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Usability testing of a web-based 3D Cadastral visualization system

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Key words: 3D Cadastre, 3D Visualization, Usability

SUMMARY

Many countries are extending their cadastral visualization systems in the third dimension. The reason for this stems from the increasing complexity of contemporary cities, the growing 3D approach in other fields (including 3D spatial data acquisition, spatial data processing and visualization), which made 3D cadastre technologically feasible, and the need to overcome the issues of 2D visualization. The visualization of cadastral parcels in 3D is a challenge, since legal boundaries are, in many cases, invisible in the real world; so how can we properly represent something that is not visible to our eyes? This paper results from research that looks into problems of occlusion and ambiguous perception (in terms of position, size and shape) of objects in the context of 3D cadastre visualization. The exploration of specific interaction techniques is essential to overcome these issues.

The aim of this paper is to provide 'lessons learned' resulting from the implementation of a 3D cadastre prototype that was built with the specific goal of trying out several visualization options of 3D cadastral information in a web environment. A usability test was carried out to obtain feedback from different groups of users. Usability is meant in terms of effectiveness and efficiency of the system and users' satisfaction. The test users were subdivided into groups according to different professional domains and expertise. During the test, the users are asked to perform a series of tasks typical of cadastral systems. Each task is accompanied by a description to give the users some context. Then, each user is asked to answer a questionnaire about his or her experience. The results are used to extract general feedback. The outcome of the usability test is crucial to point out the detected limitations in this early stage of the prototype development. Design changes can then be made according to the feedback of the test users.

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1. INTRODUCTION AND MOTIVATION

Cadastral systems aim at making information available to everyone, thus sharing and visualizing it on the web would help to fulfil this purpose. An interactive 3D visualization system representing the third geometric dimension in a flexible way would give the user the possibility to explore the complexity of the 3D world and overcome most of the issues of 2D techniques (Pouliot, et al., 2018).

The typical issues of 3D visualization such as occlusion and difficulties in the perception of position, size and shape of objects are combined with the issues related to 3D cadastre, like underground or unbounded volumes representing certain parcels. In addition, combining topography (i.e. earth surface and reference objects) and legal boundaries (i.e. cadastral parcels) contributes to create a more familiar view of the world. Although, this makes the visualization even more challenging due to the growing number of objects in the viewer (Pouliot, et al., 2018).

The research contained in this paper is part of a broader study about visualization and dissemination of 3D cadastral data, as described in two former papers: ‘Visualization/dissemination of 3D cadastre’ (Cemellini, Thompson, de Vries, & van Oosterom, 2018) and ‘Developing an LADM compliant dissemination and visualization system for 3D Spatial Units’ (Thompson, van Oosterom, Cemellini, & de Vries, 2018). Along with these two papers, a 3D cadastre prototype has been developed. The prototype contains data about the area of Brisbane, Australia and, in particular: 2D and 3D cadastral parcels/survey plans from the Queensland Digital Cadastral Database (DCDB), register of Rights, Restrictions and Responsibilities (RRRs), persons/parties, a 2.5D terrain surface (i.e. a DTM), and reference data (i.e. topographic objects in 2D and 3D) (Cemellini, Thompson, de Vries, & van Oosterom, 2018).

After this introduction (Section 1), Section 2 provides some background information about the 3D cadastre prototype, while Sections 3, 4 and 5 explain the whole usability test process from the design of the tasks to the analysis of the results. Section 6 concludes the paper and provides ideas for future work.

2. BACKGROUND INFORMATION ON THE DEVELOPED PROTOTYPE

2.1 Overall system architecture

Adopting a web-based solution is optimal for dissemination of the data as web browsers offer a relatively hardware/software independent platform, reaching many possible users without great efforts at the user side. This section contains an overall description of how all the parts

of the system work together in synergy. A custom-made Java encoding software extracts the 2D and 3D cadastral parcel geometry for a certain selected area from a PostGIS database into KML encoded files that are placed on the web server. In order to retrieve the persons/parties and the RRRs related to the 2D and 3D parcels a Web Feature Service (WFS) is set up that gives access to a number of Land Administration Domain Model (LADM) views in the database. Apache Tomcat is used as a web server and GeoServer is used as WFS server.

At the client side, a geo-information aware WebGL based solution is applied to visualize the 3D parcels (and reference objects) and interact with the cadastral information (Cesium JS based client). An overall diagram showing the server-client system architecture is shown in Figure 1.

