A Geocodification for 3D objects terrestrial surveys

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1. Introduction

Nowadays, there is a real need for 3D urban data. 3D modeling (3D GIS, virtual cities…) applications are diverse and need to be fed with data; realistic virtual walks, noise level simulation, water overflowing and natural risks simulation, visual impact of a future housing estate or an advertising board, intervisibility analysis for mobile phone antenna, archeological city reconstruction…
Most of the time, 3D data are collected by terrestrial or airborne laserscanning or photogrammetry techniques (sometimes complementary to existing 2D footprints of objects). Laserscanning techniques especially provides huge amount of data; indeed, millions of points can be measured in only a few seconds with these techniques. It allows to collect easily highly complex geometrical information. However, post processing of so dense clouds of points can be very long and complex and there is still a lot of manpower needed to obtain proper 3D models. Semi-automatic algorithms exist to overcome this limitation, but such algorithms can still be time consuming because of the huge amount of data (EL-HAKIM, WHITING, GONZO, GIRARDI 2005, PENARD, PAPARODITIS, PIERROT-DESEILLIGNY M. 2006, DEVEAU M., PAPARODITIS, PIERROT-DESEILLIGNY, CHEN, THIBAULT 2005).

In 2D land surveying, it is now common to apply geocodifications (also called “field to finish”) associated to measurements with total stations. Although each point as to be measured one by one, this method requires very reduced post processing step and need a minimum of relevant points. Our proposition is to expand this approach to 3D cases.

Considering the new standards called CityGML (http://www.citygml.org/) about 3D urban objects and its level-of-details subdivisions, we can argue that a 3D geocodification used with a total station could provide relevant information. Indeed, knowing that CityGML can be divided into five levels of details (LOD) from the DTM (LOD 0) to the architectural model involving the inside of the buildings (LOD 4), a 3D geocodification would provide information for LOD 1 and 2 (level of detail low and middle – buildings' geometry with functional details like doors or windows) that needs a reduced number of points and could be combined with photogrammetry and/or lasergrammetry for the other LODs.

The purpose of this paper is to present a work done at the University of Liege about the development of a 3D geocodification prototype applied to urban spaces. After a short description of the basics of 2D geocodification, we will present several 3D geocodifications and a real case study. We will end with a discussion about benefit that geocodification could bring in some cases of 3D data acquisition.

Basics of 2D geocodification

Geocodification (field to finish) is a method applied to measurements with total station that allows automatic generation of a plan based on alphanumeric codes associated to the measurements. The underlying idea is that a code is associated to every single measured point (depending on point's nature and characteristics) and then succession of codes can be interpreted automatically; algorithms create geometrical features in a file or a database which can be used to draw a plan with all geometrics objects and associated symbols. Most of surveying software use 2D geocodification (to name but a few: Topofast, Covadis, Strada Polaris, Mensura, *etc*.)
. In addition of the reduction of the post processing steps, codification can be seen also as a set of guidelines for field measurements.

Even if codes are different from software to software, the basics of geocodification (the way objects have to be measured) remain the same. The figure 1 shows different examples. A punctual entity like a tree can be measured with one point in the center associated to the "TR" code. A rectangular polygon like a road gully can be measured on three corners with an insertion point ("RG" code), a point giving the length and a point giving the width ("RGP" code). A linear entity like a fence can be measured with an opening point ("FE0" code) followed by a few linking points ("FE1" code) and a closing point ("FE2" code). In this last case, an algorithm draws a straight line between each new linking point (or closing point if it is the last one) and the previous one (linking point or opening point if it is the first one) in the order of the measurements.

