Preliminary Investigations into the Usability of 3D Environments for 2D GIS Users

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Summary

Although the need for 3D GIS is growing, migrating from traditional 2D to 3D GIS can be frustrating due to the familiarity of users with 2D. This paper describes a preliminary investigation into the problems that users encounter when migrating from 2D to 3D environments from a theoretical perspective and via two usability evaluation tests: Cognitive Walkthrough and User Testing. As expected, the results demonstrate the influence of 2D perceptions when interacting with 3D GIS and that users experienced more difficulties interacting in 3D, resulting in lower confidence and satisfaction.

KEYWORDS: 3D GIS, usability, usability evaluation

1. Introduction

Three-Dimension Geographic Information Systems (3D GIS) are becoming increasingly popular due to the availability of 3D data, visualisation and analysis tools. However, they present a new challenge for users accustomed to working with 2D GIS, in particular in terms of the interaction paradigms as well as conceptual issues (Billen & Zlatanova, 2003). These include much greater familiarity with 2D mapping, in particular given the long history of paper maps (Billen & Zlatanova, 2003; Goodchild, 2010) and insufficient knowledge of 3D analytical functionality and its potential applications (Ellul & Haklay, 2006).

To date, a significant portion of 3D research has focused on technical developments, with the usability of the resulting software taking second place despite its importance (Hossain & Masud, 2009). However, new directions of GIS usage, including 3D GIS, provide additional usability challenges (Brown *et al.*, 2012).

This paper explores how the usability of 3D GIS can be improved through a usability study focussing on users migrating from 2D to 3D environments. Preliminary recommendations for interfaces and interaction paradigms are also presented.

2. Background

2.1 Evaluating Usability

Nielsen (2012) evaluates software usability using five metrics: learnability, efficiency, memorability, errors and satisfaction, Two usability evaluation methods (UEMs) are proposed: Cognitive Walkthrough (CW) and User Testing (UT). CW simulates a specific user's goals and problem-solving process (Nielsen & Mack, 1994) in a specific scenario. The

CW practitioner's guide (Wharton *et al*., 1994) recommends creating a persona (a virtual person having the characteristics of one or more real users) to conduct this study, with the tester then evaluating the software from the perspective of the persona. For UT, real world users are assigned specific tasks relating to those that typical users would carry out, and are monitored while these are carried out, and subsequently interviewed. According to Nielsen (2000), 5-7 users are sufficient to discover 80% usability issues through UT.

2.2 Usability of 3D GIS – Previous Work

The growth in GIS packages and their increasingly widespread use since the 1980s has led to the identification of the importance of their GUI (Graphical User Interfaces) (Haklay & Skarlatidou, 2010). Hildebrandt & Timm (2014) investigate navigation in 3D worlds, and propose a navigation technique for virtual 3D city model by using a semantic, hierarchical, multi-scale structuring having advantages to support novice users. They note that in a 3D scene people still need 2D map in different scales to gain the whole picture of the geographic environments. Oulasvirta *et al*. (2009) focused specifically on the 2D/3D migration and understanding the visual cues in 2D and 3D map (on mobile devices) that people look at when finding their; way in the real world, concluding that buildings, with texture are important in this context. Zhang & Moore (2014) compared how the different platforms (VR, CAD and GIS) help the users to perform tasks in 3D environments. However, the few studies that exist in a 3D context focus on 3D visualisation and ignore the 'information' aspects of a GIS.

3. Data and Software

The 3D dataset used was located in Sheffield provided by Ordnance Survey, and included road features, land use and a total of 1560 buildings at LoD1 (Level of Detail 1, without roof detail) mixed with LoD2 (with roof detail) (LoD are described in Kolbe et. al. 2005). The buildings are stored in 3D geometry as MultiPatch features (Figure 1) and the dataset covers an area of 1km square.

