The Lloyd's Register Tangible VR Book: A Playful Mixed-Reality Interface for Exploring Maritime Heritage

Marcelo F. Coelho[1][0009−0000−7237−6865] and
Jorge C. S. Cardoso[2][0000−0002−0196−2821]

[1] University of Coimbra, DEI, Coimbra 3030-290, Portugal
[2] University of Coimbra, CISUC/LASI, DEI, Coimbra 3030-290, Portugal.
mfcoelho@student.dei.uc.pt, jorgecardoso@dei.uc.pt

Abstract. This paper presents the Lloyd's Register Tangible VR Book, a playful mixed-reality interface that combines a physical book with immersive virtual content to support interactive storytelling. Using a smartphone-based VR setup, users interact with printed pages augmented with markers that trigger spatially distributed digital media, including 3D models, archival images, narration, and 360º environments. The system allows content to be arranged across multiple spatial planes around the user, encouraging exploration and comparison of materials within an immersive setting. We demonstrate the system through the case study of the Fullagar, the world's first fully welded ship. The resulting experience transforms archival materials into an interactive narrative that users can physically navigate and explore. This work shows the potential of low-cost tangible mixed-reality systems for playful, physically grounded exploration of complex content in public and educational settings.

Keywords: Tangible interaction · Virtual reality · Interactive storytelling · User experience

1 Introduction

The Lloyd's Register Foundation Heritage Centre[3] is rich with historical and technical insights into ship design, construction, and maritime safety, dating back to the 1760s. Despite their value, these materials are difficult to explore in engaging and interactive ways due to their complexity and format, which are not well-suited for modern educational environments: material consists of static, sometimes difficult to read, digitized records. Research indicates that static presentations of complex documents can lead to disengagement, particularly when these materials require specialized knowledge to understand [5]. This highlights the need for more intuitive, interactive formats to make such resources accessible. Studies show that hands-on, immersive learning environments, such as those incorporating Virtual Reality (VR) or Mixed Reality (MR), significantly improve engagement and retention of complex subjects [3].

[3] https://heritage.lrfoundation.org.uk/

Based on prior work [4] that outlined a design space for marker-based Tangible User Interfaces (TUIs) for VR, we built a smartphone-based tangible VR book system. A physical book with 2D barcodes is enhanced with digital immersive content using a smartphone VR enclosure. While the book serves as the main interaction method to explore the story contents, the system supports different spatial layouts for the immersive content: anchored on the marker/page; in front of the user; to the sides of the user; around the user as 360º images or video. The system also allows MR mode by using the smartphone's camera.

Using data from Lloyd's Register as a case study, we created the VR Book[4] with the story of Fullagar - the world's first fully welded ship.

Our contribution is threefold: (1) a tangible mixed-reality book interface for interactive storytelling, (2) a flexible system for spatially placing immersive content around the user, and (3) a replicable, low-cost platform suited for public exhibitions and educational contexts.

The system potentially enables a playful form of exploration, where users actively navigate and build the narrative by physically interacting with the book and spatially distributed virtual content. With this project we aim to understand if content shown in Extended Reality (XR) is seen as engaging and whether it affects learning. We also want to understand the impact of content layout on user experience.

2 The Tangible VR Book System

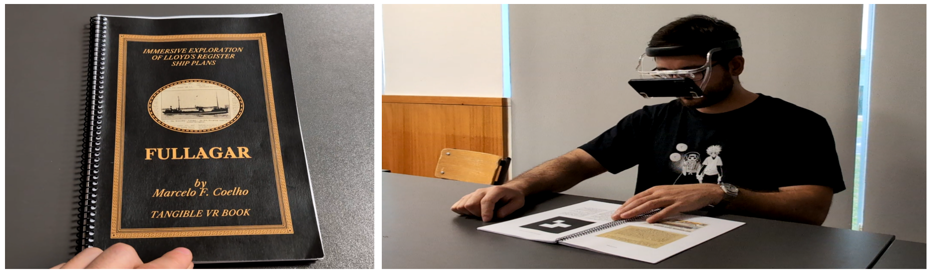
The system combines a physical book with a smartphone and mobile VR headset (Fig. 1). By scanning a QR Code to load a WebXR mobile application and placing the smartphone on an MR enclosure (Fig. 1b), users get access to an interactive environment through a look-to-trigger interaction mechanism. The experience can include images, audio (including narration), video, static and animated 3D models, and 360º images or video.

Content can be distributed across four spatial interaction planes (Fig. 1c): on the marker, in front of the user, to the left, and to the right. When multiple elements exist on a plane, a navigation bar (Fig. 1e) allows switching between content.

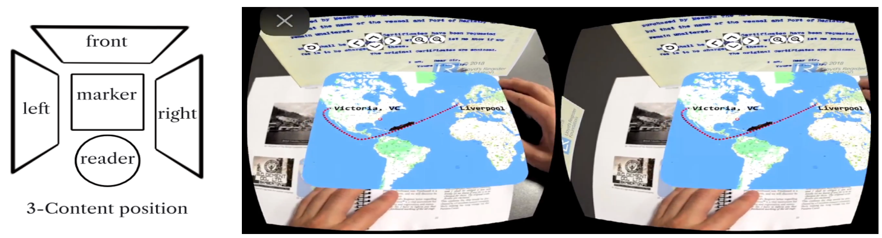
Users can interact with content in multiple ways (Fig. 1d). Documents (images) can be zoomed into for detailed inspection and repositioned within the scene. 3D models support scaling, rotation, and translation, allowing users to examine them from different perspectives. Video content includes standard playback controls (Fig. 1e). These interactions support exploration, potentially leading to higher engagement with the material.

