Elements of quality assessment of French OpenStreetMap data

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ABSTRACT. New concepts like free data or Volunteered Geographic Information (VGI) recently emerged thanks to new Web 2.0 technologies. The OpenStreetMap project is the most significant VGI example. It aims at producing free vector geographic databases using contributions of Internet users. The problem of spatial data quality is a key question in this context of freely downloadable geographic databases.

This paper studies the quality of French OpenStreetMap data. It is an extension of the work of Haklay (2008) on the area of France. It also provides extra elements assessments of spatial data quality (geometric, attribute, semantic and temporal accuracy, logical consistency, completeness, lineage and usage) and uses different methods of quality control. Results raise problematic aspects of VGI spatial data quality such as the heterogeneity of processes and scales of production, or the respect to standardised and accepted specifications. In order to improve data quality, a balance has to be struck between the contributors' freedom and his respect of specifications. The development of adapted solutions to provide this balance is an important research issue in the domain of users' generated contents.

KEYWORDS: OpenStreetMap, spatial data quality, VGI, specifications

1. Introduction

With the advent of the current Web 2.0, contributors do not just look for content but are also creating it themselves, as showing the success of Facebook, MySpace, YouTube or forums. This new phenomenon generates new methods of production that Tapscott and Williams (2007) describe as the *crowdsourcing*, which consists in using the expertise of a large number of users to perform tasks at a lower cost. At the same time, the success of open source software is extended by the emergence of open databases that can be used more or less freely depending on the type of license. Thus, some new spatial data producers as local administrations (Touya, 2004) prefer to make an entire community benefit from the data they produce rather than keep data for private use. Together with the democratisation of GPS, these two phenomena meet up today turning everyone into a sensor of geographic information, able to provide a contributively created geographic information or *Volunteered Geographic Information* (VGI) (Goodchild, 2007). That is what Sui (2008) called the *wikification* of geographic information.

In this context, the rapid development of the OpenStreetMap project (OSM), born in 2004 in England, is not surprising (http://www.openstreetmap.org). Each project member is invited to submit data acquired mainly by GPS. It is then available on the website like in cartography sites as GoogleMaps or the *Geoportals*. Above all OpenStreetMap data are freely downloadable in vector format. The project, which was originally limited to English roads, has spread around the world, and allows contributors to capture topographic databases. Given the possible applications of spatial vector databases (mapping, geographic analysis, urban planning or risk prevention), the question of the quality of such data should be asked.

The COGIT Laboratory is historically involved in research aspects of spatial data quality (Vauglin, 1997; Bonin, 2000; Olteanu, 2008). Current work deals with the design of an evaluation model of geometric imprecision in vector databases. The possibility to evaluate geometric accuracy of OSM data with recent tools, paved the way to extend the assessment to others elements of spatial data quality.

The question of quality assessment also includes comparison with institutional geographic databases, as those of the French National Mapping Agency (Institut Geographique National, IGN). Haklay (2009) suggested comparing British OSM data with those of the Ordnance Survey, the English national mapping agency. In this context, the objective of this paper is to extend the work of Haklay to French data, taking into account more elements of quality of a geographic database, and using other quality control methods.

The following part of this paper describes more precisely the OSM project and its data model. The third part presents the selected elements of spatial data quality and the study areas. The fourth part proposes an assessment of OSM data quality, regarding the elements of spatial data quality presented previously. Then, the fifth part discusses of the place of specifications in the OSM data production process. Finally, the article ends with a conclusion and perspectives of further research.

2. What is OpenStreetMap?

2.1. The OpenStreetMap project

OpenStreetMap (OSM) is a collaborative project like Wikipedia, started in England in 2004 by Steve Coast. The aim of OSM is to create and provide free geographic data. The project aims to compensate the lack of free data because geographic data, even freely available, are provided with licenses restricting the use of information and the creativity according to project leaders. The data are distributed under the license “Creative Commons Attribution-ShareAlike 2.0 license”. This license allows using the data completely freely, in condition to distribute any derived data under the same license. For instance, corrected OSM data can not be sold.

Data stored in OSM by contributors of the project are modelled and stored in tagged geometric primitives (see 3.2). For example, a road is a polyline with tags *highway* = "primary", *oneway* = "no" and *name* = "N10". Geometric primitives are of three types: points, paths (polylines) and relationships (linking points and paths with tags) that are not really *geometric* primitives. The surfaces are represented by closed paths. There are quite precise specifications listing the accepted tags and fields of values (Figure 1). A contributor can submit a new tag or a new value that can be added to the specifications after a vote. Even if it is not advised, the contributor is free to use tags and values outside of these specifications. To facilitate the work of the contributor, there are also information files showing how to tag a given situation: in the Figure 2, the situation of the image is modelled by 3 items (2 roads and a tramway line). Data are available from any area specified for export in a specific XML based format. It has to be translated if anyone wishes to use the data in another application.

Data is captured using GIS software adapted to OSM data with editing functions to create OSM geometric primitives and tag them. Different software exists to edit and capture OSM data (Potlatch ®, JOSM ®, Merkaartor ®). In such software, data can be created directly but come generally from free sources like personal GPS tracks. Different datasets have been made available by government agencies for the OSM project, like TIGER data of the United States, Prototype Global Shoreline (NGA) or Landsat 7 satellite imagery. In France, the official authorization to capture geographic objects using cadastral data has been given in 2009.

OSM applications currently aim to foster mapping creativity of potential contributors of geographic data. Thus, there are various sites proposing OSM data as CloudMade (route calculation) or GeoFabrik (which provides OSM data in shapefile for example). Allan (2008) offers maps suitable for cyclists.

3.2. Analysis of the OpenStreetMap data model

Institutional geographic databases are structured in classes, attributes and relationships (Goodchild, 1992). An object of a geographic database belongs therefore to a class, for example *road segment*, and has values for different attributes of the class, such as "Highway" for the attribute *nature* and "20m" for the attribute *width*. The BD TOPO ® IGN is composed of thirty classes divided into different themes such as hydrography, buildings or transportation systems.

As stated previously, OSM data follow a different model rather used in the management of Internet resources, the Resource Description Framework (RDF) defined in Manola and Miller (2004). Information is modelled as a triplet (resource, property, value). In the case of OSM, the resource is a geometric primitive with coordinates, the property is a tag and the value is a value of the tag. The triple follow the form: (point(x, y); highway; primary). This RDF information is represented in XML as in Figure 3. Compared to a conventional structure in classes and attributes, RDF allows the easy integration of not obvious objects to identify in classes, but on which we know certain properties. Lemmens (2006) explains that the RDF is particularly effective if it is coupled with a RDF *Schema* model that describes resources and properties with a vocabulary. In the case of OSM, specifications are not as structured as in a RDFS model.

The RDF structure can pose several problems. It is quite complex to translate data into RDF classes and attributes. Several solutions are possible to switch from one to another, but the translation into classes inevitably generate losses on the tag information and the number of classes is not easy to decide. For example, tags that characterise highway roads may include points, lines, or surfaces and the separation into classes is not clear. The reverse transition is automatic (Lemmens, 2006). Another problem concerns identification of real world objects. The ideal way would be to carry a unique identifier on the real world entities, or on an object. In the case of OSM, identifiers refer to the geometric primitives, which generate difficulties to manage and update databases.

Nevertheless, structuring geographic data in a RDF format can also prove interesting. Goodwin et al (2008) translated Ordnance Survey Administrative database in RDF to facilitate interoperability but using ontology to formalise properties contrary to OSM. Goodwin et al (2008) also noticed that topology relations explicitly stored in RDF allowed good querying performance.

