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Beyond Dynamic Drawings: Restoring and Reusing Interactive 3D Visualizations in a Humanities Context

Hugo C. Huurdeman | ORCID: 0000-0002-3027-9597
Corresponding author
4D Research Lab, University of Amsterdam, Amsterdam, the Netherlands
Faculty of Educational Sciences, Open Universiteit, Heerlen, the Netherlands
h.c.huurdeman@uva.nl

Charles van den Heuvel | ORCID: 0000-0001-9638-400X
Faculty of Humanities, University of Amsterdam, Amsterdam, the Netherlands
Knowledge and Art Practices, Huygens Institute, Amsterdam, the Netherlands
charles.van.den.heuvel@huygens.knaw.nl

Etienne Posthumus | ORCID: 0000-0002-0006-7542
Information Services Engineering, FIZ Karlsruhe, Karlsruhe, Germany
etienne.posthumus@partners.fiz-karlsruhe.de

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Abstract

In recent years, interest in three-dimensional visualizations as a complement to traditional text-based humanities scholarship has surged. These visualizations allow for new analysis methods and may serve as an interpretative tool, potentially leading to new insights for creators and viewers. However, contrary to more traditional publications, a myriad of preservation issues occurs from the moment a 3D visualization is created. This data paper illustrates the complexity of preserving 3D visualizations in a humanities context using six interactive visualizations produced in

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the *Dynamic Drawings in Enhanced Publications* project (2013). The visualizations serve as a concrete case study for the restoration, preservation and renewed publication of 3D content. This data paper sketches the general preservation challenges that led to non-functional interactive visualizations. The authors detail the process of restoring the visualizations from the original data and opening them up for potential reuse. To underline reuse possibilities, the authors provide tentative examples for VR and AR platforms. After presenting the dataset, they discuss the implications of the restoration process for future preservation practices of unstable interactive content. The authors introduce a 'composite elements approach', combining visual and non-visual levels of documentation necessary for the maintenance of interactive visualizations.

Keywords

3D visualization – digital preservation – digital restoration – history of science and technology – enhanced publications

– Related data set "Dynamic Drawings – restored interactive 3D visualizations" with DOI www.doi.org/10.5281/zenodo.7785658 in repository "Zenodo"

1. Introduction

Three-dimensional technologies offer a wide range of new possibilities to enhance traditional text-based scholarship and to contribute to new knowledge. As Lischer Katz et al. (2019) indicate, they allow for "interactive engagement with and analysis of spatially complex artifacts, spaces, and data, which enables the possibility of new insights". As such, they facilitate enhanced methods of analysis (Papadopoulos & Schreibman, 2019; Sullivan & Snyder, 2017). The process of 3D modeling in itself serves as "an interpretative and exploratory tool" (Piccoli, 2018) that may help us "to confront and define our own gaps in the historical record" (Sullivan & Snyder, 2017). 3D representations of fragile or inaccessible artifacts provide access and analysis possibilities that would be impossible otherwise (Lischer-Katz et al., 2019). Finally, educational benefits arise from the use of 3D representations as well as immersive learning environments (Grayburn et al., 2019; Lischer-Katz et al., 2019). In a humanities context, a wide variety of projects illustrate the versatility of three-dimensional representations, including a simulation of crowds in the Colosseum (Gutieerrez et al., 2007), a 3D reconstruction of the Battle of Mount Street Bridge (Papadopoulos & Schreibman, 2019), a geo-temporal model of an ancient Egyptian temple (Sullivan & Snyder, 2017) and the reconstruction of an Amsterdam 17th century regent house based on archival sources within the Virtual Interiors project (see also Huurdeman & Piccoli, 2021; Piccoli, 2023).[1]

