Authoring Tools for Mixed Reality

Jack Brett
jbrett2@bournemouth.ac.uk
Bournemouth University
United Kingdom

Charlie Hargood
chargood@bournemouth.ac.uk
Bournemouth University
United Kingdom

ABSTRACT

This work explores the need for a comprehensive understanding of best practices in mixed reality storytelling authoring tools. With the rapid development and increasing adoption of mixed reality technologies, there is a growing demand for effective tools that enable the creation of compelling and immersive narratives. To address this need, a literature review was conducted that encompassed three key areas: Games, Interactive Digital Narratives (IDN), and eXtended Reality Installations (XRIs). By synthesizing the consensus on best practices from these diverse domains, this paper aims to provide valuable insights into the design and development of mixed reality storytelling authoring tools. The review of literature revealed a range of perspectives and approaches in each domain. Based on this analysis, a survey of existing mixed reality storytelling authoring tools, highlighting their strengths, weaknesses, and notable features is presented. By examining the principles that underlie these tools, key design considerations for creating effective authoring tools was established. The findings contribute to the development of a holistic framework for designing mixed reality storytelling authoring tools that take into account the unique affordances and challenges of this emerging medium. By synthesizing best practices from multiple disciplines, this paper provides a valuable resource for researchers and practitioners interested in exploring and advancing the field of authoring tools for mixed reality.

1 INTRODUCTION

This paper presents a survey of the current state of the art in authoring tools. Its objective is to define their characteristics, and understand contemporary consensus on the strengths, weaknesses, and user experience of different forms of tool design as part of a broader project on the state of the art of mixed reality authorship. The research questions guiding this paper are:

(1) How can an authoring tool be defined?
(2) What is the current state of the art in authoring tool design?

The paper focuses on providing best practices and categorizing authoring tools in specific domains. It discusses these best practices and synthesizes them into key points before delving into the analysis of the findings. The domains covered include Interactive Digital Narratives (IDNs), video games, and eXtended Reality Installations (XRIs), with a particular focus on designing tools for location-based and narrative-rich experiences. The ultimate goal of this research is to develop authoring tools for heritage sites and museums that can create engaging interactive Mixed Reality (MR) experiences for potential visitors.

1.1 What is an authoring tool?

An authoring tool is a software application that enables designers, developers, or "authors" to create specific solutions within a particular domain. Defining the boundaries of authoring tools requires careful consideration, taking into account user proficiency, artifact complexity, and various definitions proposed by researchers and practitioners. In this paper, a suitable definition is provided through evaluation, integrating prior research and addressing the project's requirements. This definition serves as a framework for the subsequent sections and assists in defining custom tools for the project.

Initially, there was a broad assumption that an authoring tool would allow users to create a wide range of artifacts. However, a more focused understanding emerges from considering descriptions provided by [13, 14, 24] and other online sources [4].

While sources and previous attempts to define authoring tools differ as to their specificity, demands for technical skill, and form we can agree a set of three principles to define tools:

(1) **Support the creation of a defined form**: Authoring tools are technology for the creation of a specific form or medium of work - such as a game or Hypertext.
(2) **Aid in overcoming the technical barriers to authorship**: authoring tools may include technical skills such as programming but all prioritise aiding the author in overcoming the technical barriers of their medium and to streamline the process.
(3) **Prioritise accessibility**: Authoring tools seek to bring the creation of its target medium within reach of new creatives. They use templates, predefined functions, and GUIs to minimise learning curves.

2 EXISTING STATE OF THE ART

Following the first principle of our definition we have arranged our review based on three forms and their respective research fields: Games, IDNs/Hypertext, and XRIs. There are overlaps between these categories, and prior work has established how both games and IDNs can been seen as, or understood through the lens of, Hypertext [20], but we use the focus on play, narrative, or extending reality as a lens to initially categorise this work.

2.1 Authoring Tools for Games

Video game authoring tools primarily exist in commercial settings. These tools can be classified into three distinct groups: *Full Graphical Engines*, *Genre Engines*, and *Extensive Plugins*. Full graphical engines are used by experienced users to create complete games (this includes engine IDEs such as Unity and Unreal) [3, 8, 16, 18], *genre engines* cater to specific game categories (such as, *RPG Maker* [10]), and *extensive plugins* extend existing engines with additional

functionalities [6]. The target users vary from beginners with basic technical knowledge to proficient programmers (although all users do require some knowledge or experience of game development). A notable gap was observed in accessible authoring tools for absolute novices and non-technical individuals, particularly in the realm of mixed reality game experiences.

