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Mixed Reality as a Tool for the Design and Implementation of Virtual Exhibits

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Abstract

This work aims to use Mixed Reality (MR) as a method for the creation of virtual exhibitions. With the rise of digital content being used in GLAMA (Galleries, Libraries, Archives, Museums, and Academia), there is a gap in the literature surrounding MR approaches to assist in the exhibition creation pipeline. For this, we propose a novel approach that uses MR to spatially map out environments and have produced a bespoke toolkit called "Exhibit-MR". This uses Microsoft HoloLens 2, and was created in the Unity games engine. This application provides an accessible way to create exhibitions without the need of external software or technical experience, which has limited many frameworks in the past. This is due to its semantic understanding of environments paired with the development environment. This approach will be validated in a future user based study outlined in this work utilising the System Usability Scale to gain an understanding from the GLAMA sector to whether this approach could be adopted, and streamline virtual exhibition creation in the future.

CCS Concepts
• ***Human-centered computing*** → ***Mixed / augmented reality; User interface toolkits;*** • ***General and reference*** → *Design;*

1. Motivation

Extended Reality (XR) - being an umbrella term encompassing Mixed Reality (MR), Augmented Reality (AR), and Virtual Reality (VR) - is being increasingly applied to a range of applications since the development of affordable, consumer-grade devices [IUMV23]. There has been specific interest in the GLAMA domain (Galleries, Libraries, Archives, Museums, and Academia), where the application of XR offers a solution to a number of contemporary challenges.

Within cultural heritage (CH), there is a need to incorporate new and exciting technologies to grab individuals' attention. This can be attributed to the traditional museum struggling to keep up with modern times, as visitor numbers are dropping without new technology [ARSPR20]. Similar conclusions are met by Buhalis [BK22], where Gen Z express that CH can benefit from XR; later stating that these sites require considerable modernisation to create transformative experiences.

One of the fastest-growing trends in exhibitions is the addition of immersive technology displays [Par20]. However, with this emerging technology, creating dynamic and bespoke spaces can still prove to be a difficult task. This often requires expensive software, hardware, and expert technical knowledge.

XR presents significant potential for enhancing the planning and creation of virtual exhibitions by enabling spatial visualisation of artefacts within their intended exhibition context. Nevertheless, existing development solutions frequently lack inbuilt spatial integration with the surrounding environment and often demand considerable technical expertise during creation. The approach presented in this work seeks to address these limitations through a spatially aware system that captures the geometry of the exhibition space, allowing exhibition items to be placed on walls, ceilings, or floors with accurate spatial positioning. This will be achieved through an intuitive authoring process that facilitates use by individuals with minimal prior training. These characteristics will render the system particularly suitable for exhibition design, supporting realistic spatial planning, rapid iterative development, and accessibility to a broad range of curators and designers.

2. Background

Digitisation processes are becoming integral parts of development strategies in GLAMA. Today, the modern museum visitor expects innovative technology to improve the quality of the interaction gained [ARSPR20].

Bekele [Bek22] found that incorporating interactive technologies benefits customer satisfaction by having an improved sense of presence and learning being achieved. Garcia [GRSMGL19] drew

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similar conclusions, noting that the incorporation of this technology can assist in the learning process in heritage contexts. There is also the benefit that incorporating MR can indirectly assist with preservation. For example, creating digital archives that can last forever without degrading. Furthermore, these digital artefacts have the added benefit of being virtually handled without risk of damage, making experiences more personal [Fal24].

Previous work has noted that an expectation to include these experiences is clear [ARSPR20] and it has been found that XR enhances museum curation and exhibition practices, by providing new ways to interact with museum items [SE24]. The choice of platform can be difficult as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) each have their advantages in creating unique and memorable experiences. The issue is that these all have varying implementations and interactions. Regarding each platform, creating spatially aware systems also produces its own set of challenges. Looking into galleries and museums specifically, the question becomes: how are these experiences being created?

