Exploring input modalities for interacting with augmented paper maps

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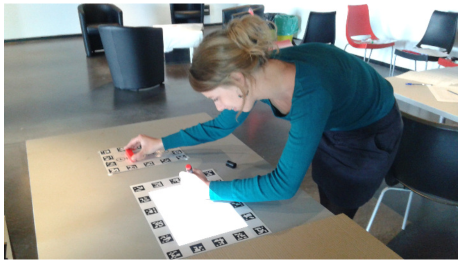

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Abstract
Interactive geographic maps are today widely available, but remain mostly limited to standard interaction contexts. We introduce a spatial augmented reality map, in which a virtual map is projected on a physical piece of paper. In a preliminary study we compared interaction techniques based on multi-touch, tangible and spatial modalities for three common map functions: zooming, panning, and changing the basemap. Our results suggest that object-based and spatial interaction may be advantageous over multi-touch in our augmented reality setup.

Keywords
interactive maps; tangible interaction; projection mapping; multi-touch; interactive paper; augmented reality

ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies; H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities

Introduction
Interactive geographic maps are nowadays largely available, for instance through online services and on mobile devices [11]. These maps provide features that go beyond the current possibilities of classical paper maps,

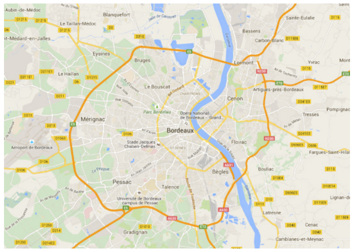

Figure 1: Default Basemap, Map data ©2015 Google, accessed with UnfoldingMaps

Figure 2: Satellite Basemap, Microsoft®BingTM Maps, accessed with UnfoldingMaps

Figure 3: Watercolor Basemap, ©Stamen Design accessed with UnfoldingMaps

such as route calculation, visualization of traffic, changing basemap styles, or zooming and panning.

While, some map interfaces (such as GoogleMyMaps or OpenStreetMaps) even allow users to contribute to the content, users generally still prefer traditional paper maps for map annotation. Moreover, the existing interactive maps remain mostly limited to standard interaction contexts based on traditional screens and input devices such as mice, keyboards or multi-touch inputs (tablets, smartphones). Alternative interaction techniques have so far been scarcely explored. Few geographic map prototypes are based on novel interaction techniques, such as tangible interaction or spatial augmented reality [3]. Consequently, many research questions around these novel ways of interacting with maps remain to be explored.

We suggest that spatial augmented reality, which consists in augmenting physical objects with digital infomation [2], and tangible interaction, which refers to interacting with the digital world through the use of physical artefacts [12], are promising approaches for interaction with geographic maps. In our prototype, we use augmented reality to display a virtual map on a physical piece of paper, thus keeping features of both media. Thanks to the digital map base, users can pan, zoom and even change the basemap. At the same time, the paper base allows users to manipulate the map physically and so to interact in a more "natural" way, as well as to draw on the paper using regular pens. We explored interaction techniques for three common map functions (zooming, panning, and changing the basemap). In this paper we present a preliminary study comparing different interaction techniques based on multi-touch, object-based tangible and spatial modalities for these three map functions. It appears indeed interesting to compare these modalities as they possess certain advantages. Touch-based interaction is today wide-spread as most people use smartphones or tablets, yet these devices are less adapted for certain tasks than paper (e.g. drawing with standard pens). Object-based tangible interaction is attractive to a large diversity of users [4]. Finally, the benefits of spatial interaction with digital content have scarcely been explored. Our results suggest an advantage of object-based and spatial interaction over multi-touch in our augmented reality setup.

Related work

In this paper, we focus on previous studies on merging paper and digital maps. Different ways of overlaying digital information over paper maps have been studied, such as using Anoto pens [8], PDAs [10], see through displays [9], projections [10], or tangible objects [3]. Maps combining tangible objects and projections have been used in exhibits [1] as they proved to be efficient for managing crowds and more attractive than virtual tools [6]. To our knowledge, none of the previous studies has systematically compared different interaction techniques for specific map functions (e.g., zooming).

System description

Our project aims at offering new input and output modalities for users interacting with map information. To this end the system displays a digital map on a physical sheet of paper. First, users choose the displayed map excerpt by zooming and panning using one of the techniques described below. Furthermore, users can also pick the basemap that suits their task the best: for example, a satellite view might be more helpful for navigation (Fig. 2), but a watercolor representation can be more stimulating for artistic expression (Fig. 3). We have integrated those basemaps using the Unfolding library [7].

