Use of Depth Cues for the Annotation of 3D Geo-Virtual Environments

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Abstract:
An increasing number IT applications and systems applies 3D geo-virtual environments as user interfaces, that facilitate the intuitive communication of spatial information, whereby depth cues play an important role for mental reconstruction of the depicted scene. These applications require the integration of application-specific information, represented by annotations such as textual labels or symbols, in analogy to labeling in traditional 2D maps. This contribution presents first results on how to improve information transfer with respect to annotations used within. We found that automated annotation techniques, used in traditional 2D map presentations, if applied to 3D geo-virtual environments, can damage depth cues and, thereby, possibly harm the human perception. Illustrated by examples, we show the override of different depth cues and discuss possible solutions. Finally, we propose a number of user tests, whose results are needed to improve the quality of automatic label placement techniques in the future.

Introduction

In cartography and GIS, a growing number of applications are being extended towards 3D geo-data modeling, management, and visualization. This trend can be explained by several reasons. First, an increasing number of companies offer a fast, cost-efficient and detailed process for the 3D data acquisition, so that 3D data becomes widely available. Second, the availability of 3D data models enforces research on techniques that take advantage of the additional dimension and increased precision. Finally, specialized applications and geo-services, e.g., Google Earth, NASA Worldwind, Microsoft Virtual Earth, lead to a growing user bases becoming familiar with 3D geo-virtual environments.

Annotations are essential elements to enhance geo-virtual 3D environments with meta information about visualized objects, such as application-specific, thematic, or attribute information. Annotations occur in the form of text labels, iconic symbols, or 3D geometries. In contrast to a separate legend, they effectively provide information in place or near the reference, allowing a viewer a more direct and error-free access. The way how annotations are added to a depiction depends on the intended tasks for the result. The annotation process includes the selection of the visible annotations (e.g., thematic, spatial, or by

the view frustum), the presentation style (e.g., font type, font size, or color), as well as the placement position. In general, annotations should be placed legible, over or close by the object they are referencing, and without overlaying other scene elements or annotations. For the automated annotation placement on two dimensional maps a number of techniques have been developed [CMS95], [ECM96], [EKW03], but little is known whether these techniques can be applied on 3D geo-virtual environments without adaptations, or how they need to be extended.

This contribution presents first results on how to improve information transfer with respect to annotations used within. Evaluating existing implementations, we found that techniques used in traditional map presentations and illustrations can disturb depth cues and thereby harm the perspective impression. In the following, we illustrate these cases by examples and discuss possible solutions. For the further development of automated annotation techniques, we propose some user test related to different perception issues.

3D Cartographic Information Transmission

Multimedia maps and 3D geo-virtual applications follow semiotic guidelines, similar to traditional cartography, with the basic intention to maximize benefit in gaining and transmitting spatial related information. For this task, multimedia, interaction and 3D with their support of different sensual modes, enhance information transfer for a bidirectional communication process [Gol99], which become important on graphical restricted displays, such as small scale displays [Rei03]. At the same time demands for high geometric precision of map elements and perceptibility of the content have to be met [Mac01]. For instance, a precise use of localization for a dense set of annotations leads to overlapping and thus to illegibility. Selection and repositioning has to be done to keep perceptibility. On the other hand, repositioning may lead to a damage of topology (neighborhood), especially when small scale maps with high information depth are created.

The grade of multimedia, interaction, precision, perception, and abstraction depends on the used interface. For example, the traditional interface "paper" provides high precision, well-defined perceptional procedures for the elements and a high grade of abstraction, but lacks of multimedia, interaction, and immersing information transmission. In constrast, digital displays provide limited resolution, which cause perceptional discrepancies, but a high grade of multimedia and interactivity. An immersing information transmission with low textual abstraction can be established on digital displays with 3D geo-virtual

environments, which provide a kind of natural spatial recognition by physiological and psychological depth cues [Alb97].

3D geo-virtual environments visualized through 2D media, e.g., depictions based on perspective projections of 3D scenes, make use of depth cues, which are basically independent from the human ocular system and only focus on cognitive procedures. The damage of these depth cues causes misleading information transfer and, in most cases, makes intuitive perception impossible. In case of annotations used in 3D geo-virtual environments various cases of disturbed depth cues occur and an demand for specific solutions. A classification of these cases helps to clarify applicability and dependencies of annotations for cartographic purposes within 3D geo-virtual environments.

