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Exploring real world points of interest: Design and evaluation of object-centric exploration techniques for augmented reality

Markus Tatzgern *, Raphael Grasset, Eduardo Veas, Denis Kalkofen, Hartmut Seichter, Dieter Schmalstieg

Institute for Computer Graphics and Vision, Graz University of Technology, Graz, Austria

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ABSTRACT

Augmented reality (AR) enables users to retrieve additional information about real world objects and locations. Exploring such location-based information in AR requires physical movement to different viewpoints, which may be tiring and even infeasible when viewpoints are out of reach. In this paper, we present object-centric exploration techniques for handheld AR that allow users to access information freely using a virtual copy metaphor. We focus on the design of techniques that allows the exploration of large real world objects. We evaluated our interfaces in a series of studies in controlled conditions and compared them to a 3D map interface, which is a more common method for accessing location-based information. Based on our findings, we put forward design recommendations that should be considered by future generations of location-based AR browsers, 3D tourist guides or situated urban planning.

1. Introduction

Mobile devices such as smart phones allow users to access location-based information anywhere and at anytime. For instance, tourists can query information about surrounding points of interest in a foreign city, a task which can also be supported by mobile tourist guides [1]. The information is commonly presented using a spatial representation, such as 2D or 3D maps. 3D maps even allow exploring real world objects freely since they are not bound to the egocentric viewpoint of the user. However, mobile map solutions are not optimally designed for urban exploration [2] and provide limited capabilities to access the data and to relate it to the real world. For instance, users of 3D maps often try to align the virtual viewpoint of the map with their egocentric viewpoint for easier orientation, a strategy that is not well supported by the interface [3]. The only alignment feature 3D maps offer is to align the exocentric top-down view with the general viewing direction of the user. Another issue of currently available 3D maps is that the camera view of the object is often occluded by nearby structures, which is especially problematic in densely built-up areas (Fig. 2).

Augmented Reality (AR) is a natural choice for exploring location-based information of real world objects, because AR overlays information directly into the user's surroundings. For instance, a user can easily access additional information about a building in an urban environment by pointing an AR-enabled mobile phone into its direction. However, in contrast to a map interface, users are limited to the inherent egocentric reference frame of an AR interface, which becomes an obstacle

* Corresponding author. Tel.: +43 3168735085.
E-mail addresses: tatzgern@icg.tugraz.at (M. Tatzgern), raphael.grasset@icg.tugraz.at (R. Grasset), veas@icg.tugraz.at (E. Veas), kalkofen@icg.tugraz.at (D. Kalkofen), seichter@icg.tugraz.at (H. Seichter), schmalstieg@icg.tugraz.at (D. Schmalstieg).

