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# Ontology for reference geographical data facing the challenge of applications diversity

**Fatiha IBANNAIN, Morocco**

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## SUMMARY

This paper will investigate the contribution of reference data ontology as a mechanism of data accommodation for the requirements of a wide user's category. The development of tools and models taking account of doers' diversity is essential to face the integration problems, especially the semantic ones. Accordingly, the reference data identification constituted the first step of our approach to set up a reference model as a basic structure to be adapted to a large range of applications. The establishment of an ontology, which takes as a starting point the common practices between producers and users of reference spatial data enable to notify, initially, the definition approach of the reference objects types during the features cataloguing, then, the concepts retained at the time of conceptual modeling. Three principles are maintained to sustain this ontology. They concern (1) the independence and the complementarity of the objects types, (2) their adaptability to specific domains, and (3) their hierarchy. This approach is justified by the viewpoints of data producers and users, the existing data configurations and their former application scopes; so as to limit the semantic inconsistencies. A feature catalogue compliant with the standard ISO 19110 is elaborated according to those principles. The objects types are defined to elaborate specific conceptual models; then, the model of reference is designed in a total way with the aim of consolidating the various models to make it possible to constitute databases that share the same diagram. The exploitation of the reference model within the framework of a national SDI will be a considerable asset for data integration while mitigating the problems of heterogeneity commonly noted during the use of data resulting from different models and disciplines.


## 1 INTRODUCTION

Even if the importance of geographical information is evident, the optimization of its exploitation-with the intention of its pooling- still meets technical and legal difficulties in many countries as the case of Morocco. The main technical embarrassments are summarized in standardization problems, often relating to the omission or the apprehension -which becomes obsolete-, of the design phase witch is essential to any information system development (Noucher 2006, Billen and Al 2008). It is a problem of raising the current questions (Why, What, Whom and How) that must be examined before starting the geographical data modeling. In spite of the plausible obviousness of some of these questions, the consideration of the various replies constitutes the base of a coherent modeling.

In this paper, we return on those aspects while stressing the fundamental concepts inherent to spatial information by referring to some works that contributed to look further into knowledge relating to shared information. We discuss the means to identify the conflicts sources and to reconcile the view points in an attempt to support the setting up of a reference model, like a basic structure to be adapted to a wide range of applications. We present then the approach continued to structure such a model in the case of Morocco passing through the establishment of an ontology which starts from the current practices of producers and users of geographic data; and focuses the reference data that we present as an accommodation means to new users needs.

## 2 MODELLING AND SPATIAL DATA ONTOLOGIES

Modelling can be comparable to an information synthesis since it implies a simplification of real world phenomena complexity. This generalization is based on assumptions defined at the beginning of modelling. It represents a set of rules -dictated by our perception and guided by our knowledge- and will constitute the specifications that define a given model. These considerations translate in fact conceptualization levels that permit to better understand particular domains by using their ontologies. In the case of the geographical data, beyond the technical or institutional difficulties, data handling encounters problems of data comprehension when produced by others. The data comprehension must constitute the main interest of investigations at the initiation of any data integration approach in prospect for a decision (Noucher and Al 2008).

### 2.1 Geographic information surrounds

Geographic information results from a real-world representation which tries to communicate a simplified sight translating reality. Its exploitation supposes the integration of geographic data referring to various fields and putting in interaction as many categories of users. She claims a good comprehension of the different users needs. That requires the implication of the various doers to reach a consensus on the objectives and the priorities, and consequently, on the accords on the national standards and criteria concerning the essential authorizations. The attention must still be concentrated on the development of models and tools for the exploitation and the management of geographical information (Molenaar 1998, Donnay 2002, Noucher 2006, Parent and Al 2006).
Everywhere, the national doers, aware of the strategic aspect of geographical information, initiated settlement forms to set up a favorable framework to data handling. These approaches could benefit from technological advances appeared in the geographic information field; namely the development of standards, formalisms and models. Conceptual and semantic modelling still arouses the interest of recent research as data accommodation mechanisms to new user's needs. It constitutes an effective means to clarify and formalize knowledge, and consequently to face the challenges of diversity in geographical information domain.