In this data paper, we focus on visualizations produced during the *Dynamic Drawings* project (2013), a project involving Huygens Institute researchers of the history of science and technology, a curator (Museum Boerhaave), a game developer (Wild Card), scientific programmers (DANS) and a publisher (Brill Publishers). The goals of this collaborative project were to create new publication formats for didactics and research of the history of science and technology to support reuse by developing new archiving methods and business models for enhanced publications combining the contents of books with data on websites. Experiments were carried out with "the development, preservation and reuse of animations of static illustrations of scientific laws, processes and the working of mechanical instruments and tools" (Van den Heuvel et al., 2013). The collaboration process resulted in six interactive scholarly visualizations: an *Astrolabe* (*1*) to measure time, to explain Rene Descartes' theory of light *refraction* (2), *Swammerdam's microscopic drawings* illustrating his views on the evolution of various species (3), Early Modern educational materials on *Surveying* for understanding elementary rules of triangulation (4), the geometrical design of *Fortifications* (5) and finally a *Mill model* devised by Agostino Ramelli to put hypotheses of physical laws to the test (6). The visualizations were described by extensive metadata, directly linked to related publications and images, and to source data archived at DANS.[2] As such, the project adhered to the FAIR principles (Wilkinson et al., 2016).

While screencasts still demonstrated the functionality of the Dynamic Drawings visualizations, the interactive versions were not functioning anymore in current web browsers and plug-ins,[3] illustrating the generally unstable nature of interactive 3D visualizations. However, the preservation of these resources is of key interest, as there is an increasing interest in combining traditional paper-based humanities scholarship with additional digital content, for instance in enhanced publications (Bardi & Manghi, 2014; Breure et al., 2011; Breure et al., 2014; van den Heuvel et al., 2013, 2014), in 3D scholarly editions (Papadopoulos & Schreibman, 2019) and virtual research environments (Huurdeman & Piccoli, 2021; van den Heuvel, 2018). In this data

1 www.virtualinteriorsproject.nl (retrieved 15/02/2024).

2 The original website is depicted in Figure 1 (http://demo-brill.dans.knaw.nl). A partially archived copy is available in the Internet Archive: https://web.archive.org/web/20190901022600/http://demo-brill.dans.knaw.nl/ (retrieved 15/02/2024).

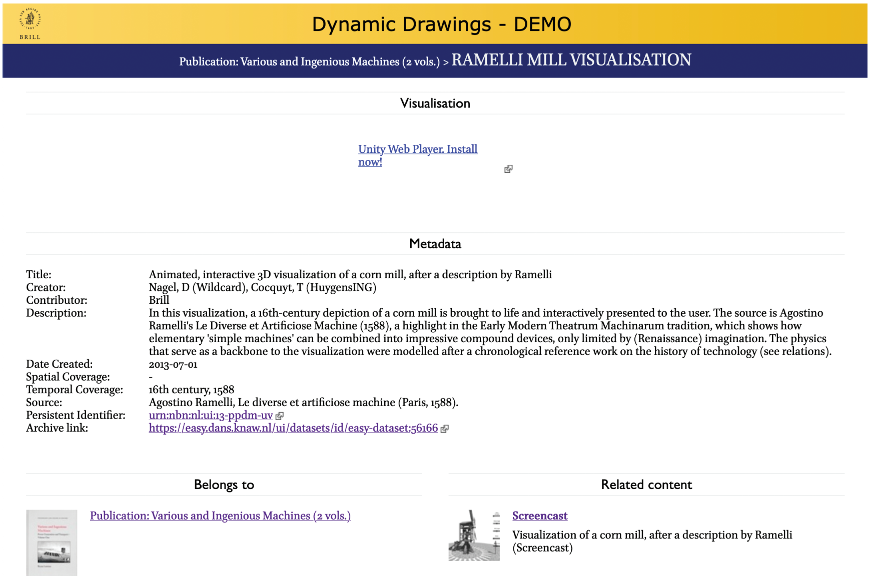
3 The used Unity Web Player is deprecated and not functioning anymore within recent Operating Systems and browsers.

paper, we use the Dynamic Drawings 3D visualizations as a case study for the restoration and preservation of 3D content.

