The Role of Volunteered Geographic Information towards 3D Property Cadastral Systems (2): A Purpose Driven Web Application

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SUMMARY

VGI has not proved to be readily suitable to replace well-established accurate methods and technologies such as those of full standard cadastral surveys. Even so, VGI potentialities as relevant source of geospatial data have been widely acknowledged. As such, some authors have defended that VGI may in fact play an important role such as at a local cadastral jurisdiction level towards local spatial data infrastructures. As far as property cadastre is concerned, the full extent 3D complexity inside a property is in many instances only known to their occupants, thus making crowd sourcing perhaps the only economically feasible approach for its capture. While the crowd cannot be expected to conduct a full cadastral survey, it may be possible to ask them to indicate at least the location of complex 3D situations and thus to facilitate local authorities' understanding of the extent of some cadastral issues. As such, it was argued in our previous work that geoinformation from the crowd might in fact be taken into account as an interim step before a full surveyed 3D cadastre is eventually achieved. As such, possible room for VGI in the context of 3D cadastre was discussed, and a hierarchical framework of levels of data acquisition to be used at local cadastral jurisdiction level was proposed. Such framework is revisited in this paper.Given context above, this paper focuses primarily on two aspects. Firstly, to review technical requirements of the official cadastral process in Portugal in order to identify which sorts of cadastral data are likely to be acquirable/not acquirable through VGI. Secondly, to design and to implement the prototype of a web-based application (IGV3Dcad) envisaged for general public usage to flag different land and property ownership situations. Having information about the extent of the 2D/3D issue is also fundamental to making a decision as to whether a 3D cadastral approach is actually needed and hence to further invest resources in even more expensive 3D survey.

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1. INTRODUCTION

1.1 General context

The widespread of the world wide web (www) and its growth in sophistication in the range of interactions has prompted the interest in using this technology for many purposes, such as supplying content to some www sites by users – the so called user-generated content. This phenomenon, which has been termed as Web 2.0 (Goodchild 2007a), also includes the creation, assemble, and dissemination of geoinformation provided privately and voluntarily by common citizens, not necessarily trained or holding formal qualifications to deal with this sort of data. This activity in particular, which was firstly termed by Goodchild (2007a) as "volunteered geographic information" (VGI), has evolved rapidly during the past few years and is boosting a huge impact on geographic information science (GISc). The term VGI has caused itself a certain debate on whether contexts within which geoinformation is 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.

Given its nature, VGI raises some key aspects related to credibility, reputation and trust. Given these issues, several other authors have explored VGI potentialities for their own purposes in the context of specific applications. Based on Elwood et al.'s (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 to data integrity.

Given facts above, it is generally acknowledged that VGI has not proved yet to be readily appropriate to contribute to fundamental nationwide SDI and has not been in fact 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).

Even so, some authors have defended that it may still play an important role towards land administration such as at local or regional levels (Genovese and Roche 2010, Keenja et al. 2012, McDougall 2009, Navratil and Frank 2013).

Even so, some others have explored VGI's potential as a source for SDI and have indeed showed how VGI might be a relevant source of geospatial data towards several different purposes. 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).

Further to the works above, Navratil and Frank (2013) discussed the types of geospatial data potentially used in general land administration (like 2D/3D property cadastre), and analised categories above in order to identify the areas where VGI can provide reliable contribution. Authors above 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, authors above came to the conclusion that VGI can indeed support traditional data collection mechanisms where direct observation is possible but heavily time-dependent though (McLaren 2011, Navratil and Frank 2013).

As stated above, the integration of VGI into SDI seems to be in fact one of the most pertinent issues. Some authors (including Genovese and Roche 2010, Gould 2008) have demonstrated how such task is indeed technically awkward to be accomplished. Nevertheless, Genovese and Roche (2010) also added that local level SDI appear to be easier to integrate VGI. In addition, due to the fact that VGI deals with lager scale geospatial data relating to more specific fields of interest, some authors have defended that VGI may play an important role at local or regional levels (Bisher and Kuhn 2007, Genovese and Roche 2010, McDougall 2009, Navratil and Frank 2013). As such, Genovese and Roche (2010) added that different local SDI could be connected together in a further step and used then to build upon top-level SDI. In the context above, we argued that a national 3D cadastral system can be seen as a top level SDI resulting from the integration of several lower level local SDI towards which VGI may relevantly contribute (Duarte de Almeida et al. 2014b).