## 2.2 Semantic aspect of the geographical data

The representation of the real-world objects in a geographical database requires a clear and precise semantic definition. The good communication is improved with formalisms ever since they can be easily interpreted. However, geographical space is enough complex to be formalized by objects and their interactions. Thus, a data dictionary is ideal to enrich the description of real-world phenomena. It constitutes in fact a part of the whole metadata but has the advantage of being more flexible than a metadata set and more easily accessible to the end user (Pantazis and Donnay 1998).

The contents of a data dictionary are influenced by the target public. This adaptation concern to user's needs is present at all development levels of an information system. The main issue is the risk of doers' objectives divergences that condition the viewpoints, and thus the choice of the tools and work environment (Pornon 2007).

So we insist on the specifications value at the time of the implementation and the exploitation of the geographical databases. They comprise even the database diagram which represents part of the metadata (Sheeren 2005) and they can be intended for various categories of users. For data producers, the specifications can be used to guide operators during the data acquisition. In addition, they constitute an effective interpretation means which can inform about the potential of information use.

## 2.3 Models, ontology and integration

The current context of geographical information field is marked by the doers' diversity and consequently their multiple viewpoints implying increasingly varied behavior area and so different horizons. The difficulty of communication and information sharing is then perceived at various echelons. In the case of several databases that are conceived independently, the interoperability problem is due partly to semantic inconsistencies. Generally, two levels of interoperability are definite, syntactic and semantic. A solution based on ontology was proposed for the semantic level. The aim is to give a sense to the vocabulary used by the various doers and accordingly to generate multiple definitions for each identified object. It is a question of defining ontology in a higher level inspired by existing ones. These below ontologies, described as secondary, are merged to check the completeness and to reach a consensus (Laurini 2007).

In the same way, (Noucher and Al 2008) stress the importance of real-world representations supporting multiple subjective perceptions of the same object. It is particularly useful within the geographical reference frame which constitutes a common concern for a range of users. Namely, the ontologies that are specific to particular fields can be exploited in prospect for a content adequacy to the various doers' objectives.Other works were interested in the definition of a common vocabulary to represent shared knowledge. (Gruber 1993a) recommended the recourse to ontologies to establish agreements on the contents specifications of shared knowledge. The goal is to develop mechanisms for the ontologies definition to be transportable between representation systems. (Wache and Al 2001) were interested in the ontologies role for information sharing by focusing the approaches based on ontologies for information integration. The question of information sharing was also raised for specific domains implying the sharing of knowledge relating to these fields within the frame of integrated information systems (Fonseca and Al 2000, 2002). The diagrams enrichment can thus be supported by formal ontologies which facilitate the communication between different communities through the integration possibility of databases subsequent generally to different conceptualizations. Two concepts of ontologies were distinguished. On the one hand, "ontology of application" returns to conceptual diagram of geographical database which represents a perception resulting from the mental process of real-world abstraction as objects. Parallel to this aspect, "ontology of domain" is definite as a representation of objects types which one can meet on the ground. This definition returns, in fact, to topographic concepts (Gesbert 2005).

The distinction between these two aspects of ontology, in the geographical information domain, refers to the degree of specifications respect, and, consequently to the quality of the geographical data. It is also the basis of our investigations about ontology which consider these various abstraction levels as a preliminary to develop a diagram to be generic as well as overall. These investigations were the object of a research centered on the modeling of the reference geographical data like precondition to the installation of a national SDI in Morocco and enable to constitute a first draft on integration problems and the means to attenuate them (Ibannain 2009). In the following, we will clarify these aspects by raising the importance to return on the fundamental bases of geographical information to determine an interest center shared by the various national doers. Hence, we reveal the approach continued to establish the principles of ontology relating to reference geographical data by amalgamating the concerns of their producers and users of geographical data and by capitalizing their practices.

## 3 ONTOLOGY OF REFERENCE DATA

The word "reference" evokes an information notion or an element to be used as guide or reference mark1. In the context of spatial information, this definition remains applicable. The term "reference frame" was always associated to geodetic infrastructure. Several changes in geographical information domain evolve this sense and we talk also about geographical reference frame. It concerns a collection of basic geographical data which interest a broad community of producers and potential users of geographical information. In the following, we qualify this data collection as reference data. The identification and the definition of reference data in Morocco constituted the first step towards the envisaged modelling. Initially, we exploited the land register and the cartographic data produced and utilized within the National Agency of Land register, Cadastre and Cartography (ANCFCC), the official producer of land register and cartographic data in Morocco. Indeed, the basic topographic maps still constitute the major component of geographical data while the economic land register appears as a promising source of information for the large scale applications. The preliminary study of the internal cartographic data structure permitted to take note of mapped details. Nevertheless, a redefinition of objects and their attributes was necessary to mitigate the limits of cartographic structure. Similarly, the structures of existing databases in the cadastre differ from one to other resulting in inconsistencies on several levels. The omission of modelling phase -prior to data processing- is evident as well in the land register as in the cartographic data production.

