The Role of Volunteered Geographic Information towards 3D Property Cadastral Systems

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Key words: Volunteered Geographic Information (VGI), Spatial Data Infrastructure (SDI), Property Cadastre, 3D Cadastral System

SUMMARY

General mapping, and particularly cadastral mapping, is a highly expensive activity and many governments are no longer willing to continue covering the even increasing costs of surveys. As far as Portugal is concerned – our ultimate field of interest – ongoing 2D property cadastre surveys have revealed to be rather complex, laborious and expensive given Portugal's territory tissue with a few millions of rather small real estates scattered across a rather irregular topography.

Accurate collection methods of even more detailed cadastral data towards 3D cadastral systems are required. Practical acquisition of such data in the field for the purposes above constitutes the main question raised in this paper. It is believed that issues above could be tackled, at least to some extent, by considering Volunteered Geographic Information (VGI). At a time with increasing demands and when public sector resources are declining, VGI should in fact not be seen as a threat but as a potential opportunity for mapping agencies in all domains.

Although a VGI approach may not be suitable yet to totally replace standard accurate methods and technologies, such as those used in full measured cadastral surveys, it is argued that VGI may well be considered as an interim step before full surveyed cadastre is eventually achieved. With this regard, a framework consisting of five validity levels of cadastral data is proposed in this paper to be tested and used in a first stage at local government level. VGI was therefore considered and taken into account in designing such framework, whose different levels of validity (in terms of precision and different sorts of accuracy) are fundamentally based on the associate source of information. For the purpose, five possible data sources have been previously identified.

The goal of this paper is mainly exploratory in finding potential room in the context of 3D cadastre for VGI to be brought in and how to accomplish it. Future work will entail the identification in more detail of which sorts of cadastral data (2D, 3D or simply descriptive) may be acquired through a VGI approach. Nevertheless, preliminary considerations are drawn on some foreseen sorts of cadastral data that may potentially be acquired with a VGI approach. The design of a participatory web-based application is proposed too.

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1. INTRODUCTION

1.1 General context

Most information needed by policymakers is related to locations on the Earth. Despite some practical difficulties, it is clear that 3D geoinformation is becoming increasingly important towards decision-making. Research has demonstrated the actual added value of 3D information over 2D in these cases: an overall more efficient integration of urban vs. regional planning and management, especially when dealing with 3D underground/aboveground infrastructures. There has been consistent research within geoinformation science (GISc) on the concept of 3D for more than a decade now; for instance, merits of 3D GIS techniques have been widely debated, tested, and have been proved to be quite advanced. Nevertheless, several potentially involved parties are still reluctant to invest in 3D data, 3D techniques, and applications. As a consequence, large administration processes relating to urban/rural planning often run up financial losses simply because generic geoinformation is not part of the process (Stoter 2011, Stoter et al, 2012).

GISc is never a goal in itself, it is a "serving discipline", and hence without applications it may well turn useless (Stoter 2011). A pertinent example is property cadastre as a whole, in fact our ultimate field of interest. Property cadastre and associate cadastral systems[1] play a prominent role in general land management and are indeed widely acknowledged to be the basis of a healthy economy. Regardless of country, an up-to-date property cadastral system is fundamental for a sustainable development and environmental protection.

Current worldwide property cadastral registries use 2D parcels to register ownerships rights, limited rights, and public law restrictions on land. In most cases this is sufficient to give clear information about the legal status of real estate. But in cases of multiple use of space, with stratified property rights in land, the traditional 2D cadastre is not, or only in a limited way, able to reflect the spatial information about those rights in the third dimension. As a matter of fact, the growing density of land use in urban context is consequently increasing situations of vertical demarcation between real estate properties. The issue is not so much the need for simple 3D visualisation capabilities of a stratified reality – though a very much pertinent aspect. The real issue dwells in the linkage between a 3D geometry/topology structure and legal concepts on stratified ownerships, which is far less tangible. In other words, the real difficulty is the materialisation of legal concepts that a human being may well be aware of in the field, but a 2D computerised system is in principle incapable of discerning.