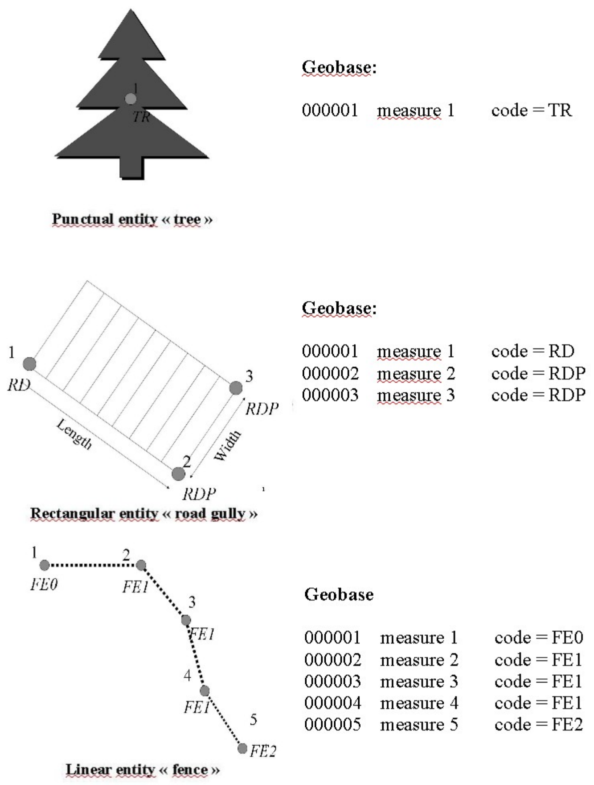


Figure 1. Examples of 2D geocodifications

We can notice that software like 3D Civil (AutoDesk) include 3D field to finish. But they only use the concept of linking with lines. Therefore, this kind of geocodification only allows making 3D models with lines (wireframe), not with sides (faces) or solids

A geocodification contains different kinds of codes which have to be memorized by the user on the field. So we try not to have more than ten different kinds of code to keep an easy method that really makes the surveying operations easier for the user. Therefore, geocodification must be both simple and efficient, keeping in mind that it is the compromise between seven factors that we defined:

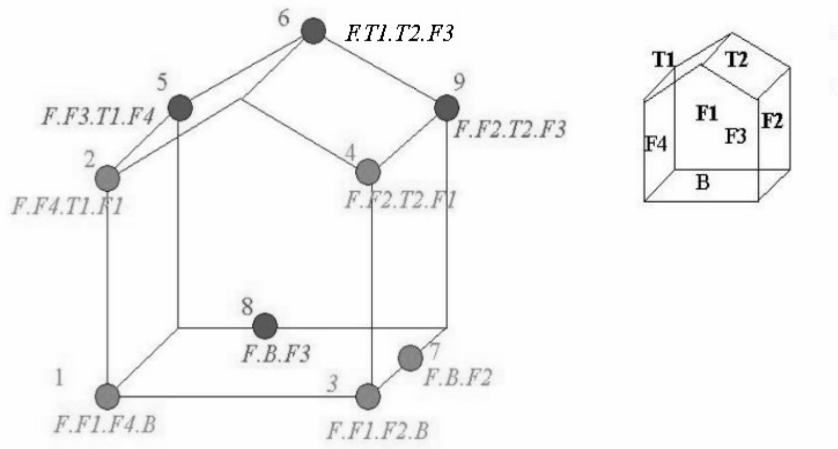
- The user must be not too constrained in the case of missing or hidden key points.
- The number of points to measure per object must be low.
- The codes must be not too complicated (the method is applied on the field).
- Codes must be not too long (the user has to enter it into the system – total station keyboard).
- Geocodification must cover a wide range of possible objects in a given domain (ideally, every single object should be identifiable with a specific code).
- The drawing generated by the algorithms must be of highest semantic and geometric quality.
- Topology inside and between objects must be respected.

2. From 2D to 3D

In this preliminary research, we only cared about geometric aspect of objects and especially flat sides objects. Actually, attributes of objects could recorded as well (for GIS purposes for example) but this aspect is not different from the 2D case.

2.1. Geocodification by side building

The first developed method covers all the flat sides objects. It is important to start with a flexible method: in this way, the user can always find a solution on the field. This method, called “codification by side building”, uses the side of an object as a primitive contrary to the 2D geocodification which uses the line. The basis is very simple: measuring at least three points per side to determine the plan describing it. Of course, line and vertex contain very interesting points because they respectively belong to two or three sides at the same time, which means less points to measure. Therefore, for each measured point, the name of the side(s) it belongs to has to be recorded. After having collected at least three points per face, the algorithm can uses the equation of a plan describing the faces (with the use of a lest-squared adjustment when more than 3 points are collected) to draw all the sides and vertexes of the objects..