3. Selections of quality elements and study areas

3.1. Elements of spatial data quality

Several elements (or components) are proposed to describe the quality of geographic databases (Vauglin 1997). Using Guptill and Morisson (1995) and Kresse and Fadaie (2003), the following elements are selected to assess the quality of OSM data:

- *Geometric accuracy*: assesses the positioning and geometries resolution from the ground reality.

- *Attribute accuracy*: assesses the accuracy of attributes captured according to the specifications of the database.

- C*ompleteness*: evaluates if all data are present in the database.

- *Logical consistency*: assesses the degree of internal consistency as modelling rules and specifications (including respect of integrity constraints (Servigne et al, 2000)).

- *Semantic accuracy*: assesses if the semantics carried by the objects correspond to the real world.

- *Temporal accuracy*: evaluates the actuality of the database relative to changes in the real world.

- *Lineage*: concerns the lineage of objects, their capture and their evolution.

- *Usage*: evaluates how well the database fits for the use that will be made.

The assessment of some elements - for instance geometric or attribute accuracy - involves the recourse of reference datasets to perform comparisons. In this case, the BD TOPO ® Large Scale Referential (RGE) from IGN is used to evaluate the quality of OSM data.

3.2. Study areas

To complete the assessment of the elements of spatial data quality evocated above, different study areas are used, due to several constraints. These areas are presented in this part in order to justify the failure to conduct a systematic analysis on a given and spatially limited area.

The region of *Hendaye* was initially supposed to be the study area. This region is composed of a variety of landscapes (mountains, valley plains and littoral) and presents both rural and urban areas. The availability of reference datasets is also a key asset to conduct analysis in this area. It is used to assess geometric accuracy (for points and polylines primitives) and semantic accuracy using the themes *road network* and *coastline*. Unfortunately, the waste of polygonal objects in a critical size on the theme *lake* - which is the most adapted to perform this task - obliged to use another study area.

To complete the assessment of geometric accuracy for polygonal objects, the mountainous region of *l'Alpe d'Huez* appeared to be particularly convenient. Indeed it presents a sufficient set of objects on the theme *lake* to perform comparisons with a reference dataset. It is also used for the evaluation of attribute accuracy.

The assessment of logical consistency is realised in two different areas, particularly along *La Seine* and *La Garonne* rivers - two of the largest French rivers - in order to analyse inter-theme topological consistency between themes *waterways* and *administrative limits*.

Other elements of spatial data quality, as completeness and temporal accuracy, are performed on the entire French territory, using all the OSM data available. Some focuses on 75 equally distributed areas are performed, in order to analysis the spatial distribution of contributors' involvement.

Several illustrations are also proposed in different areas of France, as the departments of *La Creuse* and *La Seine-Maritime*, or the towns of *Paris* and *Toulouse*.

4. Quality assessment of French Openstreetmap data

4.1. Geometric Accuracy

To estimate geometric accuracy, comparisons are made between the OSM data (data sets to compare) and BD TOPO ® (reference datasets with a metric resolution). “Homologous” objects are selected and matched manually to avoid errors related to an automatic process. Differences in position are then computed on each pair of homologous objects. A specific application is developed in Java, based on the GeOxygene library (Bucher et al, 2009).

4.1.1. Points primitives

The comparison test of points is realised on road intersections from road layers of the two databases in the region of Hendaye. Pre-treatment using a topological map from GeOxygene allows generating nodes, corresponding to road intersections. A sample of 207 pairs of homologous point objects is achieved by manual selection, trying as possible to cover the entire study area (Figure 4).

For each pair of selected point objects, Euclidean distance is used to generate a distance distribution drawn in Figure 5 and summarised in Table 1. The distribution of positional differences presented in Figure 5 shows a concentration between 2.5 and 10 meters. The average positional difference, computed from the sample, is about 6.65 meters. This distance is close to the average difference of about 6 meters observed between OSM and Ordnance Survey datasets according to Haklay (2009). Important differences - the maximum distance recorded is 31.58 meters - are relatively marginal. They are certainly due to errors of capture by the operator or by the precision of the GPS. These errors don’t constitute outliers, because the matching has been supervised manually. This first result shows a classical distribution with a concentration of errors between 2 and 10 meters. Nevertheless, no specifications guarantee this result, as indicated by large differences in the distribution.

4.1.2. Linear primitives

To characterise positional differences between linear objects, two distances are used: the *Hausdorff distance* and the *average distance*.

The Hausdorff distance measures the maximum deviation between two polylines, as shown in Figure 6a. The Hausdorff distance dH between polylines L1 and L2 is defined as follows: dH = max (d1, d2)

where d1 represents the maximum of the shortest distances from L1 to L2 and d2 is the maximum of the shortest distances from L2 to L1.

The average distance between two polylines, introduced by McMaster (1986), measures a distance defined by the ratio between the surface S separating the two polylines L1 and L2 with their average length, as shown in Figure 6b. The equation of the average distance *dM* is defined as follows:

$$dM = \frac{S}{\frac{L1 + L2}{2}}$$

Two tests are performed to characterise the geometric accuracy of linear objects from OSM data: using road and coastline layers. For the road network, a selection of 50 pairs of homologous linear objects in the region of Hendaye is used.

The distribution of Hausdorff distances shown in Figure 7, indicates a concentration between

5 and 15 meters with a peak between 5 and 10 meters. The average of maximum deviations (Table 2) reaches 13.57 meters. It is important to nuance the interpretation of extreme values (beyond 20 meters), which may be biased by the introduction of extremities of polylines (departure and arrival nodes) in the computation of Hausdorff distance.

Distribution of average distances as shown in Figure 8 and Table 2 is fairly spread, but in relatively small distances (0 to 6 meters), knowing that in the reality, a road is around 6 meters wide. Nevertheless, nothing indicates if OSM segments represent the axis of the road, as it is clearly specified in the specifications of the BD TOPO®.

The distribution of average distance on road network confirms the observation made by Haklay (2008) showing differences about 6 meters, but the observation of Hausdorff distances reveals relatively large local heterogeneities in the OSM dataset.

A comparison of the theme coastline is also conducted in the region of Hendaye, after extraction of three pairs of homologous linear objects (Figure 9). Some portions of the coastline, with important differences, have not been taken into account. Indeed, the coastline specified by IGN on the BD TOPO® (level of highest tides with a 120 coefficient) can penetrate deeply inlands in some estuaries. This area however may not be represented in OSM data, because of the lack of specifications of capture, and the subjectivity of the operator in his perception of the coastline. But before computing differences, a simple observation reveals the heterogeneity of the OSM coastline production process. Some portions of the OSM coastline are perfectly superposed to the one provided by the NGA (Prototype Global Shoreline) and some other not (in estuaries or urban areas). This situation well illustrates the cohabitation of two production process methods for a same layer (NGA extraction and manual capture by a contributor) and has a significant impact in the computation of differences.

The couple No. 1 (Figure 9), captured in urban areas, presents smaller differences than the two other couples (Hausdorff distance of 25.93 meters and average distance of 0.82 meters). Couples No. 2 and No. 3 (Figure 9), captured in areas of bays and cliffs, present significant differences, respectively Hausdorff distances of 139.66 meters and 154.56 meters, and average distances of 32.21 and 26.58 meters. The curvilinear abscise difference between the two couple’s reaches 11% of the total length of the reference dataset (BD TOPO®).

In this example, it is clearly observed that the cohabitation of two sources of capture generates heterogeneities in the differences computed. The analysis shows that large differences correspond to the part of coastline extracted from the NGA, and small ones to the part captured manually by a contributor in urban area. Such results are particularly interesting because they illustrate the importance of defining precise specifications of capture.

4.1.3. Polygonal primitives

To characterise differences between polygonal objects, the distance used is the surface distance, proposed by Vauglin (1997) (Figure 10).