[1] The overall concept stands for a computerised land ownership registry.

3D cadastral technology is now emerging, nevertheless 3D cadastre as a whole has been attracting researchers through out the world for nearly a decade now to better register and spatially represent real world overlapping situations. Some pilot studies have been accomplished so far, and several authors (including Abdul-Rahman et al, 2012; Khoo 2012; Soon 2012; Stoter et al, 2012; Wang et al, 2012; Ying et al, 2012; Zhao et al, 2012; Abdul-Rahman et al, 2011; Stoter et al, 2011; Van Oosterom et al, 2011; Hassan et al, 2010; Chong 2006; Stoter and van Oosterom 2006; Valstade 2005; Stoter 2004; Stoter et al, 2004) have demonstrated that indeed 3D representations of airspace and subterranean parcels are currently required given that 2D+half representations are unable to handle 3D measurements, spatial queries, or visualisation.

1.2 Motivation

As far as Portugal is concerned (indeed our ultimate goal), a prototype of a centralised distributed cadastral management system, implementing a 2D approach, has been conceived: the so-called SiNErGIC (PCM 2006); this in turn will be the basis of SNIC, the national cadastral information system. Its technical implementation is however far from being concluded due to a major issue: geospatial data capture in the field has revealed to be an endless task for it is laborious and expensive.

The first official step towards the establishment of a national registry of land parcels in Portugal was taken back in 1801. Clearly stating how authorities were aware in those days of the great value of a measured coordinate-based cadastre, cosmographers [2] were the practitioners of those days appointed by royal decree to be in charge of the organisation of both “a cadastre and a general registry book of real estates within the kingdom”. Nevertheless, such a registry was never launched for several reasons though until 1836, when the national real estate registry (the “Registo Predial”, see Figure 1) actually started being implemented (Silva et al, 2005). However, it was not until 1926 that coordinated cadastre surveys have actually started. Given Portugal’s territory tissue, with a few millions of small real estates scattered across a rather irregular topography, fieldwork has revealed to be a rather complex and demanding operation and has not covered the whole country yet. Coordinated cadastre surveys are currently being accomplished district-by-district covering both kinds of real estates, rural and urban (Figure 1). By the end of 2013 more than 50% of the mainland’s territory had been surveyed, though this only corresponds to roughly 1/3 of the total number of properties in the country.

A 3D cadastral system requires even more detailed geospatial data and hence various and accurate collection methods of geospatial data are required. Practical acquisition of such data in the field for the purposes above constitutes the main issue we seek to raise in this paper. We strongly believe that the consideration of Volunteered Geographic Information (VGI) to feed such an information system may well to contribute to tackle, at least to a certain extent, some of the issues mentioned above.

[2] One who studies, describes, depicts, and measures the Earth and/or the visible universe, including geography and astronomy.

