Transparency Performance in the 3D Visualization of Bounding Legal and Physical Objects: Preliminary Results of a Survey

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Key words: 3D Visualization, Properties Limits, Transparency Performance Analysis, Visual Variable Assessment, Online Questionnaire

SUMMARY

This paper presents a third, subsequent, experiment to assess the performance of various visual variables for better visualization of 3D cadastre models. The case study is a 3D spatial representation of an apartment building with co-ownership units. The third experiment focuses on the following hypotheses "Transparency is performing to distinguish two groups of bounding objects such as physical (e.g., walls) and legal (administrative units) and to give the impression of ownership". These objects are distinct and essential for use by notaries, one category of user of 3D cadastre models, since the spatial relationships between them may directly influence the determination of ownership, and the associated rights and responsibilities. The methodology is based on online questionnaire showing twelve 3D models where participants are invited to test their ability to decide if the wall of a specific apartment belonged to them or not. For data analysis, groups of participants are categorized according to being skilled in cadastral data manipulation, and in 3D data visualization. This paper presents preliminary results of those tests.

RÉSUMÉ

Ce papier propose une troisième étude en ligne concernant l'évaluation de la performance des variables visuelles lors de la visualisation 3D de modèles cadastraux. Le cas d'étude est un modèle 3D représentant des unités de condominium comprenant des parties privées et communes. Cette 3^{e} expérimentation se base sur les hypothèses suivantes : La transparence est la meilleure technique de rehaussement pour la distinction entre deux catégories d'objets soit les murs et les limites cadastrales et pour établir le lien de propriété de ces objets. Ces deux catégories d'objets et leur distinction dans l'espace sont essentielles pour les notaires lors de l'établissement de droits et responsabilités associés à une propriété. La performance est évaluée à partir d'un questionnaire disponible en ligne où les participants sont invités à tester leurs habilités afin de déterminer si le mur leur appartient ou non. L'analyse des résultats est distinguée selon l'expérience des participants à la manipulation de données cadastrales et la visualisation 3D. Ce papier présente donc les premières analyses tirées de ces tests.

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1. INTRODUCTION

Considering the importance of 3D visualization for cadastral systems, as stated by Fendel (2001) and Pouliot (2011), many studies have been undertaken to experiment with and enhance the visualization of 3D cadastres. Some applications were designed to demonstrate the feasibility and advantages of using 3D geo-visualization software for cadastre data (De Vries & Zlatanova, 2004; Miguel et al, 2011; Aditya et al, 2011). However, these developments focused mainly on technical issues. Their cartographical foundations have not been studied sufficiently, according to the graphical semiology theory of Bertin (1983), with its visual variables, currently applied to 2D maps. In 2012, a preliminary experiment was conducted to investigate which among these visual variables (position, orientation, size, shape, value, color and texture) are more appropriate for geo-visualization of 3D legal units (apartments) in 3D cadastres (Wang et al, 2012). Appropriateness was evaluated based on whether a visual variable can be selective or not in the context of visualizing 3D cadastral features. “Color” and “size” were found to be fully suitable for each requirement. “Shape” and “position” were less effective because of interpretation confusion for visualization. Based on these preliminary results, a second experiment was conducted in 2013 with notaries in the form of face-to-face interviews about the semiology of the 3D cadastral model (Pouliot et al, 2013). That time, three visual variables (color, value, texture) and three enhancement techniques (adding labels, moving elements and transparency) were tested against six major notarial tasks. The results showed that, in a way similar to the case of 2D cartography, color (hue) was one of the most promising solutions for visualization tasks when selection is required. Moving the elements by changing the distance between floors of a building was useful for facilitating the view of each floor. Notaries considered texture helpful to represent walls, but they did not prefer this variable. For value, no conclusion could be given, because interviews with notaries showed heterogeneous results for each task. The use of transparency was helpful in some cases, specifically when reading annotation (official measures). But confusion arose when too extensive geometry of 3D lots was viewed simultaneously and transparency is unnecessary when the geometry of the lots is fully visible. Surprisingly, the simple “Black and White” visual solution (black for boundary and white for surface) showed acceptable performance.

Although a preliminary evaluation of the performance of each visual variable was collected in that experiment, some limitations to this evaluation have been identified:

- A great many factors, from the complexity of the model to the environmental setting, have the potential to influence the performance of visual variables.
- The settings of some visual variable may induce problems of understanding, e.g., inappropriate selection of color or texture.

- Only four notaries were interviewed, meaning conclusions are limited.
- Interacting with video animations was not necessarily satisfactory for 3D visualization.

Overall, the second experiment was not extensive enough to fully assess whether the assessment of the fitness of visual variables is specific to notarial tasks and 3D visualization (compared to 2D plans). These limitations were taken into account to produce a new experiment.