Further to considerations above, we identified and discussed in previous exploratory work possible room for VGI in the context of 3D cadastre at a local cadastral jurisdiction level (e.g. municipal, regional, or state/federal level). As such, a hierarchical framework of levels of data acquisition to be used at local level was proposed – within which VGI is taken into consideration (this framework is reviewed below in Section 2.1). As argued, VGI may in fact be taken into account as an interim step before a full surveyed 2D/3D cadastre is eventually achieved (Duarte de Almeida et al. 2014b).

1.2 Motivation

Further to our previous work, this paper focuses on preliminary considerations about some foreseen sorts of cadastral data that may be acquired through a VGI approach – not necessarily relating to 2D or 3D geometry, but also text-based descriptive information. As such, three main tasks were undertaken:

- To review technical requirements of the official cadastral process in Portugal, which include technical specifications for data structure, content, quality (e.g. accuracy and precision), format, or metadata;
- Given all sorts of cadastral data above, to identify which of these could be potentially acquired via VGI;
- To identify which sorts of cadastral data that are likely to be not provided by any sort of VGI approach.

Finally, this paper focuses on the design and implementation of a prototype of a web-based collaborative application mainly established for the report of 3D cadastral occurrences, either common or complex. It is a crowd source App that implements a purpose driven approach mainly meant for so called "bounded volunteer citizen networks", typically with some sort of interest and/or expertise in the field. The development of such application has two main objectives:

- To draw conclusions on to what extent a VGI approach can actually be used towards 3D cadastre;
- To draw conclusions on whether a 3D approach is pertinently needed in implementing general cadastral systems.

We must emphasise at this stage that Portugal context (in fact our ultimate goal) is taken in our research as test environment for illustrations purposes. Concepts and ideas can be easily generalised and virtually applied to any other country, state or region in the world.

2. BACKGROUND

2.1 A hierarchical framework of levels of cadastral data acquisition

In many instances, the full extent 3D complexity inside a property is only known to their occupants, thus making crowd sourcing perhaps the only economically feasible approach for its capture. While the crowd cannot be expected to conduct a full cadastral survey, it may be

possible to ask them to indicate at least the location of complex 3D situations and hence to facilitate local authorities' understanding of the extent of some cadastral issues.
In our previous work, it was argued in fact that geoinformation from the crowd might be taken into account towards 2D/3D cadastre as an interim step before a full surveyed cadastre is eventually achieved. As such, a hierarchical framework of levels of cadastral data acquisition was proposed (Duarte de Almeida et al. 2014b). Such hierarchy is fundamentally based on the associate source – within which VGI is taken into consideration (**Table 1**). As suggested by some authors (including for instance, Onsrud and Rushton 1995, Maué 2007), the acquisition level referring to a particular geoinformation collection should be made part of its metadata. Such supplementary information enables a given collection of geospatial data to be properly shared by stakeholders.

Table 1. A hierarchical framework of cadastral data acquisition levels to be used at local cadastral jurisdiction level

Framework of 2D/3D Cadastral Data Acquisition Levels
Level 5 – Full 3D geometric survey promoted by the national cadastral authority.
Level 4 – 3D geometric survey undertaken by non-official cadastral entities (either private or public).
Level 3 – Private initiatives (including developers' project plans).
Level 2 – Volunteered geographic information (VGI).
Level 1 – 3D data mining-based inference, for instance from postal address databases.

Table 1 above summarises possible levels of cadastral data acquisition to be considered for cadastral data. In the current version of the table, Level 1, 2, 3 and 4 cadastral data should be used carefully until they are eventually subjected to a quality/validation control process. Those data are hence susceptible of turning into official 3D cadastral data after such process.