The data paper is organized as follows: first, we describe the problem of preserving interactive 3D content (Section 2), followed by an outline of the conducted restoration process (Section 3), as well as tentative cases for reuse. Then, we describe the updated dataset itself (Section 4) and finally outline implications from the restoration process (Section 5) in our conclusion and discussion.

2. Problem

When starting the restoration, approximately seven years had elapsed since the original visualizations were constructed. At this point, the associated project website was still online, but the interactive visualizations did not function anymore (see Figure 1), due to various challenges in the preservation of interactive and three-dimensional content.



Note: This webpage focuses on the Ramelli Mill visualization and associated information.

FIGURE 1 Dynamic Drawings website as of August 2020, with a non-functioning Unity Web Player interactive visualization

The interactive applications for Dynamic Drawings were created using Unity, a game engine. The versatility and availability of this platform have made this a popular choice not only for creating games, but also for 3D and Virtual Reality applications in the context of cultural heritage and research (see e.g. Papadopoulos & Schreibman, 2019; Szabo, 2019; van den Heuvel et al., 2013). However, using proprietary game engines also poses a risk for preservation: future support is dependent on the parent company. As Lischer-Katz et al. (2019) indicate, such a tool is "constantly being updated", and it is difficult to ensure consistent functionality and behaviors of a particular VR environment over time.[4] Thus, this requires constant adaptation of 3D interactive content to remain functional.

The example of Unity illustrates some of the preservation issues which arise in the context of 3D interactive content. The manifold challenges include reliance on third-party and proprietary tools, rapid obsolescence of hardware and software, the inherent complexity of the 3D data objects to preserve, a lack of documentation thereof and unclear object boundaries (see Delve et al., 2012; Lischer-Katz et al., 2017; McDonough et al., 2010). This is complicated by a lack of common standards for both the production and sustainability of 3D and VR content. As Hardesty et al. (2020) indicate, this "leaves long-term preservation needs unfilled and preservation activities undefined or sketchy at best", inhibiting preservation efforts by libraries and archives.[5] In this data paper, we use the Dynamic Drawings 3D visualizations as a representative for this larger group of cases, to explore how non-functional 3D content can be restored, republished, reused and preserved.

3. Method: Restoring a Dynamic Drawings Visualization

We illustrate the restoration process of the six interactive scholarly visualizations using the Ramelli Mill, from Agostino Ramelli's book *Le diverse et*

4 This is exemplified by the Virtual Harlem project (see Carter, 2006 and https://scalar.usc.edu/works/harlem-renaissance/index [retrieved 28/02/2024]), one of the earliest VR environments in the Humanities. Its preservation "involved moving the project to a new VR platform every few years, which typically required recreating most of the VR environment from scratch". This was caused by incompatibilities, but also by the lack of import/export functionalities (Lischer-Katz et al., 2019).

5 Even though in the Dutch context an infrastructure for the publication and preservation of 3D scholarship is being created, see https://pure3d.eu (retrieved 28/02/2024), restoration of (non-functional) previous interactive 3D visualizations is not the prime focus of such initiatives.

artificiose machine (1588), as depicted in Figure 2. The interactive visualization (Nagel & Cocquyt, 2013a) made use of Ramelli's depiction of the mill and the accompanying text, as well as a historical-technical overview of the evolution of mill technology (Lawton, 2004). Since it could not be taken for granted that the mechanism would actually function in real life,[6] various hypotheses were