[1] Translated from Wikipédia 2008

The consideration of the conceptual basis appears essential to a coherent development of an integrated diagram as a reference data framework at a national scale. Thus, we have recourse to some inherent aspects to data producers and users objectives besides the existing data configurations. These considerations enable us to highlight the main problems related to data use, even by the initial producer to derive other products. At this point, we are interested particularly in semantic inconsistencies that constitute one of the obstacles facing interoperability. The semantics description is essential for information management. Moreover, ontology allows, not only to explain the concepts by using a common vocabulary, but to reproduce the sense of the concepts and relations which link them (semantic Web 2005). In this way, we carried out the features cataloguing in compliance with the standard ISO 19110 (ISO/TC 211 2005) and to the ontological approach which we proposed for reference data.

## 3.1 Feature cataloguing or ontology of reference data?

### 3.1.1 "Feature cataloguing

The development of a feature catalogue concretizes our analysis. The catalogue contains the description of all current data according to a genuine structure. This structure translates into objects, attributes and relationships all the inventoried data. Moreover, this first step of the modelling process takes into account the requirements of the main categories of reference data. The various objects have been distributed among several generic abstract feature classes which have been characterized by attribute values constituting surrogate metadata for the objects belonging to each class. Finally, eleven object types have been defined (table 1) with the constraint that an object cannot be present in more than one data model in order to avoid object redundancy.

Table 1: Description of reference objects types

| Object types | Description |
|---|---|
| **GEODETIC REFERENTIAL** | Abstraction of all the elements of the geodetic reference frame. |
| **LIMITS** | Abstraction of political, administrative, cadastral and zoning limits, and any other delimitation. |
| **RELIEF** | Abstraction of all the objects describing the configuration of the Earth surface, such as it is determined by the variations of this surface using the relief forms. |
| **HYDROGRAPHY** | Abstraction of all the objects describing the organization of the hydrographical network and water bodies, according to the layout of the relief, the disposition and the topography of the solid masses which contain marine water, and also all the hydraulic installations related to the human activity. |
| **TERRESTRIAL TRANSPORTATION** | Abstraction of all the components of the road network |
| **RAIL NETWORK** | Abstraction of all the components of the rail network |
| **STRUCTURES** | Abstraction of permanent constructions and structures such as buildings and constructions in relation to the various networks and the equipment installations. |
| **AIRPORT FACILITIES** | Abstraction of the objects conceived for the takeoff and the landing of aircrafts, as well the installations for the passengers and freight as the aircraft storage and maintenance. |
| **PORT FACILITIES** | Abstraction of navigable water bodies and harbour installations. |
| **EQUIPMENT** | Abstraction of the objects which come under the domain of the electric components and any equipment of communication, industry, mines. |
| **VEGETATION** | Abstraction of entities which compose vegetable cover as well as surfaces covered of vegetation. |

### 3.1.2 “Limits” as example of object types cataloguing

The definition of the object type « Limits » is based on the semantic of this term that signify an abstract line delimiting an area. Beside the features classes enabling the restitution and the characterisation of political, administrative, cadastral and zoning limits, we have recourse to others types of delimitations. “Vegetation limits” is an example of physical delimitations subsequent to« Vegetation » object type. In the same way, the boundaries of watershed units represents a special delimitation composed of crest lines or water dividing line that we have defined -in the same catalogue- as ensuing from the object type “Relief” (table 2).

Those features classes can be considered as delimitation; but are catalogued, each one, according to other object type among the eleven object types defined above. The classification approach intends to be adapted to many applications by means of two essentials goals. In one hand, the definition of data sets according to the concerned theme; and in the other hand, the anticipation of interactions between different objects types taking into account the situations implicating, in addition, the sharing of some attributes or methods by several feature classes although they depend on distinct objects types (multiple inheritance).

