Browsing Spatial Photography using Augmented Models

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Figure 1: Hand-held Augmented Reality for spatial browsing of photographs registered to physical model

Abstract

Both digital and physical 3D models of buildings as well as historical photographs of architecture are used for a wide range of needs, from research in humanities and information technologies, museum contexts and library studies, to touristic applications. Spatially oriented photographs play an important role in visualizing and browsing contemporary as well as historical architecture, starting with the ground-breaking Photo Tourism project [4].

We present a technique to combine physical 3D models of buildings with spatially registered historical photographic documents in a hand-held Augmented Reality (AR) environment. Users are enabled to spatially explore historical views of architecture by selecting photos from a collection of images which are then utilized as textures for the physical model rendered on their respective mobile device. We compare different methods to select photos registered to a physical model in hand-held AR.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality Human-centered computing—Visualization—Visualization application domains—Geographic visualization

1 Introduction

Photographs are an essential source for historical research in the Digital Humanities (DH). Numerous digital image archives, containing vast numbers of photographs, have been set up within digitization projects. Our research focuses on creating methods and techniques to enable DH researchers to address spatial investigations and to make their findings available to the general public.

3D visualizations correspond with human viewing habits and allow intuitive presentation of further information, like, e.g. the location, appearance and surroundings of an object, and showing photos at the respective camera position where they were taken. Spatial user interfaces employing AR technology are employed in museum contexts in outdoor, room-scale, as well as model-sized installations for that purpose. In this paper, we present a visualization and interaction technique for browsing collections of spatially registered photography of architecture, combining historical photographs with physical 3D-printed models of buildings.

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Figure 2: Photographs registered to 3D model

2 State of the Art

Structure-from-Motion (SfM) workflows have been employed to extract further 3D information from 2D photos. In addition to merely location-based browsing, Snavely et. al. use camera pose (location, orientation, and field of view) and sparse 3D scene information from SfM to create interfaces for browsing collections of photographs [4].

Schindler et.al. generate time-varying 3D models to index large collections of images serving as a tool of historical discovery, revealing information about locations, dates, and contents of historical images [3]. 3D pointclouds, models and textures have since been brought into desktop applications for easily accessible navigation and browsing of spatial and temporal photo repositories [1].

Textured physical models using spatial AR have been used to disseminate findings from cultural heritage (CH) research in museums. Ridel et. al. introduce spatial interaction methods for projected AR to highlight details on CH artifacts [2].

3 Methods

We combine physical 3D-printed models of architecture with spatially oriented historic images in a hand-held AR environment.

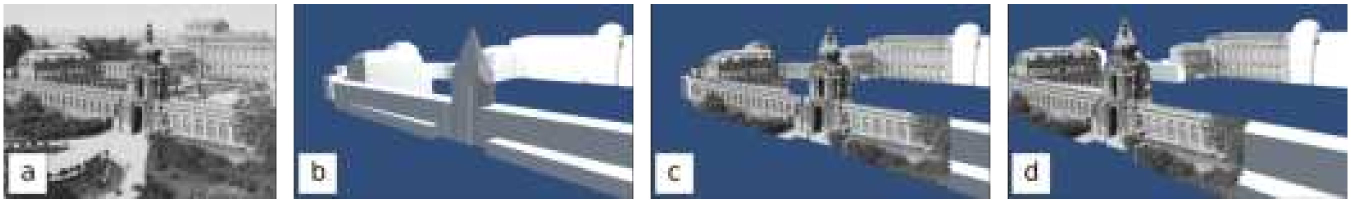

Figure 3: (a) Historic depiction of Dresdner Zwinger. (b) LOD2 CAD model provided by the city municipality. (c) Projection of image to model and usage as texture. (d) Changing viewpoint with applied texture, structures hidden in the original image are left blank.

3.1 Spatial AR Browsing

A subset of historical photos in the utilized media repository *Deutsche Fotothek* are spatially oriented in the coordinate system of the underlying 3D model created by a previous SfM workflow, providing location, orientation, and field of view of the camera for each photo (cf. Figure 2).

3.2 Texturing with Registered Photographs

Photographs represent a projective transformation of real-world 3D scenery onto a 2D plane using a camera with a given optical system.

We create historic textures for registered models of architecture by UV mapping vertices of the respective 3D model to the historic photography. UV coordinates are calculated by casting rays from the position P of the photographer to each vertex V in the model, through the projective plane of the currently processed image I. Collision detection of rays with models in the scene is performed to detect visibility of vertices from position P. Parts of a building that are not contained in I, because they are either outside of the view frustum of the camera (cf. Figure 3c) or hidden by other structures (cf. Figure 3d), cannot be textured with information contained within I and are left blank.

Employing photos as textures allows for the usage of very coarse 3D models of buildings, as details are provided by comparably high resolution photos. In this work, we use an LOD2 model of Dresdner Zwinger containing just 1889 triangles (cf. Figure 3a-c).

3.3 Hand-held AR with Physical 3D Models

3D models procured from the city municipality are 3D-printed into physical models to be used in a hand-held video see-through AR setup containing a 10.1 inch Android tablet (Samsung Galaxy Tab A 10.1, cf. Figure 1). Tracking of the model is provided by Vuforia *Model Targets with Advanced Recognition* in a Unity application, combining the digital model of the building with a media repository of spatially registered historical photography.

We render the textured digital model (cf. Section 3.2) on top of the video of the tracked physical model, discarding parts that are not contained in the respective photo selected by the user. Spatial movement of the tablet can be performed to view buildings from a perspective diverging from the perspective of the photo, but still being able to perceive the historical appearance of the building depicted in the historical image (cf. Figure 3d and Figure 4).

3.4 Evaluation of Interaction Methods

We performed an initial evaluation of different interaction methods as part of our user-centered design approach to allow selection of images to be used as textures. Direct selection of images by touching proved to be too imprecise, since even small changes in orientation during interaction induce large changes in position of the displayed photos. Spatial distance selection by automatically switching to the photo closest to the position of the tablet suffered from poor conformity with user expectations, as it was often not intuitively clear which of the photos was closest to the user in 3D. We decided on showing available spatially oriented photos registered with the physical model using a tap and hold gesture on the tablet's display (cf. Figure 1). An image can then be selected and assigned as a texture by spatial movement of the tablet to position the image into the center of the display and releasing the tap.

Figure 4: AR view of physical model (white) with historical texture

4 Conclusion

We have presented a method for browsing of and interaction with photographs in an environment featuring physical 3D models and hand-held AR. A method for texture-mapping of spatial photography to coarse 3D models was used to provide historical views of the depicted buildings, allowing for change in perspective by spatial movement of the users.

UV mapping of model vertices to image coordinates can be produced in real-time but has shortcomings. There are triangles where not all vertices are contained in the processed image in the general case, so interpolation will produce incorrect results at some point in the model. Discarding these incomplete triangles will create holes in the rendering of the model, depending on the subdivision of the CAD model (cf. Figure 4).

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