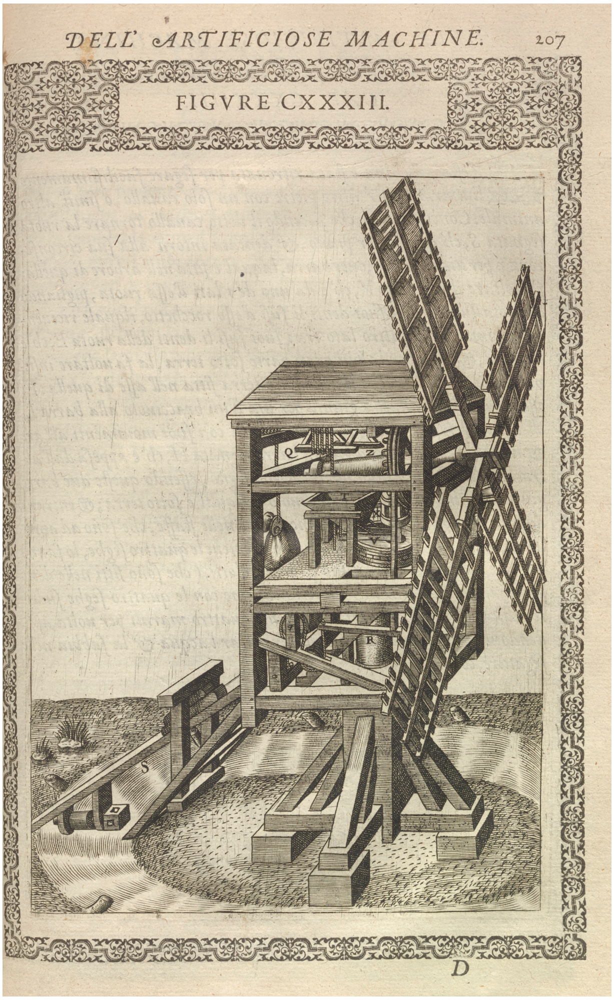


FIGURE 2 Original engraving in Agostino Ramelli's book (Ramelli, 1588)

6 Van den Heuvel et al. (2013). An interesting observation was that the depicted mill in Ramelli's book could not actually 'work', due to an issue in the mill design, as well as exaggerations and omissions 'for more dramatic effect', leading to some necessary changes in the 3D modeling process.

tested in the context of the reconstructions. The final interactive visualization was driven by a dynamic algorithm and could be influenced by the viewer using five sliders. We chose this specific example since it combines some challenging components in terms of preservation: a 3D mill model based on several historical sources and several tightly integrated physics-based interactive features to test out hypotheses in literature (Lawton, 2004).

To ensure 3D applications keep functioning, several preservation strategies are available (see e.g. Delve et al., 2012; McDonough et al., 2010; Vanstappen, 2020). Common strategies include 1) technical *preservation* of the original hardware and software, 2) *emulation*, simulating an older system on a newer host platform and 3) *migration*, moving an experience to a new platform which is currently supported. Further, *re-enactment* or *re-interpretation* (Guttenbrunner et al., 2010) is the full reconstruction of a particular experience using a different technology than the original one. Each of these strategies comes with specific advantages and drawbacks and often requires specific expertise and considerable effort.

