Virtual and Augmented Reality Interfaces for 3D Mesopotamian Environments and Artefacts – A Survey

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This paper surveys twenty years of published works and implementations of virtual reality (VR), augmented reality (AR) and 3D repositories relevant to ancient Mesopotamia. Results are sorted according to type, relevance to cuneiform, evaluation, and availability. Of the eleven published works and five applications that satisfied the inclusion criteria, only one involved immersive VR, seven were related to cuneiform, only two were open source and there was little reporting of evaluation. The paper explores the design, development, and evaluation challenges involved in the creation of immersive, educational, and engaging 3D, AR, and VR experiences and looks ahead to future opportunities such as AI-assisted content generation.

Virtual reality, Augmented reality, 3D interfaces, Mesopotamia, Cuneiform

1. INTRODUCTION

There is something of a consensus that 3D repositories, and VR and AR technologies have the potential to widen access, engage, educate, satisfy and inform individuals across a range of topics. At the same time, there are concerns about VR hardware practicalities, visual fidelities and cybersickness, as well as concerns that some positive outcomes may relate more to enjoyed experiences rather than the promotion of learning (Makransky et al., 2021). There are also concerns that despite the considerable promise of 3D, AR, VR and immersive technologies, and early expectations and enthusiasm, there has been disappointing progress in terms of adoption (Hall et al., 2019). However, challenges aside, 3D, AR and VR experiences have repeatedly demonstrated significant educational potential (Kamińska, 2019) that can engage individuals by enlivening artefacts, concepts, environments and histories. This potential is significant in digital heritage applications and, particularly, for artefacts and histories, such as those from Mesopotamia, which are generally less accessible to learners. Mesopotamia was the fertile region between the Tigris and Euphrates rivers (in modern-day Iraq and Syria) where human civilization began some 5,000 years ago. Here, the first cities were built, and humankind's first system of writing evolved from pictograms to a highly sophisticated 'cuneiform' script impressed in handheld clay tablets. Unfortunately, there are few displays of Mesopotamian artefacts in museums worldwide, and very few displays of cuneiform tablets. Where they are displayed, the significance and cultural context of these artefacts can be very difficult to communicate in conventional exhibition displays but could substantially benefit from immersive AR or VR.

Figure 1: *A close-up of a cuneiform tablet with information (left) as shown in a virtual museum (right) (artefact models courtesy of National Museums Liverpool (World Museum))*

2. BACKGROUND

There is a growing body of research relevant to i) 3D acquisition of ancient artefacts and ii) 'computational Assyriology' that analyse and reconstruct artefacts,

and perform automated transliterations, translations and content analyses (Sahala, 2021). Yet, there are few Assyriological VR environments and games (Hanes, 2019). However, virtual heritage experiences for Mesopotamian history and engagements for cuneiform tablets (see Figure 1) have considerable potential to engage and educate, especially, given the relative lack of exhibited Mesopotamian collections and the physically unprepossessing nature of cuneiform artefacts (Woolley et al. 2021; Rhodes et al., 2022).

3. METHODOLOGY

Searches were conducted for 3D, AR and immersive VR Mesopotamian published works and available applications, projects and databases. For the published works: Google Scholar, IEEExplore and the ACM Digital Library were searched for from 2003 to 2023 with search terms including "Mesopotamia", "Assyriology", "Virtual Reality", "VR", "AR", "Cuneiform", and "Museum", etc.

Inclusion criteria: VR, AR, 3D interactions or repositories relevant to Mesopotamian history and artefacts AND published works or available implementations between January 2003 and January 2023.
Exclusion criteria: Works limited to the reporting of 3D acquisition, image analysis and content interpretation, etc. OR 3D/AR/VR interactions not relevant to Mesopotamia or cuneiform, etc.

The type of implementation, the category (or motivation), the development software/tools reported, and the availability of implementations and source code were determined and recorded.