The academic research and publications pertaining to authoring tools specifically for creating video game experiences are limited, resulting in a lack of expert reviews and evaluations. However, insights were obtained through firsthand usage of the tools by the researchers and examination of writings by authors who employed these tools in their own experiences [16, 18]. From this collective information, a compilation of common issues and a subsequent set of best practices emerged.

A common limitation appeared to be the steep learning curves required to use the tools efficiently. While many tools, such as Unity Engine [18], allow the creation of a host of different experiences and games, it was observed through using such tools that the creation of specific concepts was complicated to implement. Example projects and tutorials only extend to basic functionalities and developing more intricate experiences that many authors envisage often requires the use of complex programming knowledge, leading to increased resources regarding time and energy inputted to achieve the desired outcome. The use of user generated content can help ease this frustration as beginner authors can make use of tool sets and specific plugins [6] to help appease the creation of their more complex designs.

Compatibility issues with external tools and the risk of projects becoming outdated due to frequent tool updates were also prevalent concerns [8]. Furthermore, authors expressed frustration with the limited flexibility of the tools, as they imposed predefined functionalities and restricted developers from extending or customizing them to suit their specific needs. Consequently, this led to creative constraints and the need for workarounds that compromised performance. Insufficient support and inadequate tutorials exacerbated these issues, prompting experienced developers to devise their own systems instead of relying on pre-built solutions (a common issue when engaging first hand with such tools during this research).

However, the findings highlighted a set of best practices for designing game authoring tools to enhance user experience and productivity. In summary, these practices include prioritizing user-friendly interfaces and tailoring the workflow to specific end users, rather than aiming for a one-size-fits-all solution [7].

Intuitive on-boarding experiences with comprehensive tutorials and example projects are typical UX design principles and were found to be crucial for enabling designers to quickly grasp the software and rapidly prototype their ideas. Many of the tools that were used lacked such principles and led to longer development times as time was dedicated to understanding the tool rather than being able to build from a foundation. The availability of extensive libraries and the ability to incorporate user-generated content further fostered creative freedom [18]. Optimization features were an important aspect identified for handling graphically intensive or performance-demanding game elements, while intuitive design ensured that performance metrics were easily understandable [29].

Ensuring that there is an easy way to feedback will lead to rich information on how to improve an authoring tool throughout its lifetime [7]. Implementing such features is imperative for improved user experiences which lead to authoring tools that are easy to comprehend and ensure that the end user has the most flexibility in their creation of new experiences.

2.2 Authoring Tools for IDNs

Authoring tools for the purposes of creating IDNs were the most prolific and were found extensively within and outside of academia. Drawing upon the work of Shibolet et al. [24], three main groups were identified: Parsers, Hypertexts, and Hybrid tools. Parser tools (such as, [23]) offer *command-interface-based textual narratives* [24] that is facilitated by a specific domain language or a menu system that offers a more user-friendly approach. Hypertext tools are *lexia-tree based structured* [24] and are navigated by clicking portions of the text (such as, [11]). Finally, Hybrid tools include graphical based tools (such as, [2]) and more bespoke tools (such as [27]). These tools either aid in creating narratives of a graphical nature or a designed for a specific use case.

Typically, parser artifacts lean towards providing open navigation and aim to create a sense of a generated world, while hypertext resembles a choose-your-own-adventure book, focusing more on delivering a narrative and style rather than game-like mechanics. This differentiation is not absolute, though, as game engines allow text-based authoring, and some tools for interactive digital narratives (IDNs) offer real-time graphical rendering. However, the main distinction between these tools lies in their user interfaces, features, and emphasis on either graphics or text.

Notably, authoring tools in the IDN domain were primarily designed for authors with limited technical expertise, making their design patterns and practices particularly relevant to this research. The initial survey yielded an extensive collection of over 113 tools (in which a complete list can be made available), with a substantial portion originating from academic sources. Consequently, a wealth of best practices and reoccurring areas of weakness emerged from the analysis of these tools, providing valuable insights for this research.