Geobase

000001	/	code = OBJ.HOUSE
000002	measure 1	code = F.F1.F4.B
000003	measure 2	code = F.F4.T1.F1
000004	measure 3	code = F.F1.F2.B
000005	measure 4	code = F.F2.T2.F1
000006	measure 5	code = F.F3.T1.F4
000007	measure 6	code = F.T1.T2.F3
000008	measure 7	code = F.B.F2
000009	measure 8	code = F.B.F3
000010	measure 9	code = F.F2.T2.F3

Figure 2. Example of geocodification by side building

Unfortunately, in this way, we do not have always the necessary information to draw the right lines and the right sections of plan (see figure 3). We could develop an algorithm which chooses the right intersections automatically basing on convex objects, but the figure 3 shows that this method is quiet unstable.

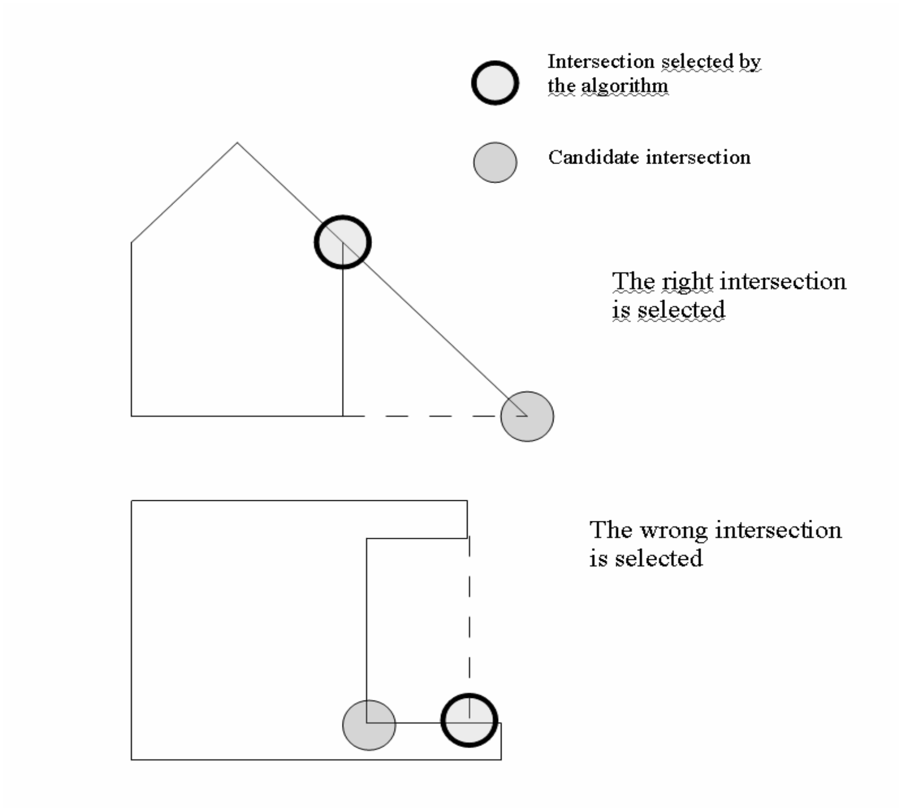
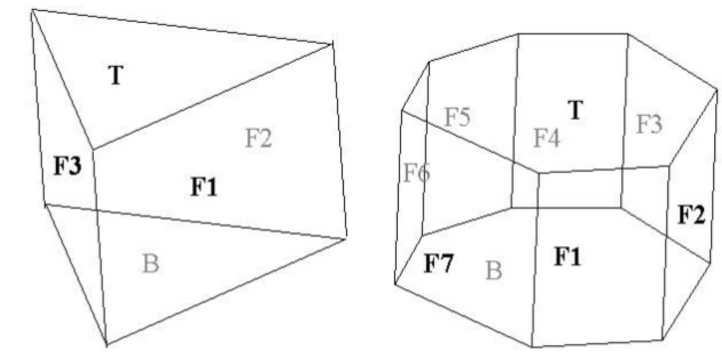


Figure 3. Selection of plan's intersections with a “convex object” algorithm

Therefore, we have to complete this method with a new code: connectivity between sides. This information let the algorithm knows which sides are neighbors (in other words: which sides have common lines). In this way, we know which plan's intersection is actually the right edge. We can also find vertexes which result from the intersection of three contiguous plans. The connectivity code can be written in a fastidious way: describing all the contiguous sides for each side (then, one line per side). It can also be described in an implicit way with one line per object if the geometry allows it. For example, the figure 4 shows that an object with a superior side and an inferior side joining lateral sides can be described by an implicit connectivity codification. That means that a user should be able to create his own implicit connectivity before going on the field.