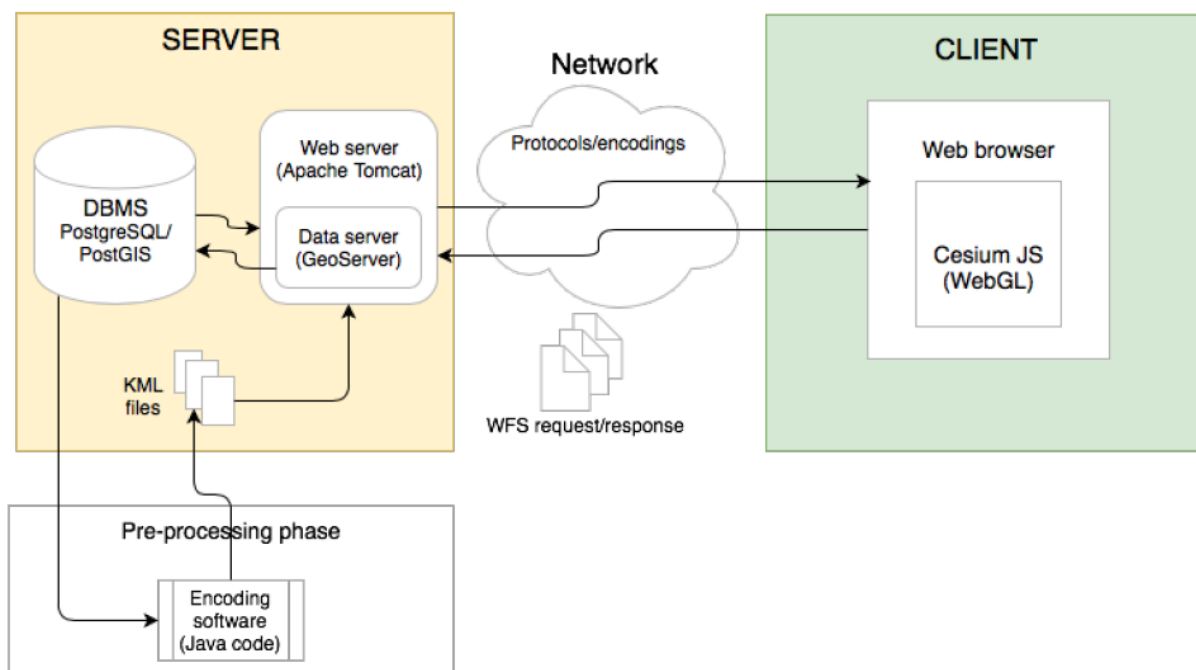


Figure 1. Server-client system architecture diagram of the 3D cadastre prototype

Since the amount of data made available in the client is not huge at the moment, there was no need to put in place tiling/caching techniques, although in the future development the amount of data could increase considerably, when for example the whole dataset of the Queensland DCDB would be hosted. In that case, the client should load only a portion of the information, as all data in the DCDB would be far too much. Server-client caching techniques could be used to manage the communication between server and client when panning over the area.

One of the design questions in this project is about the definition of the server-client interaction, and in particular whether it is better to have the parcel geometry already extracted and stored in files on the server, or, more flexible, to convert on the fly from the database to the 3D client when the user demands it. A second question is, what the most suitable transfer format should be: KML (as currently), JavaScript Object Notation (JSON), or a new format such as GL Transmission Format (glTF).

2.2 Conceptual model

The data is organized in a conceptual model, which has been described by Thompson, van Oosterom, Cemellini, & de Vries (2018). An updated version of the model is shown in Figure 2. The storage schema has been designed with the purpose of being LADM compliant and accommodate a variety of data sources.

The Land Administration Domain Model provides a formal framework for describing land administration data, such as cadastral and deeds data. It is implemented by developing an application schema of the LADM model. Also, it enables involved parties, both within one country and in different countries, to communicate based on a shared vocabulary, suggested by the model. The storage schema of the 3D cadastre prototype shows the structure of the DB. The actual schema is based on the Queensland DCDB schema with some additions. The orange tables were already present in the Queensland DCDB. Four new tables (coloured in red) have been added: *Plan*, *Polyhedron face*, *QC Right* and *QC Party*. The *Unit nr* attribute has been added in the *Plan* table, while the *ObjectID*, *Unit nr* and *Unit part* attributes have been added in the *Parcel* table. Finally, the ‘views’ that have been added are indicated with a blue box and a *QC* prefix, for Queensland Cadastre.

