Engaging audiences with Cultural Heritage through Augmented Reality (AR) Enhanced Pop-Up Books

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Abstract

One of the core activities of memory institutions is to provide access to heritage material from their collections so that it can be used in formal and informal educational activities. Although this type of access is beneficial for audiences, we argue that current digital technologies for access still require users to know in which collection they must look for a specific subject or type of content. Although collection aggregators, such as Europeana and Google Arts and Culture, have made it easier to access content across collections, there is still a lack of engaging interfaces which can draw the interest amongst a wide range of audiences for exploring heritage material. In this research, we propose a tangible interface for accessing Cultural Heritage (CH) content in the form of a pop-up book. Pop-up books are a highly engaging way to get audiences to interact with materials in archives and collections. Our approach is creative and playful as it takes advantage of both the narrative and the three-dimensional and tactile nature of pop-up books so that audiences can engage with digital content through Augmentation Reality (AR). The technical contributions of the paper include a method to enable real-time interaction between the physical elements of the book and the virtual content. Unlike other AR pop-up books that generate purely virtual pop-up content, our design preserves the original 3D model inside the books and generates virtual effects on those objects, making our application more appealing and engaging than other AR books. This approach and technical method are deployed using a commercially available pop-up book with stories about various famous landmarks in the city of London. Content drawn from heritage collections enriches the stories told in the book with additional visual content and interactions. Initial tests of this approach suggest that it has the potential to engage audiences who will not be traditionally inclined to access other platforms with CH content.

CCS Concepts

- General and reference → Surveys and overviews; Reference works; Applied computing → Arts and humanities;

1. Introduction

This research explores how a pop-up book can be used as a tangible interface to engage with Cultural Heritage (CH) digital content in collections of museums, galleries and archives. In this way, the research seeks to improve the type of access to heritage content, beyond the traditional web-platforms, which are provided either by the institutions themselves or by aggregators such as Google Arts and Culture \[\text{Goo}\] and Europeana \[\text{Eur}\]. Although these collection aggregators have made it easier to access content across collections, there is still a lack of engaging interfaces which can draw the interest amongst a wide range of audiences for exploring heritage material.

This research addresses these shortcomings by proposing an experience — rather than a web-search — as an entry point for accessing Cultural Heritage content in collection and archives. We present a tangible and engaging interface in the form of a pop-up book. Our approach is creative and playful: it takes advantage of the books’ existing narrative as well as the three-dimensional and tactile nature of pop-up books. In this way, audiences can engage with digital content through Augmentation Reality (AR) by interacting with the physical elements of the book.

Our approach has the potential to benefit memory institutions or tourism organisations who commission Cultural Heritage books which are related to cities, nature or historic themes. The developments also make it possible to incorporate digital content from their collections in either existing or new publications.

The technical contributions of the paper include a method to enable real-time interaction between the physical elements of the book and the virtual content. Compared with other AR pop-up books, our design preserves the original 3D model inside the books and generates virtual effects on those objects, making our application more appealing and engaging than other AR books. We also prototyped the proposed approach using a commercially available...
pop-up book with stories of landmarks in the city of London by Jennie Maizels [Jen11]. This book, illustrated in Figure 1, contains three-dimensional models of historical buildings in London and is targeted to children between 5–9 years of age. We used the London scenes in the book to develop interactive engagement with virtual scenes as well as cultural heritage content. Hence, content from different collections, including from London museums and galleries, is used to enrich the stories displayed in the book.

Figure 1: London pop-up book by [Jen11] deployed in this research to prototype the proposed AR engagement approach.

The paper is structured as follows. Section 2 presents related work, in particular in the area of Augmented Reality (AR) interactions within pop-up books, as well as related Cultural Heritage examples. In Section 3 we present the model and development phase of the research to produce a prototype with the ideas proposed. The early evaluation of the prototype is then presented in Section 4. Finally, conclusions and further work is presented in Section 5.