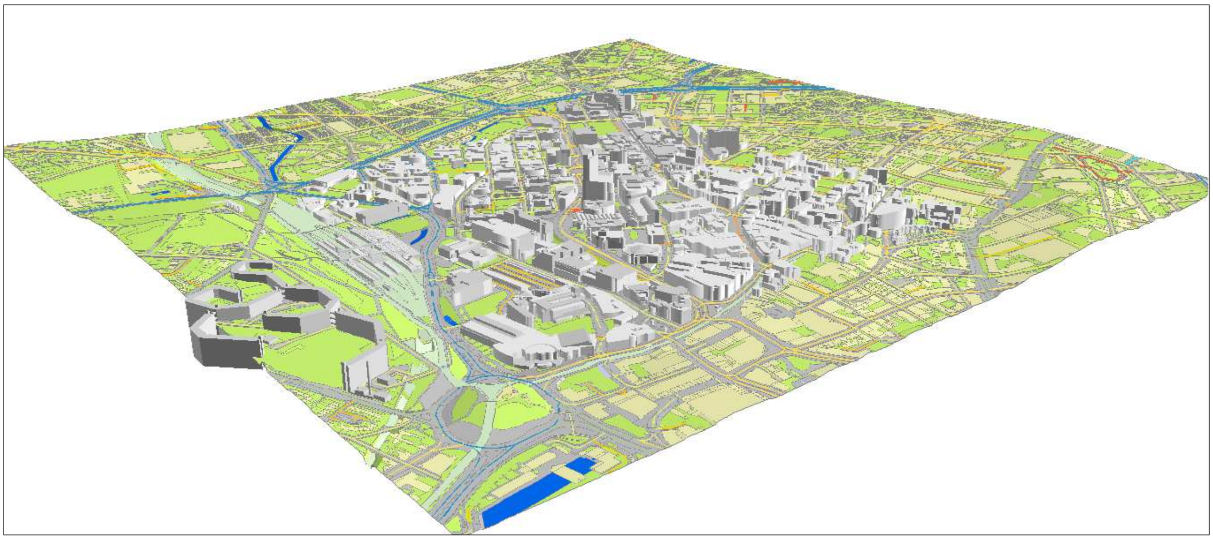

Figure 1: The Sheffield dataset layers displayed in ESRI ArcScene 10.2

In order to observe how the users perform the tasks in 2D and 3D environments, and maximise the opportunity for transferable skills from 2D to 3D, ESRI ArcMap 10.2 (2D) and ArcScene 10.2 (3D) were chosen as the platforms for the evaluation experiments.

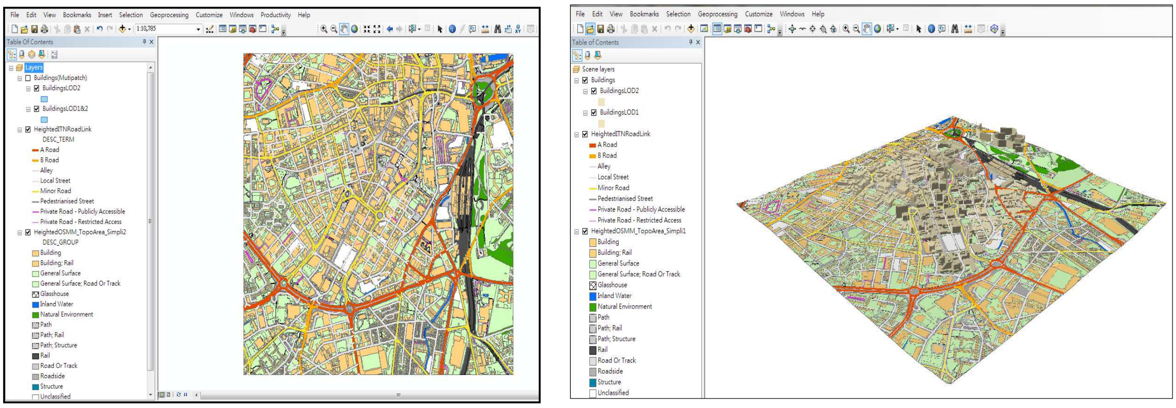

Figure 2: The Sheffield dataset layers displayed in ESRI ArcMap 10.2 (left) and ArcScene 10.2 (right).

4. Methodology

Figure 2 shows the preliminary interface presented to the user in the 2D and 3D case. Identical cartographic styles were used in both environments. Five major tasks were implemented as shown in Figure 3.