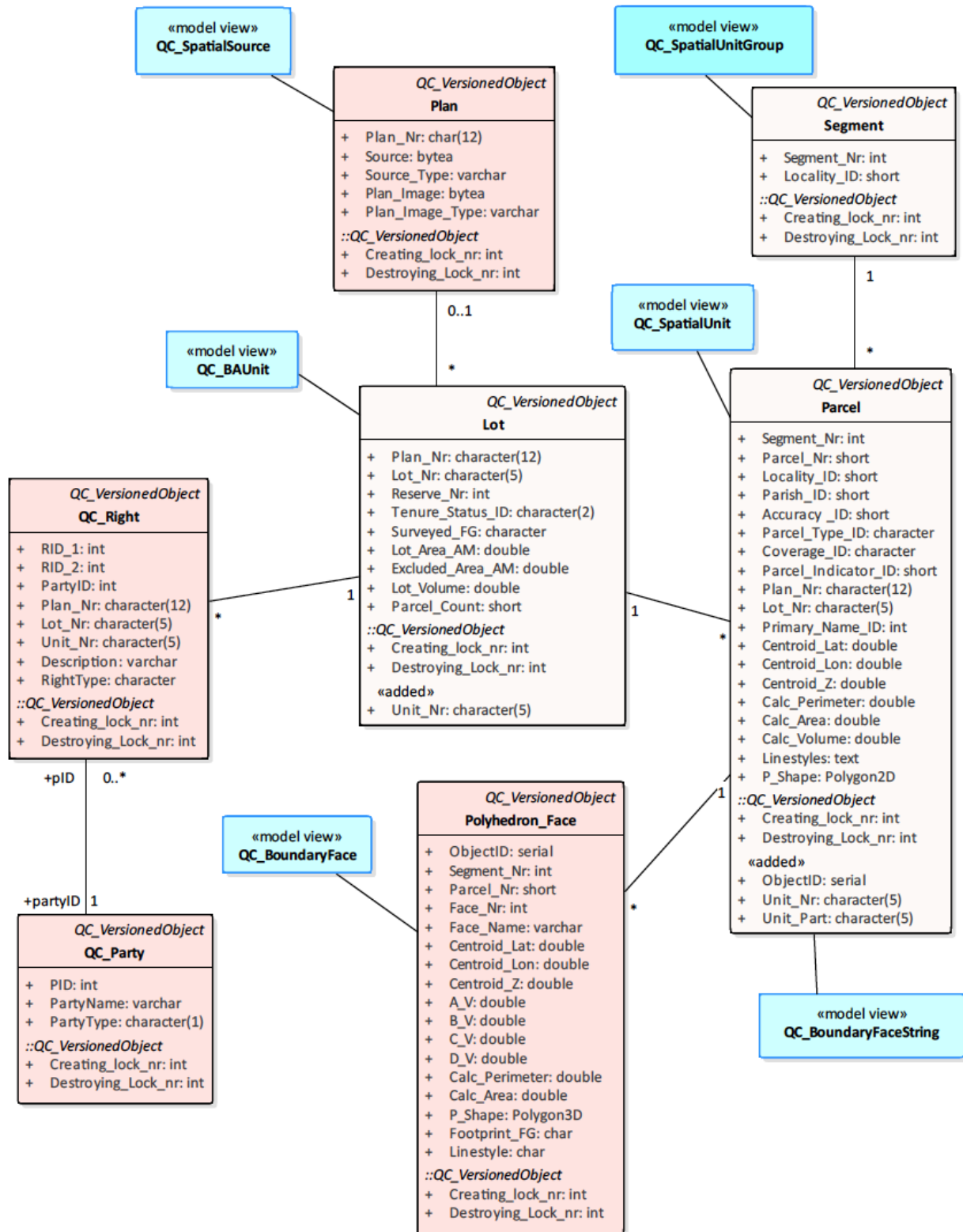


Figure 2. Database schema of the 3D cadastre prototype. Original tables from the Queensland DCDB are shown in light orange. New tables are shown in red, while the 'views' are in blue

2.3 Used tools and other aspects of the implementation

Different 3D visualization platforms have been analysed in order to choose the most suitable one on which to build the 3D cadastre prototype. Among them: iTowns, Cesium JS, OSM Buildings, WebGL Earth, GeoBrowser 3D and ESRI CityEngine Web Viewer.

Eventually, Cesium JS has been chosen to develop the 3D cadastre prototype; the existence of a live code editor, which allows the developers to edit and run the code directly in the web browser is good to facilitate the development phase. Moreover, Cesium JS has the largest community of users among the platforms analysed, making it the best candidate for the development of the prototype (Cesium, 2018).

Finally a set of requirements to be implemented has been defined by Cemellini, Thompson, de Vries, & van Oosterom (2018). Some implementation priorities have been defined and at the time of writing the requirements included in the prototype are the following. Requirements related to 3D visualization:

- *Navigation tools and view controls.*
- *Tooltip*, which shows information about the parcel and the administrative data related to it.
- *Integration of topography* (i.e. a DTM).
- *Transparency.*
- *Object selection and highlight.*
- *Object search*, to check which parcels are owned by a certain person.
- *Dynamic elevation tool* to solve the problem of subsurface visualization.
- *Camera start-up position*, implemented to start up the viewer at the right location.

Note that the last two items in the list were not included among the initial requirements defined by Cemellini, Thompson, de Vries, & van Oosterom (2018), but they have been added to overcome some technology issues and to increase the user-friendliness of the prototype.

Furthermore, the following requirements related to the web viewer are also included in the 3D cadastre prototype:

- *Platform and browser independence* thanks to the WebGL technology.
- *Layers control*, although it is not possible for the user to add his own layers or modify the existing ones (i.e. by changing the level of transparency). On the other hand, the users can toggle on and off the 2D parcels according to the information that they want to visualize.
- *Support for topographic visualization* from a technological point of view.
- *Support for geo-referencing* thanks to the virtual globe technology.
- *Underground visualization* is now possible as a result of the vertical shifting of the parcels.
- *Open source platform.*
- *Possibility for the platform to be extended.*

The last requirement on the list is probably the most important one, since it made possible the implementation of all the others by changing the JavaScript source code of Cesium JS and add new functionalities to the already existing ones (i.e. feature highlight and layer control among others). Figure 3 shows the interface of the 3D cadastre prototype containing the GUI elements just described.