There were multiple sources and papers which outlined evaluations of their novel tools from the perspective of the authors [14, 26]. From our review a number of key issues emerge:

- Real-world applications are overlooked, limiting understanding of long-term performance in diverse contexts [7]
- Usability testing is constrained by small participant numbers and researcher involvement, emphasizing the need for to gather insights from a larger participant pool [7]
- Evaluations focusing solely on end artifacts neglect the authors' experience and their potential for creativity [14]
- Narrow recruitment of domain experts limits perspectives, requiring diverse user groups for broader accessibility
- Reliance on qualitative data raises reliability concerns, warranting exploration of quantitative and empirical approaches for more robust evaluations [7].

In addition to observations and play testing, the research drew upon existing literature to identify key principles for developing authoring tools specifically for IDN artifacts. Notably, Green's work on UX design for IDN authoring tools provided valuable insights. Green's 5 principles of UX design regarding authoring tools [14]

was analysed, in which two key takeaways emerged. Firstly, it is crucial for authoring tools to enable users to swiftly navigate to specific areas of their projects, facilitating rapid prototyping and testing. This is particularly important considering the complex branching narratives often found in IDNs. Methods such as tagging, visually intuitive interfaces, and the use of visual metaphors appear to aid users in easily accessing desired sections of the story. Secondly, ensuring a clear and manageable representation of the story within the authoring tool is vital for effective organization, content management, and testing. Green emphasized the use of "visual metaphor" interfaces as a common practice to enhance the readability and comprehensibility of the story and its branching connections (with which there may be many in long and complex narratives).

An intuitive interface is crucial for authoring tools, allowing users to easily create and manage story elements, including branching paths and interactive elements. This principle aligns with Green's [13] work and is especially significant for IDNs, which often have complex narratives that can be challenging to navigate. Visual storytelling plays a vital role in enhancing immersion and engaging the audience. Therefore, it is imperative for authoring tools to provide stress-free importing of images, illustrations, and videos, along with libraries of user-generated content for easy access. It was observed that many authoring tools in this domain were lacking in this aspect, although some intentionally prioritise complex narrative creation over incorporating video game authoring tool paradigms. Striking a balance between high-fidelity artefact creation and accessibility for a wide range of authors remains a challenge in this field. Additionally, the ease of exporting and accessing created artifacts is a crucial consideration, with web-based tools [5, 15] that eliminate the need for additional downloads or logins being some of the most favourable examples.

Immediate feedback and defined outcomes for choices contribute to depth and replay value in IDNs. This principle expands on the previous point, emphasising the inclusion of UI elements such as clickable buttons in authoring tools to offer more than just writing functionalities. Notably, there is a subset of tools dedicated to creating "point and click" narrative experiences [1], which begin to blur the boundaries between video game and IDN authoring tools. Collaboration and co-authoring support are essential to facilitate seamless work among multiple creators. However, many authoring tools lack true collaboration and co-authoring features. Additionally, a "history" feature that allows other authors to track project changes over time is often absent. Borrowing ideologies from source control in software development could promote team collaboration and maximize creativity in IDN authoring tools.

In summary, these principles and practices highlight the importance of an intuitive interface, visual storytelling, immediate feedback, defined outcomes, collaboration support, and effective exporting in authoring tools for IDNs.

2.3 Authoring Tools for XRIs

Despite being a technology that is still emerging there are already an abundance of authoring tools for XRIs. Further investigation revealed the reasons behind this abundance. Many of these tools are designed for educational purposes, serving both classroom environments and practical implementations in museums and similar institutions. As the creators of XR experiences in these contexts are typically not experts in complex game engines, there is a demand for simpler tools to facilitate their creations. Additionally, the growing popularity of augmented reality (AR) and advancements in hardware have prompted more authors to explore AR for various applications, including marketing. Consequently, there is a need for user-friendly authoring tools to aid the development of AR solutions.