2. Related Work
2.1. Augmented Reality in Cultural Heritage
With its ability to mix virtual content with the real world, Augmented Reality (AR) has become a popular way to engage with Cultural Heritage in situ, such as at an archaeological site or in a museum. As such, several contributions within the computer graphics community have been made in this area. Vlahakis et al. [VKT’01] presented an early outdoor system which uses image matching techniques for users to visualise virtual monuments on an archaeological site via an AR Head-Mounted Display (HMD). Since the introduction of smart-phones and AR frameworks, such as Vuforia, ARKit and ARCore, Augmented Reality has become easily accessible to heritage organisations. Bekele et al. [BPF’18] present a review on the state-of-the-art in augmented-, virtual-, and mixed-reality systems as a whole and from a cultural heritage perspective. Moreover, Web-based AR technologies based on WebGL allow accessing experiences with Cultural Heritage content through the browser [RDB’19].

Now that AR technology has become relatively mature, there is a need to design compelling interactive experiences with physicality. In particular, there is still a need for engaging experiences which can be accessed beyond the visit to a heritage site. This leads us to investigate novel ways to engage with heritage content through interaction with physical objects which are already engaging and interactive. Thus, in this research, we use the pop-up book as a means to target younger audiences engaging with Cultural Heritage.

2.2. Augmented Reality in Pop-Up Books
Augmented Reality (AR) has been used to create virtual pop-up book experiences. One of the earliest examples was the Magic-Book, developed by Billinghurst et al. [BKP01], for informal and formal educational experiences. Using coded targets, the system tracked a page of the book and virtual 3D content appeared fixed to the book.

Many authors have extended and revised this approach. Ucelli et al. [UCDAS05] describe a similar idea focused on helping children understand the concept of the theory of colours. Clark et al. [CD12, MNZ’15] propose books which enable using textures acquired from the book to colour virtual content. Papagannias described an AR system to help people appreciate invertebrates and potentially help overcome phobias [noa].

Further research proposes different types of interactions with physical elements on the book while allowing for user-control of virtual elements [DWHB12, MKZ’11, RRM’12, SPFL08]. For instance, Willis et al. [WSM13] propose a tool for interactive storytelling which allows tangible objects to be moved and manipulated to dynamically control and interact with projected imagery on the printed media. Research on the design of virtual content and interaction in AR applications has also been investigated identifying immersion, engagement and interactivity as major components to explore further with this type of technology [LP19, GDB08].

Almost all of this research is based on the idea that the only physical object is a book: all the pop-up content is purely virtual. As a result, the research does not consider the benefits that physical pop-up books provide. Pop-up books are one of the most tactile and interactive types of books. They allow readers to experience creative 3-dimensional artifacts related to the stories [AS82].

A prototype was developed using Unity and ARKit on iOS for engaging virtually with the commercially-available pop-up book.

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which is shown in Figure 1. The book contains pop-up paper models representing landmarks in the City of London [Jen11]. We chose to use the pages that contain the paper model of Tower Bridge, shown in Figure 2. An icon of London and the United Kingdom, the bridge was built between 1886 and 1894. When built, Tower Bridge was the largest and most sophisticated bascule bridge ever completed [Tow]. Today, this bridge serves multiple purposes: a historic landmark, a museum, and a bridge that provides vehicle and pedestrians access to the City of London.

Figure 2: top) physical elements in the 3D scene of the pop-up book, bottom) Pop-up paper model representing Tower Bridge in the city of London augmented with virtual content (a virtual tour guide).