2. DESIGN OF NEW EXPERIMENTS

Two important factors guided the design of the new experiments applied to 3D spatial representation of apartments (co-ownership units). First, among the six notarial tasks tested in 2013, one was of more specific interest: how users determine non-ambiguous spatial relationships between two 3D objects. For instance, distinguishing the limits of the 3D lot and the associated building is of prime importance to establish ownership and, consequently, the responsibility and rights associated with the legal object. Second, due to time constraints, instead of thoroughly studying each visual variable, research about only one variable, which is prevalent and special for 3D visualization, seems more feasible. Based on these concerns about the establishment of spatial relationships between objects occupying the same space, and if required to select one visual variable, transparency looks promising since it would best show occlusion (Cheung & Stone, 2011; Colby & Schol, 1991; Elmqvis, 2007; Viola et al, 2004). However, very little research has focused on how to use transparency as an encoding channel for applied requirements (Cheung & Stone, 2011). Our experiments will be a new contribution, testing the performance of transparency for visualizing superimposed legal and physical objects of 3D cadastre models. We have then identified two hypotheses: 1) Transparency is performing to distinguish two groups of bounding objects such as physical (e.g., walls) and legal (administrative units), 2) Transparency is performing to give the impression (the notion) of ownership. This paper presents preliminary results about them.

In order to avoid certain limitations identified in our previous experiment, a greater number of participants is targeted. An online questionnaire was designed to show several versions of 3D cadastral models with varying level of transparency. Two criteria are used to select the participants: people having expertise or not with cadastral data, and people skilled or not in 3D visualisation (spatial data). Regarding the set of 3D models to be tested, the alternative is to modify the level of transparency and the category of 3D spatial relationship of interest. Based on a literature review (Cheung, 2011; Colby & Scholl, 1991; Singh & Anderson, 2002) and taking into account the alpha (α) composing, Metelli's theory and Weber-Fechner's law, three levels of transparency are estimated to be representative: High (13%), Medium (36%) and Low (100%). The simple black and white model (black for boundary and white for surface) is also tested.

Concerning 3D spatial relationships, based on the DE-9IM, eight topological relationships between two objects are possible (equal, disjoint, intersect, touch, contain, cover, covered by,

within). For this experiment, we only tested the relationship TOUCH. Figure 1 illustrates two possible tested situations where in 1A the wall belongs to the private unit 101 while in the 1B, the wall belongs to the common part. In total, 12 3D models of co-ownership apartments acting as a case study have been prebuilt and used to be presented to the participants.

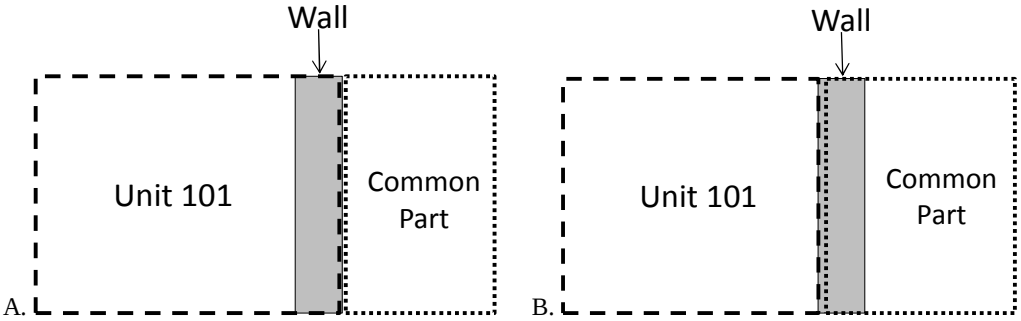


Figure 1. Two examples of the spatial relationship TOUCH: A. between a private unit (#101) and a common unit, B. between a private unit (#101) and a wall part of the common unit

3. ONLINE QUESTIONNAIRE

The questionnaire is presented in the form of a website running on Internet and it is supposed to be answered in 15 minutes. Participants have access to the questionnaire by typing the URL "3dcadastre.com" in their web browser. The questionnaire is organised around three sections. Section A is about the participant's profile, four questions are asked:

- What is their training background?
- What is the frequency of manipulating cadastre data?
- What is the frequency of manipulating 3D visualisation engine?
- If participants have color identification deficiency?

Section B is a demonstration on how to use the 3D visualisation interface (for example, how to manipulate the mouse, information about transparency and the simulated case study). Section C is the true experiment where twelve 3D models showing one level of an apartment are subsequently presented to the participant. All the 3D models were defined as simple as possible in order to keep the focus on the transparency (and not the object geometry for instance). Each time, the participant has to answer two questions (1) Is the wall belongs to you (or your apartment), (2) The level of certainty of their response. For the second question, three possible answers exit (fully confident, half confident, not confident). The question will allow us to moderate the results of the tests.