The surface distance dS is therefore computed: dS = 1 - $\frac{S(A \cap B)}{S(A \cup B)}$

where dS [0, 1]

where dS = 0 if A = B and dS = 1 if A B = Ø

The surface distance is defined in the interval [0, 1]. If the distance is equal to 0, the two polygons are equal, if the distance is equal to 1, the two polygons are disjoint. The comparison of polygonal objects is carried on the theme lakes in the mountainous region of *l’Alpe d'Huez*.

A 2500 km² study zone has been previously delimited, corresponding to 106 OSM lakes. In order to perform comparisons, lakes represented by polygons with holes or multiple polygons are eliminated. Finally, a sample of 68 pairs of homologous surfaces is used (Figure 11).

The distribution of surface distances (Figure 11) shows a concentration peak between 0.1 and 0.25, which corresponds to quite low differences. Indeed, Bel Hadj Ali and Vauglin (1999) proposed a polygon object matching process partly based on surface distance and considered such distribution as showing little difference. They compared buildings from cadastral and topographic data (considered as quite close in position and shape) and noticed that 25% were under 0.05, which is not the case here, and 70% were between 0.15 and 0.45.

However, comparison of polygonal primitives requires both a comparison of positions but also of shapes. To cope with this requirement, granularity and compactness measures were carried out on the same dataset (Table 3). The granularity measure used simply returns the shortest segment of the polygon. It measures resolution differences and the standard deviation shows great heterogeneity compared to BD TOPO®. Compactness is computed using Miller's measure (McEachren, 1985):

$$C = \frac{2\pi \times area}{perimeter^2}$$

Compactness differences allow assessing shape differences between OSM lakes and BD TOPO ones. Table 3 show that, here, the differences are small.

4.2. Attribute accuracy

Table 4 shows quantitative results on attribute accuracy while Figure 12 shows qualitative assessment on attribute accuracy. Quantitative results show that the main tag of each type of objects analysed is mostly informed (except for roads where the ratio is only 85%) while the secondary attributes are rarely informed. Qualitative results are based on the same method as for geometry but using here the Levenstein distance that compares strings. Qualitative results show that only 55% of the lake names (of the sample of 68 lakes in the region of *l'Alpes d'Huez*) are as informed as in the BD TOPO®, but when they are, the names are nearly identical (a distance of Levenstein between 1 and 3 generally corresponds to simple spelling mistakes).

4.3. Semantic accuracy

Semantic accuracy assessment is also carried out on the nature or function of 585 roads represented in the tag *highway* in OSM data that was compared to the *nature* attribute of BD TOPO® roads. The main roads, corresponding to "Motorway" and "Primary" values have semantically correct classification as nearly 100% have their BD TOPO® homologous classified the same way. But only 49% of the secondary roads are semantically correct compared to BD TOPO®. The error made by the contributors is mainly the underestimation of road importance: roads considered as "secondary" in BD TOPO® are classified as "Residential" or "Tertiary" in OSM data. The number of local roads in the OSM sample was to low to do the same comparison. Our interpretation is that when semantic classification specifications are clear like for main roads, the semantic accuracy is good which pleads once again for better specifications.

Other qualitative remarks can be made on the heterogeneity of attribute values allowed in OSM. The *One Way* tag, when filled, contains in the whole French road data the values 0, 1, -1, yes, no, true or false.

Semantic and attribute accuracy are not guaranteed by the specifications which explains the quantitative and qualitative results. Several issues explain the low accuracy:

- Specifications, by their global reach, are extremely detailed but don’t cover a classification commonly accepted by all contributors, who according to their profiles will be concerned in a limited part of the semantic possibilities. This causes semantic incoherencies depending on contributors: for example, secondary, tertiary and residential roads will not be classified in the same way.

- Even if it is not recommended, you can enter tags and values that are not present in the specifications.

- There is not a commission for the management of names, no more than recommendations for formatting (capitalisation, prefixes, etc. ...). There is therefore a very high inaccuracy in the names that are captured in the tag "name": for example on the same point of interest, we can have "Eglise Saint Jacques" and "Ecole Saint-Jacques".

As a consequence, standardised specifications are highly recommanded to improve semantic and attribute quality of OSM data.

4.4. Completeness

Goodchild (2009) claims that completeness is one of the most significant aspects of VGI quality. Measures of completeness are presented in Table 5. Regarding the number of objects, OSM is far from being complete for every theme considered. Regarding the total length/area of objects, the difference is less important. This result means that smaller objects are more likely to be absent, reflecting the fact that contributors are more focused on capturing attracting objects (the most useful for their interest).

It appears that the data density does not depend only on the density of information on the territory but also on the density of OSM contributors, that clearly excludes a number of territories (Figure 13). Thus, territories are best represented in rich areas and / or with a young population as shown by the extracts of the 15th arrondissement of Paris (Figure 14a) or the University Paul Sabatier in Toulouse (Figure 14b). The middle-size towns remain captured quite exhaustively. But lacks are observed at larger scales (street level) in some areas (Figure 15a). Completeness becomes very problematic in rural as in the Creuse (Figure 15a) where only a public utility mission would require surveys. Even in tourist areas like the Côte d'Azur, there are empty areas. Our assessment is confirmed by a more systematic analysis performed on English OSM data from Haklay (2009), who has shown that disadvantaged areas were less well covered.

4.5. Logical consistency

The logical consistency measures the consistency of different database objects with other objects of the same theme (intra-theme consistency) or objects of other themes (inter-theme consistency). For example, linear roads must be captured in network and must share the same geometry as the administrative boundaries when it is the case in the reality. Respect for logical consistency is generally done by the introduction of integrity constraints (Servigne et al, 2000). However, OSM does not contain any integrity constraints. Respect for logical consistency depends on the carefulness of each contributor during the capture. This results in many problems of logical consistency. Different cases are presented below.

Regarding intra-theme consistency, connectivity of roads is relatively assured (approx. 95%) using the snapping capacity of the capture tools (Figure 16a) while in the BD TOPO ® for instance, this error is guaranteed at less than 1% using auto-correction tools. Furthermore the structure of the network is not at all guaranteed (Figure 16b) while a good model finishes each line at every intersection (Egenhofer, 1993). Another example, observed on the theme *lake*, illustrates the same real world entity represented by multiple captures (Figure 17b). In all of these cases, the bad intra-theme consistency limits the use of data.

Regarding inter-theme consistency, Figure 17a and Figure 18 show how the capture of the administrative boundary has been carried out independently of the roads or the coastline, which generates strong inconsistencies. Moreover some statistics have been computed on river/administrative limit consistency, along the rivers *"La Garonne"* (on 158 km) and *"La Seine"* (on 137 km). 68% of the tested administrative units are not topologically consistent with rivers with great heterogeneity.

4.6. Temporal accuracy

The process of publication and diffusion of a particular update is fast in OSM, where contributions are automatically integrated without moderation. But the management of updates is not systematic and depends on the interests of contributors. Table 6 shows the evolution of French OSM data in number of objects over three months: a 30% mean increase for all objects. This evolution illustrates the reactivity of OSM contributors, but although the evolutions are mainly completions of new objects rather than updates of existing objects.

4.7. Lineage

A data lineage is provided: a comment about the data storage is associated to the contributor. However, we don't know how the data were captured except the software used. Also, the support used is not informed, as GPS tracks, satellite imagery or external datasets. This can be quite annoying in the case of data for which methods can be multiple or even illegal. Instead, in the BD TOPO ®, a source attribute informs the method used to capture data (photo restitution, map or field collection...).

Moreover, the historic of modifications is not kept, making the integration of institutional data difficult: if the geometry is changed, it becomes impossible to propagate the official updates. Goodchild (2008) claims that each contributor cannot be trusted the same between institutions qualified as *authoritative* and simple contributors that are at most *asserted*. Coleman et al (2009) confirms such confidence differences and proposes an option of calling upon moderators like in Wikipedia to control the different types of contributions. A proper lineage metadata would allow granting trustful contributions with rights forbidding less trustworthy contributions to update them.