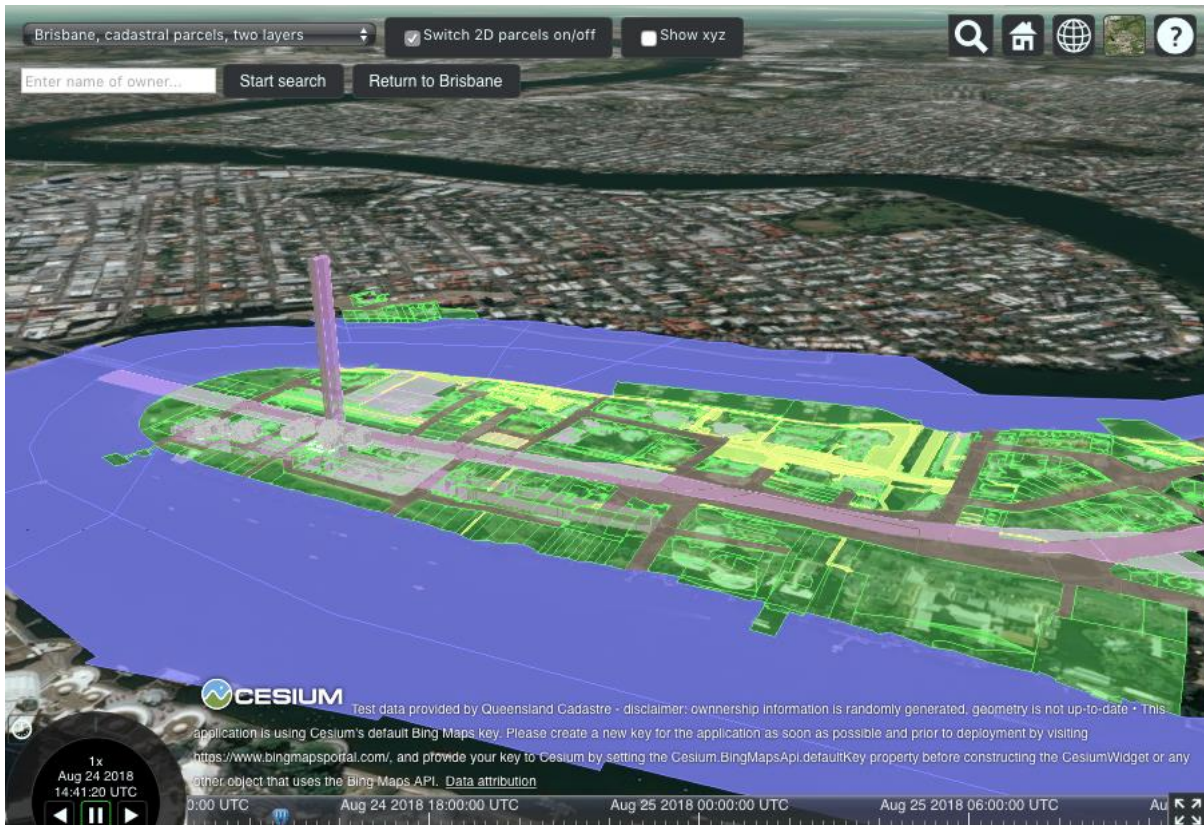


Figure 3. Interface of the 3D cadastre prototype

2.4 The dynamic elevation tool

The dynamic elevation tool mentioned above needs special attention since it was not included in the initial list of requirements contained in Cemellini, Thompson, de Vries, & van Oosterom, 2018. The dynamic elevation tool is needed to overcome the problem of underground visualization. This tool would provide the possibility to move the 3D objects up or down of a user defined amount to be able to visualize in detail the underground parcels that are hidden by the earth surface.

The advantage of using this tool is that the user can have a reality-like visualization at the viewer start up (i.e. with the parcels in the correct location and height) and, if needed, alter the visualization in order to better visualize the hidden parcels. This results in a better understanding of the situation, the user still has a feeling of the actual context of the parcels before the visualization gets distorted to visualize the details. Different implementations of the dynamic elevation tool are possible according to the set of objects to be shifted, the direction of the shift and the graphical control element used to power the tool:

Set of objects

The set of objects to be considered is central in the implementation of the dynamic elevation tool since it determines which and how many objects are altered from their initial position.

- A single parcel could be shifted in case the user needs to analyse in detail the boundaries of that specific parcel, without the context provided by the surrounding objects.
- A (sub-)set of parcels could be used when the user needs to inspect an underground object composed of multiple parcels (i.e. the ‘Clem’ tunnel in the Brisbane city centre)
- All the parcels could be shifted if there are no occlusion issues involved in the visualization and the user wants to have a comprehensive view of both above ground and underground parcels.

In addition, the set of object could grow (i.e. adding new objects to the set) or shrink (i.e. removing objects from the set) according to the administrative/spatial queries that the user wishes to perform.

Direction

The term refers to the orientation of the shifting of objects with respect to their initial position.

- Vertical. Shifting the parcels in vertical direction, from the bottom towards the top, is probably the most straightforward way to implement this tool.
- Horizontal. After the parcel has been raised above ground, a horizontal shift could be applied in case other parcels occlude the view of a parcel. This functionality is similar to the sliding tool (described in Cemellini, Thompson, de Vries, & van Oosterom, 2018). This is a good way to look inside a building by making all parcels of a specific floor part of an active set of objects when sliding out.
- In every direction. Nevertheless, in case the user requests a higher degree of freedom, the tool could be implemented by allowing the shift in every direction, maybe also supporting rotations of objects.

Graphical control element

The graphical control element in a Graphical User Interface (GUI) refers to an element of interaction.

- Drop-down menu. The use of a combo box/drop-down menu allows the user to choose between a limited set of predefined Z values to shift the (selected) parcels.
- Text entry box. Using a text entry box allows the user to type any Z value without minimum and maximum value restrictions. Although, the risk is that the users types an invalid or non-meaningful value.
- Interactive slider. The implementation of a slider/track bar is, likely, one of the most advanced options for the implementation of the dynamic elevation tool, since it allows performing an interactive elevation on the fly and it does not have the problem of inserting invalid values.

For the purpose of this research, the dynamic elevation tool has been implemented by means of a drop-down menu on the whole set of parcels (included the DTM) supporting a shift in the vertical direction only.

3. GENERIC REMARKS ABOUT USABILITY TESTING

This section describes the usability test that was carried out by potential users to assess the developed 3D cadastre prototype. In order to carry out usability tests it is important to give a definition to the term "usability" in this particular context.