Explicit connectivity code

B.F1.F2.F3
T.F1.F2.F3
F1.F2.F3.B.T
F2.F3.F1.B.T
F3.F1.F2.B.T

Implicit connectivity code

BT.3

Explicit connectivity code

B.F1.F2.F3.F4.F5.F6.F7
T.F1.F2.F3.F4.F5.F6.F7
F1.F2.F7.B.T
F2.F3.F1.B.T
F3.F1.F4.B.T
F4.F5.F3.B.T
F5.F4.F3.B.T
F6.F5.F7.B.T
F7.F1.F6.B.T

Implicit connectivity code

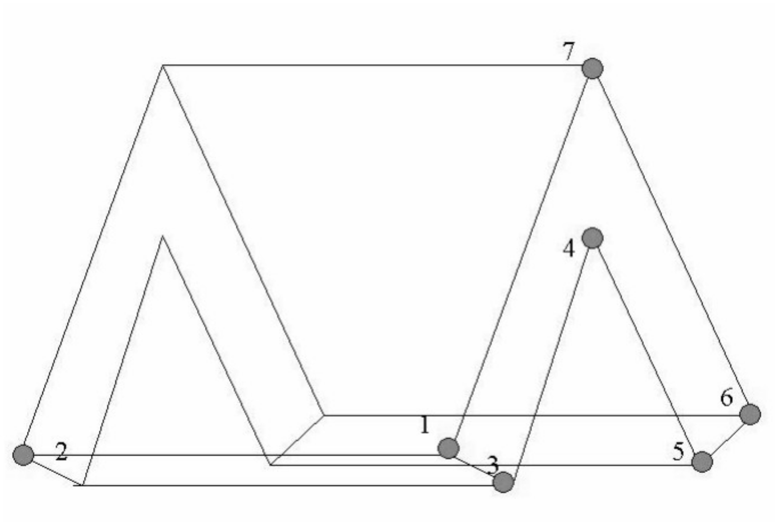
BT.7

Figure 4. Examples of explicit and implicit connectivity codification

Codification by side building can by applied to all flat side objects. It presents other important advantages like the freedom in choosing points and the increasing precision of the sides geometry with the increasing number of measures. However, the complexity of the method increases with the number of sides of the measured object. Thus, the user has to memorize the name of all sides he is measuring. Therefore it is necessary to propose other methods which could be combined with it. These methods are less flexible and correspond to more limited application domains but are easier and faster for the user.

2.2. **"Linking by side" geocodification**

The "linking by side" (figure 5) is a method directly inspired by the 2D geocodification of linear entities (seen previously). In this case, the linking is not done with lines anymore but with sides. It is typically used for extrusions. The difference with the linear linking is that linking by side needs a parametric point giving the "height of the linking side". In the example of figure 5, the "LS.0" code is the opening point taken on the bottom of the side, "LS.2" is the parametric point taken on the top of the side, "LS.1" is a linking point (a side with the same height than the previous one is drawn with a linking method) and "LS.3" is the ending point. We have develop a similar method called "linking by parallelepiped" for which a second parametric point giving the depth of the linking parallelepiped is needed.



Geobase

000001	measure 1	code = LS.0
000002	measure 2	code = LS.2
000003	measure 3	code = LS.1
000004	measure 4	code = LS.1
000005	measure 5	code = LS.1
000006	measure 6	code = LS.1
000007	measure 7	code = LS.3

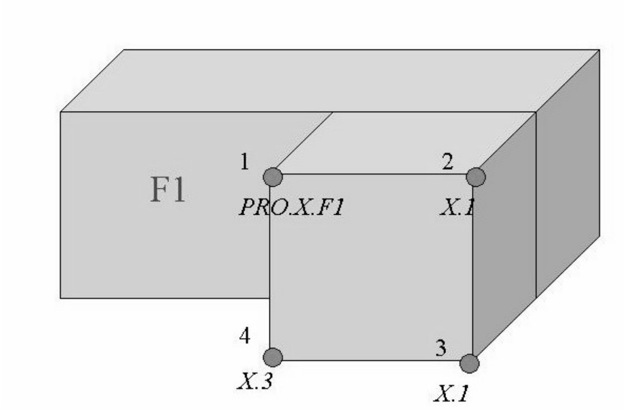
Figure 5. Example of a « linking by side » codification

The best advantage of this codification is its simplicity: the user does not have to remember any previous sides' IDs as with the codification by side building. The number of points measured also tends towards the minimum required. However, it is applicable to a limited category of objects.