Regarding the 3D models, and for these first tests, six levels of transparency are tested in correlation with two spatial relationships schema (see figure 1). We limited this test to six levels of transparency for efficiency purpose; we estimate that 15 minutes is the maximum acceptable time for doing an online questionnaire. If time is longer, people will give up. It will also allow use to pre-test this methodology with a limited number of 3D models, and if the

results are promising, further 3D models may be built. In final, twelve 3D models are presented to the participants. The transparency is always applied to the face of object. Table 1 presents the list of tested solutions while Figure 2 shows two examples of the 3D models tested.

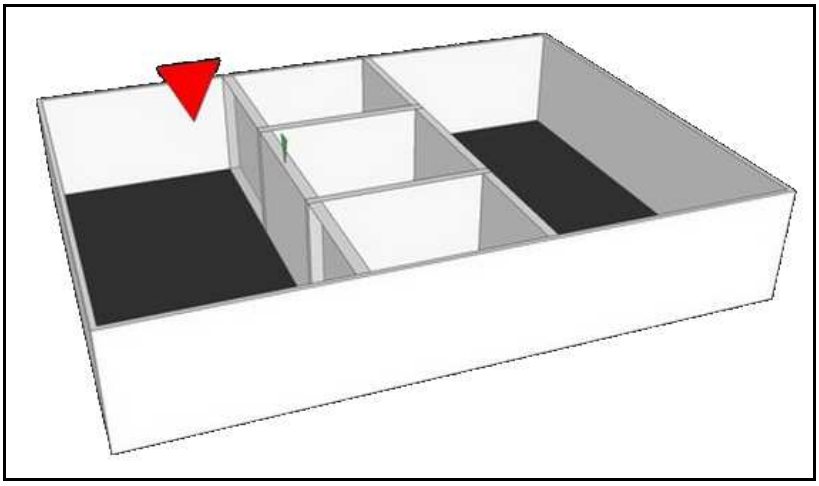
Table 1. List of tested 3D models with their related Alpha values

		Alpha Values		
Test #	**Wall belong to Private unit**	**Face of the Private unit**	**Face of the wall next to the private unit**	**Face of the wall next to the common part**
1	Y	100	100	100
2	N	100	100	100
3	N	13	100	100
4	Y	13	36	100
5	Y	36	13	100
6	N	36	100	100
7	N	13	85	85
8	Y	13	33	85
9	N	60	100	100
10	Y	60	20	100
11	Y	20	60	100
12	N	20	100	100

For each 3D model, the question refers to the unit marked by a red arrow that belongs to the participants and a green arrow pointing the wall for which a respond is expected. In order to mitigate the influence of carry on effect, which we estimate that user may become more fluent by viewing more visualization solutions, the order of the test is fully random. During the test, time is also recorded in order to evaluate the efficiency of the users. We did not provide rolling back option for participants to eliminate answering twice the same question.

Concerning more technical information, the website is built based on asp.net and use a SQL server to store the test data. The 3D models were designed in Sketchup, an easy and accessible platform, and we used the "Sketchup 3D warehouse" web viewer to enable online viewing. 3D warehouse is the online publication platform of Sketchup, and it allows us to maintain the visualization schema with original 3D model and limit format transfer. For information, Sketchup 3D warehouse web viewer is built on WebGL (a fundamental javascript API for 3D and 2D rendering in web browser).

Solution #1



Solution#4

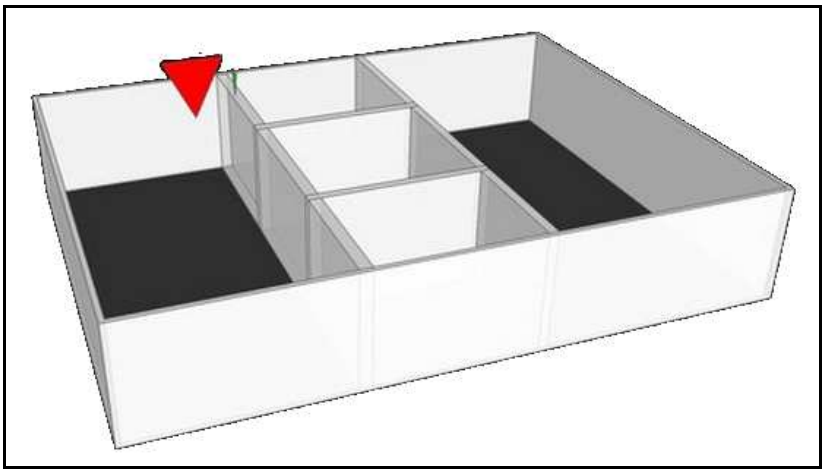


Figure 2. Two examples of 3D models tested (red arrow marks the unit under investigation)

4. PRELIMINARY ANALYSIS OF THE RESULTS

Until now, specific invitations were sent to students having a major in notary and in Geomatics. But in fact, every people can do the test. 32 participants currently answered the full questionnaire but the survey is still opened and running. Table 2 shows some statistics for all tested models (weighted percentage of correctness is obtained by dividing the correctness by the certainty).