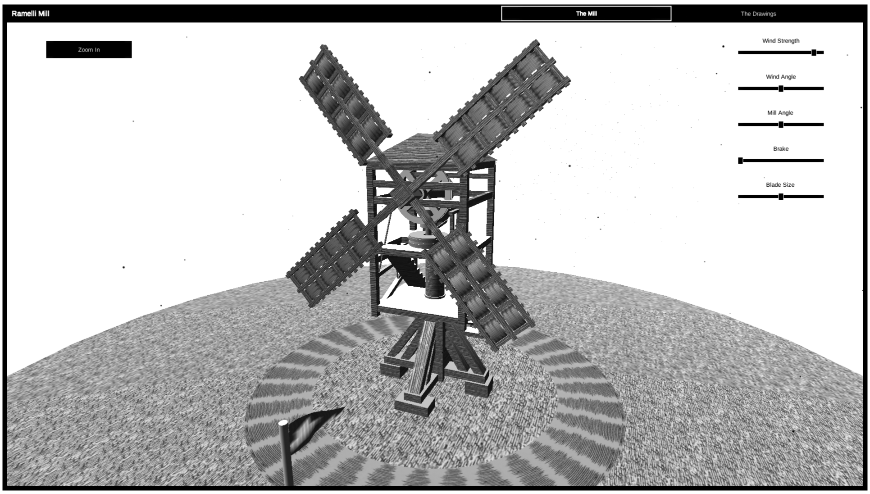
3.1. *Restoration Method*

Even though the interactive visualizations, such as Ramelli's mill, were not functioning anymore, persistent identifiers and archive links had been utilized. This way, we could revisit the original files and data, as deposited at DANS in different formats, such as images, video screencasts, the Unity source files and the Unity Web Player applications.

For the restoration of the six interactive scholarly visualizations, we chose the *migration* strategy to move the Unity source code to a new platform, since this would allow for full possibilities to export and re-use assets (Delve et al., 2012), as opposed to preservation or emulation approaches. As a reference point for migrating the 3D visualizations, we took the screencasts produced at the time of their creation.

As a first step, we intended to migrate the source files obtained from DANS to a recent long-term support (LTS) version of Unity. Illustrating the rapid pace of technology development, it turned out that the source files could not be opened using the current Unity desktop application. The Unity version in which the files were created, on the other hand, was not functioning anymore in current versions of Windows or MacOS. Therefore, we pinpointed the last working Unity version in which the Unity source files could still be opened, to perform gradual upgrades. Each subsequent upgrade of Unity resulted in various issues in the interactive visualization, which ranged from minor (a slight visual degradation) to severe (a non-functioning application in the Unity version at hand).

Three main challenges occurred in this step. First, the issues in changed *programming code syntax* – the underlying logic for the behaviors of the visualizations – were generally small, but prevented the application from working. Second, problems with the *visual appearance* of the 3D scene occurred, for instance missing directional lights, or issues in the cropping of the view of the camera within the 3D space. These issues degraded the visual appearance and functionality of an application. Third, the most pressing issue was the obsolescence of features and systems in Unity. As Unity is used as a game development platform, it quickly evolves and leaves behind support for prior functionality over time (see, e.g., Lischer-Katz et al., 2019), such as a specific physics module which guides the behavior of objects in the wind. In the case of the Ramelli Mill, for instance, this meant that a flag indicating the current wind direction had disappeared. Therefore, additional development was needed to *recreate* and *re-interpret* (see Guttenbrunner et al., 2010) certain functionality in the applications, using the original screencast as a reference (e.g., using the new physics features of the current version of Unity). The result of the migration was a set of restored visualizations which were virtually indistinguishable from the originals.



Note: Using sliders, various properties (such as wind speed, wind angle and mill angle) can be adapted. Using a dynamic algorithm, the movement of the mill blades is simulated. The flag indicates wind direction.

FIGURE 3 The restored Ramelli Mill in the WebGL viewer

As a second step after successfully migrating the visualizations to a recent version of Unity, we could *export* elements of the application to various open output formats. Static 3D models were exported to FBX[7] and subsequently converted to other formats, such as GLTF and OBJ.[8] The ancillary exporting of included 3D models produced an independent archive item, which adds further redundancy (Baker & Anderson, 2012), and which may also serve as a basis for re-use. Also, new opportunities arose: for the first time, the application could be utilized via browsers on mobile phones and tablets via an exported WebGL version (see Figure 3).[9]

3.2. *Beyond Dynamic Drawings: Re-using the Dataset for Other Purposes*

Using the exported 3D models as a starting point, we prototyped alternative presentation approaches using the same assets of the Ramelli Mill, in virtual reality (VR) and augmented reality (AR). First, we imported the 3D model into a prototype 3D research environment created in the context of the Virtual Interiors project (Huurdeman & Piccoli, 2021),[10] which enables experiencing the visualization on different platforms including VR headsets (see Figure 4). Viewers can walk around the mill, experiment with lighting settings, and select the mill's constituent components to view associated images as well as excerpts from Ramelli's original text. While the original Ramelli Mill visualization allowed for exploring the physics related to the mill, this prototype demonstrates how visualizations and underlying textual and visual sources can potentially be more tightly integrated.