The movable objects in the book, such as flaps and hinged paper models, enabled us to experiment with different types of interactions. For instance, it is useful to detect whether a flap is lifted or not, or whether the bridge is opened or closed in order to allow the virtual character or other virtual objects to move under the bridge. To do this, we treated the book as being composed of the following set of elements:

1. Page: This element represents the page in the book that the pop-up elements are attached to. It is the base coordinate frame. All other elements are expressed relative to this page frame.
2. Static Page Element: This 2D physical element is rigidly attached to the page. It is used to highlight specific areas, such as the markers used in the alignment procedure which is described later.
3. Flap Page Element: This is a 2D physical element which is fixed to the page with a hinge joint. It has a single degree of freedom which is the rotation about the hinge. It includes a ghost flap (which displays a written story about a ghost at the Tower of London when opened), and the Olympic park flap (which reveals an image of the Olympic Park and refers to the history of the London 2012 Summer Olympics)
4. Movable Page Element: This is a 2D page element which allows more general motion. It includes sliding and rotating. In particular, a boat image hinged to the page, which is a cardboard image that can be manipulated across the foldable pop-up model of Tower Bridge when the bridge is lifted.
5. 3D Model Element: These are the main features of pop-up books which incorporate foldable three-dimensional models. These are created by the interaction of multiple page elements that interlock with one another. The main model we chose to augment was a foldable pop-up 3D model of Tower Bridge. Similarly to the real one, users can lift the elements of the bridge in the paper model.

3.1. Element Recognition and Tracking

To support registration and interaction, we must be able to track the different elements in the pop-up book. We achieved this using ARKit’s 2D and 3D image recognition and tracking capabilities, which takes as input the reference image or object to be used for recognition. For this, the different elements to be tracked were digitised to create the reference images. Figure 3 shows the reference image targets used to track a static and a flap page element which can be lifted to reveal information about Henry VIII and Elizabeth II.

To track 3D models, we make use of the scanning tool provided by Apple. This is easily installed and used on any iOS devices with a version higher than 11.0. To get an accurate detection model, we followed a specific procedure for scanning, including 1) positioning the object in a suitable environment, 2) specifying a bounding box based on the object; 3) scanning the object from different angles; 4) adjust the origin of the scanning result; and, 5) exporting the scanning result as .arobject file used for later detection. Figure 4, shows how we built this model for the foldable pop-up model of Tower Bridge.

The object recognition system generates a point cloud of the 3D
Figure 4: Object Tracking of foldable Tower Bridge paper model

object mostly for tracking purposes. Unfortunately, it is not possible to use the point cloud to recover the status of the bridge by object tracking. Instead, we make use of image tracking. This produces an estimate of the image target position and orientation every time a target image is detected. Hence, we use a small part of the texture on the moving bridge paper model as the image target. This is shown in Figure 5. We then detect whether the bridge is opened or closed, by monitoring the image’s height $d_{\text{open}}$ above the book page. In particular, it is greater in the “open” position than the “closed” position. When the movable bridge is closed, we trigger an invisible model that blocks any virtual content moving across the bridge. This model is made invisible as the bridge in its open position is detected.

Figure 5: Tower Bridge paper model in its opened status

3.2. Aligning Virtual and Physical Content

The virtual scene is anchored to a coordinate system fixed to the book page. Therefore, we must align the virtual model in the AR system with the actual page in the real physical scene. The challenge lies in the fact that the AR tracking system returns pose relative to a world-fixed coordinate frame, and this coordinate frame is reset every time the application is started. Therefore, we must estimate the position and orientation of the book page in the tracking coordinate frame. In general this requires solving for six degrees of freedom — three for the position and three for orientation. However, we were able to use ARKit’s image detection functionality to obtain the three unknowns for positioning. We also assumed that the book is placed sitting on a flat surface so that two dimensions of orientation are also fixed. As a result, there is only one unknown (rotation angle about the gravity vector).

Although we could determine these unknowns by treating the book page as a single large image target, we found this approach to be unstable in practice. The reason is that to track the book page, the system had to track the entire physical scene, including the page and all of the physical elements. Variations in the physical positions of the elements, together with lighting and shadow differences, made the tracking unreliable and noisy.