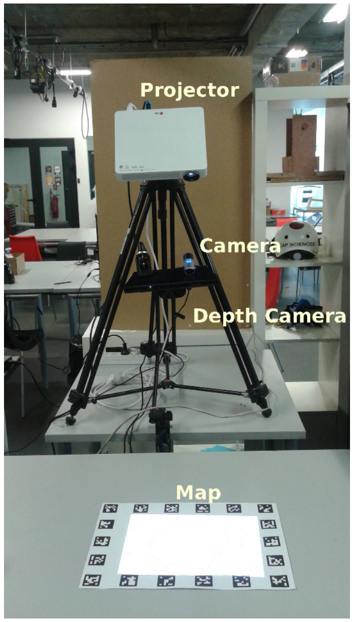

Figure 4: Prototype

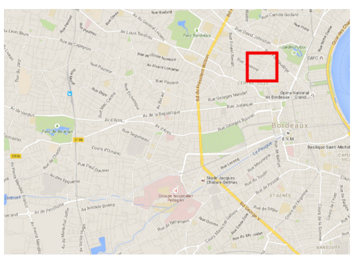

Figure 5: Example of a drawing the user has to find on the map and copy, Map data ©2015 Google, accessed with UnfoldingMaps

Prototype implementation
Our system is based on PapARt [5], an augmented-reality framework that was initially designed for enhancing artistic creations by allowing users to manipulate materials they are familiar with (paper, pen) combined with digital information. Composed of an overhead projector and an RGB-camera (Fig. 4), the system displays images on paper sheets carrying ARToolKitPlus markers [13] placed on a table. Thus, the projection moves as the paper changes position. PapARt installations also include a depth camera (kinect) to detect when the user or an object touches the sheet of paper. Furthermore, we added a color-based object recognition algorithm. To sum up, this system provides three different ways to interact with the system: tangible interaction using physical objects, touch-based interaction, and spatial interaction, i.e. moving the paper sheet. In order to explore interaction possibilities for specific map tasks, we implemented interaction techniques for three map functions (panning, zooming and changing the basemap) each based on one of the modalities. Touch-based interaction is today widely used, tangible object-based interaction has raised a lot of interest in research but has rarely been used for geographic maps and in general fewer studies have explored spatial interaction.

For panning, the touch-based technique involves a fixed menu with eight arrows for different geographic directions (N, S, E, W, NE, NW, SE, SW) that is displayed on the map (Fig. 6). Users can touch an arrow to move the map excerpt in this direction. Bringing back the finger to the center of the menu or removing the finger stops the panning. The object-based panning uses the same arrows printed on an external sheet of paper (Fig. 7). Users can put a small object on the desired arrow to move in the corresponding direction. Placing the object on the center or removing it stops the navigation. The spatial positioning is based on the movement of the sheet of paper. The arrows are, this time, fixed on the table (Fig. 8). The user can then move the sheet of paper in the direction of an arrow to navigate. Placing the sheet of paper back in the center stops the navigation.

For the zooming feature, the touch-based technique involves a scale that appears on the map image when the user touches the sheet of paper (Fig. 10). By moving the finger along the scale the user zooms in or out. We have chosen this implementation as it proved technically more stable than the pinch gesture that is the standard gesture in multi-touch applications for zooming. The object-based technique involves a printed scale on which the user could slide a bar object (Fig. 11). The position of the bar on the scale defines the zoom level of the map. For the spatial zoom, a scale is placed on the left of the table (Fig. 12), and the position of the sheet of paper regarding this scale changes the zoom level.

Finally, for changing the basemap, we implemented a touch-based technique involving a pie menu that is displayed when the user touches the paper (Fig. 13). By moving the finger on the piece of pie corresponding to the desired basemap style, the user can select a new basemap. The current basemap is represented with a red border. For the object-based technique, we created three small-scale objects, one for each basemap (Fig. 14): a miniature city for the basic basemap, a satellite for the satellite view, and an easel for the watercolor style. Putting one object in a dedicated area of the table changes the current style of the map to the corresponding basemap. In the absence of objects in this area, the basemap remains unchanged. For the spatial technique, we defined three vertical areas on the table corresponding to the different basemaps (Fig.