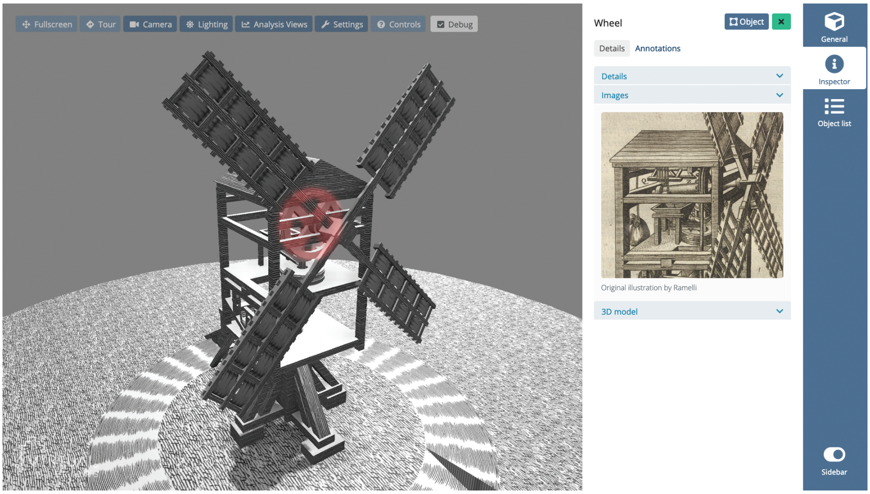
Second, we created an AR-version of the Ramelli Mill, by converting the 3D models to formats compatible with AR-enabled devices, such as phones and tables. This makes it possible to virtually place the Ramelli Mill in a real environment, to examine it from all sides and to interactively experiment with its physicality and dimensions (see Figure 5).

7 Best results were achieved using the recent FBX exporter package (https://docs.unity3d.com/Packages/com.unity.formats.fbx@2.0/manual/index.html (retrieved 24/02/2024), allowing for interoperability and "round-trip workflows between Unity and 3D modeling software".

8 GLTF: www.khronos.org/gltf (retrieved 24/02/2024). OBJ: www.fileformat.info/format/wavefrontobj/egff.htm (retrieved 28/02/2024).

9 An application exported from Unity can be viewed, but not edited anymore.

10 Demonstrator: https://3d-demo.virtualinteriorsproject.nl/index.html?app=dd-ramelli-mill (retrieved 15/02/2024). Archived version: https://web.archive.org/web/20240129143837/https://3d-demo.virtualinteriorsproject.nl/index.html?app=dd-ramelli-mill (retrieved 15/02/2024). Demonstrator source code and further details: www.doi.org/10.5281/zenodo.5171879 (retrieved 15/02/2024).



Note: Elements of the model can be selected to view additional information, and annotations can be added to the model.

FIGURE 4 Demonstration of Ramelli Mill in Virtual Interiors 3D/VR viewer

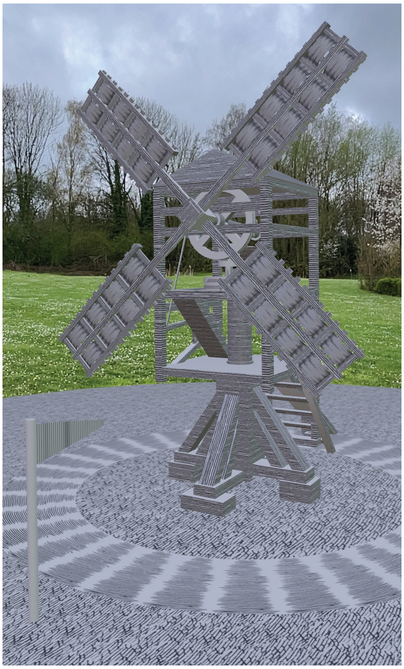


FIGURE 5 Augmented Reality version of the Ramelli Mill.

