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Augmented reality interactive exhibits in Cartographic Heritage: An implemented case-study open to the general public

Keywords: interactive museum exhibits; augmented reality; computer vision; location aware systems

Summary:

This paper presents the application of the PaperView system in the domain of cartographic heritage. PaperView is a multi-user augmented-reality system for supplementing physical surfaces with digital information, through the use of pieces of plain paper that act as personal, location-aware, interactive screens. By applying the proposed method of reality augmentation in the cartographic heritage domain, the system provides the capability of retrieving multimedia information about areas of interest, overlaying information on a 2D or 3D (i.e., scale model) map, as well as comparing different versions of a single map. The technologies employed are presented, along with the interactive behavior of the system, which was instantiated and tested in three setups: (i) a map of Macedonia, Greece, including ancient Greek cities with archeological interest; (ii) a glass case containing a scale model and (iii) a part of Rigas Velestinlis' Charta. The first two systems are currently installed and available to the general public at the Archaeological Museum of Thessaloniki, Greece, as part of a permanent exhibition of interactive systems.

Introduction

Maps and scale models constitute two types of exhibits that are frequently met in museums worldwide. In order for visitors to be able to understand and explore such exhibits, substantial related location-related information is required. Typically, museums offer such information by (a) overlaying text and/or images directly on the map surface, and (b) providing associated support material (e.g. posters, descriptive text, illustrations) in nearby stands or walls. A problem associated to the first case is the limited available space (if such an approach is possible at all) and also the fact that the actual exhibit content becomes visually cluttered. In the second case, a key drawback is that visitors have to share their attention between the exhibit and the information and mentally correlate the two. An unsolved issue shared by both approaches is multilingualism, since information for each additional language requires supplementary space.

Every map and especially old maps include very dense and precious information, very difficult to retrieve and study without special digital techniques. In this context, this paper presents how the application of the PaperView system (Grammenos et al., 2011) in the domain of cartographic heritage can considerably aid towards overcoming the aforementioned limitations, also providing added-value tools facilitating the exploration and the comprehension of any type of 2D or 3D map. PaperView is a multi-user augmented-reality system for supplementing physical surfaces

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(such as maps and scale models) with digital information, through the use of pieces of plain paper that act as personal, location-aware, interactive screens. The technologies employed are presented, along with the interactive behavior of the system, which was instantiated and tested in the form of three prototype setups.

Background & Related Work

Augmented Reality (AR) is a variation of Virtual Reality (or VR) which superimposes digital information in the real world (Azuma, 1997). The most common approach is to use a handheld (e.g., mobile phone, PDA), or a wearable display (e.g., Sparacino, 2004) to overlay visual digital information onto real-world live video, acquired through a camera. An alternative approach is to project information in the real world, as was originally suggested by Wellner (1993) in the DigitalDesk system. In this context, a handy tool is what is usually referred to as a “magic lens” (Bier et al. 1993). At an abstract level, a magic lens is a “tool” comprising a (passive or active) surface in which visual information is presented regarding the piece of physical area that is located underneath the lens. In this direction, Reitmayr et al. (2005) augmented paper maps using a PDA and a rectangular piece of cardboard with a black border to browse images. A limitation of this approach is that only a single PDA and one cardboard can be tracked. Following a different line of thinking, Bimber et al. (2006) presented an approach for digitally augmenting pictorial artwork, also supporting user interaction through a secondary screen and a mouse. Holman et al. (2005) project a windowing environment on physical paper to simulate the use of digital paper displays. The pieces of paper and the user fingers are augmented with IR markers in order to be tracked. The Magic Lenses framework (Brown and Hua 2006) employs a handheld mirror-like prop with an attached magnetic tracking sensor and a “selection icon” with a secondary display to augment a 3D image projected on a workbench. In order to tack this icon, a surface coated with the retro-reflective material is used, along with an IR camera and IR illumination. Izadi et al. (2008) present a rear-projection surface that can project a second image through it onto a sheet of projection film placed on it, acting as a magic lens. In order to be tracked, the magic lens is augmented with either passive or active tags. More recently, Spindler et al. (2009) developed a system that tracks a sheet of paper augmented with IR-reflecting markers which is used to explore the 3D space over a tabletop. The authors identify four different types of data spaces (volumetric, layered, zoomable, temporal) and suggest related navigation techniques.