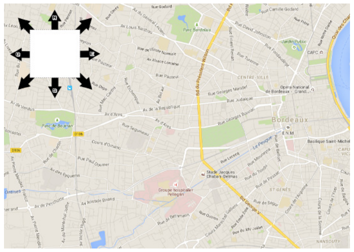

Figure 6: Touch-based panning, Map data ©2015 Google, accessed with UnfoldingMaps

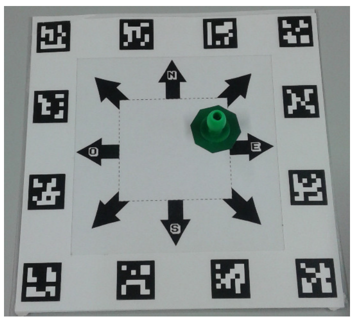

Figure 7: Object-based panning

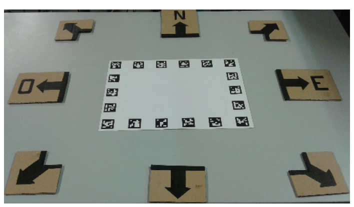

Figure 8: Spatial panning

15). Putting the sheet of paper below one of those areas changes the basemap correspondingly. The design of the tangible objects and the drawings representing the spatial areas were based on a questionnaire study that had been conducted prior to the implementation of the prototype.

Experiment

The goal of our study was to compare three modalities (touch-based, object-based and spatial) for three different map functions (zoom, panning and changing the basemap) in order to identify advantages and disadvantages of each technique for a specific task.

Feature	Gender	Laterality	Age [σ]
Pan	5 / 7	11 / 1 / 0	24.75 [3.02]
Zoom	5 / 7	8 / 4 / 0	29.42 [13.26]
Basemap	3 / 9	9 / 2 / 1	27.25 [4.29]
Total	13 / 23	28 / 7 / 1	27.14 [8.22]

Table 1: User population: gender (f/m), laterality (right-handed/left-handed/ambidextrous), and average age

Protocol

In order to compare the different interaction techniques, we performed an experiment at "Cap Sciences" science center with 36 users that were recruited from the visitors (see Table 1). Three groups of 12 users were formed and each group was assigned to one function (panning, zooming or basemap).

Each user had to perform the same task three times using touch-based, object-based, and spatial interaction in counterbalanced order. After each technique, we asked users to fill out a questionnaire regarding their satisfaction with the technique. After the three experiments, a final questionnaire invited users to grade each technique (Likert scale from 1 "very bad" to 10 "very good") and provide qualitative feedback. In order to motivate users to carefully test the techniques, we introduced a game. The maps contained hidden drawings that appeared when interaction techniques were used (e.g., for zooming, the drawings were hidden in the different zoom levels and could be found only by zooming in or out, see Fig. 5). Users were given 3 minutes to find a maximum of those drawings. They had to trace each drawing they found with a felt pen on the paper sheet. Once the drawing completed, the users were free to search for a new drawing and so forth until the end of the three minutes. The order of apparition of the drawings was defined randomly in order to avoid learning effects. To sum up, each function was evaluated in a 3-condition within-participants study. We measured satisfaction with a questionnaire and efficiency as the number of found drawings (maximum 13) within 3 minutes.

Results and discussion

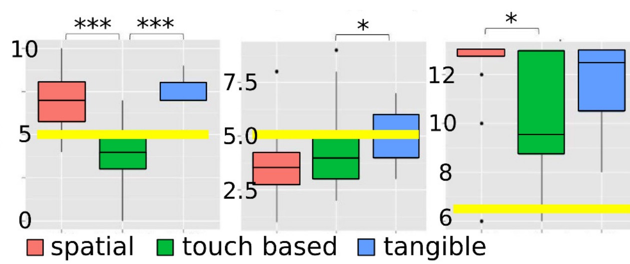

Figure 9: Boxplots showing the statistically significant results: (a) grades for the zooming task, (b) grades for the panning task, (c) scores for the basemap task. The yellow line indicates 50% of the maximum value. *p<.05, ***p<.001.

We performed statistical analysis for each map function regarding satisfaction and the number of drawn figures. Shapiro-Wilk tests revealed that distributions were not normal, thus we performed Friedman tests for all analysis.

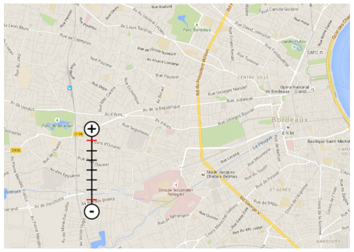

Figure 10: Touch-based zooming, Map data ©2015 Google, accessed with UnfoldingMaps