4.8. Usage

Following the precedent discussion, we agree with the conclusions of Haklay (2009) that typical applications of OSM vector data appear to be limited to mapping. Navigation applications are limited by the problems of logical consistency: it is necessary to restructure all data in a GIS to use them for navigation, but then the lack of completeness, as attribute accuracy, would cause errors hardly acceptable. Road and river topological inconsistencies would also prevent the network from being automatically pruned (Touya, 2007) which is necessary to display it at different scales. Even classical geo-processing process like generating administrative polygons from limits massively fails because of low quality logical consistency. Urban planning applications would be limited in particular by the strong heterogeneity of geometric precision. Finally, any application based on OSM data would face major problems of updating management.

The strong heterogeneity of OSM data resolution also affects their mapping. Ruas (2004) shows that resolution and scale represent key concepts in cartographic visualisation linked to generalisation purposes (Mackaness et al, 2007). Differences in resolution between themes, or with other themes, severely limit the possibility of automatic generalisation, and therefore, a correct representation of data at different scales. This also blocks a real definition of the reference scale of these data, which corresponds in the optimal scale for mapping (Mackaness et al, 2007).

5. Specifications to Improve VGI Quality

The evaluation of different aspects of OSM data quality reveal the key role of specifications to ensure quality as several error types come from a lack or fuzzy specifications. The specifications of a geographic database gather the selection and modelling choices of the database. In OSM, the specifications are rich and complex but informal, instead of being recorded in written formalised and well accepted specifications. A contributor is advised to follow the specification but does not have to. For instance, the inaccuracy of the coastline (Figure 9) is due to a lack of capture specifications. Expert contributors aware of the challenges of quality and consistent contributions will strictly meet the specifications while novice contributors will probably ignore them. Goodchild (2008) agrees with the idea that VGI data lack standardised and precise specifications to be quality geographic data. Indeed, he claims that although crowdsourcing has proved qualitative in different domains, geographic information has particularities that require modelling and capture agreements.

Gesbert (2005) proposes a formal model for geographic database specifications to allow the specifications to be machine-interpretable. Abadie (2009) extends this formalisation to propose an XML specification model that helps to detect automatically inconsistencies in data, which could be useful to improve OSM data.

The definition of a reference scale and of a resolution (Ruas, 2004) is also related to the definition of specifications. The capture of a contribution should be based on a reference scale, a resolution described in the specifications to avoid resolution heterogeneity.

OpenStreetMaps clearly lacks reference scale ranges: captured data should be specified to be used in a specific scale range where its quality and resolution is good enough like in the *ScaleMaster* (Brewer and Buttenfield, 2007). Actually, each OSM feature has its own reference scale and resolution (buildings and built-up areas do not have the same resolution but coexist in OSM) but the information is not available in metadata.

However, Coleman et al (2009) show that the majority of VGI contributors are occasional contributors and mostly *interested amateurs* that could be afraid of strict specifications for contributions. The success of VGI lies in the simplicity of contributions and many debates in the OSM contributor community show that should not be too restrained, even to improve quality. We believe that the improvement of OSM data quality requires to find the ideal balance between specifications and contribution freedom. A convenient way to reach such balance is to use automatic consistency checking with strict specification. Brando and Bucher (2010) propose to let contributions be simple and free but to check contribution consistency with the specifications. The automatic process would provide corrected and consistent information to the contributor that would be free to accept the modifications or not.

The importance of specifications in the quality assessment of OSM data highlights the change of paradigm in the concept of spatial data quality, devised classically between internal quality (respect of specifications defined by the producer) and external quality (fitness for use). In the case of VGI, the contributor can be a producer and a user in the same time. He can contribute for himself but also for the entire community and determines himself his level of compliance of specifications.

6. Conclusion and further work

In conclusion, this article has presented a quality assessment of the reference site for free and contributively created data OpenStreetMap. After describing the project and its data model, an assessment of OSM data has been performed on different elements of spatial data quality. It constitutes an extension to the work of Haklay (2008) in France, but also proposes a larger set of quality assessment (points and polygons primitives for geometric accuracy, attribute accuracy…). Results show the advantage of responsiveness and flexibility of OSM, but also the problematic aspect of heterogeneity in OSM data, limiting highly the possible applications. This heterogeneity is particularly explained by to the cohabitation of different data sources, processes of capture, and contributors' profiles, highlighting the importance to follow accepted specifications.

The possibility to find the ideal balance between specifications and contributors freedom has been raised, opening the way to new research issues, as the contributors' assistance with an automatic checking of contributions consistency with specifications.

This work also illustrates the difficulty to conduct a systematic analysis, due to the lack of OSM data contributions in some areas. Performing this task constitutes a further work, as well as a more precise assessment according to specific geographical contexts.

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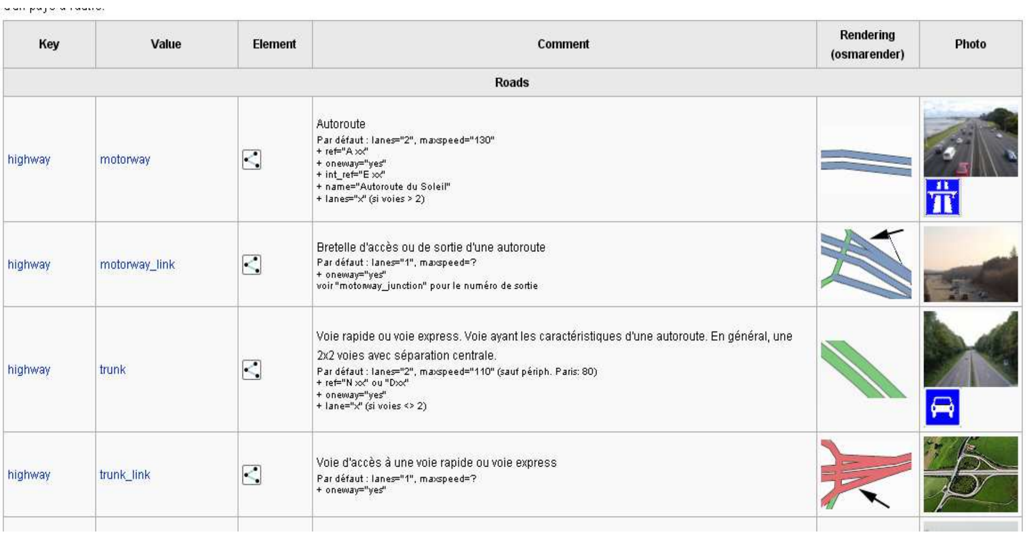

Key	Value	Element	Comment	Rendering (osmarender)	Photo
Roads					
highway	motorway		Autoroute Par défaut : lanes="2", maxspeed="130" + ref="A xx" + oneway="yes" + int_ref="E xx" + name="Autoroute du Soleil" + lanes="x" (si voies > 2)		
highway	motorway_link		Bretelle d'accès ou de sortie d'une autoroute Par défaut : lanes="1", maxspeed=? + oneway="yes" voir "motorway_junction" pour le numéro de sortie		
highway	trunk		Voie rapide ou voie express. Voie ayant les caractéristiques d'une autoroute. En général, une 2x2 voies avec séparation centrale. Par défaut : lanes="2", maxspeed="110" (sauf périph. Paris: 80) + ref="N xx" ou "Dxx" + oneway="yes" + lane="x" (si voies <> 2)		
highway	trunk_link		Voie d'accès à une voie rapide ou voie express Par défaut : lanes="1", maxspeed=? + oneway="yes"		

Figure 1. Preview of the specifications (in French) of the tag "highway".