If we now aggregate these individual results and take the following rules for making decision about the effectiveness of the transparency : Performing if the weighted percentage of correctness is >60%, and not performing if the weighted percentage of correctness is<40%. In between these intervals, decision will have to take into consideration the other criteria. We may argue few elements regarding the two investigated hypotheses.

Hypothesis 1 (Transparency is performing to distinguish two groups of bounding objects such as physical and legal units): This data analysis has to focus on the correlation in the results when we compare the legal units (private and common parts) and the wall. These results show that the transparency has major impact on the decision making process. For example, it is clear that B&W models (solutions #1 and #2) were not a good visualisation chart. For the other solutions, we found a correlation factor of 75% for the weighted correctness when we compare the results based on these two categories of objects; that is a high correlation. With the limited number of results, no advantage of using low or high transparency to one of the categories was identified since it was balanced 50% for each.

Table 2. Statistics of the 12 tested 3D models

Test #	Percentage of correctness	Weighted % of correctness	Percentage of certainty	Average Time elapse (sec)
1	38%	19%	42%	26
2	72%	38%	39%	20
3	53%	46%	73%	24
4	72%	72%	100%	18
5	75%	62%	75%	20
6	59%	52%	80%	16
7	50%	31%	66%	23
8	69%	51%	67%	22
9	66%	60%	86%	28
10	63%	51%	73%	18
11	69%	56%	78%	22
12	56%	46%	80%	18

Hypothesis 2 (Transparency is performing to give the impression of ownership): This data analysis has to focus on the correlation in the result when we compare the private unit and the common part. When private units have high transparency faces then 100% of the results got good performing results. Nevertheless when private units have low transparency faces then 50% of the results performed. These results do not currently allow us to state any conclusion about this second hypothesis. Additional tests are required.

Regarding the time elapse ranging from 16 to 28 seconds/test, the correlation coefficients with the other criteria were generally low but the trend was clear, longer is the time elapse, higher is the uncertainty of the decision of the participant. Which somehow confirm that participants were fully engaged in the tests since they spent more time when they were not sure about their decision.

One last aspect of the analysis is about the discrepancy of the results based on the skills of the participant concerning cadastral data manipulation and 3D visualisation. The correlation coefficient between the percentages of correctness with the skill in cadastral data manipulation is 38%, while it is of 12% with skill in 3D visualisation. We may perceive a certain level of correlation between the correctness and the skill in cadastral data manipulation but clearly there is no correlation with the skill in 3D visualisation.

5. CONCLUSION

We proposed in this paper the evaluation of transparency in 3D visualization scenarios for responding two tasks: distinguish the private and the common parts, and establish the ownership property. Twelve 3D models representing one level of apartment unit were used and 32 participants via a questionnaire available on a web site ran tests. The results are mitigated. The use of transparency clearly impacts the decision making of both tasks. For instance, B&W models are not a good visualisation chart. We were nevertheless not able to state about if using low or high transparency better performed. When private units have high transparency faces then 100% of the results presented good performing results for establishing the property ownership. This is for sure one way to get more investigation. Obviously, we need additional results and data analysis to fully figure out correlation effect between the study variables. The questionnaire is still running at 3dcadastre.com, and more robust data analyst will be generated soon.

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BIOGRAPHICAL NOTES

Jacynthe Pouliot is a full professor at the Department of Geomatics Sciences (www.scg.ulaval.ca) at Université Laval, Quebec, Canada and currently the head of the Unit. She is an active researcher at the Center for research in Geomatics (www.crg.ulaval.ca) and owns a personal discovery grant from the Natural Sciences and Engineering Research Council of Canada. Her main interests are the development of GIS systems, the application of 3D modeling techniques and the integration of spatial information and technologies. Since 1988, she is a member of the Professional association of the Quebec land surveyors. She is also involved in the supervising committee of the 3D Ethics Charter (www.3dok.org) and member of the FIG working group on 3D Cadastres.

Chen Wang obtained his MSc in Geographical Information System in East China Normal University, China. He is now a PhD candidate at the Department of Geomatics Sciences at Université Laval, Québec, Canada. His current research topic is about assessing the visual variables for 3D visualization of legal units associated to apartment building.

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