Results of the Public Usability Testing of a Web-Based 3D Cadastral Visualization System

**Peter VAN OOSTEROM, Marian DE VRIES, The Netherlands,
Barbara CEMELLINI, Italy, and Rod THOMPSON, Australia**

Key words: 3D, usability, Digital cadaster, Land management

SUMMARY

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 uses the results from research looking 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. After an initial internal usability test (with colleagues/ friends of the developers) our 3D Cadastres web-based dissemination prototype was improved. Next a public usability test is carried out to obtain feedback from different groups of professional users (legal, survey, ICT backgrounds). 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. In this paper we present the main results of the public usability test of the 3D Cadastres web-based dissemination prototype.

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1. INTRODUCTION

All around the world 3D Cadastres are getting more popular and being put into practice. 3D Cadastral parcel data is being collected for various types of objects (legal spaces related to apartment units, tunnels, airspaces, etc.) and rights or restrictions are being attached. The resulting data are stored in the Land Administration databases of the involved organizations. However, using this 3D Cadastral data by persons other that the ones submitting the 3D surveys (designs) or building the 3D information systems, is rather a challenge. In this context, we have in mind legal professionals, financial (mortgage) experts, but also the general public. Key to solving this challenge is developing intuitive 3D visualization and interaction tools, and in order to be able to reach broadest possible audience, a web-based solution is strongly preferred.
The research contained in this paper is part of a broader study about visualization and dissemination of 3D cadastral data, as described in three former papers: ‘Visualization/dissemination of 3D cadastre’ (Cemellini, Thompson, de Vries, & van Oosterom, 2018), ‘Developing an LADM compliant dissemination and visualization system for 3D Spatial Units’ (Thompson, van Oosterom, Cemellini, & de Vries, 2018), and ‘Usability testing of a web-based 3D Cadastral visualization system’ (Cemellini, Thompson, van Oosterom, & de Vries, 2018). Along with these papers, a 3D cadastre prototype has been developed. After the first and internal usability test with TU Delft Geomatics staff and MSc students (Cemellini, Thompson, van Oosterom, & de Vries, 2018), the prototype has been improved based on the results of the first usability study. This paper now reports on the second and public usability testing with participants being professionals in the sector and who were invited via the FIG 3D Cadastres Working Group.
The reasons why the non-expert use of 3D cadastral data is so hard, is caused by issues of 3D visualization such as occlusion and difficulties in the perception of position, size and shape of objects, 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 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).

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

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. 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.

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). The following tools related to 3D visualization are included in the prototype: 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, and Camera start-up position (implemented to start up the viewer at the right location); see Figure 1.