Figure 2. Preview of an information leaflet to tag situations. Here, a tramway line.

```
  <node id="25213726" lat="43.3020693" lon="-0.3420626" version="3" changeset="52741" user="be
uid="43565" visible="true" timestamp="2008-06-04T16:10:13Z">
    <tag k="name" v="Station Shell"/>
    <tag k="postal_code" v="64000"/>
    <tag k="created_by" v="Potlatch 0.9c"/>
    <tag k="amenity" v="fuel"/>
    <tag k="fuel_lpg" v="yes"/>
    <tag k="is_in" v="PAU"/>
    <tag k="source" v="stations.gpl.online.fr"/>
    <tag k="address" v="65, Avenue MarÃ©chal Leclerc"/>
  </node>
```


Figure 3. Example of a geometric primitive (a point) tagged in RDF in the XML export format of OSM.

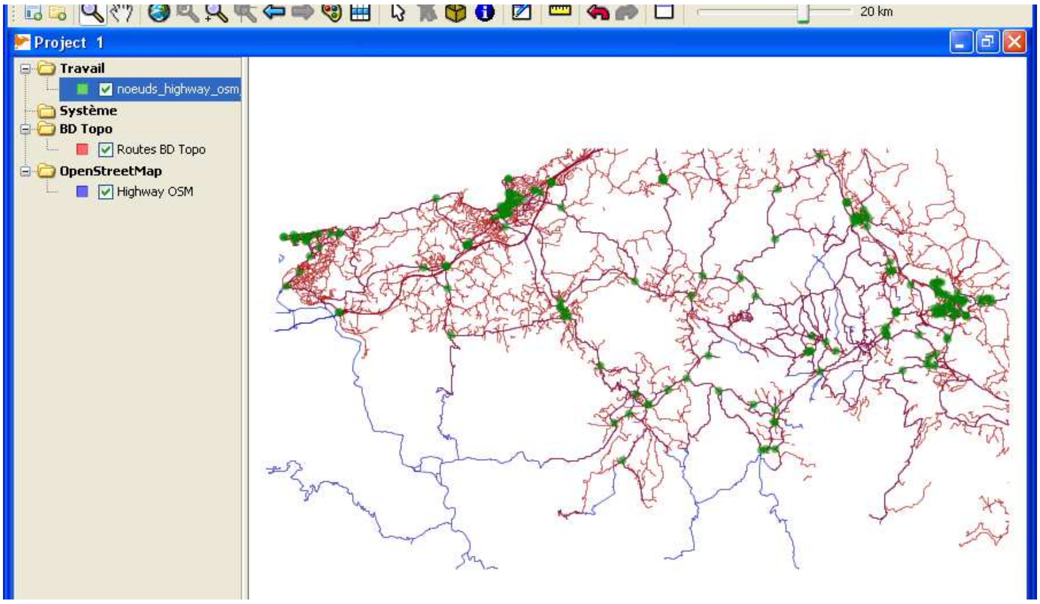

Figure 4. Localization (in green) of the 207 pairs of homologous point objects

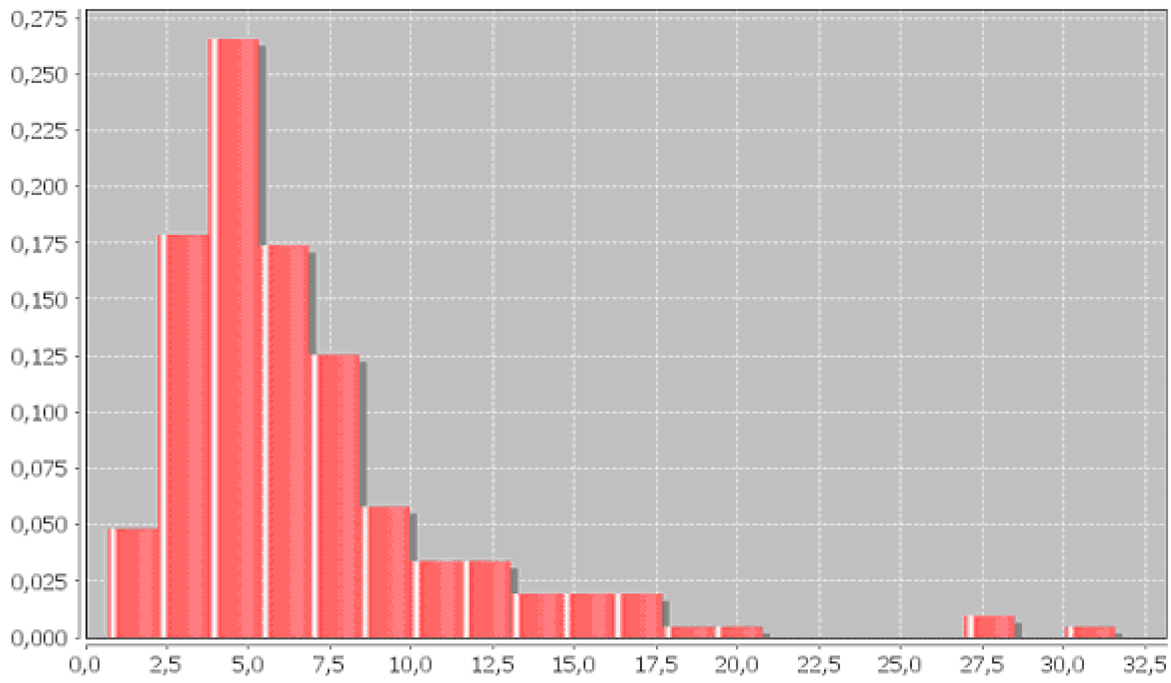

Figure 5. Distribution of Euclidean distances from the sample of road intersections