According to the ISO 9241-11 usability is: *'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use'*. Thus, usability is about effectiveness, in other words, whether users can complete tasks and achieve their goals. Usability is also about efficiency, which is often measured in time and effort for the user to complete his tasks. Finally, usability is connected with user's satisfaction and his opinion about the product/prototype (ISO, 2018).

The absence of frustration while using something is what makes it usable. For this reason, usability is considered an issue only when it is lacking or absent. Usability testing is considered a research tool, a fundamental evaluation method which enables to assess a product or, in this case, a prototype. This process uses people as testing participants who are sampling the user groups to which the prototype is addressed (Rubin & Chisnell, 2008). Although usability testing is a crucial phase for the assessment and further development of the 3D cadastre prototype, some limitations of this approach must be pointed out:

- *Testing is an artificial situation.* In other words, it depicts an actual situation of usage, but it is not the situation itself. Therefore, in some cases this can affect the results.
- *The results of the testing do not prove that a product works.* The results depend on the way in which the test is conducted and it is not guaranteed that they are reliable.
- *The participants are not always fully representative of the actual user groups.* The actual end users of the prototype can be hard to fully identify, thus the completeness of the representatives depends on your ability to identify the target audience.
- *Testing through a questionnaire with sample users is not always the best method to assess usability.* In some situations, other techniques are preferred in terms of costs, time and accuracy. An example is a method called 'expert review', a heuristic evaluation made by an expert in the field, called to assess the prototype.

In spite of these limitations, usability testing is still considered a valid method to evaluate the usability of a product and to spot its weaknesses (Rubin & Chisnell, 2008). Through usability testing, developers can have direct information about the usability and user friendliness of their applications and an insight into the possible issues encountered by the testers (Ivory, 2003).

4. DESIGN OF TASKS AND FORMULATION OF A QUESTIONNAIRE

The first phase of usability testing involves the definition of the potential user groups of the 3D cadastre prototype. Finding real users can be difficult and time consuming, so it is better to start this phase as soon as possible in the development process. It might seem logic that the bigger is the number of users willing to participate in the testing, the more accurate the results will be. However, Nielsen (2000) demonstrated that five users are enough to spot about 80% of the potential issues. He calculated the number of problems found in prototypes according to the equation:

$$N(1 - (1 - L)^n)$$

where n is the number of users, N is the number of usability problems and L is the proportion of usability problems determined from the testing of a single user. The typical value of L is given, and it is about 31%, averaged from a substantial number of projects studied. Figure 4 shows the plot of the curve for $L = 31\%$.

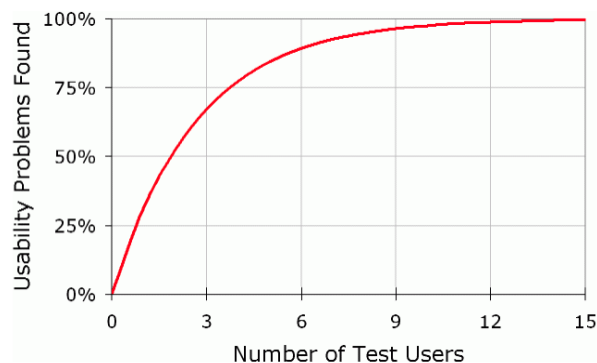


Figure 4. Percentage of usability problems found according to the number of test users. Plot of the curve for $L=31\%$, where L is the proportion of usability problems determined from the testing of a single user (Nielsen, 2000)

In short, each additional test person provides a diminishing added value. This is due to the fact that different users will observe the same thing multiple times generating a bunch of redundant information and very little new insights. No more than 15 test users are needed to discover 100% of the issues. Only in case the prototype is addressed to highly different groups of users, then it is recommended to take a bigger sample of test users (Nielsen, 2000). In the context of the 3D cadastre prototype, the potential users can be condensed into six different groups, in particular:

- Researchers in the field of 2D and 3D cadastre (including staff of the MSc Geomatics for the Built Environment of TU Delft);
- Professionals using cadastral applications (lawyers, notaries, engineers, architects, land surveyors, building managers, etc.);
- Managers in the government and municipal authorities in charge of the maintenance of the cadastral system;
- Public and private entities, companies;
- Students of Geomatics for the Built Environment at TU Delft;

- General public, citizens.

Note that, this is a non-exhaustive list and new groups of end users can become apparent, being this a rather important innovation in the field of cadastre. Additionally, some studies recommend testing the prototype on ‘extreme users’, which means both regular and non-regular users. Regular users are professionals and people involved in the field of cadastre, while non-regular users are people that are not involved in the field and do not have any (or only little) knowledge of cadastral applications (Dam & Siang, 2018). In the list above, non-regular users are represented by the general public/citizens.

Once the users have been identified and selected, the next step is to define a clear goal that the users have to keep in mind while performing their tests. The overall goal is to ensure the usability of the 3D cadastre prototype. More in detail, this means that the prototype must:

- be useful to the target users;
- help users to be effective and efficient in performing their tasks;
- be easy (or even satisfying) to learn/use;
- eliminate issues and frustration for the users (Rubin & Chisnell, 2008).