2.3. Prominence and sinking

A “prominence” (figure 6) or a “sinking” (figure 7) of an object O1 designates a side A with x lines (x>2) that can be joined by x sides (one side per line) perpendicularly to a side S of O1 that we call “support”. The prominence stands outside the object O1 and the sinking stands inside.

In the case of the prominence, the “PRO.X.F” code is applied to the first measured point. X is the name of the prominence; F1 is the name of support side. This point is also the start of a linking by line code (2D geocodification). The following points complete the linking to draw the outline of the prominent side. The others sides joining the prominent side perpendicularly to the support side are calculated and drawn by the algorithm.

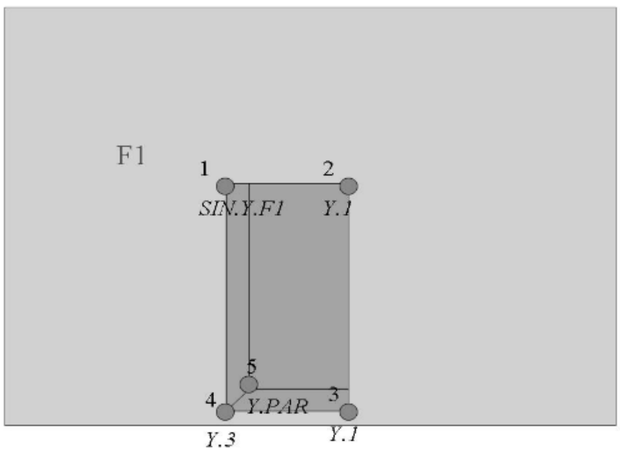


Geobase

000001	measure 1	code = PRO.X.F1
000002	measure 2	code = X.1
000003	measure 3	code = X.1
000004	measure 4	code = X.3

Figure 6. Example of prominence codification

The codification of a sinking is quiet similar to the prominence, except for a parametric point ("Y.PAR" code) giving the depth of the sinking. Indeed, the linking of the sinking is measured on the support side (not the sinked side) because its points are more accessible for the user.



Geobase

000001	measure 1	code = SIN.Y.F1
000002	measure 2	code = Y.1
000003	measure 3	code = Y.1
000004	measure 4	code = Y.3

Figure 5. Example of sinking codification

The prominence and the sinking codifications are complementary to the geocodification by side building. For example, the framework of a building can be measured with this last method while doors, windows or chimney can be considered as prominences or sinkings.

2.4. Object repetition

The last method we present is the "object repetition" (figure 8). It uses the properties of geometric similarities that we find in urban spaces (like the steps of a stair, for example). An object called "model" has to be measured once with one of the previous methods to be replicated in other positions by measuring one insertion point and eventually two orientation points (if the orientation is different) on "copy" objects.

Concerning the model, we have to apply the "INSM" code to the insertion point. If the copies have different orientations, we also need two orientation points coded as "OR1M" and "OR2M". It is important to choose the points of the model so that the homologue points can easily be found on the copies (like corners) and that the three points are not on the same line. On the copy, the insertion point is coded as "INS" and the orientation points are coded as "OR1" and "OR2". This codification also allows to copy an object many times with the same orientation with regular spacing from only one insertion point (for example, a straight stair). Let notice that points used for "object repetition" codification can also be used for other codifications (using code separators).