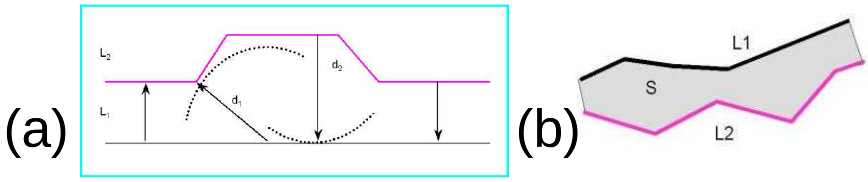

Figure 6. Hausdorff distance (a) and average distance (b) between two polylines

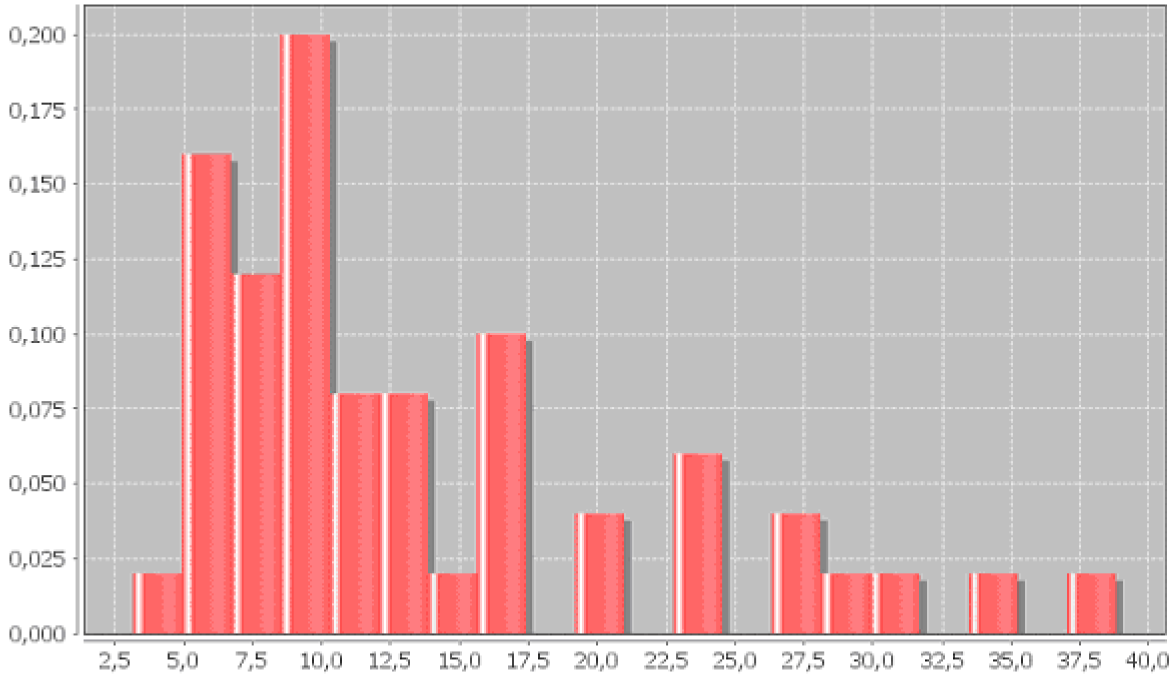

Figure 7. Distribution of Hausdorff distances from the sample of roads

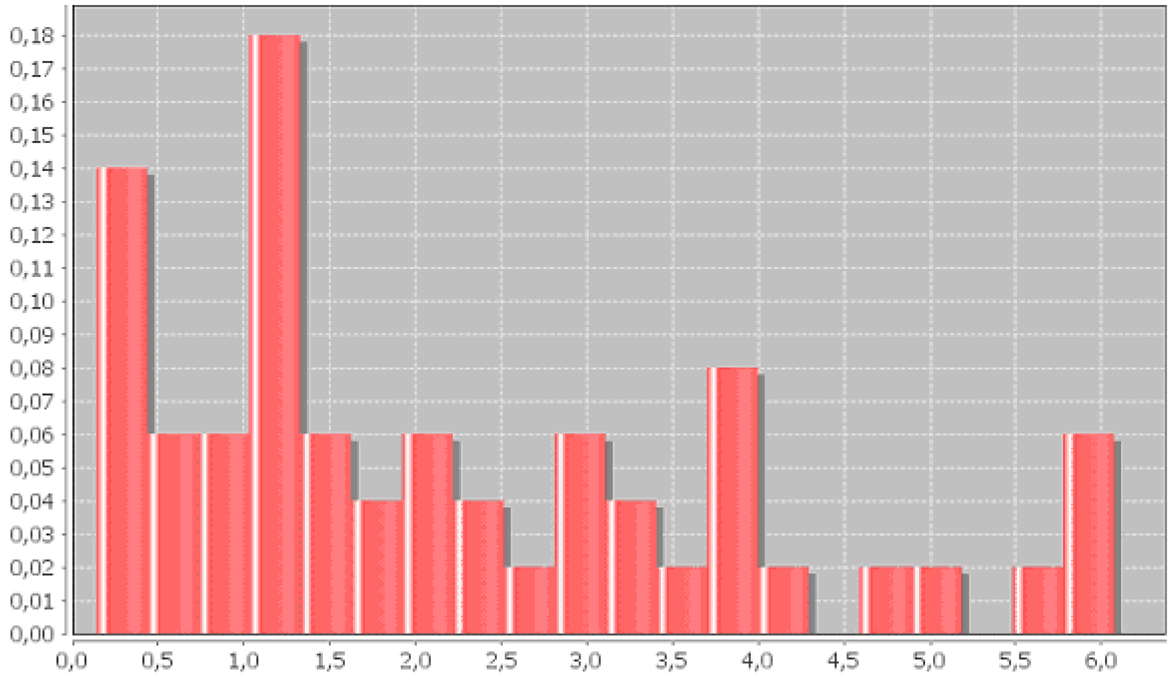

Figure 8. Distribution of average distances from the sample of roads

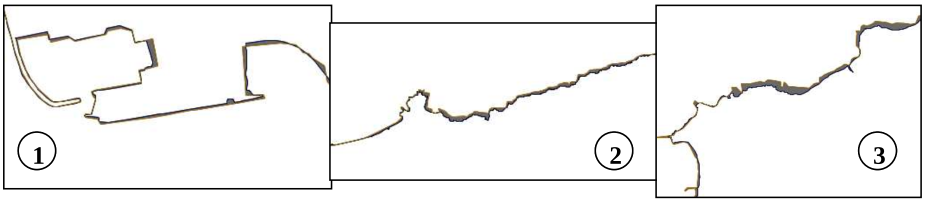

Figure 9. Representation of the 3 sample couples of coastlines. The grey area shows the gap between each couple.

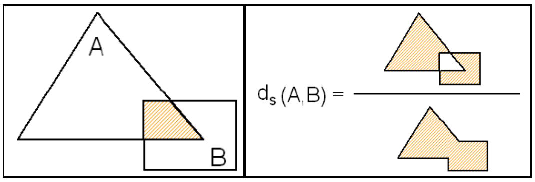

Figure 10. Surface distance between two polygons.

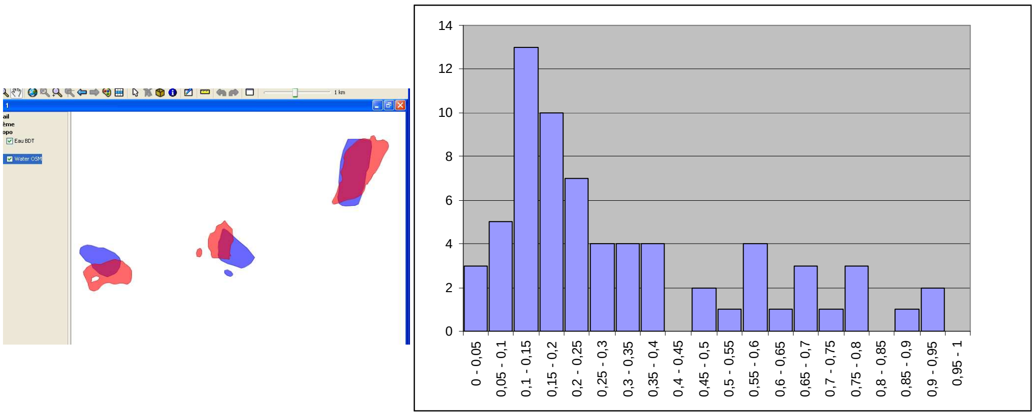

Figure 11. Selection of OSM polygonal objects (blue) and BD Topo (red) and distribution of surface distances.

Statistics	Levenstein distance Value
Maximum	23
Minimum	0
Median	2
Mean	4,96
Standard deviation	6,90
Coefficient of Variation	1,39

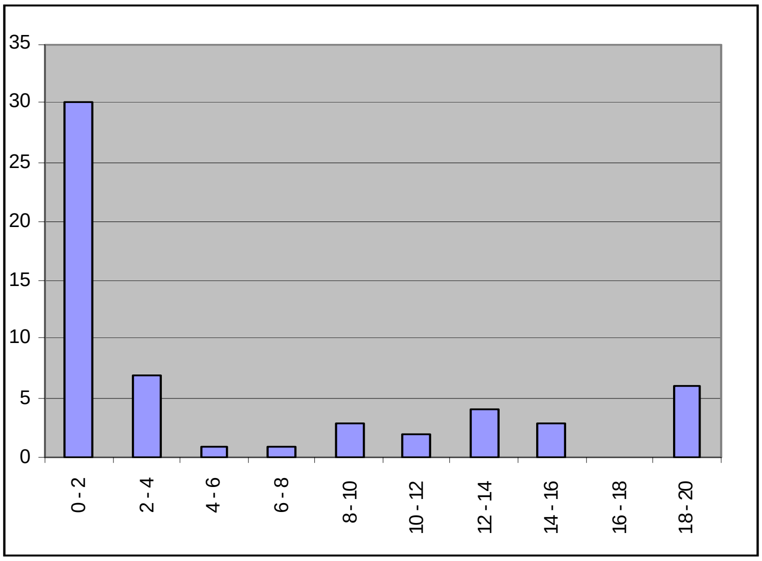

Figure 12. Statistics of Levenstein distance between lake names in OSM and BD TOPO® and distribution of the distances on the right.