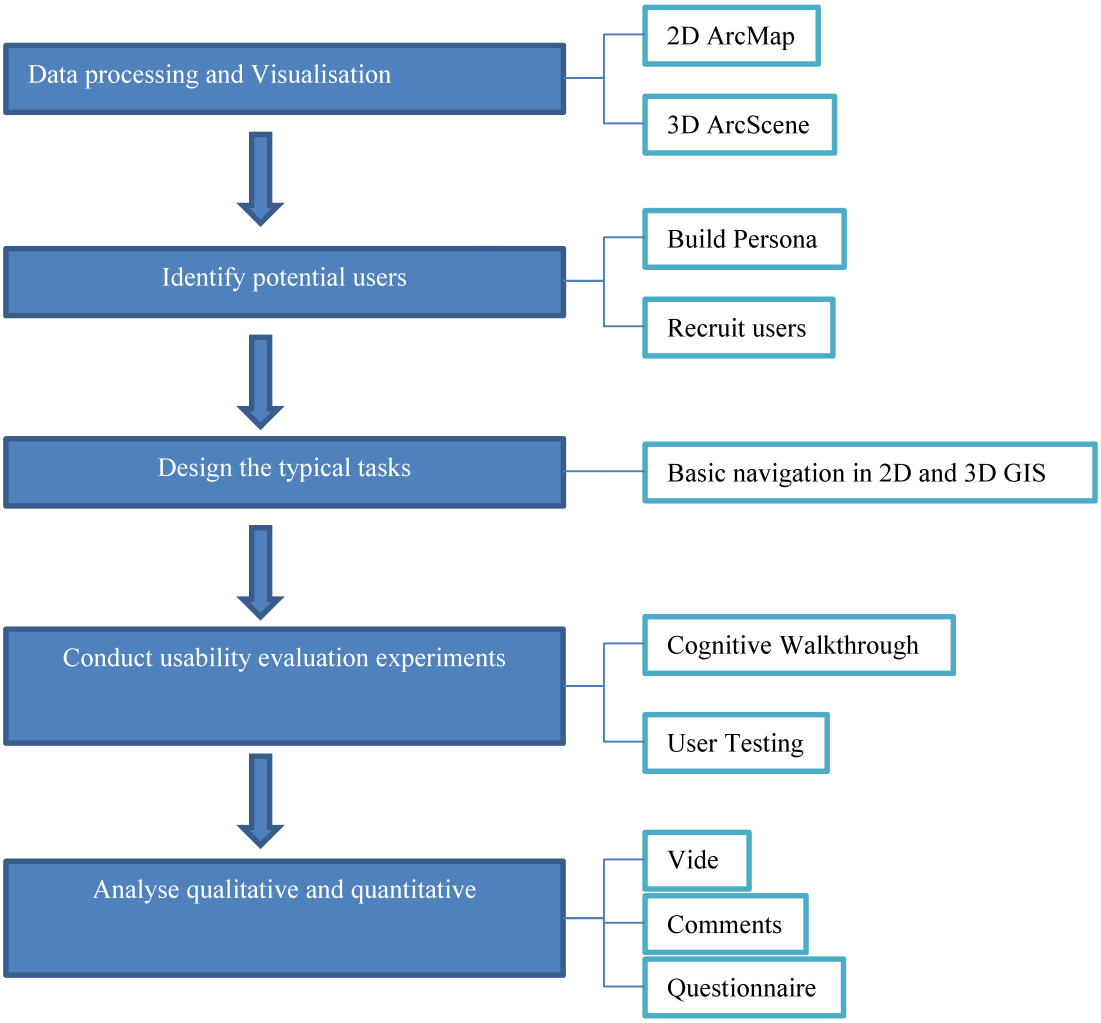

Figure 3: Overview of methodology

For the CW, a primary persona (female, age 32, 2D GIS experienced) was built based on a real user working in urban planning development. The tasks in the scenarios were designed to meet the potential goals of the user. As required by the CW approach, the evaluator walked through the tasks, noting the issues, evaluating how the user would act and make decisions and if the user could complete the tasks.