3D Geo-Virtual Environments

The extension of concepts, algorithms, and applications towards the third dimension represents still a major point on the research agendas in the geo science and computer science communities. Frequently, the keyword "3D" often refer to different aspects:

- **3D Data Models:** Modern data acquisition techniques, e.g., laser scanning, or stereoscopic aerial photography, permit a fast, high-detailed, and cost-efficient production of geo-data that overcome the spatial limitation of planar surfaces. As a result, 2.5D digital terrain or surface models and 3D city models, including buildings, city furniture, and vegetation, becomes widely available and more usable, facilitated by the evolving standards, e.g., CityGML [KGP05]. In addition, the demand for 3D geo-data is increased by applications that already benefit from 3D geo-data, e.g., virtual city planning applications, noise simulations, or spatial visibility calculations for advertisement and security monitoring.

- **3D Visualization:** Printed maps and GIS applications commonly use two-dimensional representations, e.g., 2D points, line, or polygons, to depict spatial information, like points of interest, railroads, or land-use data. Driven by the increasing availability of 3D data models and modern graphics hardware, included in today's standard computers, more and more applications visualize these 3D data sets directly. After the preparation for a 3D scene graph representation (e.g., for terrains, buildings, or vegetation) and the definition of a virtual (perspective) camera, images can be generated for every position and viewing direction.

- **3D Presentation Media:** Independently from the contents, paper maps and com-

puter screens are two dimensional presentation media. If they show perspective views on 3D objects, we are, however, still able to mentally reconstruct these scenes. A step towards an immersive, more real-world experience, can be reached by using 3D presentation media, such as stereoscopic viewing techniques, e.g., color coded stereo, shutter glasses, or head mounted displays.

In the following, we use the term 3D geo-virtual environments to refer to the most common applications using 2.5D and 3D geo-data today: the 3D visualization using a perspective view transformation, generating depictions on a standard computer screen.

Annotation of 3D Geo-Virtual Environments

The extension from 2D cartographic maps to 3D geo-virtual environments implicates a number of changes related to annotation techniques. Now, not only point, line, and area features, but as well volumetric objects, e.g., buildings, demand for annotations [MD06]. Additionally, annotations them self are no longer restricted to two dimensional representations, such as symbol images or texts.

The term "Geo" in 3D geo-virtual environments point out to the differences when annotating virtual environments that are based on a virtual terrain or globe. For example, in virtual illustrations the object of interest is normally centered in the depiction and rotating and zooming are the dominant navigation techniques. Therefore, it is obvious to look for white-space around the silhouette of the object, which than can be used for the annotations. In contrast, navigation techniques related to geo environments are often using analogies from the real world, e.g., walk/drive for virtual pedestrian/car, or the flying metaphor for birds-eye sceneries. Here, only regions showing the sky are directly available as annotation white-space.

Commonly 2D text and images are used as annotations, so applying these to 3D geo-virtual environments raises the question about the principles and rules that ensure a usable combination of both in one depiction. We found two fundamental approaches here: screen *space annotation* and the *scene embedded annotation* techniques. The screen space techniques add annotations after the perspective view transformation, such as in a separate overlay layer to the depiction. Hereby, the search space for algorithms is reduced to two dimensions, a fact that eases the annotation placement and supports the legibility of annotations by concept. In contrast, scene embedding techniques integrate annotations as additional elements into the virtual 3D scene. Undergoing the view transformation with the

whole scene, they appear perspective correct and if they were embedded in areas, e.g., facades or streets, with a strong link to their reference objects. Furthermore, this approach should be favored for the interactive positioning of annotations because this can be more intuitively done in a 3D scene than on a 2D depiction.

Even if a perspective depiction of a 3D environment is presented on two-dimensional media, e.g., on a paper sheet or a computer screen, most people are able to reconstruct the scene in their minds. For this, we are using information inherently encoded in these perspective depictions, which are known as pictorial depth cues (for an overview see [Pal99] or [Cut99]). Added annotations possibly override these depth cues, disturb the perspective impression and thereby harm the information transfer. The following paragraphs will discuss this in detail, accompanied by examples.