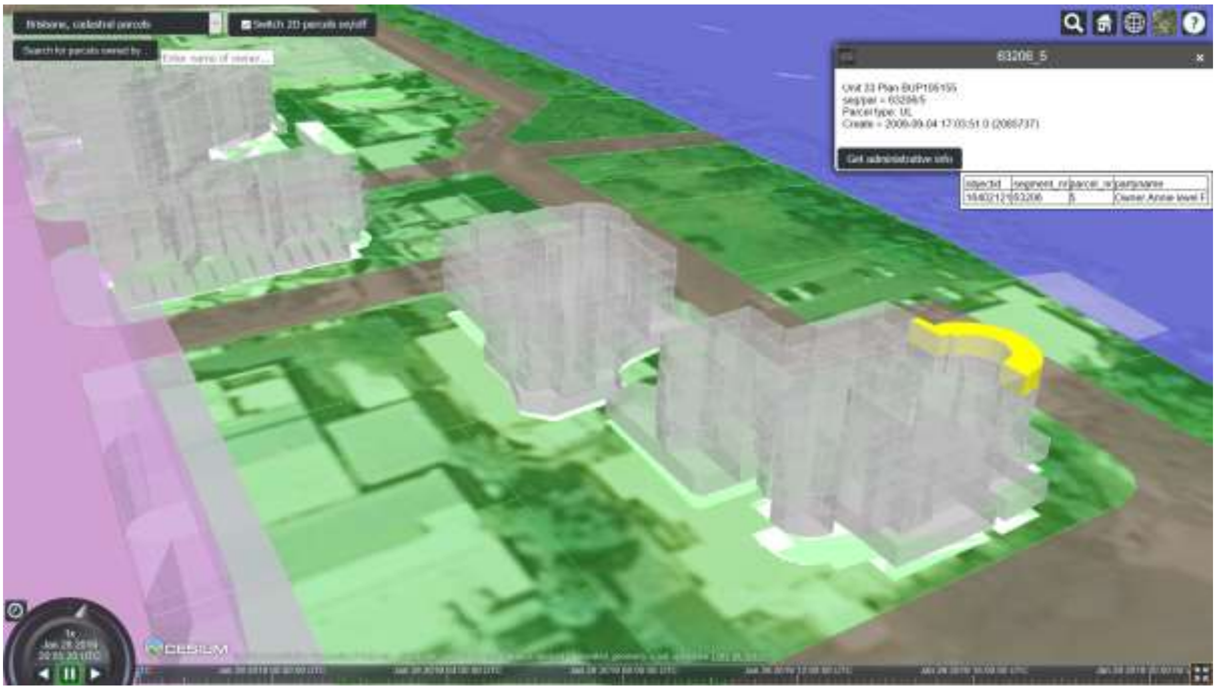

Figure 1. Web-based 3D cadastral client showing the selection of an apartment (yellow highlight, on the left side of the image)

After this introduction, Section 2 provides some background information about the organization of the usability test, while Section 3 briefly summarizes the results of the first (internal) usability test, and the improvements made to the prototype. Section 4 shows the results of the public usability test. Finally, Section 5 concludes the paper and provides ideas for future work.

2. ORGANIZATION USABILITY TEST

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. 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.

Usability testing is 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). There is the need to specify clearly-defined tasks to be carried out by the users (on the basis of the main goal).

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 5 sections (tasks) included in the questionnaire is given below:

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

In Figure 2, the Google form page for section #3 (Visualize the underground parcels) is shown. After completing a task and reporting the answer, we also ask the user to reflect on executing the task and providing feedback on the 3D Cadastral prototype, both in free text form and in form of grading. Finally, after completing all tasks (sections) 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. At the completing of the test, the test person is being informed about his/her score: for how many tasks was the right result obtained. The minimum possible score would be 0 (for none of the tasks a correct answer was provided), while the maximum score is 5 (for all tasks a correct answer was provided).

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.

13. **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.** *

    Mark only one oval.

    - ◯ About -25 m below ground
    - ◯ About -55 m below ground
    - ◯ About -100 m below ground
    - ◯ It is not possible to define the lowest value

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

    ____

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

    Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Extremely low usability	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Extremely high usability

Figure 2. Screen-dump of page of the web-based Google form, guiding the test persons through the usability test. For every section this consists of four parts: 1. Short description of context, 2. Formulation of the actual task (and reporting answer), 3. Opinion about the usability of the offered functionality for this specific task (free from text), and 4. Overall grading of usability on a scale from 1 (bad) to 10 (good).

3. IMPROVEMENTS AFTER FIRST INTERNAL USABILITY TEST

In the first usability test, 20 users participated. The majority of these users were students of the MSc Geomatics at TU Delft and researchers in the fields of 2D or 3D cadaster (including the staff of the MSc Geomatics). Two test persons were very familiar with Cesium JS, three persons used it a few times before, and the others had never used it before. We now just report the average grade as given by the users for each of the 5 different functionalities and refer to earlier publication for more details (Cemellini, Thompson, van Oosterom, & de Vries, 2018):
Section #1, Navigate (pan, zoom, rotate): 7.7.
Section #2, Switch layers on/off: 7.2.
Section #3, Visualize underground parcels: 6.2.
Section #4, Get parcel information: 7.5.
Section #5, Find parcels owned by person: 6.2.

Visualizing underground parcels was not so straightforward and some bugs were found in the 'Show XYZ' functionality. 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). The less intuitive functionality (and most difficult to achieve) according to a large part of the test users was the parcel 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.