Note: A model can be placed in the real world and moved, scaled and resized using the AR functionalities of mobile devices.

The VR and AR examples show the value of preserving, restoring and reusing 3D models in the context of research, and of additional ways to interact with and interrogate the content. This opens up new questions about the content as well as potential hypotheses.

4. Data

- **Dynamic Drawings – restored interactive 3D visualizations deposited at Zenodo** – DOI:www.doi.org/10.5281/zenodo.7785658
- **Temporal coverage:** 1588-17th century (source images), 2013 (original 3D models)

All six restored interactive visualizations from the Dynamic Drawings project (see van den Heuvel et al., 2013) are included in the updated dataset (described in Table 1 and depicted in Figure 6).

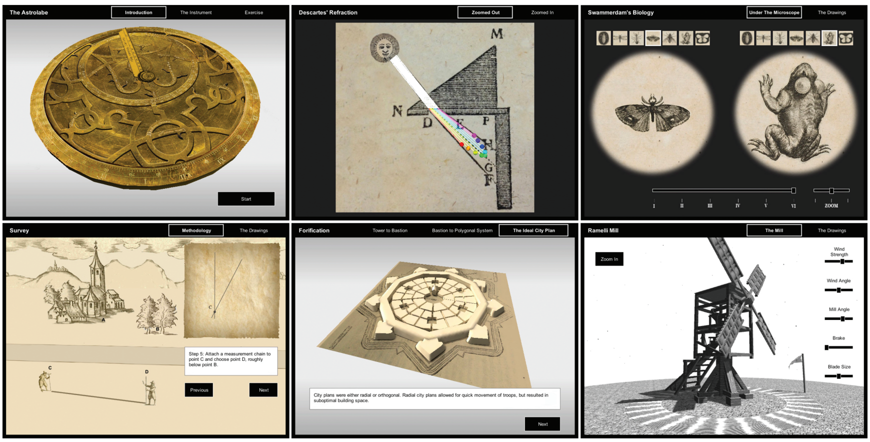
In terms of documentation, we utilize a 'composite elements' structure, combining documentation of displayed elements (via screenshots and screencasts) with textual documentation of deeper layers (interaction and dynamics) and literature sources the visualization is based on.

The dataset includes elaborate documentation (e.g., dataset introduction, persistent links, information on interaction and dynamics, and usage instructions). For each of the six visualizations, the following files are provided:

1. **Unity source files** (updated Unity project files and source code)
   - Unity files and settings. Including source code (*Assets/Scripts* folder), 3D model elements in OBJ-format (*Assets/Models* folder), images and GUI images (*Assets/Textures* folder) and Unity scene (*Assets/Scenes* folder)
2. **WebGL_application** (exported version of the application)
   - HTML files (using WebGL technology). Exports from the Unity application, which can be uploaded to a web server
3. **3D models** (if applicable)
   - Exported (static) combined 3D models from the application, as GLTF and FBX files. In addition, 3D model elements (in OBJ-format) are included within the Unity source files
4. **Documentation**
   - *Screen recordings.* For visual reference, screen recordings of the original Unity application
   - *Screenshots.* For visual reference, screenshots of the original Unity application