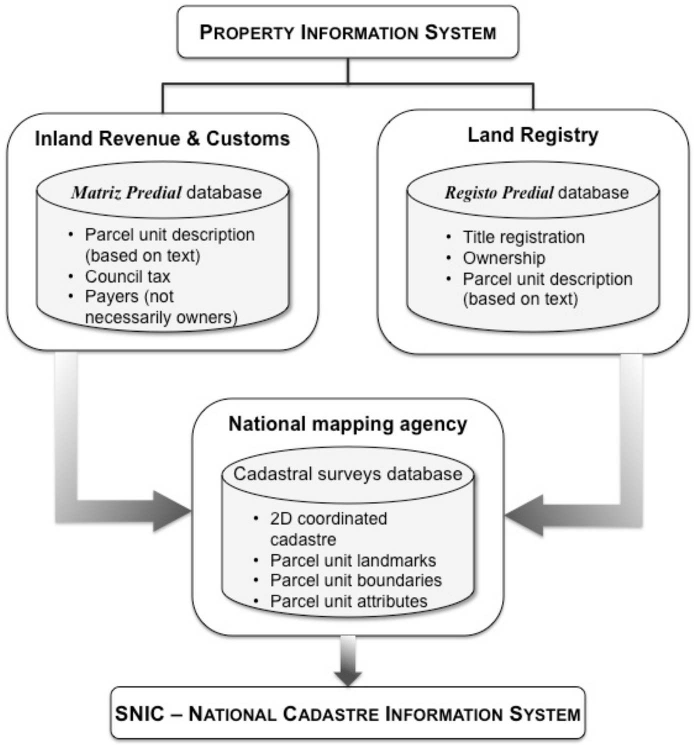

Figure 1. Overview of the current property information system in Portugal

There are in fact some arguments to believe that VGI might be a sound source of geographic/geospatial data. General mapping is a highly expensive activity and many governments are no longer willing to continue covering the even increasing costs of surveys and cadastral mapping. In addition, recent advancements in geospatial and web technologies combined with a population with means to collect and publish geospatial data, have nourished an environment in which web users may provide in their everyday life activities and hobbies vast volumes of data, consisting mostly on geospatial and temporal coded images collected by mobile devices (Coftas and Diosteanu 2010). Furthermore, several recent studies have agreed that the integration of VGI with official information provided by experts – like real estate cadastral data – would be a powerful source of novel data that can be included in Spatial Data Infrastructures (Budhathok et al, 2008, Genovese and Roche 2010, Gould 2008, McDougall 2009).

The main research question that arises from the facts above is: to what extent is VGI a powerful source of novel geospatial data in order to contribute towards a 3D cadastral system, and to what extent can it actually be combined with official geospatial data?

Finally, VGI is still an emerging research topic and its application to real estate cadastral systems has only been superficially touched. Very little research has been devoted to this topic and not many references are available from the literature yet.

2. VOLUNTEERED GEOGRAPHIC INFORMATION (VGI)

2.1 Overview

The widespread of Web technology and its access by citizens since the early 2000s has been providing users with the ability of supplying content to some Web sites, the so called user-generated content. Airline, hotel or car reservation sites, eBay, Blogs, Wikis, among others, are good examples of this Web phenomenon. They collectively constitute what has been termed as Web 2.0 (Goodchild 2007a).

The Web growth in sophistication and in the range of interactions has prompted the interest in using this technology also to create, assemble, and disseminate geographic information provided privately and voluntarily by everyday citizens, not necessarily trained or holding formal qualifications to deal with this sort of data. Although this may well be argued to be a relatively recent Web phenomenon, it has been in fact evolving rapidly during the past few years and is boosting a huge impact on the geography general discipline, and more specifically on geographic information science (GISc). M. Goodchild (2007a) first termed this as "Volunteered Geographic Information". This term has caused a certain debate on whether contexts within which geospatial data are created should be differentiated or not; indeed, Sieber (2007) and Obermeyer (2007) have noted that in some instances VGI may be intentionally generated by citizens, whereas in others those may not even be aware of their role as "producers", and hence these two realities should be considered separately.

VGI is currently understood to be an umbrella term meaning any kind of geographic data that is freely provided by Web users. VGI may also relate to public participative geographic information. VGI does not need an informatics structure specifically developed for public participation for it takes the everyday mobile device as mean for that participation. In addition, the public does not need to be particularly aware or motivated of their participation due to the fact that most of VGI is likely to be a result of recreational activities (Coftas and Diosteanu 2010, Goodchild 2007a, Goodchild 2007b). Kuhn (2007) and McDougall (2009) have interestingly compared it to a closed loop – a system incorporating feedback in the sense that VGI provides the flow of geospatial data, which requires theories and methods to control both flow and data, and which in turn works based on "product's" quality and usability feedback. These technologies and practices are indeed altering the whole context of geospatial data creation and sharing, also individuals and institutions – who play now the role of both data producers and users, and perhaps constitute geospatial data themselves (Elwood 2008).