A study by Lin [LSL*18] showcased a visitor-centred environment for a smart art gallery. XR optical cameras, alongside AR were used to create a personal and interactive museum experience in a gallery space. This technology was implemented through marker-based AR, using empty picture frames throughout the gallery. There was also the addition of interaction through pieces alongside the main picture frames that could be manipulated through AR. The main way of accessing this content was through a mobile phone, walking around the room using the device to view and interact with the virtual content. This marker-based approach provides some ability to adapt the exhibit, but the experience is tailored for this venue, making it unsuited for changing location.

Another approach was Gamin [GHSW21], where photogrammetry was used to capture underwater heritage sites situated on the seabed of the Maltese islands. Here, underwater heritage sites were transformed into 3D models available for digitised viewing through a website. Information is present in highlighted areas, and the models can be viewed in VR through the browser, connecting to a local device for viewing. Gambin's approach provides a mostly accessible way to view the content, being available on consumer handheld devices; however, it relies on users to have specific hardware to view the content through XR.

As previously mentioned, there are many options when it comes to the platform choice. Web-3D is a popular option for the creation of virtual museums and galleries, which tend to tailor towards VR experiences. Web-3D is a group of technologies used to display and navigate websites using 3D computer graphics [CR07]. There can be many benefits to using Web-3D, as it can be viewed almost anywhere as long as a capable device is present. As Web-3D is a popular choice for the creation of virtual museums, the are many frameworks that exist to simplify the development of these experiences. Examples include Mendes [MDSB10], who proposes an interactive 3D tool using Web-3D to create virtual museums. Similarly, Kiourt [KKP16] proposes a framework that has a user-focused implementation, relying on individuals to create exhibitions. Conversely, there are also disadvantages surrounding Web-3D, such as limited rendering capabilities of web browsers [YLF*23]; additionally, requiring an internet connection. These, and many more existing approaches, are often tailored towards non-expert users. This has the advantage of being more accessible to museum staff and curators, with Kiourt even moving towards the public to create virtual exhibitions. Mendes and Kiourt target one of the aims of this work, with accessible authoring tools; however, they do not consider the inclusion of spatially aware systems.

Modern game engines are proving popular in the creation of interactive GLAMA environments, due to their graphical advantages and inherent portability benefits. A museum creation tool was made by Shrestha [Shr09], which uses a game engine to allow for quick development with interactable elements; allowing for preferences to be saved for future creations. However, this approach does not relate to the layout or spatial qualities of a physical museum.

Spatially aware systems are defined as having a comprehensive understanding of surrounding environments, allowing for digital content to be overlaid onto the physical world [JLCL24]. Jang [JK23] proposes a framework for producing semantic-rich environments while improving historical knowledge and spatial expression. However, their approach is labour-intensive and requires significant work to capture these locations to use in the application. Geography Markup Language (GML) is required so a detailed floor plan can be produced and then modelled up into a 3D environment, which can later be used to embed spatial content into. This approach requires further costs in developing each experience, not able to easily translate or scale to another location.

The lack of spatially aware systems accessible to non-expert users presents a significant problem. There are tools which exist separately, but no existing tools tie together a full creation and deployment pipeline. Furthermore, there is a lack of MR being used within the creation process of these experiences. MR can be used to spatially map out rooms and gather complex data, but no existing work seeks to leverage this.

3. Methodology

There are three objectives in the current phase of research:

1. To be able to digitise physical rooms using a spatially aware application.
2. To develop an exhibition creation toolkit.
3. To integrate both the spatially aware application and the exhibition creation toolkit into a single development pipeline that can be used by a non-expert.

3.1. Participants

As this study is in its incipient design phases, we have yet to determine an intended sample size. With this in mind, we plan to use a priori power analysis to determine a suitable number of participants given our experimental procedure. The recruited sample demographic will have experience working in GLAMA contexts, specifically within the area of museum or display creation. In the event that the target sample size is not achieved, the sample may be supplemented with professionals who design theatrical sets, given the functional similarity of their skill sets. As our experimental methodology concerns the usability of our toolkit, our focus is not on prior experience with MR exhibition creation. This means there is no prerequisite knowledge needed to participate in the study.