4. RESULTS AND DISCUSSION

Tables 1 and 2 summarise the results for the applications (including projects and databases) and published works, respectively. Of the eleven published works and five applications that satisfied the inclusion criteria, only one involved immersive VR, seven were related to cuneiform, only two

Table 1: *3D/VR/AR Mesopotamian applications, projects and databases (2003-2023)*

Applications/ Projects/ Databases and *Descriptor*	Type	Category	Cuneiform-relevant?	Software/Tools	Evaluation?	In Use?	Code available?
Steam Nebuchadnezzar (2021) *Isometric city-building game*	3D (isometric game)	Game	No	Not reported	Not reported	Yes	No
Steam Ur (2022) *The Royal Game of Ur 3D*	3D (game)	Game	No	Not reported	Not reported	Yes	No
Cuneiform Digital Library Initiative (CDLI) *International cuneiform database*[1] *Pagé-Perron (2016)*	2D/3D (cuneiform archive)	Archive, Scholarship, Access	Yes	Website, various	Not reported	Yes	Yes[2]
Virtual Cuneiform Tablet Reconstruction *(VCTR) Project* [3] [4] *Woolley et al. (2022)*	AR/3D (research website)	Virtual Reconstruction, Access	Yes	Website, various	Various	Yes	Partially[5]
Sketchfab Collections *Cuneiform and Mesopotamian tagged collections* , e.g.,[6] [7]	3D	Archive, Scholarship, Access	Yes	Website, various	Not reported	Yes	No

[1] Cuneiform Digital Library Initiative (CDLI) https://cdli.mpiwg-berlin.mpg.de/
[2] https://gitlab.com/cdli/framework
[3] https://virtualcuneiform.org/publications.html
[4] The Virtual Cuneiform Reconstruction (VCTR) Project: https://virtualcuneiform.org/
[5] Source code for some project components is available
[6] https://sketchfab.com/tags/cuneiform
[7] https://sketchfab.com/tags/mesopotamia

Table 2: *Published works (2003-2023) relevant to 3D/VR/AR Mesopotamian implementations*

Published Work and *Descriptor*	Type	Category	Cuneiform-relevant?	Software/Tools	Evaluation?	In Use/Available?	Source code available?
Lucey-Roper (2006) *Discover Babylon Game*	3D	Heritage Game, Education	No	Vicious Engine (Defunct 2016)	Planned but not reported	Via archive[8]	No
Bogdanovych et al. (2012) *The city of Uruk*	3D	Education	No	Second Life	Fact recall quiz	No	No
Trescak et al. (2014) *City of Uruk 3000 BC with crowd simulation*	3D	Simulation, Education	No	Unity Game Engine	Not reported	No	No
Sanders (2015) *Virtual Tour of the Palace of Nineveh*	3D	Access, Education, Scholarship	No	Not reported	Not reported	No	No
Al-Baghdadi (2017) *3D printing, scanning and VR models*	3D	Access	Yes	Not reported	Not reported	Yes	No
Woolley et al. (2017) *Prototype artefact reconstruction interface*	3D	Virtual reconstruction	Yes	Three.JS JavaScript library	N/A	Yes[9]	No
Ijaz et al. (2017) *Virtual worlds vs books and videos (Implementation of 3D Uruk (Trescak, 2014))*	3D	Education	No	Second Life	Fact recall and qualitative feedback	Unsure	No
Woolley et al. (2020) *Virtual museum 3D artefact 'takeouts'*	AR	Education	Yes	AR for Processing, ARCore; iOS: ARKit	Not reported	Unsure	No
Hanes (2020) *Serious games - Assyriology case study prototype*	2D/ 3D	Education	No	Adobe Animate	Fact recall and qualitative feedback	No	No
Pietroszek et al. (2021) *The royal game of Ur*	VR	Heritage Game	No	Unity Game Engine	Informal feedback	Yes	No
Woolley et al. (2022) *Interactive 3D Viewer Interfaces*	3D	Access, Education, Scholarship	Yes	Three.JS JavaScript library	Ongoing	Yes	Yes[10]

[8] https://web.archive.org/web/20070516095349/http:/www.discoverbabylon.org:80/
[9] Available at https://virtualcuneiform.org/interaction3.html, superseded by Woolley et al. (2022)
[10] Available at https://github.com/virtualcuneiform/3DModelWebViewer

Figure 2: *The 'Discover Babylon' heritage game (left) and the Virtual Cuneiform Tablet Reconstruction (VCTR) Project (right)*

were open source and there was little reporting of development details and evaluation. The majority of publications and applications meeting the inclusion criteria used 3D interfaces, and only one published work used VR. Eight of the works were categorised as "educational", and five as supporting "access" to artefacts and heritage.