Several other authors have explored VGI potentialities for their own purposes in the context of specific applications. Based on Elwood et al (2012), Genovese-and-Roche's (2010), and McDougall's (2009) overall views, a global SWOT analysis may be undertaken and summarised as follows: VGI can be a fresh source of detailed, update and free geospatial data, and may constitute a strong and inexpensive opportunity for the future development of Spatial Data Infrastructures (SDI); however, integrating VGI into SDI may represent a major challenge for VGI is often seen to be insufficiently credited, structured, standardised, and quality validated; as to opportunities, these result from the constant growth of contributors and the amount of data being produced calling for new approaches to manage and take advantage of the new volunteered resources; finally, inclusion of VGI in official SDI may pose ultimately a threat do data integrity. Some of these aspects are discussed below in more detail.

As examples, Wikimapia, Flicker, or OpenStreetMap are among some of the current most known and illustrative results of the VGI phenomenon.

2.2 Key questions, concepts and methods

The emergence of VGI has shown how some issues and challenges previously indentified within geographical information science (GISc) became even more pertinent. A few others have remained as significant as before, whereas others may well face some decline in the near future (Kuhn 2007). In order to close the "VGI loop" above, Kuhn (2007) established a framework of four main research avenues (technology, cognition, semantics, and society) within which he undertook a research topic survey and identified 15 key challenges to GISc prompted by the emergence of VGI.

Given its nature, one of the key aspects of VGI is credibility, reputation and trust. Flanagin and Metzger (2008) argued that Web services, geospatial technologies as well as increasing volumes of geospatial data are revolutionising the whole context of geospatial data creation in such a way that the authors pointed out that consequences apply on geospatial data quality and reliability. These authors also noted how measurements are central to VGI credibility research and argued that credibility could be assessed in terms of "accuracy". If volunteered contributions are on what is traditionally thought as to be "factual" or "objective" geographic information, then they may be assessed based upon some sort of accepted social standard or scientific reference point. However, as far as opinion-based VGI is concerned, the authors above argued that its credibility should be assessed in terms of people's perceptions of information or source credibility. With this regard, Maué (2007), Bishr and Khun (2007), and Bishr and Mantelas (2008), have gone further to defend that trustworthiness can be used as an alternative measure of information quality. This could be implemented through trust range systems that can be used in order to make trust values explicit. Maué (2007) mentioned the eBay's rating system as an example of a well-known and well-accepted reputation system. Extending this concept to describe feature collections, the author above argued that these could be rated, tagged, discussed, or annotated, which can be implemented via metadata. Actions like these directly affect a producer's reputation value. Bishr and Mantelas (2008) in turn designed and implemented a community-based collaborative model of authority where volunteered producers make information, and their peers and users judge themselves the information quality. The authors compared it to some extent to the peer review process, though in a much larger community scale and through a Web 2.0 collaborative manner in this case.

Further to the key question on how valid VGI is, some authors have engaged in undertaking practical evaluation on how good some geospatial datasets are. These include for instance Haklay (2010), and Zielstra and Zipf (2010). Haklay carried out a comparative study between two geospatial datasets: an OpenStreetMap dataset (OSM) – possibly the most striking example of a VGI mapping application within Web 2.0 framework – and Ordnance Survey (OS) dataset mainly covering London. For the purpose, a desk-based approach was taken. At the stage of development OSM was then, the assumption was that OS dataset represented higher accuracy, especially with regards to position and attribute. As to results, analysis undertaken showed that OSM can be fairly accurate; indeed, on average within 6m of the position recorded by the OS, and approximately 80% overlap of motorway objects between the two datasets (Haklay 2010). Zielstra and Zipf undertook in turn a comparison analysis of OSM and TeleAtlas MultiNet data covering Germany. Results obtained led the authors to acknowledge that the theory developed by Goodchild (2007a) about “citizens as sensors” was well reflected in their experiment demonstrating the potential of OSM as a strong alternative to proprietary geospatial datasets especially in urban areas. On the other hand, results also made clear that VGI coverage of rural areas is relatively small and needs to be extended if more consistent information is required towards a specific non-urban application (Zielstra and Zipf 2010).