Based on the experiences and feedback of the initial usability test, the following improvements have been made to the 3D Cadastres prototype (as used in the second and public usability test):

1. more consistent data (ground+elevated): On top of the Cesium globe with areal imagery, both the 2D and the 3D parcel layers can be displayed. To enable visualizing subsurface parcels, it is possible to elevate the 3D parcels. In the improved proved prototype the 2D and 3D parcels move together, which is easier for the user.
2. improved parcel search by owner: Initial prototype could not handle well searches where specified name is somewhere in the middle of the owner name as stored in the cadastral database. This has now been corrected and making owner much easier.
3. multiple rights/owners per parcel: When a parcel has been selected, it is possible to get the legal/ administrative information. The initial prototype just fetched the first related record, the improved prototype gets all the related administrative records; see Figure 3.
4. more direct feedback: Some actions may take some time (e.g. initial loading of the data), resulting in user being unsure what is happening. This has been improved by providing some feedback on top of the interface: "Loading …"; see Figure 4.
5. back to initial position (Home-button): When zooming and panning with Cesium (or doing a topographic search), it is possible to get lost and the it may be hard to find back the 3D Parcels in Brisbane. The Cesium Home-buttom has now be programmed to always go back to initial view with the 3D parcels.

6. improve slow responses: when interacting the response was slow is some cases (and fast in others). Though in a web-based session there may be network / server delays it has been successfully attempted to speed-up some of the slower actions by improved implementation.

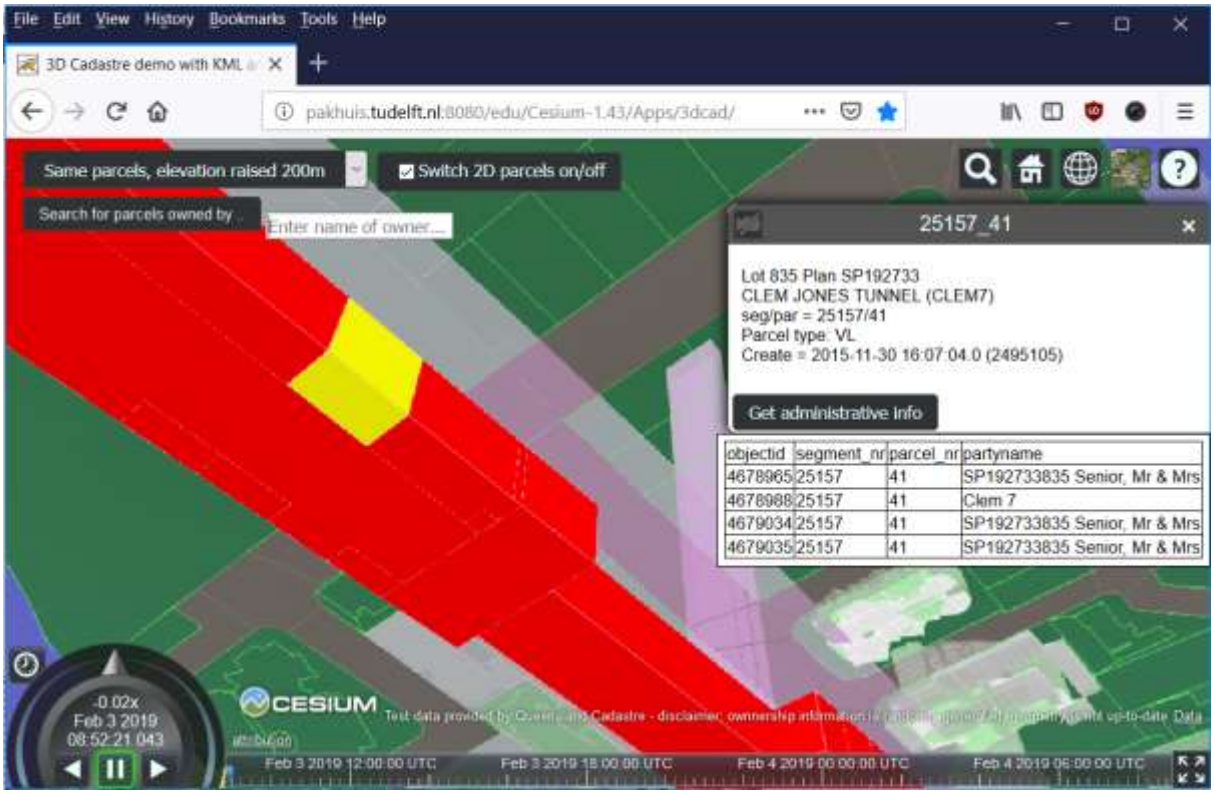

Figure 3. The improved version of the "Get administrative info" now showing all associated records (objectid's) and their related owners (partyname).