Table 2: Sample of descriptive table of feature classes of the object type “Limits”

| Feature Classes | Definition | Attributes | Subtype of feature class |
|---|---|---|---|
| ADMINISTRATIVE LIMIT « DECOUPAGE ADMINISTRATIF » | Abstract line indicating territorial administrative limits resulting in controlled administrative areas. | *name_DADM*<br>*design_DADM* | REGION, WILAYA, PROVINCE, CERCLE, CIRCONSCRIPTION, COMMUNE, MUNICIPALITE |
| CADASTRAL MAP “MAPPE CADASTRALE” | Map of assemblage intended for the progressive constitution of the land register corresponding to the land documents. | *code_MAP_CAD*<br>*scale_MAP_CAD* | |
| WATERSHEDS UNIT “UBV” | Watershed is a land area that drains to a particular point (outlet) along a stream. The watershed boundary is defined by the highest elevations surrounding the stream and marked by the water dividing line (AFT, 2008). | *name_ubv*<br>*height_exutoire* | UBVE |

Table 3: Sample of descriptive table of feature classes attributes of the object type Limits

| Attribute | Definition | Value Data Type | Value Measurement Unit | Value Domain Type | Value Domain |
|---|---|---|---|---|---|
| *name_dadm* | Descriptive or official proper name | Varchar(25) | - | - | |
| *design_dadm* | level of administrative limit | Varchar(25) | - | enumerated | REGION, WILAYA, PROVINCE, CERCLE, CIRCONSCRIPTION, COMMUNE, MUNICIPALITE |
| *code_map_cad* | Code of cadastral map | Varchar(10) | - | - | |
| *scale_map_cad* | échelle de la mappe cadastrale (nbre echelle) | Int | - | - | |
| *name_ubv* | Name of watershed unit if it is available | Varchar(25) | - | - | |
| *height_* outlet | Height at the outlet witch designates the lowest point of the watershed. | Float8 | Meter | - | |

### 3.2 Ontological approach for reference data

We can identify our definition manner of reference objects types during features cataloguing to an ontology which takes as starting point the common practices between producers and users of spatial data. With this intention, the adaptability -to a particular application- of any entity that we describe as object of reference, claims some relevance criteria. That is to say, the essential aspects which ordered the features cataloguing reflect ontology concepts which we structured as a matrix of projects control.

We used the class of concern "organization" as in the traditional matrix (Pantazis and Donnay 1996) to highlight the organizational aspects ordering reference data definition. Our interest was focused then on the purpose of reference data creation besides their former uses. The reference objects types under consideration in the phase of features cataloguing constitute the fourth class of concern. The last class that we considered is the overall coherence which reflects one of the four ontological criteria (clearness, coherence, extensibility and minimal ontological engagement) stated by Gruber to evaluate and highlight the basis of ontology (Gruber 1993b). The established classes of concern are thus analyzed according to these criteria, to arise the principles which we defined for reference data ontology (Table 4).

Table 4: Principles of reference data ontology (Ibannain, 2009)

| | **Organization** | **objective** | **Use** | **Reference objets types** | **Coherence** |
|---|---|---|---|---|---|
| **« Clearness »** ***(Descriptive level)*** | Identification of reference data and doers | Object and use possibilities | Applications domain typology | First dictionary | **1. independence / complementarity** |
| **« Extensibility »** ***(Conceptual and Organisational level)*** | **3. Hierarchy** | **2. Adaptability** | | | Multiple inheritance |
| **« Minimal engagement »** ***(Logical-physical level)*** | Constraints | **Overlap of domain** | | | Production responsibilities |

The analysis of the table above enables to express the ontology principles by considering the various classes of concern chosen. Thus, the first class -"organization"- reflects the general context of production and use of reference data. At a descriptive level expressing the criterion of clearness, our approach is concretized by the identification of reference data in Morocco, as well as the various implied doers. It is a question of highlighting data collections that interest utmost users to surround the preliminary investigations field. By combining this first element of analysis with the two following classes, namely the objective and the use of reference data, we can draw up the first typology of the current practices of reference data producers and users. The objectives motivating the production of these data and the potential uses inform about the contents and the sense of information. In addition, the degree of data adaptability is partially documented through the former applications of these data.