Other authors have focused on the redefinition of some concepts in the context of VGI creation. For instance, Budhathoki (2007) and Budhathoki et al (2008) have maintained that VGI’s emergence led to the need for reconceptualising the role of users, often referred to as “end-users”, who are no longer simple passive recipients of information in the context of VGI and therefore represent an extra value. Because it is acknowledged that those who are closer to a particular spatial phenomenon have the richest spatial knowledge, which should be captured and utilised, citizens should be seen as potential sources of geospatial information – provided that the means for that are understood and successfully created. This information can be considered at least supplementary to other sources (Budhathoki 2007).

2.3 VGI and Spatial Data Infrastructures

As our ultimate aim is to evaluate the potential contribution of VGI for property cadastral systems, we review in this section some of the work recently conducted in investigating VGI’s strengths as a potential source for general SDI.

Given the context of geospatial data community, national mapping agencies practice has been up to now about data collection, map production, and its distribution through users – often referred to as “end-users”, as said above (Budhathoki 2007). In this process, it is assumed both that: providers satisfy users’ needs, and users apply providers’ products strictly following their intent. This is a practice that Budhathoki (2007) argued to be continued with SDI. Although there have been some efforts to get some stakeholders involved in SDI development process, this has been mainly at the optimum use of product level; in fact, the potential in acquiring large amounts of geospatial data by users is still overall ignored (Budhathoki 2007, Moll et al, 2005).

Further to the fact above, some others have explored VGI’s potential as a source for SDI. For instance, Budhathoki et al, (2008), Genovese and Roche (2010), Gould (2008), and McDougall (2009) have agreed that the integration of VGI with official information provided by geomatic professionals will be an innovative and powerful source of fresh geospatial data. McDougall also argued that overall SDI models that were designed and implemented by mapping agencies back in the 1980s are still dominated by geomatic professionals and strongly mapping focused. A new SDI generation has emerged however, much more process focused and where: people, especially users, are an integral component of the SDI itself playing a vital data management role; interoperability of data and resources has a greater emphasis; more independent organisational committees or partnerships representing different stakeholders are becoming more dominant (Budhathoki et al, 2008, Goodchild 2007a 2007b, McDougall 2009).

Owing to many differences between VGI (considered as a “bottom-up” initiative) and official agency-developed SDI (a more “top-down” initiative not really intended to serve ordinary citizen needs), several authors have recognised that the integration of VGI into SDI seems to be technically awkward (e.g. Genovese and Roche 2010, Gould 2008). Nevertheless, due to the fact that VGI deals with lager scale geospatial data relating to more specific fields of interest, local level SDI appear to be easier to integrate VGI (Genovese and Roche 2010). Genovese and Roche (2010) also added that in a further step different local SDI could be connected together and used then to build upon top level SDI. It is within this context that we strongly believe that a property cadastral system can be considered as a top level SDI resulting from the integration of several lower level local SDI, towards which VGI may relevantly contribute.

2.4 VGI and land management

As stressed above, previous work voted to this matter is somewhat limited. Even so, there have been in the past two or three years some authors who have undertaken some research and practical experiments within this field of work. Some examples may include for instance Basiouka and Potsiou (2012), Clouston (2012), Keenja et al, (2012), or McLaren (2011). Basiouka and Potsiou (2013) further carried out a survey through an online questionnaire on the intentions of citizens in participating in property cadastral mapping, and analysed potential motivations there might be behind their participation.