Two examples of screenshots from applications that matched the selection criteria are shown in Figure 2. The Discover Babylon 3D heritage role-playing game was developed in 2006 using the Vicious Engine (now defunct) and was intended to provide a "vivid user experience" that would "unite museum artefacts and library information" (Lucey-Roper, 2006). The VCTR project is an international research collaboration that has created virtual interfaces and interactions for cuneiform tablets (Woolley et al., 2022).

In searching on-line for Mesopotamian 3D, VR, and AR, one encounters a number of very good undergraduate student project works particularly related to Babylon and its Hanging Gardens. There is also a 'Babylon.js' 3D graphics engine which itself may inspire Babylonian creations. Additionally, there are a limited number of on-line videos of 3D Mesopotamian-relevant model flythroughs. However, these do not relate to published works or available applications and were therefore excluded.

5. CONCLUSIONS AND FURTHER WORK

Despite the excellent educational and scholarly potential of 3D, VR and AR interactions, the significance of Mesopotamian history and despite 20 years of research and innovation, there have been very few Mesopotamian-relevant works and projects, and few of these are maintained, available or open source. The Cuneiform Digital Library Initiative (CDLI) is a notable exception, being a maintained, available and open source archive, and one that is evolving, for example, in recently adding support for the viewing of 3D artefact models.

There are substantial challenges implicit in i) acquiring and creating 3D models, ii) designing and programming applications, interfaces and environments and iii) delivering, evaluating and maintaining cross-platform applications, projects and repositories. At the same time there are limited resources in heritage sectors. Whilst game engines such as Unity and Unreal Engine aim to democratise accessible VR development, there is still a significant learning curve for developers and a substantial time investment required of VR development.

With advances in generative AI and large language models (LLMs) such as OpenAI's GPT3 and GPT4, and Google's Bard and PaLM 2, there are new and exciting possibilities for future assisted creations of interactive 3D, VR and AR interactions, generated from text prompts and other user inputs. However, there are currently very few works that explore these opportunities. Hu et al. (2023) used GPT3 and the Stable Diffusion text-to-image model to generate AR media and Wong et al. (2022) used a custom conditional generative adversarial network to explore a VR editing system with AI-generated 3D objects and terrains. Perhaps future use of generative AI will enable heritage stakeholders to create entire virtual environments populated with interactive virtual objects and virtual agents and populations.

REFERENCES

Al-Baghdadi, M.A.S., 2017. *3D printing and 3D scanning of our ancient history: Preservation and protection of our cultural heritage and identity*. International Journal of Energy and Environment, 8(5), pp. 441-456.

Bekele, M.K., Pierdicca, R., Frontoni, E., Malinverni, E.S., and Gain, J., 2018. *A survey of augmented, virtual, and mixed reality for cultural heritage*. Journal on Computing and Cultural Heritage, 11(2), pp. 1-36.

Bogdanovych, A., Ijaz, K., and Simoff, S., 2012. *The city of uruk: teaching ancient history in a virtual world*. In Intelligent Virtual Agents Conference, Santa Cruz, pp. 28-35.

Champion, E. and Rahaman, H., 2020. *Survey of 3D digital heritage repositories and platforms*. Virtual Archaeology Review, 11(23), pp. 1-15.

Collberg, C., Proebsting, T., and Warren, A.M., 2015. *Repeatability and benefaction in computer systems research*. University of Arizona TR, 14(4).

Hall, L., Paracha, S., Mitsche, N., Flint, T., Stewart, F., MacFarlane, K., Hagan-Green, G., and Dixon-Todd, Y., 2019. *When will immersive virtual reality*

have its day? Challenges to IVR adoption in the home as exposed in studies with teenagers, parents, and experts. PRESENCE: Virtual and Augmented Reality, 28, pp. 169-201.

Hu, Y., Yuan, M., Xian, K., Elvitigala, D.S., and Quigley, A., 2023. *Exploring the Design Space of Employing AI-Generated Content for Augmented Reality Display*. arXiv preprint arXiv:2303.16593.

Hanes, L., 2020. *Presenting Ancient History Through Serious Games: A Case-Study in Assyriology*. PhD thesis, University of Birmingham.

Hanes, L. and Stone, R., 2019. *A model of heritage content to support the design and analysis of video games for history education*. Journal of Computers in Education, 6, pp. 587-612.

Ijaz, K., Bogdanovych, A., and Trescak, T., 2017. *Virtual worlds vs books and videos in history education*. Interactive Learning Environments, 25(7), pp. 904-929.