TABLE 1 Summary of the contents of all six visualizations

Name of visualization	Contents and original reference
1. Astrolabe	3D visualization of an astrolabe, with adjustable rete and index. Based on an astrolabe by Michiel Coignet, 1601 (Nagel & Cocquyt, 2013f)
2. Descartes' Refraction	Interactive animation of Descartes' explanation of the refraction of light from 1637 (Nagel & Cocquyt, 2013c)
3. Swammerdam's microscopic drawings	An interactive visualization to compare Swammerdam's insect anatomy drawings (Nagel & Cocquyt, 2013d)
4. Survey / Triangulation	A user is presented with steps required to solve a surveying problem, based on 17th century instruction books (Nagel & Cocquyt, 2013e)
5. Fortification	Interactive visualization of fortification principles from Early Modern science (Nagel & Cocquyt, 2013b)
6. Ramelli Mill	Animated, interactive 3D visualization of a corn mill, after a description by Ramelli (1588). Physics based on Lawton (2004) (Nagel & Cocquyt, 2013a)



Note: Numbering from left to right, top to bottom; numbering corresponds to Table 1.

FIGURE 6 Images of all six interactive Dynamic Drawings visualizations

5. Discussion and Conclusion

Three-dimensional visualizations provide a wealth of opportunities in the context of humanities scholarship. They allow for a depth of analysis and understanding which is impossible with solely text or images. However, as we have illustrated, 3D visualizations are unstable in the sense that they may degrade and become non-functional over time. This raises severe preservation issues.

As a representative for this larger group of cases, we presented visualizations and underlying data created from the Dynamic Drawings project. Despite best efforts regarding preservation, the original interactive visualizations had become non-functional. The extensive efforts also paid off, in the sense that all original source files could be accessed, as well as screencasts depicting the original functionality. This ultimately allowed us to restore the original visualizations.

The restoration itself was a painstakingly intricate process of migration while comparing functionality with the original screencasts and performing edits as needed. After the successful migration, the source files can be utilized in a current version of Unity, opening up possibilities for adaptation and reuse in the future. Still, there are two implications of the performed restoration process via migration. First, while virtually indistinguishable from the originals, these are inherently imperfect copies, in that there are slight changes in the aesthetics of the visualizations. Second, the performed migration is ultimately temporary and may have to be repeated in the future. Therefore, we also extended our approach with exports to web-based platforms, via which the visualizations can be used on additional devices such as mobile phones and tablets, using a standard web browser. Finally, we provided exports of 3D assets to open formats and practically showed how this facilitates reuse, for instance in other VR and AR applications.

Opportunities for exchanging 3D models and their properties between 3D modeling tools have emerged in recent years. For instance, Unity's support for industry-standard FBX allows for exporting the 3D models within an application. However, the exported 3D models are only the tip of the iceberg. Export possibilities do not include various elements beneath the surface: the interaction (for instance, rotating the Ramelli Mill) and the dynamic elements of a visualization (for instance the physics model which drives the behavior of the Ramelli Mill). These are tightly interlinked with and generated by the used tool to create the visualization, such as Unity. Therefore, a hybrid approach is necessary: depositing the source files and exports where possible, but also providing extensive documentation. For future projects involving unstable media, we suggest the use of a 'composite elements' approach, where documentation of the 'visible' surface level of the application (via screenshots and screencasts) is combined with textual or schematic documentation of deeper layers, including user interaction and dynamic elements. Moreover, in this case, the full preservation target is the whole enhanced publication, which includes the textual and visual content of the publication(s) a visualization was based on – for instance, Ramelli's book (1588). Together, this forms a reference point for future migration, emulation and recreation of visualizations.

The moment a 3D visualization is conceived, its future is already in doubt. Thus, as indicated by various authors (e.g., Alliez et al., 2017; Lischer-Katz et al., 2019), there is an urgent need for common preservation standards, further open file formats, best practices and longer-term infrastructure (some of which have recently been initiated by projects such as Pure3D and 4CH[11]). Responsibilities also belong to the content creators, for instance by providing open formats wherever possible and documenting their efforts, and to repository owners, e.g. by providing guidelines. As Lischer-Katz et al (2019) indicate, 3D/VR should be considered scholarly products in their own right and should be managed through their lifecycle similar to other types of research data. Through our dataset and this data paper, we provide new handles for best practices for the preservation of 3D interactive content in the humanities and beyond.

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