The PaperView System

The PaperView system (Grammenos et al., 2011) comprises a surface to be augmented, a projector, a color camera, and a conventional PC with audio speakers. Additionally, rectangular pieces of plain white cardboard of various sizes are employed which feature a colored frame. A computer vision system tracks the position and pose of the paper surfaces, as well as the activation of any related interactive areas by the users’ fingers which may touch this surface. The vision system detects the quadrilaterals corresponding to the cardboards based on the knowledge of the color of the border of each cardboard using a color similarity metric (Smith and Chang, 1996). Then, the silhouettes of the detected contours are traced and fitted with straight lines. The system estimates the transformation that maps the detected quadrilateral(s) to rectangular regions, using a *homography*. The identity of each cardboard is maintained over time. To increase robustness and suppress jitter, the trajectories of the polygon corners are tracked using *Kalman filtering* modeling location and velocity. The 3D location and pose of the cardboard is estimated given the size of its

edges in the image and its size, during setup, by placing the cardboard in a frontoparallel posture on the surface of the table. Additionally, rectangular areas dynamically defined by the application (i.e., “soft” buttons) are continuously checked for differences using a background subtraction method. The image projections of these areas are tested for the occurrence of skin-colored blobs, using the method in (Argyros, Lourakis, 2006) and, at the same time the neighboring area of the nested quadrilateral is checked for occlusions. Finally, all the information generated by the vision system is passed through a custom middleware layer to an application, which implements the system’s user interface.

In essence, PaperView follows the paradigm of augmentation of maps using real world objects suggested by Reitmayr et al. (2005), extending it by supporting multi-user interaction, finger-based input and concurrent tracking of diverse border colors. In contrast to PaperWindows (Holman et al. 2005), SecondLight (Izadi et al. 2008) and Spindler et al. (2009), no IR markers are necessary to augment the paper or the users’ fingers. Also, unlike Magic Lenses (Brown and Hua 2006), no magnetic tracker or special coating of the table surface are used.

In the domain of cartographic heritage, PaperView has been instantiated and tested in the form of three setups:

1. a map of Macedonia, Greece, including ancient Greek cities with archeological interest;
2. a glass case containing a scale model of an ancient farmhouse;
3. a part of Rigas Velesinlis’ Charta.

The first two demonstrators are currently installed and available to the general public at the Archaeological Museum of Thessaloniki, Greece, as part of the “Macedonia from fragments to pixels” permanent exhibition of interactive systems (www.makedonopixels.org - exhibits “Multimodal Diverse travel” and “One day in a farmstead”). The later prototype is available as a demonstration at the premises of ICS-FORTH.

Ancient Macedonia Map

The system (Figure 1) comprises a large wooden table (2.2x1.2 m²), the surface of which is covered by a printed map of Macedonia, Greece. The printout does not contain any text or other kind of data. Underneath the table there are two sound speakers and high above it, hanging from the ceiling, there are a high-definition (1920x1080) video projector and a camera. Initially, the location (as red spots) and names of ancient Greek cities with archeological interest (in English and Greek) are projected on the map surface. At the one side of the table surface, brief bilingual instructions are also projected.



Figure 1: PaperView version augmenting a map of ancient Macedonia.

On two of the sides of the table, there are two cases containing several pieces of white cardboard (30x30 cm²) which are at the visitors' disposal. Each cardboard piece has a colored frame. One of the four sides of the frame has a different color compared to the remaining three. This side is considered to be the cardboard's "bottom" side, i.e., the side against which all text is aligned. The color of the other sides is used to denote the cardboard's language (e.g., green is for Greek and orange for English). Multiple users can concurrently use the table.



Figure 2: Visitor interaction with the system: (left) "map mode"; (right) "info mode".

The visitors' interaction with the system operates as follows:

1. When a visitor places a cardboard piece over the table surface, an image is projected on it, showing a satellite view of the respective printed map area ("map mode" – see Figure 2, left). Furthermore, a magnifying glass is projected on the paper's centre. If a city's name intersects with a piece of paper, then the name's letters are rotated so that they are aligned with the paper's orientation.
2. As the visitor moves the cardboard around, the size of the magnifying glass changes. The closer it gets to a city's location, the bigger it gets, in order to facilitate city selection. If the magnifying glass is located over a city, then a multimedia slideshow starts ("info mode" – Figure 2, right). The slideshow comprises a series of pages, each of which may contain any combination of text, images, and videos. At the bottom area of the slideshow, a toolbar is projected containing an indication of the current page and the total number of pages (e.g., 4/23), as well as buttons for moving to the next/previous page. The visitor may interact with these "soft" buttons using his/her fingers (Figure 2, right). The information projected on the cardboard is always rotated so that it is kept aligned to the "bottom" side.
3. If the paper is taken off the table's surface, the buttons disappear and the user can move to the next/previous page, by tilting the paper right or left, respectively. In this case, the projection is appropriately distorted (Figure 3, left), so that the visual content registers correctly to the paper surface. In order to avoid accidental browsing actions, page change does not happen instantly. Instead, an arrow-shaped progress bar is presented on the paper (Figure 3, right) and takes about 1 second to fill.