These considerations were at the base of the reference objects types definition enabling to constitute the first classification within the framework of a "bottom-up" approach of features cataloguing. The definition of object types, at a generic level, was based on taking into account all data relating to each object type. The definition approach reflects an information synthesis at the bottom to arrive at the higher level.

3.2.1 Principle 1. Independence and complementarity of objects types

The coherence checks constitute the subject of the last concern class considered. They translate the first principle that we defined for reference data ontology, namely "independence and the complementarity" of the reference objects types. Indeed, these checks enable to avoid the overlapping between the domains covered by the various objects types at a general level. According to the specified detail level, the coherence can relate to features which concern several objects types, by having recourse to the concept of multiple inheritance which underlines the complementarity of the objects types authorizing thus the overlapping of their domains.

3.2.2 Principle 2. Adaptability of objects types to specific fields

The analysis on a descriptive level translating the criterion of clearness permits to accumulate knowledge on reference data whose first concrete result is the data dictionary. The differentiation of data set was done thereafter without ambiguity, enabling to constitute reference objects types fulfilling the criterion "adaptability of objects" to a maximum of applications. The taking into account of the objective of data sets creation and their former uses, made it possible to identify the properties which an object must have to meet a specific field needs. In other words, the objects qualified of reference are defined in a complete way, independently of their context. Their exploitation in a particular application must be done in a functional way while ensuring extensions to the specific field concerned.

3.2.3 Principle 3. Hierarchy

As considering above, the features' cataloguing was made with the intention to ensure the adaptability of reference objects to various scopes of application. The objects types are defined in order to work out as many conceptual models. The conceptual reference model consists of a hierarchy which is concretized by specialization relations binding the various objects types to the reference object type. Finer specify level, specialization relations can join some features classes other generic features classes. The definition of these relations during features cataloguing is resulting from a conceptualization preliminary to formalized conceptual modeling.

# 4 ONTOLOGY OF REFERENCE DATA TOWARDS AN INTEGRATED DIAGRAM

## 4.1 Conceptual modelling of reference data

The data conceptual modelling consists in describing structured information according to a coherent diagram by specifying the constraints and the conditions to satisfy. The data cataloguing enabled us to define eleven object types. This classification was based mainly on the characterization of the feature classes in terms of plausible afterwards treatments.

Resorting to international expertise – in term of existing models of reference (IGNB, 2003; IGNF, 2002; Ordnance Survey, 2006) – permits to improve the perception and the definition of some feature classes. Beside, the exploitation of the environment dedicated to the conception of spatial database on Internet, so called Web2GIS (Laplanche, 2006), simplified the development of the various models thanks to the direct import of feature classes from the reference feature catalogue previously carried out. It is enough to associate their spatiality to feature classes and to gather them within packages. The specific models are consolidated via a generic model that we described as reference model (figure1).