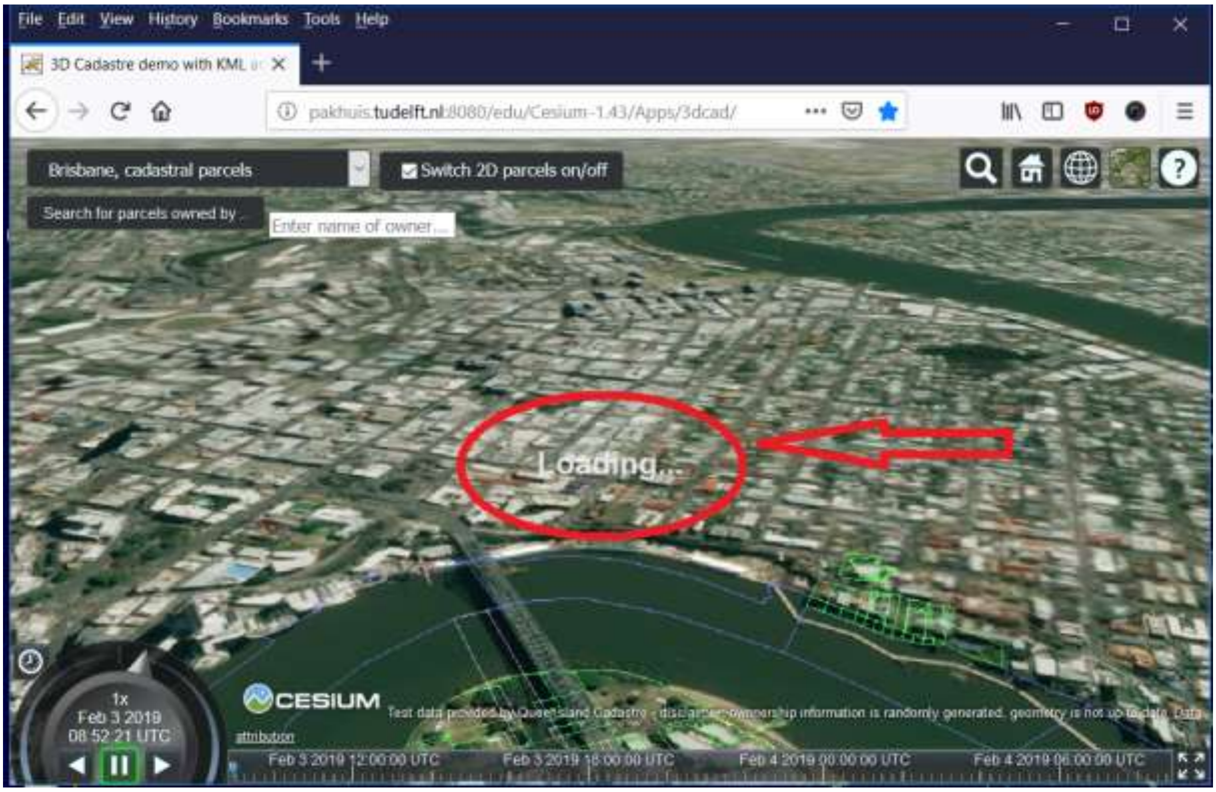

Figure 4. Showing a feedback message during the loading of data, which takes some time. Note that the message "Loading…" (red oval and arrow added to this image) is actually blinking, giving the users the impression of ongoing activity.

4. RESULTS OF SECOND AND PUBLIC USABILITY TEST

The final part of the usability test foresees the presentation and analysis of the responses obtained from the test users over a period from 8 November to 22 December 2018. The feedback and suggestions of the 17 members of the FIG Working Group who took part in the questionnaire will be used to improve the prototype in the future.

In order to read the results in a meaningful way, it is important to know two factors that will influence the overall feedback of the questionnaire: the composition of the group representatives and their knowledge and familiarity with the online Cesium platform.

As can be seen in the pie chart in Figure 5 more than a half of the users are researchers in the field of 2D and 3D cadastre. In addition, a significant portion of users is composed of professionals and students in the geo-information field. Overall, these specialized representatives are supposed to have a solid background about cadastral/spatial data and geo-web applications.