A web-based authoring tool can be used to structure the book's content, defined using a JavaScript Object Notation (JSON) structure, enabling flexible creation of new narratives by associating media files with specific barcode markers and defining the layout of the content.

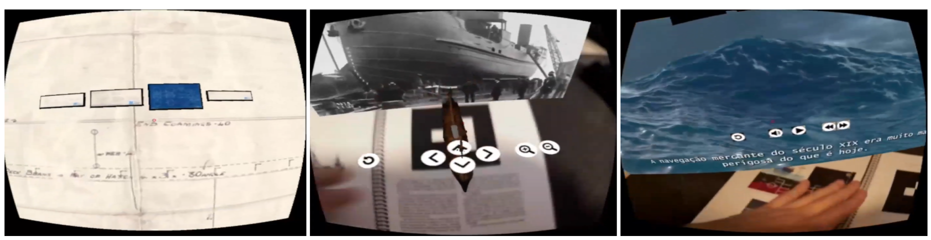
[4] Demonstration video available at: `https://vrlab.dei.uc.pt/lrvrbook/`



(a) Cover (b) Usage



(c) Interaction planes (d) User view in VR showing an interactive map



(e) Navigation thumbnails; reset, zoom and rotation controls; video controls

Fig. 1: Lloyd's Register Tangible VR Book

2.1 Lloyd's Register Tangible VR Book

We instantiated a tangible VR book with Lloyd's Register material to present the story of "Fullagar". Users learn about Fullagar (1920–1937) story through the following timeline: 1920 launched as first welded ship → 1924 sandbank accident → 1924–1925 renamed *Caria*, sold to Vancouver, later renamed *Shean* → 1930 rock cliff accident → 1935 renamed *Cedros*, sold to Mexico → 1937 collision off Ensenada: total loss.

The book has 42 pages of content and 10 barcode markers. Content was mostly taken from Lloyd's Register archive images. A few 3D models were created and animated manually in Blender. An approximate 3D model of Fullagar was created with an image-to-model Artificial Intelligence (AI). Narration was generated via Text-to-Speech (TTS) AI.

3 Lessons Learned

Although no formal user studies have yet been conducted, the system's development and public demonstration yielded several practical insights that have been incorporated into the final design.

Robustness vs. aesthetics. We initially used MindAR image tracking library[1] which allows for natural image tracking. Although this allowed for more a visually pleasing physical book where images directly related to the content could be used for page identification and tracking, it proved unreliable under variable lighting during a public deployment. We thus switched to AR.js barcode markers[2]. This improved robustness at the cost of visual aesthetics of the pages.

Reproducibility of the physical artifact. The book evolved from an A5 format with 3D-printed components to a simpler spiral-bound design with standard printed pages, reducing production complexity and improving replicability.

Preloading over dynamic updates. Dynamic loading of 3D content introduced latency. Pre-generating the full A-Frame scene and toggling visibility improved responsiveness and simplified state management. Although with a higher initial loading time, this improves the user experience during the actual use of the VR Book.

Explicit vs. implicit interaction. For large images, an initial gaze-based edge scrolling caused unintended activations due to overlap with other elements. Replacing it with explicit on-screen buttons improved interaction reliability at the cost of naturalness.

4 Conclusion

This paper presented a tangible VR system that combines a physical book with an immersive virtual environment. The current implementation demonstrates a flexible approach for linking physical artifacts with spatially organized VR content. The system is intended as a platform for interactive storytelling and educational exploration, and future work will focus on evaluating interaction layouts and expanding the content creation tools. Future user studies will compare different content distributions, including four-sided spatial layouts versus simplified centered layouts, in order to evaluate usability, engagement, and learning effectiveness

Acknowledgments. This work was supported by Lloyd's Register Foundation under grant Sg10\100005, "Tangible VR Book: Immersive Exploration of Lloyd's Register Ship Plans." This work is further funded by national funds through FCT – Foundation for Science and Technology, I.P., within the scope of the research unit UID/00326 - Centre for Informatics and Systems of the University of Coimbra, `https://doi.org/10.54499/UID/00326/2025`.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article

References

1. MindAR | mind-ar-js, https://hiukim.github.io/mind-ar-js-doc/
2. AR-js-org/AR.js (Jun 2026), https://github.com/AR-js-org/AR.js, original-date: 2020-02-28T09:03:36Z
3. Bacca, J., Baldiris, S., Fabregat, R., Graf, S., Kinshuk: Augmented Reality Trends in Education: A Systematic Review of Research and Applications. Journal of Educational Technology & Society **17**(4), 133–149 (2014), https://www.jstor.org/stable/jeductechsoci.17.4.133
4. Cardoso, J.C.S., Ribeiro, J.M.: Tangible VR Book: Exploring the Design Space of Marker-Based Tangible Interfaces for Virtual Reality. Applied Sciences **11**(4), 1367 (Feb 2021). https://doi.org/10.3390/app11041367, https://www.mdpi.com/2076-3417/11/4/1367
5. Hill, J.R., Hannafin, M.J.: Teaching and learning in digital environments: The resurgence of resource-based learning. Educational Technology Research and Development **49**(3), 37–52 (Sep 2001). https://doi.org/10.1007/BF02504914