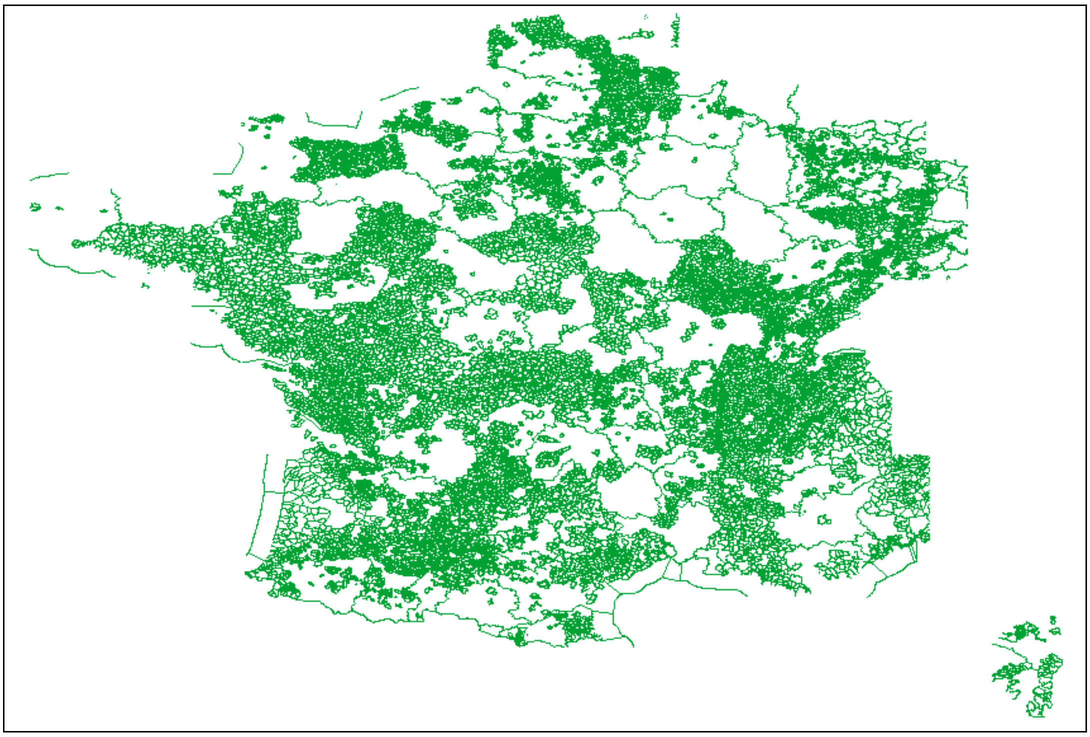

Figure 13. Heterogeneity of “Administrative Limit” layer completeness

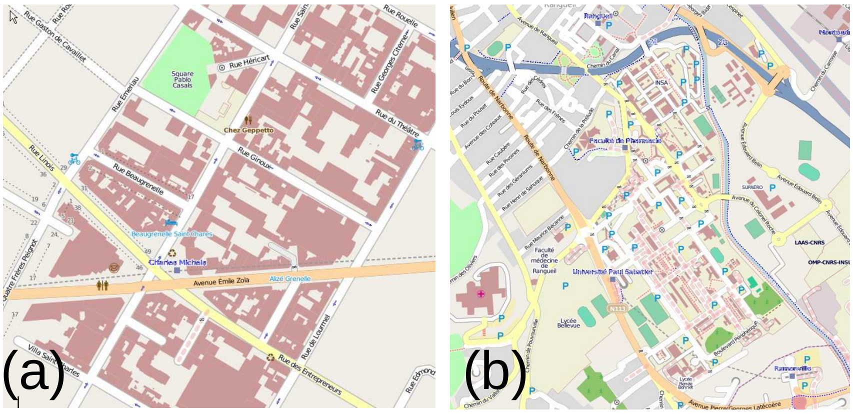

Figure 14. Extracts of OSM in areas well covered where data is quite diverse and complete: (a) in the 15th arrondissement of Paris (b) on the University Paul Sabatier in Toulouse.

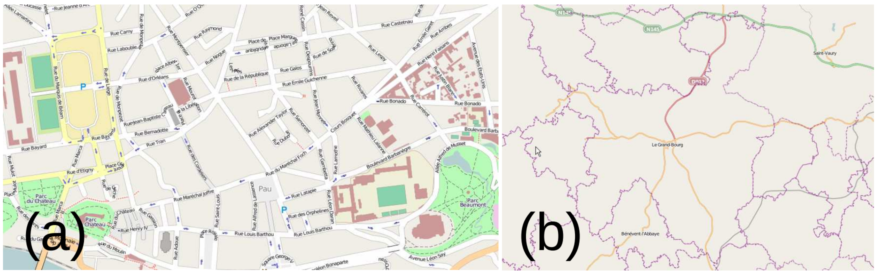

Figure 15. Extracts of OSM: (a) the town-center of Pau : medium-sized cities are moderately complete: most buildings and some streets are missing. (b) in Creuse: The information is extremely poor (municipal limits and some main roads).

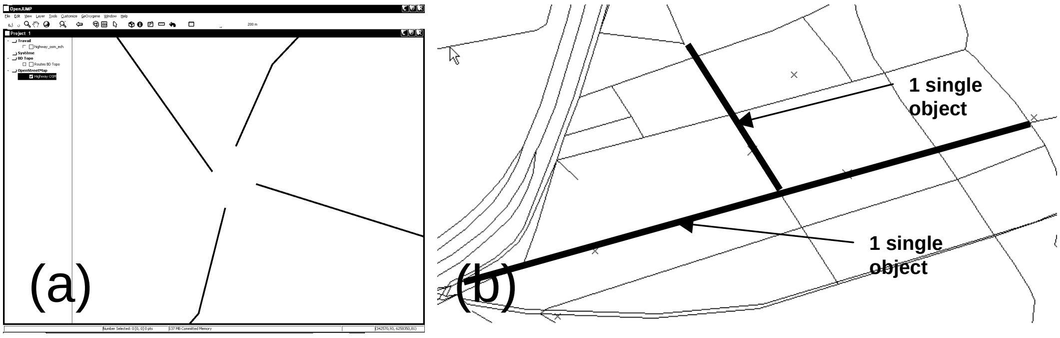

Figure 16. Problems of internal consistency in the road network: (a) roads are not connected at an intersection, (b) unstructured road network.

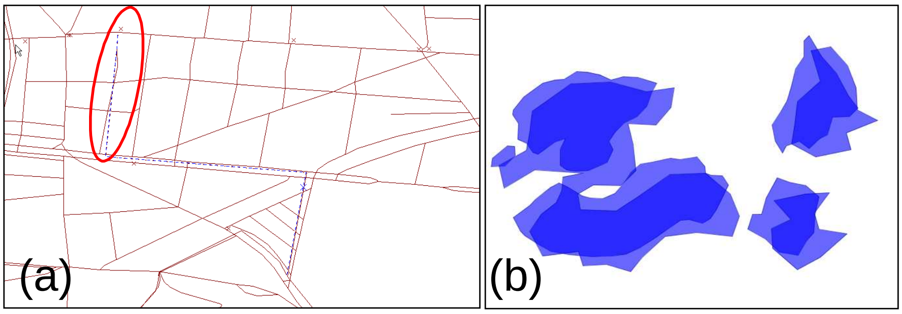

Figure 17. (a) The selected administrative limit (blue) is not at all consistent with the roads (b) Several lakes are captured in the same location.

