Towards appropriate representations of quantitative data in virtual environments

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Abstract—Displays of quantitative data within 3D virtual environments are quickly created with today's technological options but we know little about the appropriateness of such representations. This paper presents a study which experimentally tests six different proportional symbols for the display of quantitative data within virtual environments. The tested symbols are 2D and 3D bars and 2D circles with and without reference frames. Preliminary results show that circles are not as difficult to interpret as expected but 2D and 3D bars yield more accurate results with less variation. The full evaluation will be available soon.

Index Terms—3D, virtual environments, quantitative data, proportional symbols, experiment.

1 Introduction

Virtual globes or earth browser, their interfaces and the markup languages they support offer numerous possibilities for representation of various data sets in geographic context. Sometimes, it seems that data is displayed in earth browsers just because it can quickly be integrated and such visualisations can potentially made available to a large audience. However, where data sets relate to the landscape where they were collected in (e.g. data from a sensor network collecting data in a mountainous environment) a visualisation of such data sets within the virtual equivalent of the natural environment may help its analysis in relation to altitude and landform. But what are appropriate representations of quantitative data? The required formats for quantitative data representations in virtual environments, for instance KML [8] for Google Earth [7], can be created by hand or by the use of various tools such as the Thematic Mapping Engine TME [9] or GE-Graph [10]. The visualisation shown in figure 1 was created with the TME, showing children under five mortality rates per country in 2005 symbolised as 2D circles. Both screenshots (left and right in figure 1) show the same data but from two different viewpoints. Figure 2 shows another example. There, quantitative values are represented through the height of hexagonal three-dimensional bars (created with GE-Graph [10]). Trying to compare the circles showing quantitative values for the two marked countries Switzerland (red arrow) and Albania (green arrow) in the figure 1 or to read bar heights from figure 2 (right) you may start wondering how suitable such representations are.

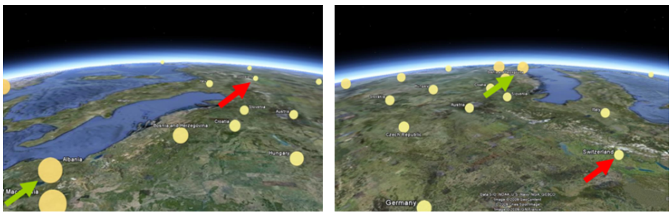

Fig. 1. Circular 2D symbols to show children under five mortality rates per country in 2005 (created with TME [3]) looked at from two different viewpoints (red arrow: Switzerland; green arrow: Albania).

Appropriate 2D representations of quantitative data have been studied for a long time and various guidelines for their creation exist (for example in [3, 5, 6, 12]). From that broad knowledge an earlier study [4] tried to derive a suitable representation for quantitative data in 3D

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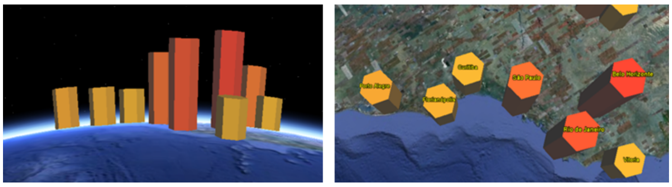

Fig. 2. Quantitative values represented through the height of hexagonal 3D bars and additionally through colour (example created with GE-Graph [4]), viewed from the side (left) and from near top (right).