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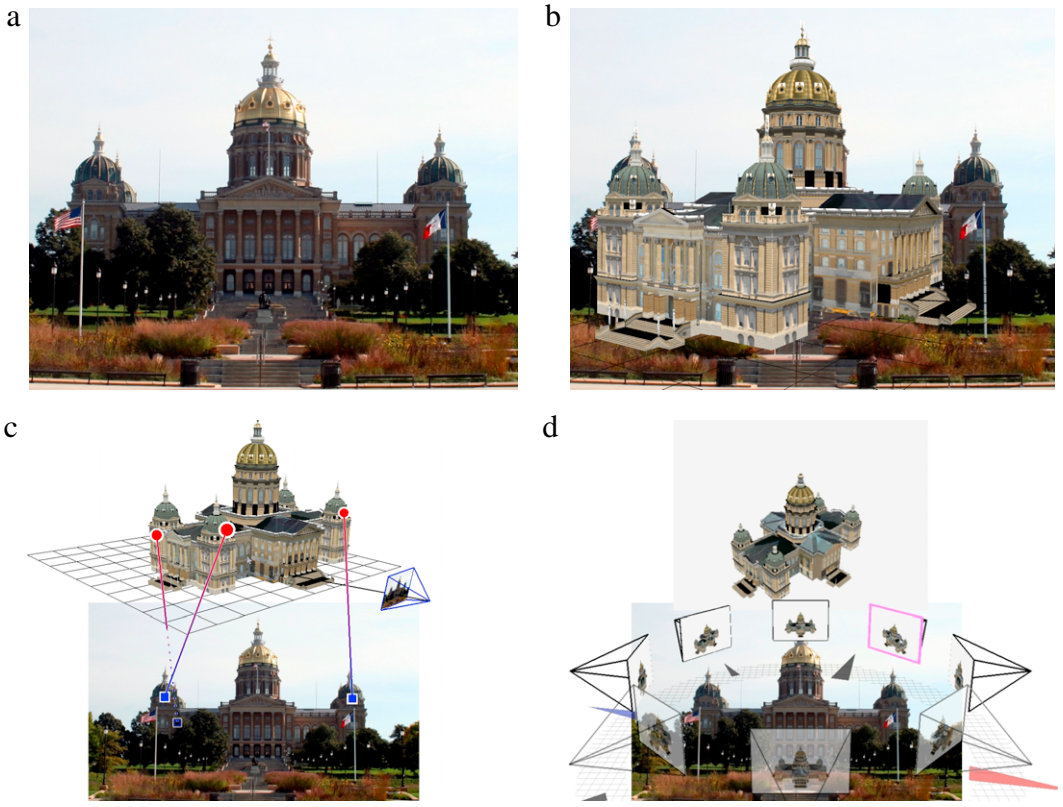

Fig. 1. (a) How can I explore the Iowa State Capitol without physically moving? We present Augmented Reality interfaces using a virtual copy metaphor to access additional views, e.g., (b) uses an in-place, (c) a separated 3D copy with visual links between virtual and real world objects. (d) We also present a spatially separated interface, which uses a 2D copy of the real world object. The available viewpoints are arranged as a circle around the real world object. The current viewpoint is highlighted.

once the user wants to explore objects that are out of reach. The user would need to physically move to a new position, which might be too cumbersome or even impossible.

To deal with these limitations, we introduce object-centric exploration (OCE) techniques for handheld AR, which use a virtual copy metaphor [4] to gain access to distant viewpoints of a real world object in the user's AR view. In contrast to 3D maps, OCE techniques allow a user to focus on the one object he is interested in. OCE techniques also do not suffer from occlusions from neighboring structures, because a virtual copy of only a single object is presented. To present additional viewpoints of this real world object, our OCE interfaces separate the virtual copy (focus) from its real world counterpart and from its surroundings provided by the AR video (context). We consider spatial and temporal techniques for combining focus and context [5]. While the former separates focus and context in space, the latter does so over time, thus removing the context from the interface. Fig. 1 shows spatial OCE techniques that preserve the context by either overlaying the copy on the context (Fig. 1(b)) or separating the copy from the context (Fig. 1(c)).

We explore different designs of OCE interfaces for the exploration of buildings in an urban setting. We perform a series of studies to evaluate our initial designs and the ability of the user to relate the virtual information to the real world. We perform studies under controlled conditions and collect real world experiences with our interfaces in a real world pilot study. Based on the results from the real world pilot study, we evaluate the performance of our designs and compare them to a more common 3D map interface. We summarize our findings in design recommendations that should be considered when developing OCE interfaces for potential application areas such as future generations of location-based AR browsers, 3D tourist guides, or situated urban planning. Relevant real world objects could be annotated with additional information that can easily be explored using OCE interfaces.

2. Related work

In line with Cockburn et al. [5], we classify the related work into spatial and temporal techniques.

Spatial techniques. Hoang and Thomas [6] provide a zoomed view of distant objects to improve interaction accuracy. However, they do not allow free viewpoint selection. Other solutions use a world-in-miniature (WIM) [7] to complement the egocentric view of the user. Bell et al. [8] use a WIM in AR that shares annotations with the real world. This concept is similar to our visual links (Fig. 1(c)), which connect the virtual and real worlds. Unlike shared annotations, in which the