In order to visually link the information presented on a cardboard piece to the site it refers to, a virtual connecting string is used. When the cardboard is close to the site, the string is green and thick. Then, as it gets further, its color gradually changes, first to orange and then to red, and its thickness is reduced. Finally, if the cardboard is moved beyond a minimum distance, the string "breaks" and the paper's surface returns back to "map mode".



Figure 3: (left) lifting the paper above the table surface; (right) tilting the paper to browse content.

Farmhouse Scale Model in Glass Case

This version of PaperView allows visitors to retrieve information about an ancient farmstead of the 4th century BC that has been excavated at Asprovalta near Thessaloniki. This is achieved by enriching a scale model (about 83x83 cm²) with multimedia information in one of the main exhibition areas of the Archaeological Museum of Thessaloniki (Figure 4). The main goal of this setup is to create a self-contained “add-on” system, requiring minimal interventions to the installation space. In order to accommodate the space limitations, an ultra short throw projector is used, and a camera with a wide angle lens.



Figure 4: PaperView version augmenting a scale model of an ancient farmstead of the 4th century BC.

The system behaves similarly to the table setup, with just the following differences (a) when the lens is located over a point of interest, a short animation is presented that starts from a view of the piece of the model located underneath the cardboard and is gradually transformed into the respective area of the actual excavation site, so that visitors can visually correlate them; (b) due to the glass surface, no information is projected outside the tracked papers; and (c) papers cannot be used when higher than a few centimeters above the surface, since the projector’s beam is located very close to the surface.

Rigas Velesinlis' Charta

The *Charta* is a twelve-sheet map (about 200 x 200 cm² in total) which represents Greece and almost the whole of Balkan Peninsula and was created by Rigas Velesinlis, one of the major figures of Greek Enlightenment (Livieratos, 2008). The content of the *Charta* is very rich and dense, including a large number and variety of themes such as toponymy, coins, geographic and conceptual symbols, descriptive and reference texts, graphic representations and images, names of persons and facts, historic and archaeological references plus specific illustrations, plans and maps within the map, etc (Livieratos 2008). The existing copies of the *Charta* in Greece have been proclaimed by the Ministry of Culture as national monuments. The research on Rigas Velesinlis *Charta* is a major project developed by the Cartography Group at the Aristotle University of Thessaloniki. It is studied both from the geometric point of view such as map projection, (Boutoura 2008) as well as for its geometric and precious thematic content, for example the coins (Pazarli 2008) using digital techniques. In 2008, it was discovered that two different versions of the *Charta* exist, which have thirteen differences (Livieratos 2008). The two versions were respectively named Version-A and Version-B. More recently, it was discovered that there are also variations among different Version-A copies of the map (Livieratos 2010).

