Today with the progressive computerization of the cadaster, a digital cadastral map (DCM) is updated. This DCM is used as a base map in many applications such as facility management. The cadaster is now a data producer. DCM updates are transferred to users with a periodicity that does not exceed three month. This update transfer follows the EDIGéO standard. DGI defined this transfer specifications (see (Direction Générale des Impôts, 1996) and (Direction Générale des Impôts, 1995)). The transferred dataset is snapshot of the DCM at the time of delivery.

For the producer, the update process leads to the creation, deletion or alteration of data. For a object item, any modification of its spatial characteristics leads to the creation of one or more new items. Therefore, due to a division, land parcel 103 is deleted. Two new land parcels are created: 103_1 and 103_2. Here, the identity of a land parcel is linked to spatial characteristics. The alteration of some other characteristics does not affect the existence of the modified land parcel.

To improve data integration in the user information system, metadata and geographic identifier are used to detect changes that occurred. Hence, we should identify what kind of information is present in the transferred dataset.

- Geographic identifier: Only spatial administrative units are identified by geographic identifiers. If the spatial characteristic of an administrative unit (e.g. a land parcel) changes, a new unit is created. This unit gets a new geographic identifier.

- Metadata: The transfer dataset does not include information about lineage. But quality information about up-to-dateness is available. This descriptor of quality specifies the valid and transactional time relative to the last update. In the transferred dataset, each object instance has such a quality descriptor.

We used two distinct mechanisms to seek modifications due to updates.

Detection based on identification: For each object type that has a geographic identifier, object instances from the producer database are compared to instances from the transferred dataset. We identify: created objects, deleted objects and unaltered objects. For unaltered objects, only spatial characteristics does not change. To identify modifications of thematic characteristics, object instance must be matched. Then, we are able to detect if thematic characteristics have changed.

Detection based on temporal information: For each object type, instances whose temporal information (transactional time) is greater than the previous transfer time are identified. These items concern new states. We use it to detect altered houses.

These mechanisms rely on metadata or geographic identifiers. This information represents changes that occurred. Metadata and geographic identifiers made it possible to identify the new state for transferred objects. These new object instances may introduce inconsistencies in the user database such as sliver polygons. These problems are identified by (Flowerdew, 1991). So far, we did not consider them. Our mechanism identifies altered data and shows the user the new state for this data.

6 CONCLUSION

Bulk data transfer are often used for update data transfer. This transfer represents the state of the world at a particular time. This data transfer does not allow the description of changes that occurred. Meanwhile metadata are used to describe transferred data. Here, we describe how metadata about temporal information or lineage represents a new state for objects which underwent modifications.

Then this metadata is not only used for documentary purposes. Metadata about lineage and temporal information improve the integration process. Indeed, only object items that were altered are integrated in the user information system. Therefore, the update process is made simpler.

In the future, interoperability should improve access and sharing of data between information systems. Data may be duplicated. For this data, copies have to be updated periodically. Metadata may then be used to identify altered instances. This is the same configuration as described in this paper. A distant GIS stores a new state of the world. Metadata associated to this data makes it possible to identify alteration undergone by this database.

We studied how metadata and geographic identifiers may represent change. This information is used to identify the new state for altered objects. Now, we should help users to incorporate these new object instances in a user database.

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