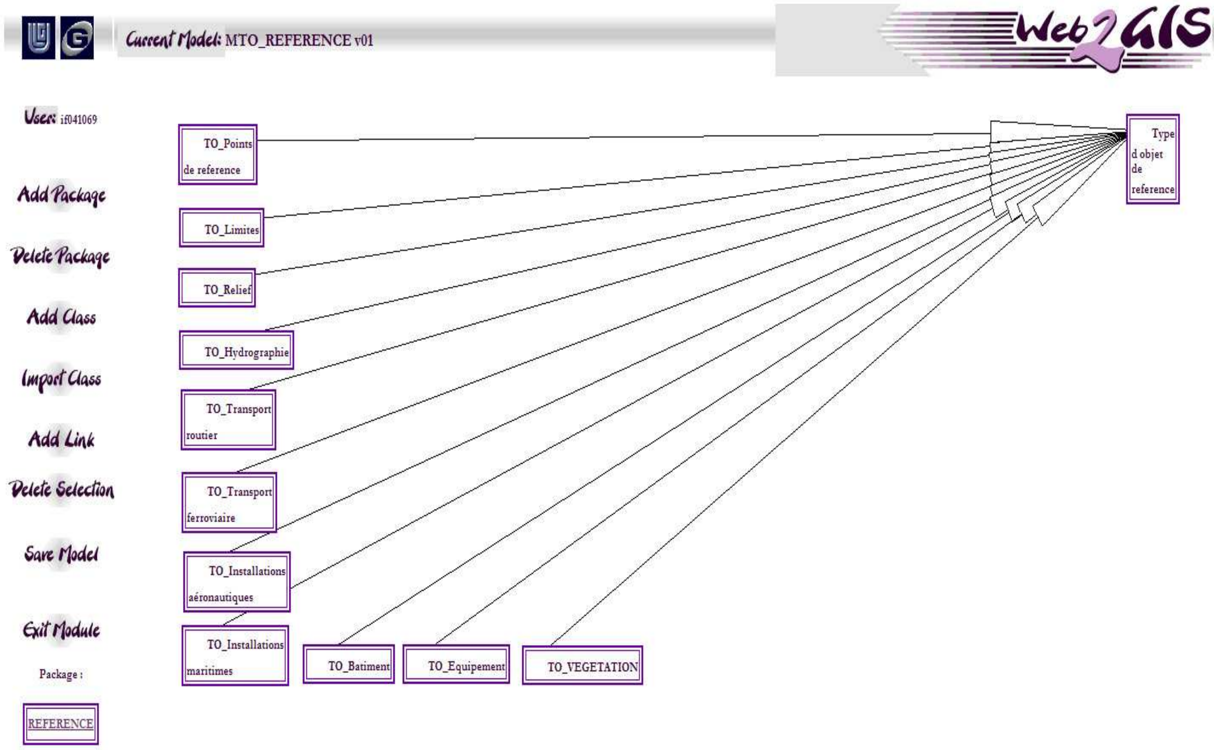


**Figure 1: Model of reference: MTO_REFERENCE**

## 4.1 Application

To concretize the capacities of the reference model by specifying test criteria (compromise between reference objects and those of the application scope), we choose the cadastre plot as example. The lands register boundaries are materialized by the establishment of cadastral mark. The existence of physical limits, which can be of a natural origin or related to the human intervention, facilitates the identification of the parcels limits. Among these limits, we can quote the fences, the rivers or the public ways. To describe the interactions connecting a cadastral parcel to various geographic entities, the object type model of delimitation "MTO_LIMITES" was amplified by the importation of two feature classes -"vegetation limit" and "fence"- from the specific models –"MTO_VEGETATION" and "MTO_STRUCTURE" (figures 2 and 3).