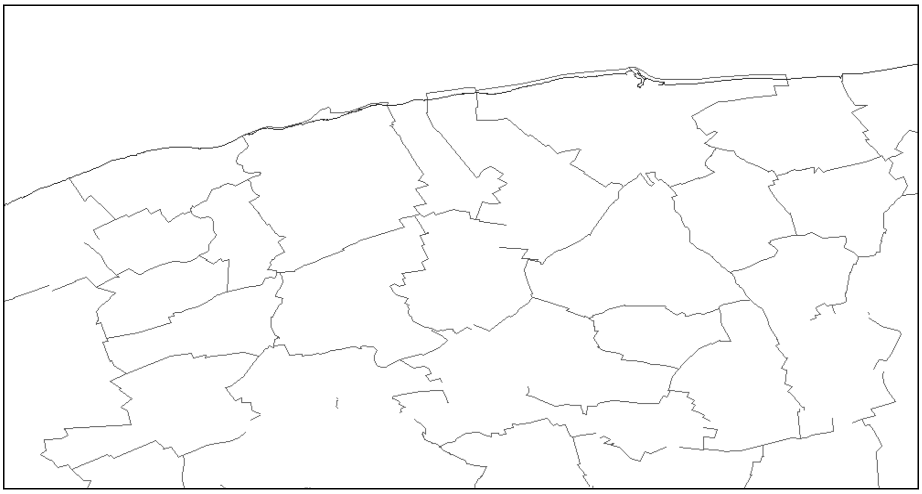

Figure 18. Example of both types of inconsistencies: between administrative borders, that are sometimes captured on the coastline and sometimes not, and between coastline and administrative borders that should share geometry.

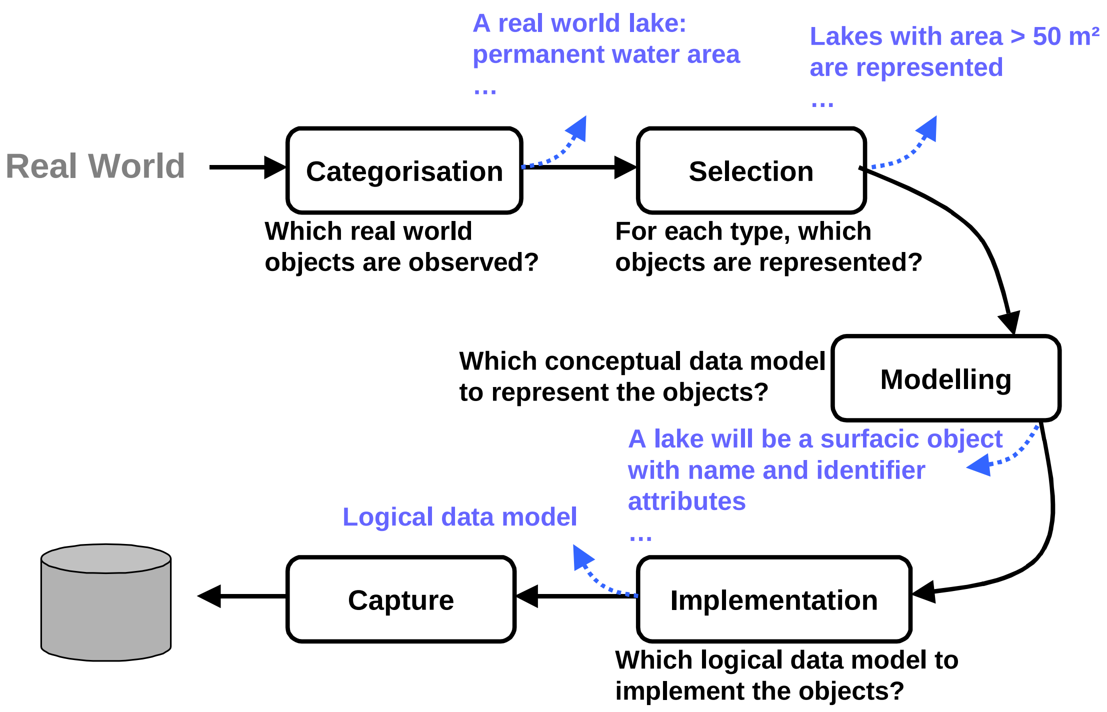

Figure 19. Production process of structured institutional databases (Balley et al, 2006).

Statistics	Values
Maximum distance	31.58 m.
Minimum distance	0.68 m.
Mean distance	6.65 m.
Standard deviation	4.54 m.
Coefficient of variation	68.25%

Table 1. Statistics computed from Euclidean distances between crossroads.

Statistics	Hausdorff distance values	Average distance values
Distance maximum	38.8 m	6.07 m.
Minimum distance	3.14 m.	0.14 m.
Average distance	13.57 m.	2.19 m.
Standard deviation	8.32 m.	1.69 m.
Coefficient of variation	61.28%	76.95%

Table 2. Statistics calculated on distances between road linear features.

Statistics	OSM granularity values (m)	BD TOPO granularity values (m)	granularity differences	OSM compactness values	BD TOPO compactness values	compactness differences
Maximum	53,91	3,3	52,94	0,94	0,91	0,44
Minimum	0,21	0,00	0,21	0,04	0,04	0,01
Mean	8,35	0,68	7,72	0,59	0,52	0,09
Standard deviation	11,09	0,91	10,99	0,20	0,21	0,11

Table 3. Granularity and compactness statistical analysis of lakes in OSM and BD TOPO®.

Layer	Geometry	Objects	Field	Informed	Non-informed	Ratio %
France_poi	Point	111440	« NAME »	111440	0	100
France_highway	Polyline	886680	« TYPE » « NAME » « ONEWAY »	756655 382896 143274	130025 503784 743406	85 43 16
France_coastline	Polyline	1200	« NAME »	47	1153	4
France_administrative	Polyline	51413	« NAME » « ADMIN_LEVEL »	838 51352	50575 61	2 99.9
France_water	Polygon	12507	« NATURAL » « NAME »	12507 2041	0 10466	100 16
France_natural	Polygon	24756	« NAME » « TYPE »	4505 24756	24333 0	18 100

Table 4. Quantitative attribute quality assessment: attribute filling of the shapefile layers extracted from CloudMade (October 2009) covering completely France.

Layer	Count in OSM	Count in BD TOPO	Count completeness	Total length/area in OSM	Total length/area in BD TOPO	Length/area completeness
Roads zone 1	585	9785	6%	575457	1283969	45%
Roads zone 2	12645	123398	10%	7158790	19337345	37%
Lakes	1157	5475	21%	24338969	29489931	83%
Rivers	623	26417	2%	897022	11247268	8%

Table 5. Completeness analysis for different object layers with the BD TOPO® as reference.

Layer	Objects – june 09	Objects – oct 09	Evolution (objects)	Evolution (%)
France_poi	76653	111440	34787	45,4%
France_highway	674205	886680	212475	31,5%
France_coastline	1201	1200	-1	0%
France_administrative	42286	51413	9127	21,5%
France_water	10531	12507	1976	18,8%
France_natural	20958	24756	3798	18,1%
TOTAL	**825834**	**1087996**	**262162**	**31,7%**

Table 6. Comparison of “France_shapefile” themes (extracted from CloudMade) between June 2009 and October 2009.