Figure 6: Users only need to scan two images to complete the alignment (Process top) Red Ghost Book, (bottom) Beefeater

To overcome these issues, we developed a calibration process which uses local features. The user is asked to find several distinctive pictures on the book page (the Red Ghost Book and the Beefeater, shown in Figure 6). When these elements are detected in the camera frame, the pose of the picture in world coordinates is recorded and the next picture shown to the user. Once all the features have been detected, a 3D transformation process is carried out to align the virtual coordinate system with the real world coordinate system of our detected targets. Let $a_1$ and $a_2$ be measured real world 3D coordinates of two features, and $b_1$ and $b_2$ be detected virtual 3D coordinates of the two features. The rotation angle $\theta$ and the rotation matrix $R_\theta$ are calculated as:

$$\vec{a} = a_2 - a_1$$
$$\vec{b} = b_2 - b_1$$
$$\theta = \arccos \left( \frac{\vec{a} \cdot \vec{b}}{|\vec{a}| \cdot |\vec{b}|} \right)$$
$$R_\theta(\theta) = \begin{bmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{bmatrix}$$

To verify the suitability of this process, we overlaid a 3D photogrammetric model of the pop-up book over by using the extracted rotation angle. Figure 7 shows the overlay is a suitable method for this alignment.

Once the virtual and physical models have been aligned, we provide a number of ways to interact with the scene. These include...
the use of a purely virtual tour guide, and physical manipulation of various elements.

3.3. Interactions Between Virtual and Physical Elements

The metaphor we used to instigate interaction is a virtual “tour guide” shown in Figure 8. The guide provides a user with a mechanism to explore virtually the elements in the page, as the character can move in the virtual space, and trigger different virtual content through different types of interactions. In this way, users can virtually explore the book’s page, revealing related content that enriches the tangible experience with the physical book.

To begin using the character, the user is presented with a green indicator on the screen to generate the initial position for the character (see Figure 2). We apply the plane detection feature of ARKit to ensure that the character is grounded on the book page. Besides, there is also a control button, which enables users to control the character’s movement. Furthermore, a reset button allows users to relocate their character whenever needed.

The augmentation of physical objects is only visible when the character is close to a physical element in the page. For instance, virtual content is triggered when the character enters pre-defined trigger bounding boxes areas shown in Figure 9. When the character exits the bounding box area, the virtual model is deactivated again.

Through this interaction, the user can trigger a 3D ghost model [BCo] which pops up when the character approaches the Ghost book flap (see Figure 10: Ghost Animation), as well as triggering fireworks when approaching the Tower Bridge paper model. Fireworks are created using the VFX Graph in Unity. Better effects can be observed when turning off the physical light source (see Figure 10: Fireworks in The Dark). Another example is implemented by using the Olympic park flap. When the character approaches this flap, the system causes an “Open it” prompt to appear to the user. By following the instruction, a video of an Olympic swimming competition is activate.

The ability for the users to move virtual objects is also implemented for the movable boat image, as illustrated in Figure 11. For this, the system tracks this image, so that a virtual boat appears when the image is detected. A “Destroy” button enable the user to deactivate the boat at any point in time.

3.3.1. Accessing CH Content From Collections And Archives

By exploiting some of the interactivity describe in the previous section, we implement further functionality to trigger content from Cultural Heritage collections and archives within the virtual space. Specifically, we allow the user to visualise spatially oriented images inspired by the Photo Tourism project [SSS06], which has also been demonstrated to work with proxy objects, such as 3D printed artefacts [NBL18].

For the prototype, we made use of visual content which is relevant to the history of Tower Bridge [Roy]. Given its popularity, the bridge has been recorded in different visual media including paintings, photographs and video. When the system detects the users’ camera near pre-defined camera viewpoints, corresponding historical images will show up. As Figure 12) shows, images have been positioned according to their corresponding camera viewpoint to allow the user to contextualise historical views of the bridge.

Furthermore, a video with a selection of photographic images of Tower Bridge through history [Jam] is also triggered by object detection. Since the object target can be detected from different positions within the book, the video rotates to always face the user view according to the camera position.
3.3.2. Occlusion

The goal of occlusion is to preserve the rules of line-of-sight in the AR scenes, so that any virtual object that is behind a real object, should be hidden behind that real object. This is an essential feature to give an immersive experience, when using a physical complex scene like ours. Hence, the virtual contents should not be displayed if there are physical objects between the virtual content and our devices’ camera.