During the review of these tools, distinct sub-groups emerged, which were categorized as *Standalone*, *MR Plugins*, and *APIs*. *Standalone* tools involved custom-built software that allowed authors to create specific mixed reality experiences [12, 22], with recent tools focusing on implementing these experiences either on-site or remotely while preserving the visual context of the intended site [28]. *MR Plugins* encompassed specific features and patterns utilized within existing engines, predominantly the *Unity Game Engine*, often employed by individuals with prior experience or programming skills [6]. *APIs* [19] shared similarities with plugins but required additional programming knowledge for integration into engines, utilization in web applications, or as a foundation for custom software development. *Standalone* tools are designed for novice creators as they offer the most intuitive design and predefined functionalities, however, lack the ability to create a variety of artefacts due to their closed nature. Contrarily, MR Plugins and APIs introduce additional complexity, expanding the potential for creating a wide array of artifacts with varying degrees of intricacy.

While some Standalone solutions showed promise for beginners by leveraging new technologies, they often lacked the depth of interactive experiences typically found in games and did not prioritize narrative creation. These tools were more suitable for developing classroom experiences, gallery exhibitions, or for marketing purposes. Thus, the identified research gap for authoring tools catering to novices, enabling them to create immersive narrative experiences while incorporating mixed reality and game design elements, remained evident.

The review of authoring tools in this domain highlighted two main issues. Firstly, there was a lack of comprehensive evaluations from authors' perspectives, resulting in a decline in tool usage over time. This was not specific to any particular tool, but rather due to the absence of evaluations and limited public availability. Consequently, many tools remained active only during the development cycle, with usage only by the internal research teams. This prevented the realization of their full potential and stalled subsequent improvements through real-world evaluations. Gathering direct feedback from authors and incorporating their insights is essential for enhancing usability and longevity [14]. Secondly, the identified tools primarily focused on achieving goals such as marketing or educational pursuits, while lacking the capability to implement game features. Although there were tools available for creating video game experiences and tools for creating mixed reality experiences, there was a scarcity of tools that effectively combined both domains. Despite these limitations, the review provided valuable insights that can inform the development of more effective and user-friendly authoring tools in the future.

Authors often encounter frustration when creating experiences at specific sites due to the lack of cohesion between the mobile-based authoring tool used on-site and the desktop support available [28]. While the desktop aspects of authoring tools offer the flexibility for complex designs and prolonged development, the limited capabilities of the on-site mobile tool hinder customization and testing of the experience at the intended location [21]. This discrepancy results in time-consuming iterations and increased frustration. Future authoring tools should address this issue by either providing a robust mobile authoring tool that eliminates the need for a desktop application or by ensuring seamless integration between the desktop and mobile tools, allowing for cohesive and comprehensive authoring across both platforms.

Another common issue with augmented reality authoring tools is the challenge of accurately depicting the real-life space being created compared to the author's expectations [28]. Since authors cannot be constantly on-site during the creation process, they often rely on desktop tools [6, 25].

This leads to the aforementioned back-and-forth development and increased timelines, or the need for additional team members for quality assurance. Research is underway to address this issue by accurately depicting real spaces using augmented reality and enabling real-time content placement [28]. However, challenges persist, especially in larger-scale settings with complex terrain. A solution may be to allow authors to create rich experiences on-site using mobile technology, but limitations in using such devices on-site complicate this goal. Improving the cohesion between desktop and mobile authoring tools remains an issue to be resolved.

Another common frustration experienced with complex authoring tools, based on personal usage and conversations with existing users, was the significant time required for compilation, irrespective of the changes made. Designing rich experiences in virtual or augmented reality often involves numerous iterations and fine-tuning to achieve desired moments or seamless integration with existing content. Consequently, extensive testing is required, and fast compilation times are crucial to maintain workflow efficiency. However, some plugins [6] and standalone tools [17, 21] suffered from this issue. Even simple changes, such as text adjustments, triggered complete project recompilation, resulting in increased development time and frustration during development and user testing. Addressing this issue necessitates developers ensuring that project compilation only incorporates the specific changes made or offering on-the-fly compilation based on developers' modifications. While this concern initially pertains to authoring tools for regarding game engines, it underscores the significance of a smooth workflow for all users across various domains and tools.