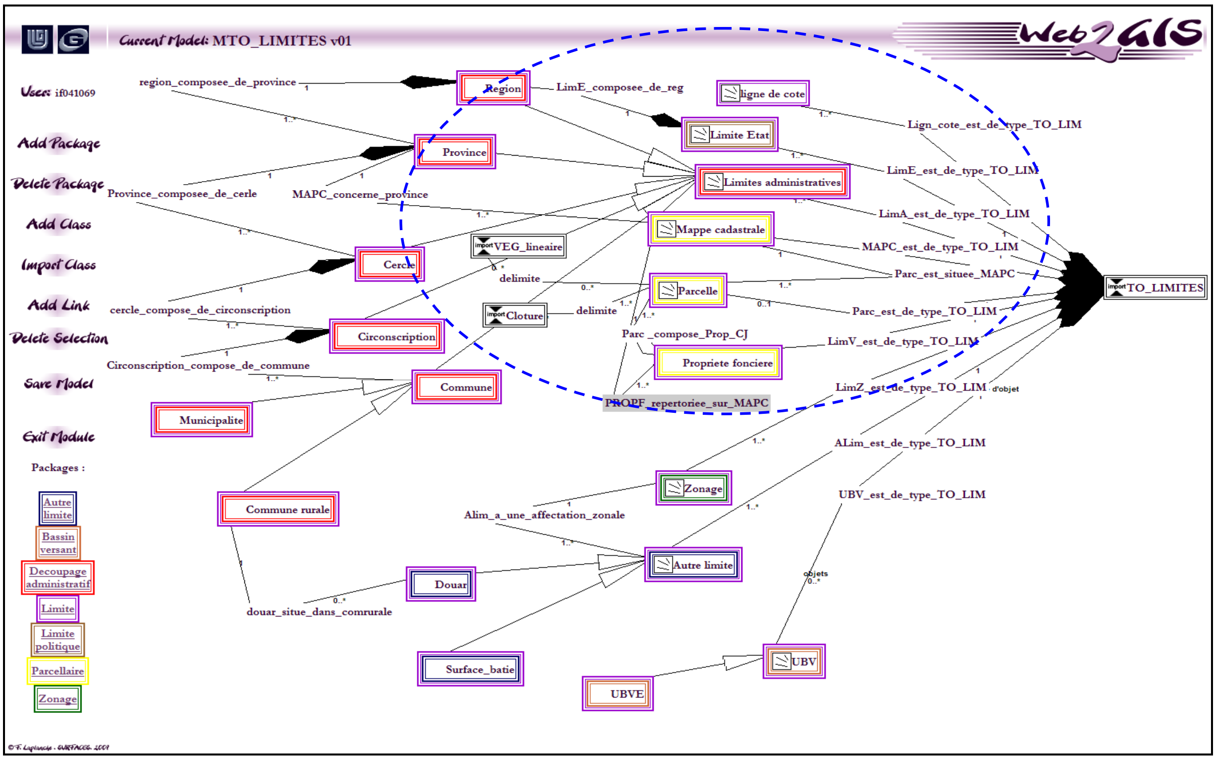


**Figure 2: Delimitation model (mto_limites) and feature classes concerned with the application**

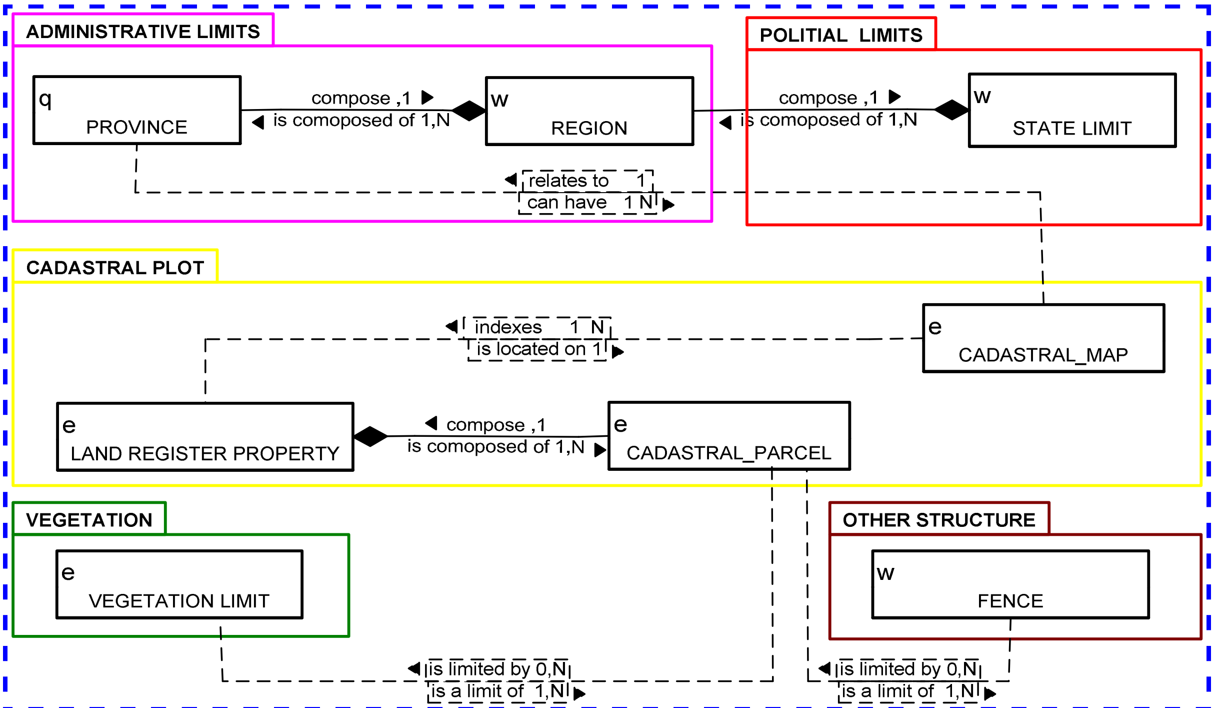


**Figure 3: Application conceptual data model**

## 4.2 Exploitation of the reference model

The exploitation of the reference model constitutes a considerable asset for data integration while mitigating the problems of heterogeneity commonly noted at the time of the exploitation of data resulting from different models and disciplines. Indeed, several approaches of classification of heterogeneity raise the semantics, diagrammatic and syntactic aspects, which obstruct geographical databases integration (Bishr 1998, Hakimpour 2003). Other work regards the great difference between the detail levels within the same domain as another problem of heterogeneity. It is the case of national agencies of cartography which lay out features catalogues corresponding each one to a given scale, generating thus, wide variations between numbers of concepts selected to describe the geographical space from scale to another. To solve the heterogeneity problems, (Gomez-Pérez and Al 2008) proposed the recourse to the cartography as mechanism which connects heterogeneous elements for the automatic generation of an ontology as of the catalogue relating to the scale 1/25 000e. Concurrently to this step which aims at the creation of an integration framework to maintain the existing databases as an option facing the lack of tools for “completely” automatic generalization, (Stoter and Al 2008) propose an data model with a semantic enrichment for integrated topographic databases. The aim is to support “semi “automatic” generalization by adding transition models between scales.

In the case of this research, the developed reference model can be exploited by various categories of users and at various detail levels. According to the user point of view, the objects type’s models can be implemented under their current form or extended by the consideration of existing ontologies of domain. In view of these work assumptions, the reference data model can be perceived like a reply to the lack noted in terms of tools for numerical geographical information modeling and management in Morocco. Thus, the model of reference stands for a field of shared interest to various disciplines. Its adoption permit to constitute databases resulting from the same CDM and consequently, to mitigate the problems of heterogeneity raised by (Hakimpour 2003) and quoted by (Gum-Pérez and Al 2008); namely the differences related (1) to conceptual modeling, (2) to the objects semantic, (3) to the databases structure and finally (4) to the entities spatial modeling.

On the one hand, the various developed CDM result from a features catalogue compliant with the standard ISO 19110. This catalogue is elaborate according to the principles of reference data ontology moved mainly by the viewpoints of data producers and users, the existing data configurations and their former application scopes; so that limits the semantic inconsistencies. In addition, the model of reference is designed in a total way to consolidate various objects types’ models around the reference object type model enabling thus the constitution of databases that share the same diagram.