As it stands, five different acquisition levels are considered in **Table 1**. However, such framework may well be adjusted by adding further levels or by removing them according to specific contexts. As such, a slightly different version of the framework may for instance reflect the differentiation between laypersons/experts and involved/independent entities.

2.2 Cadastral data potentially acquirable through VGI

Technical requirements of the official cadastral process in Portugal are summarised in a document produced by Portugal's cadastral & mapping authority that includes for instance technical specifications for data structure, content, quality (e.g. accuracy and precision), format, and metadata (IGP 2009). The flow diagram in **Figure 1** depicts the different phases of the whole process and shows how they articulate amongst them. In addition, entities that take part in each stage of the process are also illustrated.

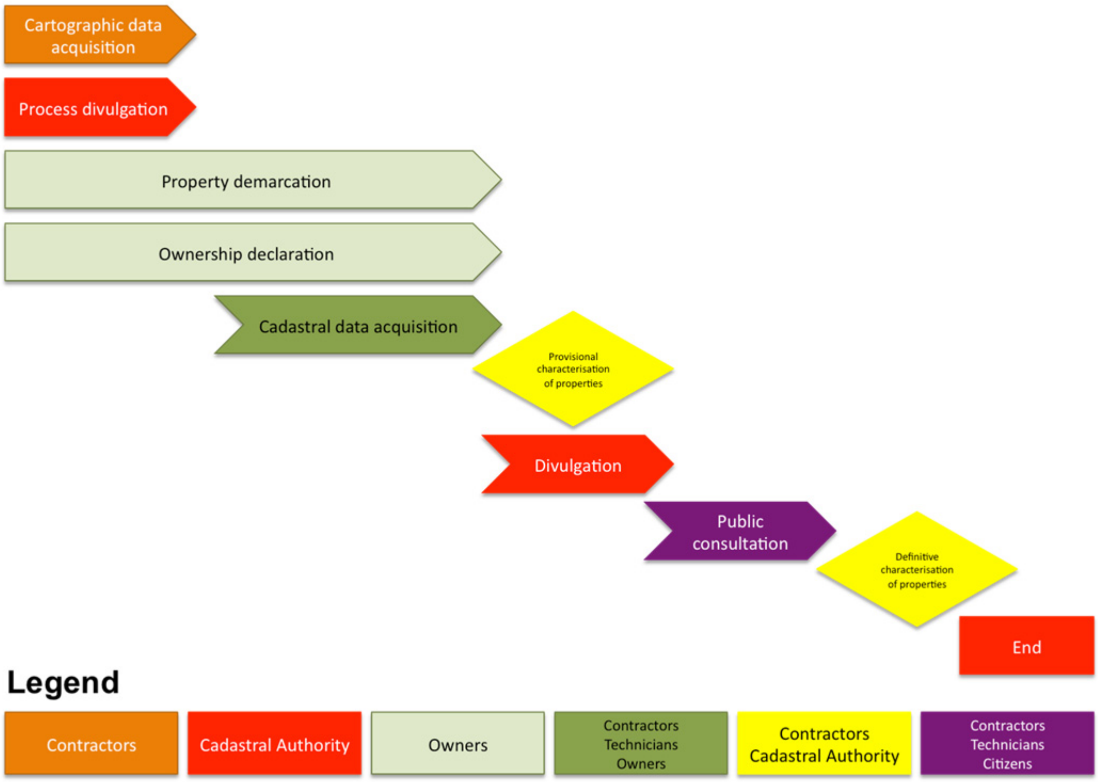

Figure 1. Overview of the different stages of the cadastral process and respective interveners (After IGP 2009)

In the official documentation above, seven chapters are devoted to the different sorts of data to be acquired, methods, and also accuracy and precision requirements. We reviewed in more detail Chapter E of IGP's document (on Data Structure & Content) and Chapter M (Cartographic Data) directly related to the different sorts of data involved in the process, and thus aspects into which VGI may potentially contribute to. In Chapter E, 24 different "Cadastral Entities" are identified and described in terms of their alphanumeric attributes. These entities are grouped into 7 "Types of Entities" (see Table 2 below).