Kamińska, D., Sapiński, T., Wiak, S., Tikk, T., Haamer, R.E., Avots, E., Helmi, A., Ozcinar, C., and Anbarjafari, G., 2019. *Virtual reality and its applications in education: Survey*. Information, 10(10), p. 318.

Lucey-Roper, M., 2006. *Discover Babylon: Creating A Vivid User Experience By Exploiting Features Of Video Games And Uniting Museum And Library Collections*. Museums and the Web, Culture and Heritage On-Line Conference, Albuquerque.

Makransky, G., Andreasen, N.K., Baceviciute, S., and Mayer, R.E., 2021. *Immersive virtual reality increases liking but not learning with a science simulation and generative learning strategies promote learning in immersive virtual reality*. Journal of Educational Psychology, 113(4), p. 719.

Nofal, E., Elhanafi, A., Hameeuw, H., and Vande Moere, A., 2018. *Architectural contextualization of heritage museum artifacts using augmented reality*. Studies in Digital Heritage, 2(1), pp. 42-67.

Pagé-Perron, É., 2016. *Cuneiform Digital Library Initiative White Paper for the Global Philology Project*.

Pietroszek, K., Agraraharja, Z., and Eckhardt, C., 2021, March. *The royal game of Ur: Virtual reality prototype of the board game played in ancient Mesopotamia*. In 2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), pp. 647-648. IEEE.

Rhodes, R. and Woolley, S., 2022, July. *Connected Virtual Experiences for Small and Less Visible Museum Artefacts*. In 35th International BCS Human-Computer Interaction Conference, pp. 1-2.

Woolley, S.I., Collins, T., Gehlken, E., Rhodes, R., and Dhar, M., 2022. *Interactive 3D Viewer Interfaces for Virtual Museum Artefacts*. 35th International BCS Human-Computer Interaction Conference (Interactions Gallery), Keele University.

Sahala, A., 2021. *Contributions to Computational Assyriology*. PhD thesis, University of Helsinki.

Sanders, D.H., 2015. *Virtual Tour of the Palace of Nineveh: Using Modern Technology to Preserve Antiquities in Danger*. Megalim Institute.

Steam Nebuchadnezzar, 2021. Nebuchadnezzar on Steam. Available at: `https://store.steampowered.com/app/1157220/Nebuchadnezzar/` (Accessed: 26 June 2023).

Steam Ur, 2022. The Royal Game of Ur 3D on Steam. Available at: `https://store.steampowered.com/app/1575580/The_Royal_Game_of_Ur_3D/` (Accessed: 26 June 2023).

Trescak, T., Bogdanovych, A., and Simoff, S., 2014. *City of Uruk 3000 BC: Using genetic algorithms, dynamic planning and crowd simulation to re-enact everyday life of ancient Sumerians*. In Social Simulation Conference.

Wong, S.M., Chen, C.W., Pan, T.Y., Chu, H.K., and Hu, M.C., 2022. *GetWild: A VR Editing System with AI-Generated 3D Object and Terrain*. 30th ACM Conference on Multimedia pp. 6988-6990

Woolley, S., Collins, T., Rhodes, R., and Polack, F., 2021. *Museums of the future: Heritage experiences in the reality-virtuality continuum*. 34th BCS HCI Conference, Embodiment of Things Workshop, July 2021.

Woolley, S., Mitchell, J., Collins, T., Rhodes, R., Rukasha, T., Gehlken, E., Ch'ng, E., and Cooke, A., 2020. *Virtual museum 'takeouts' and DIY exhibitions–augmented reality apps for scholarship, citizen science and public engagement*. In Euro-Mediterranean Conference pp. 323-333

Woolley, S.I., Ch'ng, E., Hernandez-Munoz, L., Gehlken, E., Collins, T., Nash, D., Lewis, A., and Hanes, L., 2017, July. *A collaborative artefact reconstruction environment*. In Proceedings of the 31st International BCS Human Computer Interaction Conference, pp. 1-11

Woolley, S.I., Collins, T., and Gehlken, E., 2022. *In the spotlight: The 'virtual cuneiform tablet reconstruction project'*. Mar Shiprim 22-10-2022, The International Association for Assyriology. Available at: `https://iaassyriology.com/in-the-spotlight-the-vctr-project/` (Accessed: 06 July 2023).