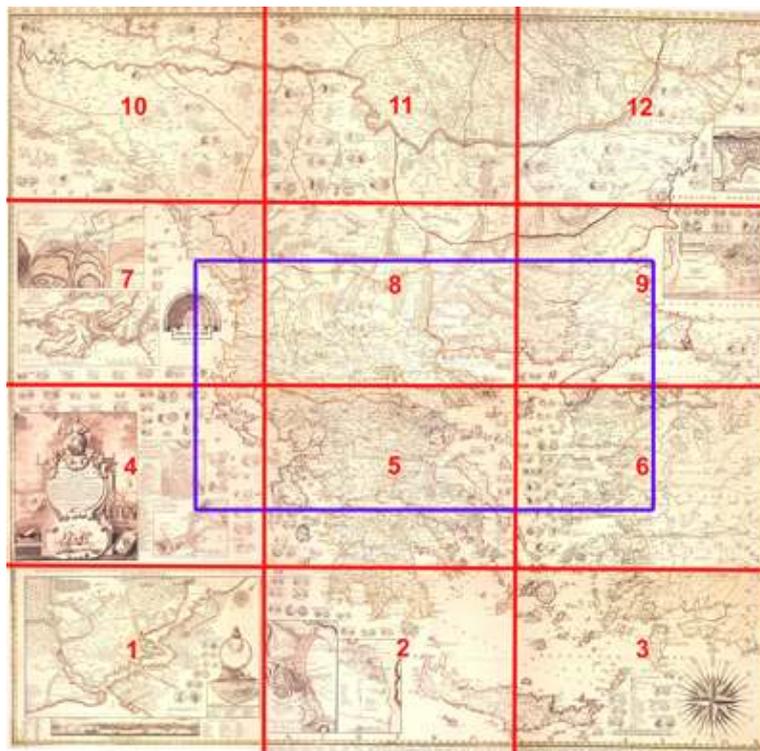


Figure 5: Rigas Velesinlis' *Charta* (from the Kapesovo copy).
The area outlined in blue is the part of the map presented by the prototype.

In this context, the first of the two aforementioned PaperView versions was adapted to allow for the exploration of the *Charta*. An infra-red camera was also added to the set-up, which tracks a custom-made electronic pen with an infrared tip. For the initial prototype, it was decided to focus on just one part of the whole map, taken from the “Kapesovo copy”, after union of the twelve map sheets using special digital cartographic procedures (Figure 5). The map is printed and then attached on a table's surface. Initially, the location and names of cities are projected on the map, as well as the outlines of areas of interest such as coins (with a blue circular outline), areas where

differences with alternative versions of the map have been identified (as green rectangles), etc. As in the other cases, users may interact with the map through rectangular pieces of white cardboard with a colored frame. However, in this case, each side of the cardboard supports different types of interaction. More specifically:

Side A: This side operates similarly to the “Ancient Macedonia Map” version of the system, also supporting the retrieval of information about areas of interest (such as coins, areas with differences, cities, etc. – see Figure 6). When an area with differences is presented, alternative animations are employed in order to assist the user in identifying those differences. For example, a transition between the two maps is shown, where the differences are highlighted in red (e.g., see a sequence of key animation frames in Figure 7). Then, a video showing the two pieces of the map sliding on top of each other is shown, accompanied by a descriptive text.



Figure 6: Retrieving multimedia information about (left) a city, and (right) a coin from the Rigas Velestinlis’ Charta.

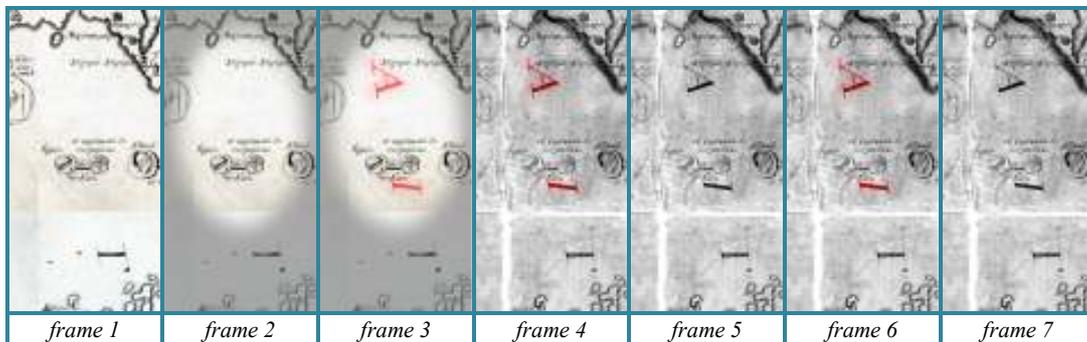


Figure 7: Sequence of key animation frames showcasing the differences between two versions of the map.

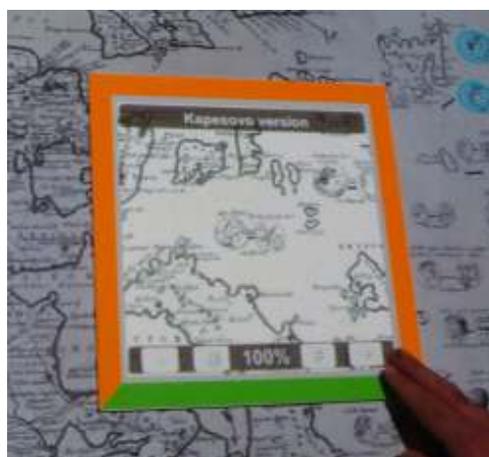


Figure 8: Interacting with the Charta using the cardboard’s Side B.