In the light of the cadastral entities summarised in **Table 2** below, it appears that a VGI approach may significantly contribute towards the overall geometric definition of cadastral objects ("Cadastral Object", Table 2). In fact, the observation of physical objects, like a fence or a wall, is relatively simple. Even so, while taking a picture with a mobile device is fairly achievable by laypeople, modelling the exact position of those objects is a bit more complex as VGI agents will need to refer to a more sophisticated technology, like GNSS. Alternatively, VGI agents could be provided with orthophotos organised by public bodies, or physical objects could be semi-automatically reconstructed based on amateur photographs taken from several angles. Methods above raise though several issues that need to be considered carefully.

Table 2. Cadastral entities and their types

Type of Entity	Entity
Cadastral object	Coordinated point PhysicalObject edge PhysicalObject polygon Lot (physical + legal objects)
Person	Legal person
Title deed	Legal object Vacant land Owner Representative Declaration
RRR (Rights, Restrictions, Responsibilities)	Land Registry description Inland Revenue description Notarial act Notary Law Court decision Court
Address	Street/town/post code Civil parish Address abroad (if applicable)
Public consultation	Confirmation Reclamation
Empty areas	Informal parcels Differed cadastre

Undertaking tasks above requires physical presence of the person at the location of measurement. This might be awkward under a VGI approach as laypeople are unlikely to hold the necessary rights to access private spaces. Thus, the only people allowed to undertake those measurements seem to be the two (or more) neighbours or other people holding the respective permission to do so. Although physical demarcation of property units by owners is legally compulsory in the context of Portugal's official cadastral surveys (as such, this action cannot be really considered as VGI), this task may well be voluntarily accomplished, either by owners or tenants, before an actual official cadastral survey is carried out.

As far as cartographic data are concerned (Chapter M), technical requirements on the acquisition of toponymy data are not as demanding. Therefore, it is believed that VGI may have a relevant contribution in terms of collection in the field of geonames as well as cultural information (including information on land and building use), as suggested by Goodchild (2007b). Moreover, such data does not need to be attached to any geometric primitive (i.e. point, line, or polygon).

Finally, VGI may well contribute towards the detection of "informal areas", not necessarily illegally developed or established, but somehow not acknowledged by authorities.

2.3 Cadastral data not acquirable through VGI

VGI agents can only document visible objects. Legal rights themselves are not observable. For instance, rights of ownership and rights of use are indistinguishable by simple observation. Moreover, property legal rights (i.e. the legal object) may not necessarily coincide with visible property boundaries (i.e. the physical object). Furthermore, misconceptions about ownerships and the process of selling/buying further confuse data collected by VGI (Navratil and Frank 2013). As such, additional knowledge must be used in cases above towards which VGI seems to be overall hopeless.

In addition, VGI may not be ready to cover photogrammetric data acquisition towards the production of orthophotos (also described in Chapter M of IGP's document). This is indeed a rather more technical operation requiring considerable amount of both technological and human resources. As such, this is unlikely to be achievable through a VGI approach.

Finally, it should also be expected poor VGI contribution in terms of uploaded data quality control (as described in Chapter G), metadata (Chapter H), data format (Chapter I), and the spatial reference system used (Chapter F). Again, these are more technical and scientific aspects that laypersons are highly likely to be not aware of.

3. THE PROTOTYPE OF A PURPOSE DRIVEN WEB APPLICATION: IGV3DCAD

This section describes the development of a web-based App envisaged for end users to flag different land and property 3D ownership situations. Although it was designed for general public usage, this sort of App is indeed more likely to be used by so called "bounded volunteers" – typically with some sort of interest and/or expertise in the field. Subjected to a standard AGILE development procedure (Dingsøyr et al. 2012, Mark 2012), the initial version of the App was sought to be as simple and straightforward as possible. Besides some other more specific features, it basically enables end users:

- To locate their land(s)/property(ies) on a 2D index map;
- To indicate whether their land(s)/property(ies) match any of the 3D cadastre cases implemented in the App.