Goodchild and Li [2012] distinguished between different methods for geospatial data quality check and categorised them as follows (categories reviewed by Navratil and Frank 2013):

- The crowdsourcing approach, based on the principle that “data may be correct if a large group of people agree on it”;
- The social approach, based on the principle that “trusted users may act as gatekeepers for data entered by other people supposingly less qualified”;
- The geographic approach, based on the principle that “data provided are compared to existing geographic knowledge”.

Further to the works above, Navratil and Frank (2013) discussed the types of geospatial data potentially used in land administration, and analised categories above in order to identify the areas where VGI can actually provide reliable contribution. These authors emphasised the fact that VGI can only provide data on topics where direct observation is sufficiently possible. Indeed, information on invisible facts, such as the ownership of a given property parcel unit, may be provided by a rather limited number of people. This represents beforehand an issue on VGI quality control given the fact that rights on land constitute indeed a large portion of information in land administration, which is not directly observable and can only be acquired by citizens with a good local knowledge. In spite of all this, the authors above acknowledged VGI potentialities and came to the conclusion that VGI can indeed support traditional data collection mechanisms where direct observation is possible but heavily time-dependent though (Navratil and Frank 2013).

3. VGI TOWARDS PROPERTY CADASTRE

3.1 Opportunities: Portugal's case

As described in Section 2, it is clear that VGI is having a dramatic impact on how geospatial data is currently being acquired and disseminated. VGI is to some extent taking over the role of national mapping agencies, which is causing a dramatic change in traditions and well-established processes. At a time with increasing demands and when public sector resources are declining, VGI should not be seen as a threat but as a potential opportunity for mapping agencies in all domains. In fact, general mapping is a highly expensive activity and many governments are no longer willing to continue covering the even increasing costs of surveys and cadastral mapping.

Recent developments in Portugal confirm the stated above. Governmental authorities are indeed aware enough of how highly expensive in situ surveys are, and while official cadastral surveys are still being carried out in the field (under the supervision of the national cadastral agency), a Cabinet's resolution set up a nationwide repository of geospatial data currently owned by the different public departments and by the private sector too. The main goal of this decision is (PCM, 2012):

- To process and check gathered geospatial data against cadastral standards towards its eventual official approval;
- To articulate and incorporate thereafter gathered geospatial data within the official SDI on cadastral information.

The value of information increases when it is actually shared (Kelly 1995, cited in McDougall 2009), and therefore this particular action of the Portuguese authorities seems to be a step forward. In fact, the lack of effective mechanism to exchange geographical information among local, regional/State, and central government and the private sector remains with no shadow of a doubt a clear impediment to more effective and efficient use of geographic information throughout society (Pinto and Onsrud 1995, cited in McDougall 2009).

In a second stage, Portuguese authorities are planning to commission cadastral surveys not only to the officially certified sector, but also to the wide spectrum of non-officially certified sector (both public and private)[3]. The emerging reality constitutes a total novelty and may well involve the need for the regulation of a "novel" profession: the "cadastral officer"[4]. It is precisely at this level that a major well-timed opportunity was seen for VGI to be taken into consideration. Within a VGI context, such a chartered cadastral professional above could well be seen as the "trusted user" in Goodchild-and-Li's social approach for data quality control.

[3] "Privados vão ajudar o Governo a cadastrar o país" – private sector is going to help the Government in cadastering the country [http://www.ionline.pt/artigos/portugal/privados-vao-ajudar-governo-cadastrar-pais]

[4] EU Level 4 professional rank.

3.2 A five-validity level framework of cadastral data

VGI has not proved yet to be readily appropriate to contribute to fundamental nationwide SDI. Even so, some authors have defended that it may still play an important role at local or regional levels (Genovese and Roche 2010, McDougall 2009, Navratil and Frank 2013). Moreover, VGI has not been officially recognised yet as a valid method for cadastral data acquisition towards official SDI. In addition, it is also acknowledged that a VGI approach may not be suitable to completely replace standard accurate methods and technologies, such as those used in full measured cadastral surveys (e.g. orthophotos, total stations, or GPS).