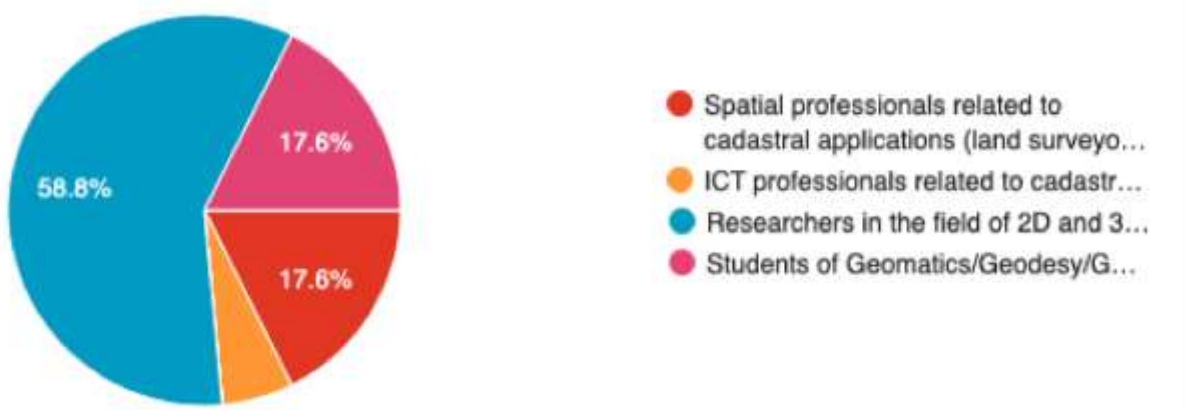

Figure 5. Pie chart showing the representatives of the user groups who carried out the questionnaire.

Only one of the seventeen users that took the test was very familiar with Cesium JS, the rest was a little familiar or completely new to the application, as shown in the pie chart in Figure 6.

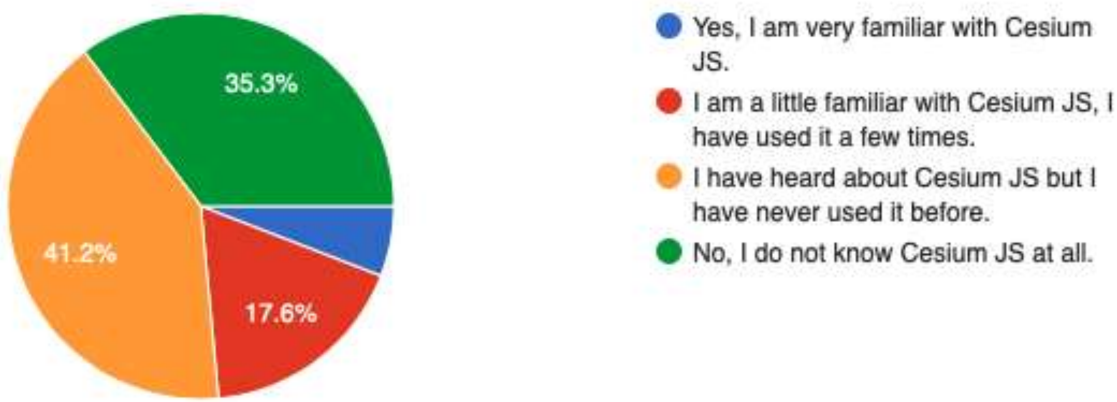

Figure 6. Pie chart showing the knowledge of Cesium JS among the test users.

An overview of the tasks is now given, highlighting the main feedback and the average score for each functionality. The weighted average score refers to the grade that the users gave to the usability of a functionality, based on their own experience. It should be noted that sections #3 and #4 were swapped compared to the initial usability test, because it was more logical to first retrieve the information about the owner of a parcel (easier task) and then perform more advanced operations like shifting the parcels and visualise the coordinates.

Section #1: Can you easily navigate through the viewer? Are the controls intuitive?
In general, most of the users (14 out of 17) carried out this task correctly. This implies that, even though most users are new to Cesium JS applications, the controls are intuitive and user friendly. The main suggestions for improvement concern mainly the loading time of the

application and the difficulty of keeping orientation within the viewer after moving the cursor from the initial position.
The weighted average score for this functionality is: 7.4.