Overriding Depth Cues – 1. Occlusion

Occlusion or interposition is one of the most important depth cues. Occlusion information can be interpreted at an ordinal scale, so it tells which object is in front of the other, but not how far away. Figure 1 shows two examples of the same conflict between annotations and correct occlusion information. Here, text labels that are aligned by the streets they are referencing, overdraw buildings closer to the observer. In some situations, this might be a better choice than splitting the text or using an abbreviation, but generally, these cases should be avoided. Instead, each text should only overlay one continuous visible part of the street.

Fig. 1: Two examples of text labels overriding occlusion information (left: campus view of the Technical University Berlin[1], right: Google Earth[2]).

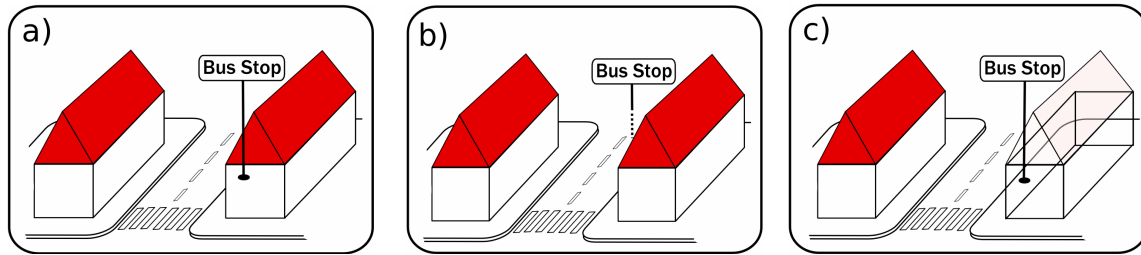[1] TU Berlin, Abt. IV Gebäude- und Dienstemanagement, http://www.tu-berlin.de/karten

Fig. 2: The problem of an occluded annotation reference with possible solutions: a) overdrawing the scene; b) reduce the link to a hint; c) using transparency.

In some applications, e.g., if the set of visible annotations is controlled by a thematic selection of the user, the problem of occluded references for an annotation can appear. As illustrated in Fig. 2, there exist several possibilities to deal with these situations: a) the reference point and the connecting line can simply overdraw the depiction, but overdraw the correct occlusion information, b) the connecting line can be drawn with a dotted end as hint for a continuation, or c) the occluder could be drawn transparently. The last variant is particularly applicable in interactive environments, where it can be triggered by an explicit user request, e.g., a mouse click at the label.

Overriding Depth Cues – 2. Linear Perspective

In perspective depictions, objects of the same size are depicted smaller with an increasing distance to the observer and parallel lines running towards the horizon join in one ore more vanishing points. These effects result from linear perspective.

On classical 2D geographic maps, the font size is often used to classify cities by the number of their inhabitants. This is a typical use of font size as a graphical variable, introduced by Bertin [Ber74]. As shown in Fig. 3 left, the direct application to perspective views conflicts with the perspective transformation rules. More often, the text is shown at a constant, just readable size, to minimize the overlay of scene elements, resp. to maximize the number of visible annotations. At least, the font size can be adapted by the distance to the observer. This allows us to increase the number of visible annotations again, even if their function is (because of the decreased readability) now reduced to the communication of the place where information can be found.

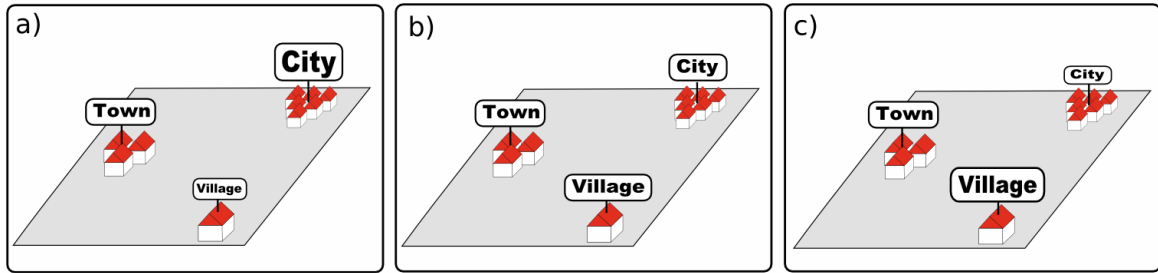[2] Google Earth, http://earth.google.com/

Fig. 3: Different font size use: a) communicating a category; b) constant screen-space size; c) communicating perspective depth.