Concerning heterogeneity problems generated by various spatial modeling for the same object, we have envisaged some mechanisms during the conceptual modeling which was led according to the principles of the reference data ontology. In this way, the principle of adaptability, supported by various enrichment forms of the reference model, rejoins the transition mechanisms planned by (Stoter and Al 2008) for semi-automatic generalization. We exploit the concept of multiple inheritance between features classes which are dependent on different objects types as well as the upgrading capabilities of some features classes or their spatial modelling.

## 5 CONCLUSIONS AND PROSPECTS

The primary objective aimed in this paper is to set up a reference model to be a basic structure which can be adapted to a maximum of applications. The features cataloguing constituted the first step towards this modeling, and enable to propose the principles of "reference data ontology". The definition of the reference objects types, while authorizing the same concept to belong to several categories, amplifies the scope of the overall reference model even as ensuring its consolidation via the interactions between the various objects types models.
Within the framework of the reference data, a repositioning of ontologies in the general process of development of a GIS would assist to enrich the relations and the spatial properties characterization with the aim of an adaptation to various applications. Indeed, the development of a GIS for a given application is based on the data dictionary witch translates the ontology of the studied field. In the case of reference data, the development of a GIS begins starting from the reflection on the data dictionary, but the context claims the rehabilitation of ontology beyond the dictionary.
A thorough reflection on ontology for reference data can be considered and would permit to extend the reference model with regards to existing "ontologies of domain" related to specifics objects types' models. The established model can be exploited by implementing all developed objects types' models. Others extensions can be added by considering various detail levels to concretize the multiple inheritance possibilities of some features classes. Hence, it would be advisable to clarify the concept of reference to decide about the exploitation level of features qualified as reference objects.

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- **Diplôme d'Etudes Approfondies (DEA)** obtenu en Juin 2006 à l'ULG, Liège, Belgique.
- **Diplôme d'Ingénieur d'Etat en Topographie,** obtenu en 1994 à l'IAV HASSAN II, Rabat, Maroc.

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## CONTACTS

Dr./Ing. Fatiha IBANNAIN
Agence nationale de la conservation foncière, du cadastre et de la cartographie (ANCFCC)
BP, 6630, Rabat-Instituts, Madinat Al Irfane, 10101
Rabat
Morocco
Mobile. +212 (0)6 64 18 88 47