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3.2. Procedure

This study plans to run over 3 three phases: Onboarding, Activity, and Evaluation - taking place on the University of Staffordshire campus, with the possibility of travelling off-site to museums.

1. Onboarding - Participants will have a demo of the Microsoft HoloLens 2, highlighting its core user-input methods. This will showcase all interaction types (Hand Rays, Distance Pinches, and close hand interaction) and provide foundation knowledge on how the HMD functions. Then they will be supplied with technical documentation with video counterparts on “Exhibit-MR” providing an operational overview.
2. Activity - Participants will then have a series of tasks to complete within the application. There will be a 30-minute maximum time to complete the tasks.
3. Evaluation - Participants will answer a questionnaire based on the application and experience. This will include 10 questions on the application, informing about its usability with follow-up questions relating to various user metrics and the experience.

3.3. Equipment

The proposed technology to be employed is the Microsoft HoloLens 2, a head-mounted display (HMD). This is due to its ability to capture spatial information and support simple interactions without the need for external controllers. Using this HMD supports all areas of the application, allowing for environmental data to be captured and user interaction to drive the exhibition creation. This centralises all functionality within a single toolkit. While other technologies (such as modern mobile phones) could achieve part of this process, having both in a user-friendly manner would be difficult. Another benefit of this HMD is that it still allows the user visibility of the physical world, with MR content overlaid. This makes it ideal for museum contexts where real-world exhibits are likely to be present among their virtual counterparts.

3.4. Evaluation Design

The design of the evaluation phase follows a two-part user validation process. The first step requires participants to evaluate the application against the System Usability Scale [Lew18], informing usability insights of “Exhibit-MR”. The second step captures information relating to user demographics, proposed use-cases, and open comments surrounding the application.

4. Artefact

The HMD utilises optical cameras and sensors to constantly capture spatial information regarding its surroundings that allow for peripheral environmental understanding. However, replicating this information inside of “Exhibit-MR”, our bespoke toolkit, requires significant technical implementation given the need to contextualise the environment into individual elements, such as walls, floors, ceilings, and furnishings. For this, the Unity game engine was used, specifically version 2021.3.15f1. The choice behind the software was due to official development packages being publicly available from Microsoft to aid in platform-specific development.

The application uses the Mixed Reality Tool Kit (MRTK) [Mic22a] from Microsoft to set up the foundations of the MR interaction. In addition to the use of MRTK, the experimental ‘Scene Understanding’ [Mic22b] package was added to the project which allows for semantic representation of real world objects as well as their geometric forms. This was crucial as it allowed the application to perform the contextual understanding of aforementioned environmental factors. This package utilises the spatial information the HMD is generating and spawns in-game objects that mimic the real environment. These objects are then manipulated through custom scripting so they can be used within the application.

Exhibit-MR features floating menus that are projected into the MR environment, which enables full control of the application; an image depicting this can be found in Figure 1. These are controlled via pushing virtual buttons with an index finger or using the distance select gesture of the HMD. This enables simple navigation whilst limiting the amount of information present on each menu, avoiding UI clutter.

Figure 1: *A screenshot from the application, showing the placement menu of a picture frame, highlighting the chosen frame in its placement phase.*

4.1. Workflows

Within the application, there are two modes that can be used: creation and viewing mode. In creation mode, various digitised objects can be virtually placed, utilising the spatial information captured through the Scene Understanding package. Examples of digitised objects include picture frames, information stands (plinths), display stands, and artefacts. These are found through their respective menus, with visuals representing each piece. When an exhibition item is selected, a custom placement behaviour is activated. A holographic representation of the object then follows the user’s chosen hand, aligning accurately with the physical environment or virtually positioned elements, such as display stands. This enables the virtual items to be positioned on the aforementioned environmental factors, as well as their virtual counterparts. This item can then be spawned into the world once the user is happy with its placement by selecting a tick button on a floating menu. This can also be seen in Figure 1.