To counter the subjectivity of the CW approach, UT was also carried out. Seven users with ages from 23-27 (4 males, 3 females) were involved in the experiments, with different levels of experience in using GIS (ranging from none to over 4 years). They were asked to complete a series of basic GIS navigation tasks in ArcMap (2D) and ArcScene (3D) firstly performing identical tasks in 2D and 3D (moving the map, selecting, measuring and identifying information with attribute data). They were then set a navigation task in the 3D environment. Tests were screen-captured (videoed) and after the tests, a questionnaire was used to investigate the opinions of the users (further detail about the tasks is given in Section 5 below).

Finally, severity rating scales was applied to analyse severity of each usability problem, rating from 0 (not a problem) to 4 (most severe problem) (Nielsen 1995).

5. Results

Table 1 summarises the results of usability problems found through CW and UT methods.

Method	No. of problems	No. of unique problems	Average of severity rating
CW	19	17	2.89
UT	27	9	3.19
Total no. of unique problems	36		

Table 1: Summary of usability problems

Table 2 shows the frequency of use in navigation tools available in 2D and 3D. The tools often used in 2D also have high frequency of use in 3D.

Basic navigation and information tool		**2D**	**3D**
Pan		O	O
Zoom in		O	O
Zoom out		O	O
Full extent		S	S
Back scene		N	
Next scene		N	
Identify		S	S
Select	by Screen Rectangle	O	O
	by Polygon	R	
	by Lasso	R	
	by Circle	N	

	by Line		N	
	by 3D box			R
	Distance (ground)		O	O
	Area		N	N
	Feature	polygon: area, perimeter	N	N
		mutipatch: height		N
	Direct 3D line			S
Measure	Height			S
Set observer				N
Zoom to target				N
Centre on target				N
Fly				S
Navigate				O

Table 2: Frequency of the use of navigation tools (O: Often, S: Sometimes, R: Rarely, N: never)

Table 3 shows comparative results in 2D and 3D, of the number of successful users, time taken and ease of use Likert scale scores (0-4, with 4 being very easy). At first glance, it appears that 2D selection is considered more complicated than 3D but in fact this was because the users took time to locate the selection tool in 2D but having done so could easily find it in 3D. Finding the tallest building in 3D was accomplished more easily as this was done visually (as opposed to by querying the buildings).

Task	**Numbers of successful users**		**Ease of Use (Likert)**	
	2D	**3D**	**2D**	**3D**
1. Scene finding – find a given location	7	7	3.29	3
2. Selecting buildings	7	5	2.86	3
3. Finding the tallest building	4	5	2.43	3
4. Measuring road width	7	7	3.14	3
5. Measure building's height		5		2.86
6. Measure 3D lines (roof sides)		6		1.57
7a. Fly Through – from a fixed point		7		2.57
7b. Fly Through – follow a route		1		1.43

Table 3: Performance results in 2D and 3D environments.