Our project does not apply real-time depth detection, but instead we use image and object tracking as a simpler way to implement a basic level of occlusion. To determine whether the virtual contents should be occluded, we acquire the geometry relationship between the real objects and the virtual object. For this, we calculate the distance between objects and camera devices.

Once the need for occlusion is identified, we deactivate the virtual content so that it is invisible for users (see Figure 13). Although this is sub-optimal compared to the perfect occlusion culling, where only the part behind the real object should be occluded, it is a workable solution.

Another type of AR occlusion is human body occlusion. We made use AR Foundation’s automated human body occlusion based on the depth information of the detected human body. With the depth detection of the human body, the human body occlusion allows the culling for the geometry part behind the human body. As shown in Figure 14, this means only the blocked part of the virtual model is hidden, and the other part is still rendered.

4. Evaluation

The evaluation of the augmented pop-up books sought to investigate users’ feedback on the prototype and the potential of the approach engaging audiences with heritage content. However, given the limitations imposed by the COVID-19 pandemic and lockdowns, effectively testing the application in a museum or with a heritage audience has been restricted. Hence, we adopted a more flexible approach that provides some preliminary results and remarks, while planning for a more detailed evaluation in the near future. By taking into account the above, the overall design of the evaluation of the AR-enhanced pop-up book involved:

Initial functional testing. This was carried out by software developers to validate the stability of the application and its performance. This has been an iterative process throughout the development stage to see whether functional requirements were met (e.g. calibration, AR interactions, AR occlusions) while eliminating system bugs.

User experience survey. Responses were collected from 26 participants (aged between 20 and 63 years old) via an online survey. This was done to collect preliminary feedback about the user experience and the general impression of the AR pop-up book. As participants couldn’t have the application installed on their devices nor have access to the book, a video demonstrating all functionalities of the demo was made accessible before asking them to respond to the survey. The results of this survey are shown in Table 1. Based on the users’ feedback, it can be argued that AR-enhanced books are promising in terms of allowing people to access content by interacting with a physical interface that has been digitally enriched. Most users found that this type of application has the potential to increase their interest in pop-up books and their content, while the
majority of them would use similar books and applications in the future. Some further suggestions to improve the application include adding sounds and making interaction livelier.

**Expert feedback.** General feedback was also provided through functional testing and discussion with a limited number of developers. Their feedback has generally been positive while also demonstrating some technical issues, including the accuracy of the methods for aligning the virtual and physical space, that can be improved in future developments. The results of this survey are shown in Table 2. Based on the experts’ survey, our application is consistent and accurate in most situations. The virtual contents pop up at the expected position. Although some experts state that the correlation between each functionality is weak, all experts believe the interaction between virtual contents (e.g. virtual guides and boat) is stable and effective. Furthermore, experts admitted that this AR pop-up with interaction on physical models is more attractive than the existing pop-up books.

More detailed evaluation to examine the response of heritage audiences and particularly young audiences and educators is planned for the future. This will include usability testing through real-time user observations in natural settings of formal and informal education. Furthermore, an evaluation will include the collection of qualitative data to analyse and articulate the overall experience and its impact in terms of awareness, knowledge, engagement, attitudinal and behavioural aspects and skills development as research in the heritage context suggests [DHU16, Art14].

5. **Conclusion and Further Work**

This paper presents research on the development of immersive and tangible interfaces to interact with Cultural Heritage content. In particular, our approach allows for users to engage with a tangible interface, in the form a pop-up book, as a means to access Cultural Heritage through AR technologies. The approach is explored as a means to engage audiences who will not normally engage with content only found in archives and museums’ collection. Instead, our approach targets young people, families or tourists who will normally be the target audiences of this type of interactive books.

Further work is planned to improve the system’s scene understanding. This includes the accuracy of the mapping between the physical/digital worlds, as well as allowing for occlusions and ap-
Q1. How user-friendly is the AR pop-up book interface?