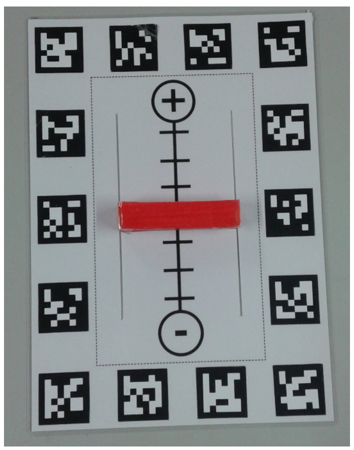

Figure 11: Object-based zooming

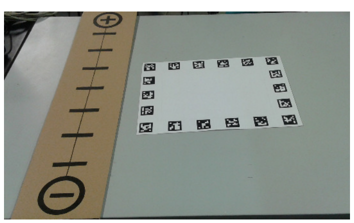

Figure 12: Spatial zooming

We observed a statistically significant result regarding users' grades for the zoom (X2=18.14, p<.001). As shown in Figure 9 satisfaction with the object-based interaction was significantly higher than for touch-based interaction, as well as for spatial than for touch-based interaction. Generally more figures were drawn for object-based interaction (M=6.3, SD=3.58) and spatial interaction (M=6.16, SD=2.44) than for touch-based interaction (M=3.8, SD=2.04), although the difference was not significant. For the panning task, there was a significant difference concerning user satisfaction (X2 = 6.39, p=0.04). Scores for object-based interaction were significantly higher than for touch-based interaction (Figure 9). There was no statistically significant difference regarding number of detected figures for the panning task. Finally, with regard to changing the basemap there was a statistically significant difference regarding the number of detected figures (X2 = 6.67, p=0.04). The detected number of figures was significantly higher for spatial interaction than for touch-based interaction. There was no statistically significant difference regarding satisfaction.

Discussion

This preliminary study has provided few statistically significant results, which might be due to the low sample size. Yet, it allowed us to identify some trends. In general, we noticed that touch-based interaction technique scored less in performance and appreciation than the other interaction techniques. This is supposedly due to the fact that the touch detection is limited by the precision of the kinect and is not as good as the detection on tablets or smartphones. Many users commented that they are used to those technologies and feel frustrated with the inferior precision of our system. We therefore intend to compare our prototype with a standard multi-touch device in our future studies. Object-based techniques were usually appreciated and effective. This is in line with prior studies on tangible interaction in museums [4]. The spatial techniques were also appreciated, even by some participants who expected this technique to be the most complicated. Consequently we suggest that the two latter interaction techniques are interesting approaches that should be studied in more details for map interaction.

All interaction techniques for panning received low satisfaction scores (below 5/10), although performance was above average. We conclude that none of the techniques was pleasant to use for this task. Indeed, users stated that they felt lost and had troubles visiting the whole map. As a solution, some of them suggested the use of a minimap as an overview. They were also missing the possibility of adjusting the speed of movement. Those problems might be related to the fact that we used a relative navigation (no absolute relation between the position of the interactive element and the position of the map excerpt). We believe that using an absolute navigation (position of the map excerpt corresponds to position of the interactive element) could solve those problems. This will be investigated in our future work.

Finally, efficiency was rather low for all zooming techniques. This maybe be due to technical problems which made it difficult to stabilize a zoom level and resulted in jumping from one level to another. Users also lost time trying to go further than the maximum zoom level and complained about the lack of visual aids regarding the zoom limits.

Conclusion and future work

As a first exploration phase for our project, we compared three modalities (touch-based, object-based and spatial) for three map functions (panning, zooming, and basemap

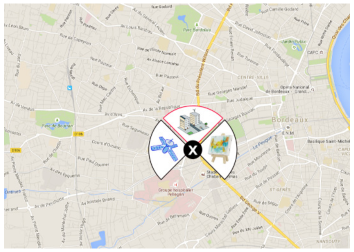

Figure 13: Touch-based basemap selection, Map data ©2015 Google, accessed with UnfoldingMaps

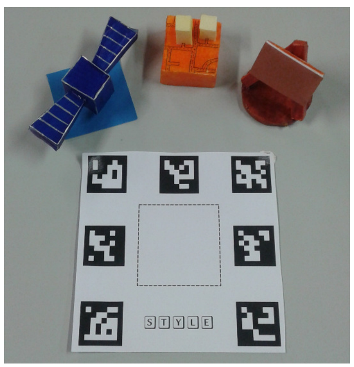

Figure 14: Object-based basemap selection

Figure 15: Spatial basemap selection

selection). This preliminary study allowed us to gain first inputs and ideas for the next steps of the project.

Tangible object-based and spatial interaction seem to be promising for this kind of augmented-reality map system. As we compared each function separately, we now need to investigate how to combine those techniques in one prototype. For example, it could be cumbersome and require a lot of space to integrate three tangible objects on a same system. Furthermore, this study allowed us to gain ideas for improving the proposed interaction techniques. For instance, we will investigate using a mini map as overview for panning and zooming. Our prototype will be exposed at the Living Lab of Cap Sciences in Bordeaux as part of a smart city project. The final prototype will allow users to select a map excerpt and to draw on the paper sheet using regular pens. By doing so, museum visitors will get the chance to express their opinion and thus to contribute ideas to the city of tomorrow.

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