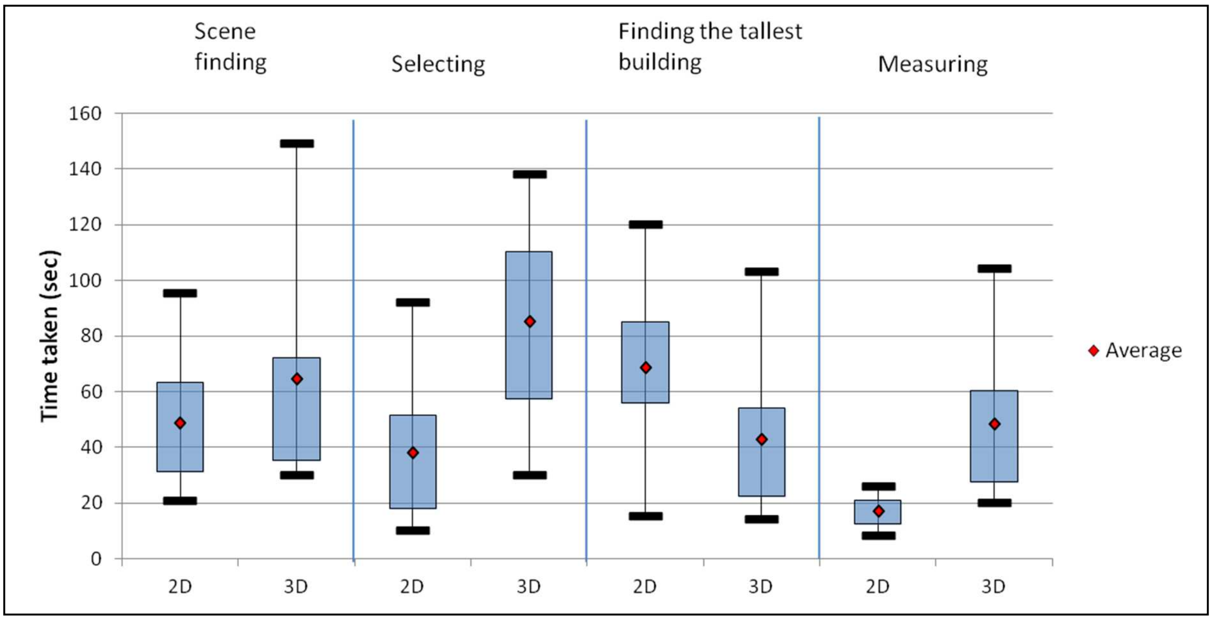

Figure 4: Plot for time taken comparison in 2D and 3D environments.

The most severe problems relate to slow speeds when interacting with 3D data, reflected in the times shown in Figure 4, followed by poor visual feedback on mouse-driven tasks in 3D. In the UT, the visual cues in 2D and 3D scenes that the users mentioned had helped them to find the given targets were similar features such as road junctions and rivers. However, the results of selecting assigned targets in 3D scenes found by each user have a bigger discrepancy than in 2D map in terms of the position, angles and scales.

Through the process of observation and by reviewing the videos, it was also observed that in this preliminary study users preferred to work with the 3D data in a similar way to the 2D map (i.e. using a bird's eye view). Users also preferred to use the tools they already have learned in 2D GIS.

Due to the novelty of the environment for the users as well as to the performance issues of the 3D model (despite the fact that it is relatively small in size) the **efficiency** in completing identical tasks in 3D is lower than in 2D (Figure 4). In terms of **learnability**, most users asserted that completing tasks was more difficult in 3D and a lack of clear tool options in the software caused problems when working with 3D.

Both 2D and 3D packages lack a good interface for **memorability**. A severe problem was also observed in terms of **error** feedback - the users did not notice the measurements that they took in 3D scene were incorrect, an issue caused by the lack of clear visual feedback as to where the user was clicking (on or above the ground).

6. Discussion

This study implemented UEMs with a focus on usability issues when migrating from 2D to 3D environments, focussing not only on visualisation but also on information – metric measurements such as height and volume, and feature identification. Although the CW was based on a persona created by interviewing one person, due to time constraints, and the UT were conducted with a small group of people with different levels of GIS familiarity, some clear observations have be made relating to the challenges when migrating from a 2D to a 3D environment.

As expected, the users' approach to the 3D challenges was framed by their 2D experience. In particular, the tendency of the users to use identical tools where available could suggest that using 3D tools from a suite of products where the user is familiar with the 2D version may help facilitate the migration process. There is also a requirement to provide appropriate visual feedback on mouse events which allow the users to know where exactly they click and to provide 3D object information identify tool to get the geometry about 3D buildings such as volume, maximum height and number of vertexes without measuring. As with any user interface, instructions for use (such as videos) are important.

7. Future work

The work described above is still at a very early stage, and additional software packages and GIS functionality should be added to the mix for a more comprehensive exploration of the topic. Users with and without 2D GIS experience should also be compared.

It should also be noted that interaction methods in 3D GIS do not as yet benefit from those used in other contexts such as videogames (Shepherd, 2008). This could include inputs such as multi-touch input devices (Jankowski & Hachet, 2013) or gaming controllers, with the inputs being translated into the 3D environment (Bowman *et al.*, 2006). Making better use of in-built graphics cards (again, used extensively in gaming) and exploring options for 3D generalisation may also help to overcome some of the performance issues experienced.

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