Each placeable object can be further customised regarding its position, scale, rotation, and texture, with information stands having text customisation. Once an object has been placed, it is temporarily cached in the game engine. This process is repeated until the

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entire exhibition is finished. Following this, all cached objects can be saved from the base menu to a save slot. Each save slot can be loaded from the creation mode to allow new objects to be placed and existing objects to be edited or removed. Figure 2 represents a partially created exhibition during the creation mode.

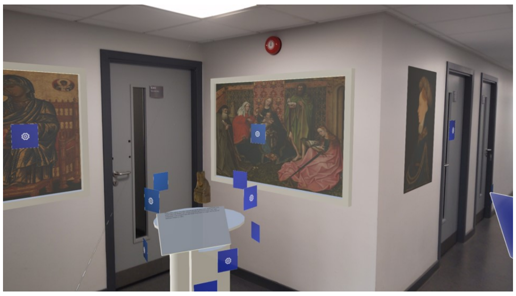

Figure 2: *A screenshot of an example virtual exhibition. This represents what an exhibition may look like, with picture frames, display stands, artefacts, and information podiums present.*

At any point in the creation process, the environment can be re-scanned to fix any spatial information which may be broken or missing. This is achieved by pressing a button on the base menu labelled "Rescan Environment" while walking around the real-world location.

The other way to use the application is a viewing mode, where pre-made exhibitions can be loaded through save slots. This disables the ability to customise or add any new content, but allows interaction with artefacts. Figure 3 illustrates a user manipulating a virtual artefact, enabling closer inspection and thus fostering a deeper understanding of the exhibition item. Virtual artefacts can be held, rotated, and scaled up/down while being touched. Real-world exhibition items themselves do not gain direct interactive capabilities through this application; however, virtual content can be integrated to augment the physical pieces. This may involve adding spatially positioned information around the artefact or providing a manipulable virtual replica for user interaction.

Figure 3: *A screen capture taken from the HMD, showing interaction with an artefact using a hand grab.*

4.2. Extensibility

The application can be expanded in all major areas. Being a toolkit, all core components would need to be edited in the game engine. This would include scripting new interaction types or changing core behaviour. However, all exhibit elements are expandable at runtime, meaning any new textures for picture frames, models for artefacts, or descriptions for information stands can be added by end users. All assets are uploaded through a persistent data path, which is imported into the system at run-time following a simple naming convention and storage location.

5. Conclusion

This paper introduces Exhibit-MR, a Mixed Reality toolkit that enables non-technical users to design and deploy virtual exhibitions within any location. Built in the Unity game engine and utilising the Microsoft HoloLens 2, the system integrates room scanning with an intuitive object placement tool that factors in the local environment. This addresses a key gap in spatially aware accessible exhibition creation tools for the GLAMA sector. Therefore the focus of this work is not on introducing new technical methods, but on evaluating how Mixed Reality can support the creation of virtual exhibitions. By leveraging existing tools, we isolate and examine the human–technology interaction process, providing insights into how MR can assist in the creation pipeline.

The proposed evaluation, using the System Usability Scale and a user survey, will assess Exhibit-MR's effectiveness and adoption potential with non-technical users. While early development shows promise, the evaluation will identify whether the system is viable for GLAMA contexts. This project represents a step toward more inclusive and scalable approaches to virtual exhibit curation, with significant potential for broader application across cultural and educational fields.

5.1. Future Work

As this is an initial exploration, there is much to consider regarding the future direction of this research. For example, further development could improve the interaction and customisation of exhibitions. However, the intended first step is conducting the study outlined in the methodology, which will provide insights into the usability of MR in the creation of virtual exhibitions. Another consideration is the comparison of this toolkit to another; currently, this is not possible due to a lack of similar tools of this nature. One potential future avenue is the exploration of concepts surrounding MR in GLAMA, such as best practices for showcasing exhibition information. Similarly, this concept could be applied in a VR counterpart to explore if insights are comparable across the two.

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