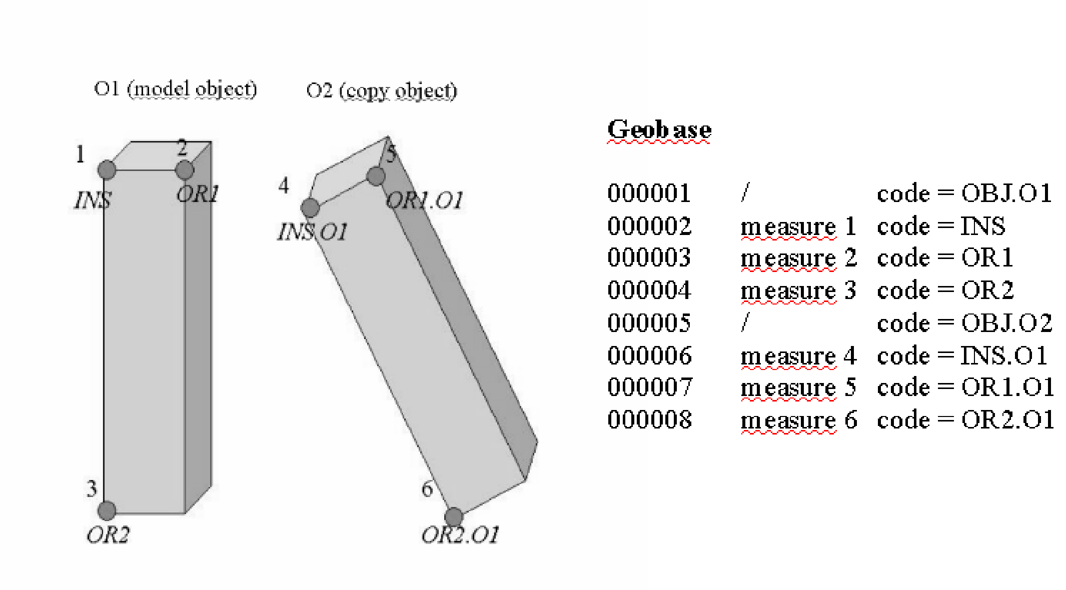


Figure 8. Example of "object copy" codification

2.5. Application

The figure 9 shows a real example of the application of our 3D geocodification. Around 50 points have been measured to draw this 3D model with a level of detail between low and middle (using CityGML classification). This building is part of the geography institute of the University of Liege (B12, Sart-Tilman, Angleur, Belgium).

Figure 9. 3D model of the B12 building of the University of Liege

The presented methods were interpreted by a PERL algorithm which involves an ASCII input file with point ID's, (X, Y, Z) coordinates and codes (obtained from the total station). The output file of the PERL algorithm is a VRML file which contains the 3D model that can be visualized with a VRML viewer.

```
OBJ.MARCHE;
C.B.F1.F2.F3.F4;
C.T.F1.F2.F3.F4;
C.F1.B.T.F2.F4;
C.F2.F1.F3.B.T;
C.F3.F2.F4.B.T;
C.F4.F3.F1.B.T;
PT3002;93.64469111;65.08983591;101.0281293;F.F1.B.F4/INSM;
PT3003;93.64442223;65.08856574;101.1057406;F.F4.F1.T;
PT3004;93.18430189;64.58649456;101.0068144;F.F4.F3.B;
PT3005;93.16565544;64.57680854;101.1023474;F.F3.F4.T;
PT3006;93.46662257;65.24922796;101.0274874;F.F1.B.F2;
PT3007;93.47467666;65.25241583;101.1072626;F.F1.F2.T;
PT3008;92.98957395;64.73940272;101.1034322;F.T.F2.F3;
OBJ.ESCA1;
PT3009;93.46480927;65.25308449;101.2725638;INS.MARCHE.REP.1;
OBJ.ESCA2;
PT3010;93.26307887;65.42803849;101.450023;INS.MARCHE.REP.1;
```

Table 1. Extract of an input ASCII file for the PERL algorithm

3. Conclusion

This paper has presented is a preliminary step in the development of an efficient 3D geocodification for the acquisition of 3D objects in the context of terrestrial survey measurement. Work still has to be done to improve its efficiency. However, the test made on the field is promising and shows how geocodification can be useful for 3D data acquisition. We believe that for levels of detail between low and middle, our approach is globally less time consuming than with comparable laserscanning or photogrammetry techniques. This is due to the almost-absence of post processing with geocodification. But as geocodification is only applicable on level of detail low and middle, this method cannot be considered as a competitor of photogrammetry and lasergrammetry but rather as a complementary source of data. Indeed, we could imagine 3D data measured with the two or three methods: geocodification for the framework and photogrammetry or/and laserscanning for complex details.

Further research direction will be to improve our approach by considering collecting other kind of information (semantic, addresses, images…) and therefore a way to populate 3D GIS *in situ*. In the dawn of the age of 3D modeling, the geocodification's role seems justified, but is still to be defined...

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