The following figure (Fig. 4) illustrates two different integration styles for a text referencing an area feature, in this example a street. On the left, the text is oriented parallel to the view plane to guaranty an optimal readability. The right variant shows the text integrated as painted on the street, but at the cost of a reduced readability. However, this supports more the perspective impression and strengthens the relation between the label and the reference. Both variants can be found in today's applications, but little is known about their impact on their usability. Larson et al. [LDC00] found that text can be substantially rotated around a vertical axis, before legibility and readability performance suffers.
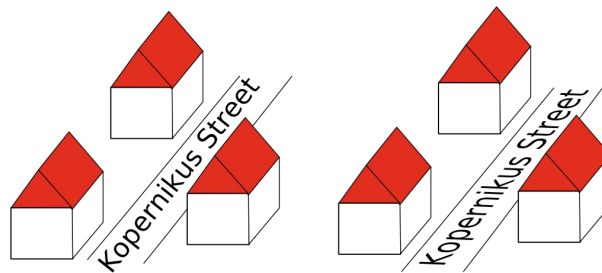

Fig. 4: Readability vs. integration into the reference element, supporting the perspective impression

Overriding Depth Cues – 3. Shading and Shadows

The shading and the shadows of and on objects work as well as a depth cue. They reveal something about the position of the light sources, objects that are not visible but cast shadows into the current view, or the surface structure, e.g., if it is polished, bumpy or corroded.

In most cases, annotations are excluded from lighting calculations. Rather, we found examples (Fig. 5), where faked shadows are used as a stylistic element, perhaps to ease the differentiation between the depiction and the annotations. Again, these effects should be avoided if they disturb the perspective impression or impair the overall understanding.

Fig. 5: Perspective fake shadow on an annotation on a two dimensional map (Example from Google Maps[3]).

User Tests Agenda

The previous examples showed deficits when mixing 2D and 3D information, but there is no strong proof if these cases only harm the aesthetic appearance or even harm the information transmission. Hence, we propose to verify the following aspects with user tests:

- The override of depth information by annotations was previously under our examination for static depictions [MDJ07]. There, we found only a small hint that this effect is noticeable by users, especially in depictions showing a high depth complexity, e.g., views of a virtual pedestrian. However, further test are needed for a precise statement, when this override is noticed and how strong it influence the human information processing.

- The perspective transformation can reduce the legibility of textual information that is embedded into a 3D object. On the other side, such embedding communicates the referenced object more precise, than a simple overlay or an additional line would do. To find a balance, there is a need for measurements of the quality of an embedded text, which enable algorithms to take a decision which variant should be preferred.

- As illustrated in Fig. 3c, even if annotations are placed parallel to the view plane, they can be scaled depending on their distance to the observer to provide an additional depth hint. This scaling can be done perceptively correct or with a user defined function that additionally limit the extensions to a defined interval, e.g., to avoid to small or to large texts. Here user test should study, which scaling functions

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[3] Google Maps, http://maps.google.com/

are usable, so that the viewer does not take a notice of the difference to a perspective correct scaling.

Conclusions

We showed by examples, how annotations that are added to a depiction without consideration of the perspective transformation rules can harm the perspective impression. To improve automated annotation techniques regarding to this point, collaboration between cartographers, computer graphic experts, psychologists, illustrators, and designers is needed. The knowledge about existing annotation techniques for maps and illustrations, the possibilities offered by modern graphics hardware, and the underlying design and perception principles has to be combined to overcome the deficits pointed out.

With the ongoing development of computer and display technologies, virtual environments with a higher interactivity and immersion will evolve. Then, for example in augmented reality applications, the need for annotation techniques that do not disturb the virtual 3D experience will become much more important. We proposed a number of user tests that would help to extend the understanding of the influence of added information to the human perception and cognition and thereby ground the base for usable techniques in the future.

Acknowledgements

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