However, further to the opportunities described in previous section, we argue that VGI may in fact be taken into account as an interim step before a full surveyed cadastre is eventually achieved. As such, we hereby propose a framework of five hierarchical validity levels of general cadastral data whose hierarchy is fundamentally based on the associate source of information – within which VGI is taken into consideration (Table 1). As suggested by some authors (including for instance, Maué 2007), the "validity level" referring to a particular geoinformation collection may be considered and should be made part of its metadata. We believe that this supplementary information will enable a given collection of geospatial data to be properly shared by stakeholders.

Therefore, as far as general property cadastre is concerned, we believe there is room for local governments namely to:

- Acquire 2D/3D geospatial data,
    - Mainly interpretation-based task undertaken in office keeping to the minimum possible field work (Dias 2013),
    - In addition, by considering VGI (as in **Table 1**);
- Data share (providing metadata on data validity, as stated above).

Table 1 below summarises the five-validity level hierarchy of cadastral data (column on the right-hand side) and how it relates to a similar framework internally set up by CMC's GCS[5] for their own purposes. Equal colours mean a potential 100% match of both frameworks, i.e.:

- Level 3 incorporates GCS's "Nível 1" and "Nível 2" (which, if wanted, may well be considered sublevels of Level 3);
- Level 4 incorporates GCS's "Nível 3", "Nível 4" and "Nível 5" (which likewise may well be considered sublevels of Level 4);
- Levels 1, 2 and 5 are the novel validity levels hereby introduced, corresponding Level 2 specifically to VGI.

[5] *Gabinete de Cadastro e Solos* (cadastre & land management office)

Table 1. Five-validity level of cadastral data framework to be used at local government level

VALIDATION LEVELS OF 2D/3D CADASTRAL DATA	
CMC[6]	**Hereby proposed in this paper**
Nível 5 – Inventário cadastral definitivo: informação proveniente de processos onde conste levantamento topográfico vectorial, registo no Registo Predial ou Matriz Predial, e Declarações de Titularidade (caso não sejam prédios do Município de Coimbra) e verificação *in situ* da área.	**Level 5** – Full 3D survey promoted by the national cadastral authority.
Nível 4 – Inventário cadastral provisório: informação proveniente de processos onde conste levantamento topográfico em formato vectorial, registo no Registo Predial ou Matriz Predial. *E.g.* inventário cadastral promovido pela CMC, informações de dominialidade, processos urbanísticos, processos de expropriação, certidões de divisão de prédio, etc.	**Level 4** – 3D survey undertaken by non-official cadastral entities (either private or public).
Nível 3 – Informação cadastral proveniente de processos nos quais conste levantamento topográfico do prédio em formato analógico.	**Level 3** – Private initiatives (including developers' project plans).
Nível 2 – Informação proveniente de processos promovidos por particulares/CMC (sem levantamento topográfico associado, mas onde conste peça desenhada com o polígono correspondente ao prédio delimitado de algum modo).	**Level 2** – Volunteered Geographic Information (VGI).
Nível 1 – Informação proveniente de processos - denúncias, queixas, reclamações, etc. - onde o prédio seja indicado por uma mancha ou ponto sem delimitação do prédio, *e.g.* pedido de limpeza de um terreno.	**Level 1** – 3D data mining-based inference from, for instance, postal address databases.
Obs. Level 1, 2, 3 & 4 cadastral data are meant to be subjected to quality/validation control and susceptible of eventually turning into official 3D cadastre.	

3.3 Complex 3D cadastral situations: room for VGI?

From the technological point of view, many property cadastral systems make use of 2D GIS but increasingly 3D GIS is being recognised as important to model the complexities of modern ownership of property – such as multiple apartments owned by different people in the same block, or rights to underground land for transport systems, utilities or mineral resources.