Side B: When the cardboard is placed over the table surface, the corresponding area located underneath it is projected on it (Figure 8). At the top side of the cardboard there is a caption stating the map version that is projected on its surface. On the lower side, there is a toolbar containing a label that indicates the current zoom level and 4 buttons:

- (1) *Zoom in:* The piece of the map that is presented on the cardboard is magnified by 10% (Figure 9). Magnification is achieved by displaying a very high resolution image of the map.
- (2) *Zoom out:* The piece of the map that is presented on the cardboard is shrunk by 10%.



Figure 9: Zooming in the map.

- (3) *View different map:* The user can view the respective area of other versions of the map (see Figure 10).



Figure 10: Viewing alternative versions of the map (left: Kapesovo, right: Kozani).

- (4) *Freeze:* The image presented on the cardboard freezes and does not change as the user moves it around. Through this functionality, users can freeze a specific area of alternative map versions on different pieces of paper and then place them side-by-side in order to compare them (Figure 11).



Figure 11: Freezing a piece of the map, to compare among different versions.

In addition to cardboard-based interaction, users can also employ the pen with the infra-red tip, in order to access some additional functionality. For example, they can draw digital paths directly on the printed map. If the path is “open” (i.e., its start and end points are apart) then the total length of the path (in kilometers) is presented (Figure 12 - left). If the path is “closed” (i.e., its start and end points are very close), then the area of the region inside the corresponding closed curve is also presented (Figure 12 - right). The path can also be drawn over the area covered by a paper. Due to the distortion of the map, the presented data are rough estimates, used to aid the user understand the real dimensions of the area presented by the map.

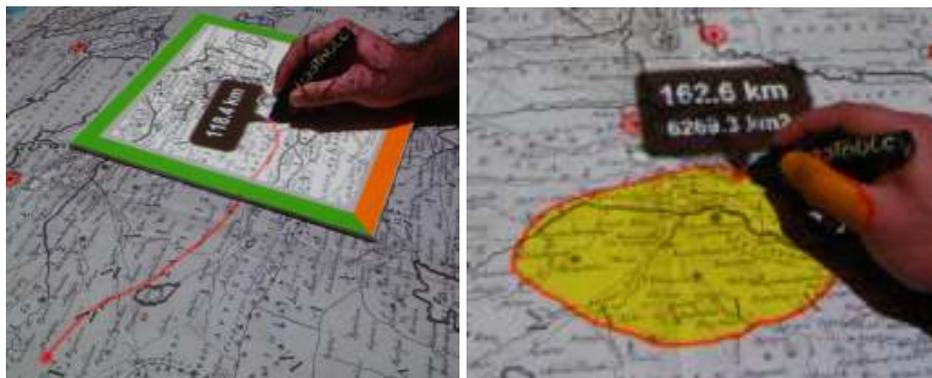


Figure 12: Using the path tool.

As the Charta embeds an overwhelming amount of heterogeneous pieces of information, besides the functionality and tools supported by the current prototype, a number of additional interaction options have been identified for future implementation, which will further aid filtering, exploration, and comprehension of the map’s content, eventually rendering this unique historical piece accessible to, and usable by, the broader public.

Conclusions

This paper has presented the application of the PaperView system as a means of exploiting augmented-reality technologies for supporting the exploration of cartographic museum exhibits and the retrieval of location-based multimedia and multilingual information. Up to now, the alternative versions of the PaperView system have been used both in a laboratory setting (the premises of ICS-FORTH) and in an exhibition open to the general public (Archaeological Museum of Thessaloniki) by several hundreds of people of various ages, nationalities and educational / technological

backgrounds with a great success. The overall opinion of the users ranged from positive to enthusiastic. In this respect, our experience so far has shown that novel interactive technologies can have a dramatic impact on the way people interact with the real world, offering unprecedented possibilities for the exploration of physical artifacts and for the discovery of related – unlimited in size or scope – knowledge. More specifically, the combination of digital, location-based, dynamic information with tangible objects (e.g., maps, models) that have an established, highly-appreciated aesthetic and haptic appeal can provide the domain of cartographic heritage with very powerful, added-value tools which can leverage its appeal and impact to the general public.

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