Section #2: Was it easy to understand which layers could be toggled on/off? If applicable, please explain the difficulties you encountered.
Once again 14 out of 17 responses were correct, therefore we can say that almost the totality of the users completed the task easily. Nevertheless, some users pointed out some improvements that could be implemented to optimize the tool. First, assign a more appropriate (and explicative) name to the functionality. Second, speed up the loading time of the datasets. Third, even though the current technology does not allow looking under the earth surface in Cesium JS, the purpose of the 200 m elevation of the dataset results still confusing.
The weighted average score for this functionality is: 7.9.

Section #3: Could you visualize the information easily? Was it easy to understand what to look for?
The correct responses to this question were 9 out of 17. The users were split into two groups: the ones that could carry out the task easily and the ones who could not carry out the task at all. The latter group suggested a list of criticalities that could be improved in the prototype to make the functionality run smoothly. First of all, the slow performance of the prototype can confuse the user; therefore it would be good to shorten the loading speed. The use of cadastre specific terminology can be difficult to understand, especially for non-specialized users. Some terms, such as “partyname”, require some background knowledge to be understood. Finally, some users could not distinguish the underground parcels from the above ground ones because of the transparent finish of the earth surface.
The weighted average score for this functionality is: 6.9.

Section #4: Were you able to navigate and see the details of the parcels from every angle? Could you see the coordinates on the screen?
With only 8 correct responses out of 17, this is the only question that did not score a sufficient result. According to the test users, the cause is to be attributed to two main factors: the fact that the coordinates are obscured by the parcels or they disappear at times, and the fact that some users criticized the way in which the underground parcels are shown, defining inconvenient the computation to deduce the real height values of the parcels.
The weighted average score for this functionality is: 5.6.

Section #5: Was the search functionality intuitive?
Almost the totality of the test users responded correctly to this question. The search functionality scored 16 out of 17 correct responses and positive feedback about the usability of the tool. In addition, some users suggested a few betterments to improve the tool, such as zooming to the highlighted area and showing an error message when entering a wrong name.
It is no surprise that the weighted average score for this functionality is 8.2, the highest in the whole questionnaire.

Additional remarks section: What is the issue that mostly limits the user-friendliness and usability of the 3D cadastre prototype?
From the remarks of the test users emerged that the main limitations of the prototype are the following:

- The slow performance of the viewer.
- The fact the icons and search options can be confusing and sometimes “buggy” (i.e. when a wrong name is inserted, no error message is shown).
- It is sometimes difficult to orientate in the viewer due to a lack of reference points (i.e. use of the North arrow).
- The different styling of the 3D parcels according to their type (volumetric and building parcels) is not clear to some users. Moreover, it could be convenient to use different colours to distinguish between parcels below and above ground level.

What functionality did you like best? What do you think is the most useful functionality?
On the other hand, the users also appreciated a number of functionalities of the 3D cadastre prototype, such as:

- The search functionality based on the owner’s name. Although a suggestion was to integrate the search tool with other attributes to make it more complete.
- The possibility to select a parcel and visualize cadastral information about it.
- The vertical shift of the parcels in order to visualize the details of the underground geometries.
- The possibility to switch on/off layers to better visualize the different datasets. Additionally, some suggested to switch the visibility of the above ground and under the ground parcels separately, in order to make the distinction clearer.

Please choose 3 functionalities that, according to you, are crucial for the improvement of the 3D cadastre prototype.
Finally, the three crucial functionalities for the betterment of the prototype according to the test users are:

- Cross-section view, a tool that cuts a slice out of a volume in order to better visualize its internal subdivision.
- 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 tool, which allows to estimate the dimensions of the parcels by performing different measurements, such as, area, volume, distance between points, and so on.

The last aspect of the evaluation of the usability test, is checking the quality of the tasks as performed by the test persons. Out of the 5 tasks, the test persons typically performed 3 to 5 tasks well and provided the right answers (and wrong answers for the other tasks). The correctness score of the test persons was on the average 3.6 points (see Figure 7).