Said that, in order to obtain feedback, there is the need to specify clearly-defined tasks to be carried out by the users (on the basis of the main goal). Here is a list of defined tasks for the 3D cadastre prototype:

- Navigate through the viewer, pan, zoom and rotate view to get familiar with the controls;
- Toggle on and off the visibility of a layer;
- Visualize the underground parcels, i.e. zoom close enough to see the details and navigate around it to see the boundaries from every angle;
- Visualize information about a single parcel, i.e. ownership information, and unit/lot/plan number, etc.;
- Search for a single owner and visualize all the parcels owned by that person.

These tasks must be formulated in a clear and not misleading way, possibly accompanied by a short explanation, i.e. an example scenario, to give the user some context about the action that he/she is asked to perform (Nielsen, 2014).

The next phase is the formulation of a questionnaire to be handed over to the test users. Before starting, the users need to fill in their personal details and answer some multiple-choice questions about the user group they belong to and their knowledge of Cesium JS.

The core of the questionnaire is composed of five main sections. Each section includes a description, a task, an opinion and a grade as shown in Figure 5.

Section #1

Please perform the following list of tasks and give us your feedback. Note: each question involves a practical task to be carried out on the prototype itself, after that a few questions need to be answered.

Description:

Please make sure you have a working Internet connection. Open the following link on your web browser to start up the prototype: <http://pakhuis.tudelft.nl:8080/edu/Cesium-1.43/Apps/3dcad/>. Before testing more advanced functionalities, it is crucial to get familiar with the basic navigation tools and view controls.

Note: it is suggested to use a mouse.

✓ **Task: Navigate to the Brisbane Airport and check where it is located with respect to the river. You can do this in two ways, if you know where the airport is approximately located just pan and zoom to the location, otherwise click on the magnifier icon and type "Brisbane Airport, Australia". *** 1/1

- South
- South-East
- Brisbane does not have an airport
- North ✓

Opinion: Can you easily navigate through the viewer? Are the controls intuitive?

Yes, the controls are very similar to other CAD programs, making it intuitive to work with. However, it is difficult/impossible to understand where north is without a compass to indicate.

Please, give a grade on a scale from 1 to 10 to the usability of this functionality. *

1 2 3 4 5 6 7 8 9 10

Extremely low usability Extremely high usability

Figure 5. Excerpt of the usability test questionnaire, Section #1. Each section contains a description, a task, an opinion and a grade

The description of the task to be performed gives context to the test user and explains why that functionality is crucial in a 3D cadastre application. After that, the user has to perform a specific task in order to answer a multiple-choice question (in which four options are possible). Once the task is completed, the user can give an opinion, which will contribute to the future improvement of the prototype. Finally, since extracting feedback in an objective way can be a rather difficult task, each section has to be graded by the user according to the usability of the functionality it relates to.

The questionnaire has been created with Google Forms, an online tool to create surveys, questionnaires, etc. The purposes of the questionnaire are (1) to guide the users through the usability test with detailed explanations, (2) to present the tasks for the test persons, and (3) to collect the answers from the test. For a complete version of the questionnaire, see Cemellini (2018). An overview of the sections included in the questionnaire is given below:

Section #1

Description: Please make sure you have a working Internet connection. Open the following link on your web browser to start up the prototype: <http://pakhuis.tudelft.nl:8080/edu/Cesium-1.43/Apps/3dcad/>. Before testing more advanced functionalities, it is crucial to get familiar with the basic navigation tools and view controls. Note: it is suggested to use a mouse.

Task: Navigate to the Brisbane Airport and check where it is located with respect to the river. You can do this in two ways, if you know where the airport is approximately located just pan and zoom to the location, otherwise click on the magnifier icon and type 'Brisbane Airport, Australia'.

Opinion: Can you easily navigate through the viewer? Are the controls intuitive?

Section #2

Description: Once you are familiar with the web viewer you can start playing with the data available by changing the visibility of the layers. The prototype contains layers with cadastral parcels both in 2D and 3D. Depending on the application, you may want to visualize certain layers rather than others.

Task: Which layers can be toggled on/off?

Opinion: Was it easy to understand which layers could be toggled on/off? If applicable, please explain the difficulties you encountered.

Section #3

Description: One of the advantages of a 3D cadastral system is the possibility to store and visualize 3D underground parcels. A limitation that many globe based web-viewers have is that the camera cannot navigate under the ground surface, making impossible the visualization of subsurface parcels. For this reason, the 'dynamic elevation tool' has been implemented, so that the parcels can be shifted up of a defined amount to be able to see the ones under the earth surface.

Task: Suppose you want to take a look at the boundaries of the underground tunnel in our 3D Cadastre test area near the Brisbane city centre. In order to do that, you have to shift the ground surface and navigate around the parcels to visualise them in detail. What is the lowest z-value? (i.e. deepest point of the lowest 3D parcel below the surface)? Note: if you shifted the parcels you have to take in to account the amount of the shift.

Opinion: Were you able to navigate and see the details of the parcels from every angle? Could you see the coordinates on the screen?

Section #4

Description: Cadastre is not only about volumes and parcel boundaries, but it is also about legal information. Every parcel has attached legal information about owner(s), ownership rights, and identification number.

Task: Who is/are the owner(s) of the underground 3D tunnel parcels?

Opinion: Could you visualize the information easily? Was it easy to understand what to look for?

Section #5

Description: Cadastre is also about people and, in particular, owners. Even though the primary focus of the prototype is on visualization, it is important for the user to have access to the 2D and 3D parcels based on ownership of persons.

Task: Search for owner 'Annie' (note fake names in database for privacy). Which is the highlight colour used to show the parcels owned by Annie?