Although some cadastral situations requiring 3D modelling are evident at street level, many others relate to situations underground or within buildings that cannot be identified at street level. There is still the possibility for cadastral authorities to conduct a detailed survey of every household; nevertheless, this has proved not to be economically feasible. It is true that a

[6] *Câmara Municipal de Coimbra* (Coimbra city council)

large quantity of cadastral data can be interpreted and obtained in office without undertaking any in situ survey (conventional or not). Even so, as much as professionals use photogrammetric data, remotely sensed data, or some of their products like analogue or digital orthophotos, there are several types of geospatial data that are not visible from above or cannot be extracted by any automated process. Examples of these data may include (Goodchild 2007b):

- The names humans attach to features – toponymy, also known as geonames or gazetteer entries;
- Cultural information, including information on the use of land and buildings;
- Environmental information, including for instance measures of air quality;
- Population information, including census data;
- Etc…

Further to the list above, we shall add to it some possible 3D complex cadastre cases likely to be not detectable at street level. As an example, we refer to one of the case studies identified elsewhere as part of our research (see de Almeida et al, 2014: case study 4). This case study refers in particular to a very much common situation especially within the medieval pattern of ancient neighbourhoods that characterise most of the Portuguese (possibly European too) towns and cities. There are instances where an apartment although mostly contained by a given building happens to incorporate a room (or rooms) that physically belongs to a next-door building. In other words what happens is that, physical structures of buildings and "their" apartments may not actually coincide.

Figure 2. Example of a complex 3D cadastre case not detectable at street level: a single apartment shared by two different buildings (de Almeida et al, 2014)

For illustration purposes, let us have a look at the hypothetical situation depicted in Figure 2 above. On the first floor of the grey building, there is a flat on its left-hand side supposingly fully contained within this building. However, the mentioned flat happens to include a room that is physically located inside the next-door white building (such flat is represented by the dashed black line in Figure 2). This is a situation where property rights clearly do not coincide with a predefined physical 3D structure. A real situation like these turns to be complex enough for it cannot be detected at street level. Would VGI – either contributed by the owner or by any local resident – tackle issues like this particular case?

4. CONCLUSIONS & FURTHUR WORK

General VGI is a wide research topic in itself. Some of the key questions raised in this paper are object of current debate among VGI specialists and are still open. Thus, it may be argued that VGI has not proved yet to be readily appropriate to contribute to fundamental nationwide SDI. Even so, it was showed in this paper how VGI might be a relevant source of geospatial data towards several different purposes.

Given the early stage of this work, the goal of the paper is mainly exploratory in finding potential room in the context of 3D cadastre for VGI to be brought in. Future work will entail then the identification in more detail of other sorts of cadastral data (2D, 3D or simply descriptive) that may be acquired through a VGI approach. As such, three main tasks have been established:

Task 1 – Given all sorts of cadastral data officially used in Portugal's cadastre – not only relating to geometry but also regarding alphanumeric attributes – to identify which of these could be potentially derived from VGI.

Task 2 – To investigate whether some cadastral data above could be, either directly or indirectly, retrieved from current sites on the Web.

Task 3 – To identify cadastral data that potentially cannot be provided by any sort of VGI approach, e.g. certain illegal features or constructions.

Nevertheless, preliminary considerations are hereby drawn on some foreseen sorts of cadastral data that may well be acquired with a VGI approach. The design of a web-based application is hereby proposed in which 3D cadastre case studies identified elsewhere (de Almeida et al, 2014) should be modelled and implemented, enabling end-users namely:

- To locate their property/properties on a 2D map.
- To upload coordinates of virtual (or not) landmarks shaping a given property's polygon.
- To identify whether their property/properties happen to match any of the implemented prototypes (de Almeida et al, 2014) – functionalities may include interactive 3D visualisation of prototypes enabling their exploration in some detail both internally and externally.
- To 3D sketch (or to simply upload a 3D sketch) of their own 3D cadastre case(s).

Finally, such application should be initially used for test purposes at local government level within real situation contexts.

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