3 DISCUSSION

In this work a review of the current state of the art of authoring tools was presented, highlighting outstanding design issues and priorities for future tools. As noted in the provided definition of authoring tools they are created for a clearly defined form and we have used that to structure our review: games, IDN/Hypertext, and XRIs. In seeking to understand the authorship of immersive experiences we might return to Ermi's work defining immersive games as a balance between Sensory, Challenge, and Imaginative immersion

[9]. Ermi's own triangle framework maps to our own three way distinction through understanding what is being authored to create these forms of immersion in mixed reality (Audio Visual Media, Play and Interaction, and Narrative) and by extension the forms which prioritise this content (XRIs, Games, IDNs) and are depicted in figure 1. It is worth noting that these are a continuous spectrum rather than a discrete distinction - all three forms may prioritise part of the immersion triangle but will cover aspects of all three. There is a
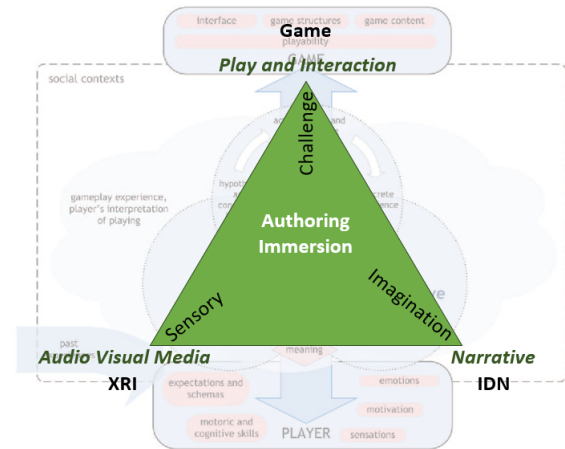

Figure 1: Our own triangle framework of immersive authorship: Sensory-Media-XRI, Challenge-Play-Game, and Imagination-Narrative-IDN layered on top of Ermi's original model figure from [9]

disparity in evidence between these points of the triangle - in terms of exploration of different tools, academic research attention, and the impact of key issues. Despite a significant quantity of immersive experiences being considered games, and a couple of high profile tools within this space, the body of research on authoring there is notably less than for IDNs/Hypertext and XRIs. Furthermore the state of the art in IDNs seems to prioritise non-technical authors and tool accessibility for novices more so than Games and XRIs. It is possible, that this is connected to the elements of immersion prioritised by these forms - that the technical challenges of interactive story structure are easier to overcome (such as through the use of the common story graph) than the technical challenges of complex interactive systems of game play or the rich media of XRIs.

An overarching issue, as echoed in the initial definition, is to clearly identify what is being authored, who is the author, and at what point in the process the tool is used (something echoed in Green's work [13]. Given the research's focus on the state of the art with regards to mixed reality, the tension between in situ and desktop authorship is a priority for this project. Improving the integration and cohesion between desktop and mobile authoring tools is crucial in addressing the challenge of enhancing the efficiency of the authoring workflow. Going forward, researchers and practitioners should ensure they have a specific target demographic in mind

for their tools or design them in a way that ensures accessibility to a diverse range of users.

Whilst this work attempts to provide an extensive review of authoring tools across multiple domains, it is important to note that there is limited expert evaluations specifically focused on these tools. Many of the insights were derived from firsthand usage and examination of researchers' experiences. Therefore, future research should aim to bridge this gap by conducting more in-depth evaluations from the perspectives of the authors, considering real-world applications and exploring quantitative and empirical approaches for more robust evaluations.

4 CONCLUSION AND FUTURE WORK

This paper has shed light on the strengths and limitations of authoring tools for games, IDNs, and XRIs. The findings contribute to a holistic framework for designing mixed reality storytelling authoring tools that account for the unique affordances and challenges of this emerging medium, benefiting researchers and practitioners in the field. Moving forward, the research will shift towards exploring the expectations of players and users in the context of mixed reality (MR) games and authoring tools. This investigation aims to gain insights into the specific needs, preferences, and desired experiences of the target audience. By understanding these expectations, a subsequent co-design process that will involve the development of multiple authoring tools through rough prototyping will commence. This iterative design approach allows for early exploration and validation of ideas, leading to the creation of functional prototypes. These tools will serve as a foundation for a larger scale study, which aims to design and implement a variety of MR games at heritage sites and/or museum settings.

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