Opinion: Was the search functionality intuitive?

Finally, an additional section allows the users to suggest ways of improving the design and point out what they did like/dislike about the existing functionalities of the prototype.

Additional remarks

- What is the issue that mostly limits the user-friendliness and usability of the 3D cadastre prototype?
- What functionality did you like best? What do you think is the most useful functionality?
- Please choose 3 functionalities that, according to you, are crucial for the improvement of the 3D cadastre prototype.

Here the user can choose among the items of the two lists of requirements or add his own suggestions.

5. RESULTS AND DISCUSSION OF THE USABILITY TEST

The final phase of the usability test consists of processing the results obtained and extracting general feedback for the future improvement of the 3D cadastre prototype.

A considerable amount of test users, 20 in total, replied to the questionnaire. As shown in the pie chart in Figure 6, the most numerous user group is composed of the students of the MSc Geomatics for the Built Environment at TU Delft (40%), followed by the researchers in the fields of 2D or 3D cadastre, including the staff of the MSc Geomatics (30%) and the general public (10%). No professionals and managers in the government replied to the questionnaire.

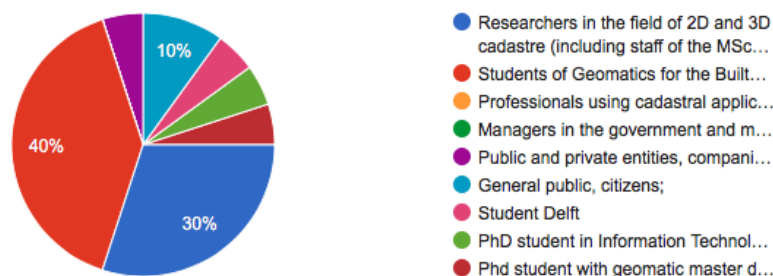


Figure 6. Pie chart showing the percentage of representatives of the users groups who carried out the test

In addition, only about 10% of the users were familiar with Cesium JS, while the rest was not very familiar with the application or never used it before, as shown in Figure 7.

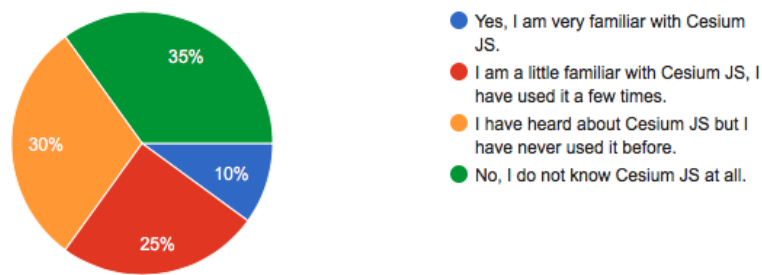


Figure 7. Pie chart showing the knowledge of Cesium JS by the different users

An overview of the tasks is now given, highlighting the main feedback and the average score for each functionality.

Section #1:

Can you easily navigate through the viewer? Are the controls intuitive?

70% of the test users stated that the controls are intuitive, which means that they found it easy to navigate through the viewer and perform the requested task. A 10% suggested inserting a North arrow in order to keep orientation after rotating the view. On the other hand, a 20% replied that the controls are not straightforward and it takes some time to get familiar with them.

The weighted average score for this functionality is: 7.7.

Section #2:

Was it easy to understand which layers could be toggled on/off? If applicable, please explain the difficulties you encountered.

It was intuitive to understand which layers could be toggled on/off for about half of the users, while a 10% stated that it was not clear at all. Including the possibility to toggle on/off the 3D parcels and make the label of the button more descriptive were the main suggestions for improvement. In addition, some users confused the drop-down menu used for the dynamic elevation tool with some kind of layers control functionality.

The weighted average score for this functionality is: 7.15.

Section #3:

Were you able to navigate and see the details of the parcels from every angle? Could you see the coordinates on the screen?

A considerable amount of users (65%) declared that they were able to visualize the underground parcels and the coordinates of the lowest parcel in the viewer. On the other hand, a quarter of the users could not find the way to properly visualize underground parcels or did not find it intuitive. The main criticisms were about the difficulty of visualizing the coordinates because they were hidden behind the volumes or the mouse hovering was not showing the values continuously.

The weighted average score for this functionality is: 6.2.

Section #4:

Could you visualize the information easily? Was it easy to understand what to look for?

This question refers to the retrieval of administrative information (RRRs and persons/parties - owners) of a selected parcel.

Three quarters of the total users responded that they found the information easily, while the rest could not achieve the task either because the WFS request gave an error or because they did not find it intuitive (i.e. the table showing administrative information was unclear).

The weighted average score for this functionality is: 7.5.

Section #5:

Was the search functionality intuitive?

Here the question refers to the object search carried out on administrative data. The opinions of the users about this functionality are divided. The first group (55% of the total) carried out the task easily and gave positive feedback, while the second group (45% of the total) could not carry out the task, either due to a WFS request error, or because they did not realize that the parcels were highlighted. Accordingly, the main suggestions were about the implementation of a bounding box around the selected parcels to give a hint about their location, otherwise while looking from a distance, the user might not notice that the parcels are highlighted. In addition, some users could not reset the search or got confused by the two search boxes in the viewer.

The weighted average score for this functionality is: 6.2.

Additional remarks section:

What is the issue that mostly limits the user-friendliness and usability of the 3D cadastre prototype?