virtual environments. Three-dimensional visualisations, such as the ones shown in figures 1 and 2, are often viewed projected onto 2D screens. Then the impression of 3D is evoked by different depth cues such as size gradient, occlusion or motion parallax [13]. When displaying quantitative data through the size of different symbols in 3D virtual environments the depth cue size gradient causes variation in the size of the displayed symbols in addition to the variation of size which is caused by the varying values the symbols represent. In Bleisch et al. [4] 2D bar charts on billboards (2D planes which always face the observer) are tested for the display of quantitative information in virtual environments. Reference grids are added to help the interpretation (application of Weber's Law [2]). The results showed that 2D bars on billboards are a valid symbolisation for quantitative data as tested for simple tasks such as finding the higher bar and comparing bar heights. The results suggest that we are able to transfer our natural interpretation of the real world also to virtual environments and/or that the constant width of the 2D bars serves as depth cue allowing the correct interpretation of the varying bar heights. If the width of 2D bars helps the interpretation by providing depth cues, then a symbol type with only one dimension, for example a circle, should be less effective. Additionally, a characteristic of 2D bars on billboards is their suboptimal visual integration into 3D virtual environments. 3D bars may integrate better but can potentially be looked at from an unfortunate angle (see for example figure 2 right were the additional value dependent colouring may be needed for a judgement) what might result in a distorted perception of the values displayed. In Bleisch et al. [4] the bars with reference grids were interpreted faster and more confidently. Based on these thoughts three types of symbols with and without reference frames (see figure 3), 2D bars (r), 2D bars with reference frame (rf), 3D bars (b), 3D bars with reference frame (bf), 2D circles (c) and 2D circles with reference frame (cf) are experimentally tested for their efficiency and effectiveness in conveying quantitative values when displayed in 3D virtual environments. The tested values are mapped to the 2D and 3D bar heights and the circle radii. Thus, the circles are mathematically scaled and not corrected for the known underestimation of circular symbols [11].

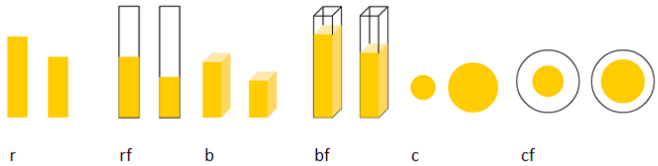

Fig. 3. Quantitative symbols (named r, rf, b, bf, c and cf) as used in the experiment.

2 EXPERIMENTAL

For the experiment 20 displays, each representing two different values within the virtual environment Google Earth [7] were prepared for each of the six symbol types (see figure 4 for an example). Additionally, each of the 6x20 displays was available either with one or the other of the two values in the foreground or background respectively, resulting in a total of 2x6x20 experimental settings. Two elementary tasks [1] are defined for each setting. Participants have to indicate the larger symbol (A, B or equal) and to judge the size of the smaller symbol compared to the larger symbol (percentage value). In a balanced within-subject design each participant works through the two tasks in 40 of the experimental settings. The settings and tasks are provided through online questionnaires and the answers managed in a relational database. The participants are students either with a geomatics background or trained in information visualisation. In total, about 40 students participate in the experiment during November 2010.

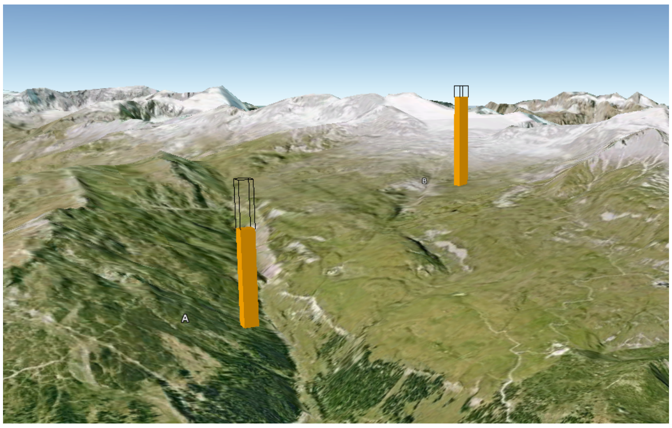

Fig. 4. Exemplary experimental setting showing two values displayed as 3D bars with reference frame in Google Earth [7].

3 RESULTS

Preliminary results from the first 12 participants show some trends. Circles are not as difficult to interpret as expected but 2D and 3D bars yield more accurate results with less variation. Different to the results in Bleisch et al. [4] all three settings with reference frames seem to take longer to interpret than their counterparts without reference frames. A difference in accuracy is less obvious. The full evaluation and results will be available soon.

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