Other functionalities to be developed as part of our future work may include:

- To upload coordinates of physical/virtual landmarks shaping a given property's polygon.
- Interactive 3D visualisation of prototypes enabling their exploration both internally and externally.
- To 3D sketch (or to simply upload a 3D sketch) of their own 3D cadastre case(s).

IGV3Dcad App is part of the main outcome of a previous research project[1] (**Figure 2**).

[1] VGI3Dcad – Volunteered Geographic Information Towards 3D Real Estate Cadastre (FCT ref.: EXPL/ATP-EUR/1643/2013)

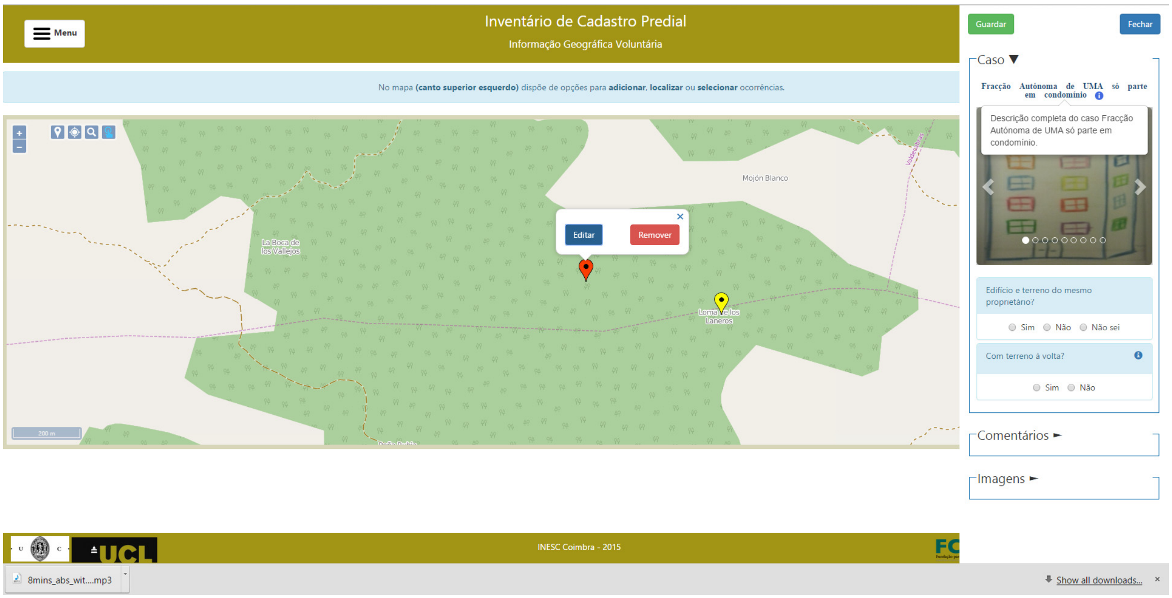

Figure 2. IGV3Dcad App: starting the 3D case association or editing process with a point (selecting from the scroll list on the top right); adding a comment to a 3D case; map view showing existing 3D cases entered by the user

3.1 App functional requirements

At the outset of the project, an initial list of required functionality and features was developed for the App with the research team aiming for a balance between simplicity of use and providing the necessary tools for the purposes. This list was modified and adjusted accordingly as review meetings of the research team were held throughout the course of the project. **Table 3** below lists the functionality offered by the first version of the App.