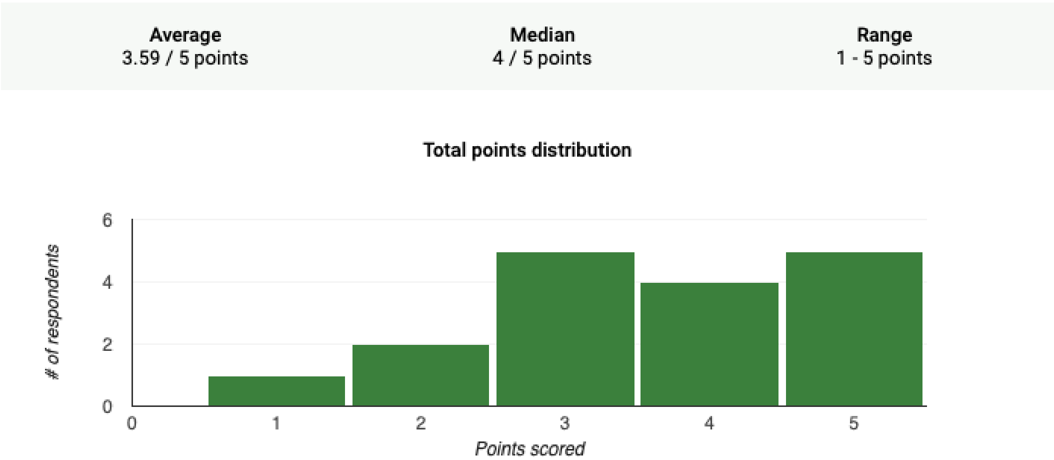

Figure 7. Bar chart showing the total points (= number of correctly performed tasks) distribution.

5. CONCLUSION

In this paper a contribution was made to solving 3D cadastral data usable challenge. Comparing the results of the first and second usability test, on the average there has been made some modest progress (with improved prototype). It should be noted that one has to be careful when comparing the first and second usability test. The average appreciation of all test persons and all tasks increased from 7.0 to 7.2 (on scale 0 to 10). When looking at the individual tasks, then for 4 tasks the average difference between first and second usability test was rather small (less than 0.7 points). Only for the last task from section #5 (Find parcels owned by person), there was a much higher appreciation: raised from a 6.2 by 2.0 points to a 8.2 score. This can be explained by the improved search by owner functionality in the second version of the prototype. Looking at the correctness of the performed tasks, this has slighted dropped from 3.7 to 3.6 (on scale from 0 to 5).
The second usability test also made clear: this research is very much a "work in progress", and therefore more activities are planned for the near future to resolve issues that now limit the user-friendliness and to add more functionality (see top-3 of suggestions as provided by the test persons). In addition, the prototype system should be further matured in a number of different ways: support for the temporal dimension (in storing, analysing and visualizing 2D and 3D parcels), use even more standardized Client-Server Protocol (making it possible to mix-and-match different client tools with different server side solutions), resolve some of the Tuning and Performance issues (as for sure needed when using nation-wide data sets), and consider Topological Database Schema and topological queries (find neighbours of 2D or 3D parcels).

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BIOGRAPHICAL NOTES

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'.

Marian de Vries holds an MSc in Economic and Social History from the Free University Amsterdam, The Netherlands (VU). She worked some years at the Free University and the University of Nijmegen, then switched to become a software developer. Since 2001 she works as researcher at the Section GIS Technology, OTB, Delft University of Technology. Focus of her research is on distributed geo-information systems. She participated in a number of projects for large data providers in the Netherlands such as Rijkswaterstaat and the Dutch Cadastre.

Barbara Cemellini obtained a bachelor degree in Urban Planning at Politecnico di Milano and a Master degree in Geomatics for the Built Environment at Delft University of Technology. Her MSc thesis project is related to the topic of the current paper. Since 2019 she is working for Jan De Nul n.v. as a surveyor of the dredging works on worldwide projects.

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.

CONTACTS

Peter van Oosterom
Delft University of Technology
Faculty of Architecture and the Built Environment
Department OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
Tel.: +31 15 2786950
E-mail: P.J.M.vanOosterom@tudelft.nl

Marian de Vries
Delft University of Technology,
Faculty of Architecture and the Built Environment
Department OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
Tel. +31 15 2784268
E-mail: M.E.deVries@tudelft.nl

Barbara Cemellini
Delft University of Technology
Faculty of Architecture and the Built Environment
MSc Geomatics for the Built Environment
2600 GA Delft
THE NETHERLANDS
Tel.: +39 3358188438
E-mail: barbara.cemellini@gmail.com

Rod Thompson
Delft University of Technology,
Faculty of Architecture and the Built Environment
Department OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
E-mail: R.J.Thompson@tudelft.nl