The main limitation for the user-friendliness of the 3D cadastre prototype was, according to the users, the ‘dynamic elevation tool’. Visualizing underground parcels was not so straightforward and some bugs were found in the ‘Show XYZ’ functionality. Additionally, the search functionality was not so intuitive, because the viewer does not zoom to the selected parcels and the users are getting confused because of the presence of two search boxes. Also, some remarks about speed were made, since the navigation/interaction was sometimes an obstacle due to the slow performance (i.e. during the load of the application and while clicking/highlighting some features).

What functionality did you like best? What do you think is the most useful functionality?

The most appreciated functionality was the possibility to get administrative information from a selected parcel, a very crucial functionality in cadastre applications. This was followed by the possibility to visualize the underground parcels (although some users did not like the actual implementation by means of a drop-down menu). Also, the search functionality was among the most useful ones according to a considerable amount of users.

Please choose 3 functionalities that, according to you, are crucial for the improvement of the 3D cadastre prototype.

The top three functionalities that are crucial for the improvement of the prototype according to the test users are:

- Object search which, in the description of the requirements, is intended as a search tool on either spatial and non-spatial data and it can be based on address, geocode, owner's name (as the one implemented in the prototype), coordinates, etc.
- 3D measurement tools, which allow to estimate the dimensions of the parcels by performing different measurements, such as, area, volume, distance between points, and so on.
- 2D overview map, to provide a vertical view over the scene in order to help the user orientate through the viewer.

6. CONCLUSIONS AND FUTURE WORK

To sum up, the usability test has been carried out by both specialized and non-specialized users, although two of the user groups mentioned in the list in Section 4 are missing: professionals using cadastral applications, such as lawyers, notaries, engineers, architects, land surveyors, building managers, etc., and managers in the government and municipal authorities in charge of the maintenance of the cadastral system. For this reason, a second usability test, including some of the requested improvements, is scheduled and members of the International Federation of Surveyors (FIG) Working Group on 3D Cadastre will be invited to participate.

6.1 Discussion of the usability test

The less intuitive functionality (and most difficult to achieve) according to a large part of the test users was the object search functionality, which in most cases did not lead to any result. Therefore, for the future development of the prototype, this tool should be improved since it has also been indicated as the most crucial in the context of cadastre. The most appreciated feature was, instead, the possibility to retrieve administrative data from the database by means of a WFS request. Accordingly, the vast majority of the users managed to perform this task correctly, giving positive feedback about the functionality. For every task the majority of the users answered the question correctly. In general, the users achieved correctly 4 out of 5 tasks with an average of 3.7 points, as shown in Figure 8.

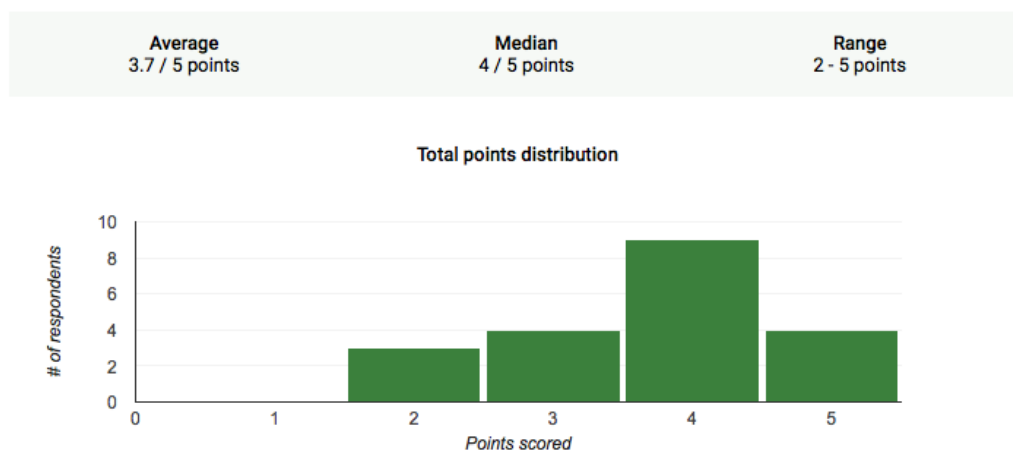


Figure 8. Bar chart showing the total points distribution

6.2 Future research

The usability test carried out after the completion of the prototype was still rather informal, mainly because of time constraints.

The limitations of the informal usability test are primarily connected with the selection of the user groups which do not cover all the groups listed in Section 4 and with the limited amount of time available to carry out the test.

A formal usability test foresees the recruitment of "extreme users" (described in Section 4) in order to have diverse test users and get insights from different perspectives. As an example, professionals in the field of 3D cadastre would be able to give more detailed feedback about the user friendliness of the prototype; on the other hand, citizens would spot more straightforward issues. The combination of expert (i.e. members of the FIG Working Group on 3D cadastre) and non-expert users would contribute to have a more comprehensive evaluation of the 3D cadastre system.

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BIOGRAPHICAL NOTES

Rodney James Thompson has been working in the spatial information field since 1985. He designed and led the implementation of the Queensland Digital Cadastral Data Base, and is now advising on spatial database technology with an emphasis on 3D and temporal issues. He obtained a PhD at the Delft University of Technology in December 2007.

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, the Netherlands. In 1990 he received a PhD from Leiden University. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology, and head of the 'GIS Technology' Section, Department OTB, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. He is the current chair of the FIG Working Group on '3D Cadastres'.

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