3.2 The sketches of the 3D cadastral cases

Before the actual design of the App, one of the very first tasks was to identify an appropriate, clear, set of diagrams depicting the various different 3D ownership situations from which the user can then pick one (see "Select a 3D Cadastral Case" functionality, **Table 3**). A systematic approach was undertaken by the research team in order to cover all potential combinations of different options, relating for instance: to the presence or absence of land in front of, to the side of, or behind the building, or to the sub-division of ownership within the building, or the sub-division of ownership between the land and the building, etc. Key differences above between cases/sub-cases taken into account resulted in a total of 96 possible configurations of land and property ownership that were sketched out. In addition, the six special 3D complex cadastral cases identified in our previous work (Duarte de Almeida et al. 2014a) were also included. Finally, it should be recalled that at this stage of our research the focus was not on accurate, geometric, 3D representations of buildings, but rather on a pre-geometry phase.

Table 3. IGV3Dcad App functionalities and description

Functionality	Comment
Register new user	Allows the user to add their details and create a password for the system
Login/logout/retrieve lost password	Allows a registered user to log in to the system and to log out when they have added their Cases. Passwords can be e-mailed to users on request.
About the project	Provides a short summary of the project, along with links to further details
Search for a location	User can type in an address, postcode or coordinates to take them to a specific location on the map.
Add a point to the map	Selecting this button puts the user in 'add' mode – any click on the map adds a new cadastral case. The user can then select the specific Case type, answer questions relating to distinctions between land and property ownership, add additional comments and upload additional documentation.
Select a 3D Cadastral Case	Scroll through a list of pre-defined Cases (with associated images and text description) to pick the model that most closely represents the property and land ownership situation of the user.
Add a Comment	Once the 3D Case is selected, the user can add a comment or additional descriptive text to be associated with the Case.
Upload a Document	Upload a sketch, photos or PDF including additional information about the Case
Edit the 3D Case	Change the 3D Case associated with the point on the map and/or edit associated comments.
Edit (move) the point	The user can relocate the point and/or change the details of the Case associated with the point.
Delete the point	Remove the point and any associated Case details from the map
Selection mode	Used to allow the user to click on existing points or pan/zoom around the map using the mouse – this cancels out editing mode, where any click on the map will create a new point.
List my Cases	Show the user a list of the 3D Cases they have uploaded to the system (note that users can only see their own cases).
Map my Cases	Show the user a map of the 3D Cases they have uploaded (note that users can only see their own cases).

Initial discussions with representatives at a local municipal government in Portugal (Coimbra City Council), as part of the User Testing process, led to the conclusion that the original list of 96 cases and sub-cases was potentially confusing for the user, in particular in terms of the distinction between the sub-cases. Moreover, tests on the first App interface revealed that the number of cadastral cases that the user was being asked to scroll through was excessive. As such, the interface was redesigned to incorporate 4 major groups – in fact, similar cases were grouped together for the sake of simplicity; sub-cases were replaced (in each group) with two questions to allow for the different types of land ownership:

- Do the same owners own land and building? Yes/No/Don't know;
- Is there any land surrounding the building? Yes/No.

A text box was inserted below those questions for users to type in additional comments. Furthermore, the user was offered an option to upload a file, which was subsequently changed to a "photo" upload. Finally, an "i" button (further "information") was also added to allow users to see a more detailed description of the Case chosen. For illustrations purposes, **Figure 3** depicts the two-tier cadastral case selection from the list of options – the illustrated Cadastral Case relates to the stratification of single-part properties within a building/condominium.

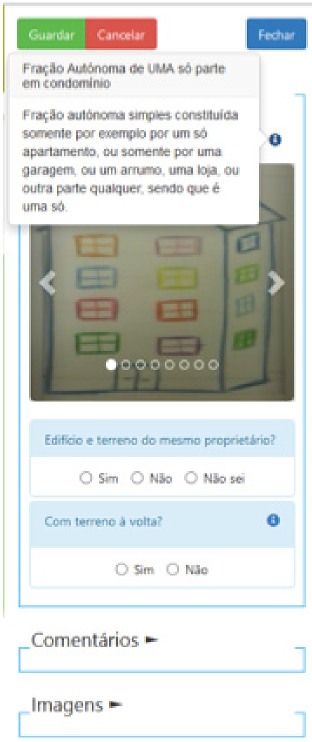

Figure 3. Two-tier Cadastral Case selection using questions (under the 3D sketch) and providing additional description of the Case ("i" button at the top-right)

3.3 App soft launch: initial testing with volunteered end-users

In a second phase of the App development, initial tests with volunteered end-users of various backgrounds were carried out aiming namely at:

- To evaluate App usability and how friendly/easy it was;
- To detect possible errors;
- To get further suggestions.