<table>
<thead>
<tr>
<th>Extremely user-friendly</th>
<th>Very user-friendly</th>
<th>Somewhat user-friendly</th>
<th>Not so user-friendly</th>
<th>Not at all user-friendly</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Q2. How useful is AR for providing additional information on traditional pop-up books?

<table>
<thead>
<tr>
<th>Extremely useful</th>
<th>Very useful</th>
<th>Somewhat useful</th>
<th>Not so useful</th>
<th>Not at all useful</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Q3. How do you think using AR and making pop-up books come alive might increase the interest in pop-up books?

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>18</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Q4. How satisfied are you with the look and feel of this AR pop-up book?

<table>
<thead>
<tr>
<th>Extremely satisfied</th>
<th>Very satisfied</th>
<th>Somewhat satisfied</th>
<th>Not so satisfied</th>
<th>Not at all satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>12</td>
<td>8</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Q5. How likely is it that you would use such AR pop-up books in the future?

<table>
<thead>
<tr>
<th>Very likely</th>
<th>Likely</th>
<th>Neither likely nor unlikely</th>
<th>Unlikely</th>
<th>Very unlikely</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Q6. Do you have any thoughts on how to improve AR pop-up books?

<table>
<thead>
<tr>
<th>Sound effect</th>
<th>Lively interaction</th>
<th>Specific instruction for each step</th>
<th>Future in the market</th>
<th>No answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 1: User experience survey results. There were 26 participant in total.

Q1. How accurate is the calibration of the coordinate system from different views?

<table>
<thead>
<tr>
<th>Very accurate</th>
<th>Accurate</th>
<th>Normal</th>
<th>Less accurate</th>
<th>Not accurate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Q2. How often the virtual component appears to the desired position?

<table>
<thead>
<tr>
<th>Always</th>
<th>Usually</th>
<th>Sometimes</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Q3. How fluent do you find the interaction between each?

<table>
<thead>
<tr>
<th>Very fluent</th>
<th>Fluent</th>
<th>Normal</th>
<th>Less fluent</th>
<th>Not fluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Q4. How often is the occlusion successful?

<table>
<thead>
<tr>
<th>Always</th>
<th>Usually</th>
<th>Sometimes</th>
<th>Rarely</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Q5. How clear to you when controlling the character and boat?

<table>
<thead>
<tr>
<th>Extremely clear</th>
<th>Very clear</th>
<th>Somewhat clear</th>
<th>Not so clear</th>
<th>Not at all clear</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Q6. Which of the issues below was the biggest problem during your experience with this AR pop-up book app?

<table>
<thead>
<tr>
<th>I experienced bugs</th>
<th>The app was missing features I needed</th>
<th>The app was confusing to use</th>
<th>The app was visually unappealing</th>
<th>The app crashed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Q7. Compared to the existing AR books, what are the advantages of this AR pop-up books? (Open Question)

<table>
<thead>
<tr>
<th>interaction on physical models</th>
<th>calibration</th>
<th>Skipped</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2: Feedback from Experts

Proprietary lighting. The graphical user interface also requires further improvement so that the experience is easy to access and enjoyable.

Physical maps are also of interest in future work, as they are also used as backgrounds for embedding digital content related to Cultural Heritage location, including photos, videos and their metadata [MOP'09, TDCB17]. These examples only differ from books in their purpose, as the map themselves are visual representations of a geographical area rather than a story. These latter examples are relevant to the Cultural Heritage domain, as content on heritage sites and environments can be associated with a geographical location.

Finally, our preliminary testing demonstrated that AR-enhanced books are promising in terms of allowing people to interact with relevant content through physical interfaces. Although testers will not normally have engaged with a pop-up book, they will consider it as a means to access AR experiences. Users also suggested enriching the experience with sounds, potentially from sound archives. As a future line of enquiry, we will consider how these experience can include a wider variety of archival media, including digitised text, audio, video and 3D models.

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