Before actual tests were carried out, volunteered end-user profiles were pre-defined. In our case, only citizens familiar with and capable of navigating on the Internet were considered for testing purposes. Two categories were pre-defined beforehand according to their academic/professional background: "GIS experts" versus "non-GIS experts". A total of 8 volunteers took part in the test process. According to our categorisation above, 6 of them were considered as "non-experts", and 2 as "experts".

Testing methodology was based on a rather brief initial summary on the purposes of our research and ultimate aim of the App. To ensure that tests were as close to a real VGI context, no details about the App and its features were given at anytime. The volunteered end-users were then invited to create an account and start exploring the App – the main objective at this stage was to check whether end-users were capable enough of figuring out how to report at least one cadastral occurrence. User/App actual interaction was fully recorded, both audio (users' oral comments) and visual (computer screen).

The separation of testing sessions in different days enabled the research team an incremental testing procedure. In fact, this allowed us enough time for suggestions made by users to be taken into consideration and possibly to be implemented before a next test occurred. In some instances users made suggestions/comments orally as they went on, in others feedback was inferred from the actual interaction between the user and the App.

4. CONCLUSIONS AND FUTURE WORK

Further to the initial testing process, it can be said that overall positive results were achieved in terms of end-users' understanding of the 3D sketches of general cadastral cases presented. To illustrate this, some specific comments on the 3D sketches is included below.

- A "non-expert" end-user said: "great 3D sketches of both common and complex cadastral cases, however: in terms of a shared property unit, the most common situation is possibly a shop on the ground floor shared by different buildings, not so much a flat; the illustration of the underground creeping freehold should be more generic not necessarily including neighbouring buildings".
- Another "non-expert" end-user simply said: "pretty illustrative 3D sketches".

Finally, only two of the eight end-users did not find the "i" button to show additional information, although one did comment that this should be made larger. Another end-user suggested that the descriptive text should pop up too as the user hovers over the Case title or even over associate picture, and noted that the number of allowed characters in the Comments is too limited. An "expert" end-user acknowledged that implementing all possible common and uncommon 3D cadastral cases is virtually impossible and proposed that this should handled by including an "Other Cases" option, which was eventually implemented.

Our initial approach to 3D Cadastral Case selection – in trying to figure out all possible combinations of options considered – revealed to be an interesting exercise. However, it could not guarantee that all possible 3D cases were actually mapped, even though it was approached systematically. As showed, it also caused issues with the App due to the large number of cases and sub-cases generated. The streamlined approach, combining sketches with additional information, sketching the diagrams, met with global positive feedback from test users.

Future work will entail the use of the App presented in this paper within real situation contexts at local cadastral jurisdiction level. Given the positive feedback from Coimbra City Council (in Portugal), it is envisaged that further testing will form part of a second phase of the project. Our research team is indeed currently investigating additional sources of funding to take this work forward.

A number of related avenues to aspects presented in this paper remain to be explored. One of the key avenues to be investigated is how we are going to get end-users engaged and keep them motivated enough to collaborate. This is actually a general open question within the VGI research field.

Other aspects will include the evaluation of possible extensions of the App with new features. Further developments may include:

- To upload coordinates of physical/virtual landmarks shaping a given property's polygon;
- To interactively visualise 3D prototypes of cadastral cases enabling their exploration, both internally and externally, in more detail;
- To 3D sketch (or to simply upload a 3D sketch) of their own cadastral case(s).

Finally, it is strongly believed that further testing of the App within the context of real world situations will enable us to draw conclusions on:

- To what extent a VGI approach can actually be used towards 3D cadastre;
- Whether a 3D approach is pertinently needed or not in implementing general cadastral systems.

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