Creating the Animal Mummy 3D Viewer

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From Research to Outreach at the Allard Pierson

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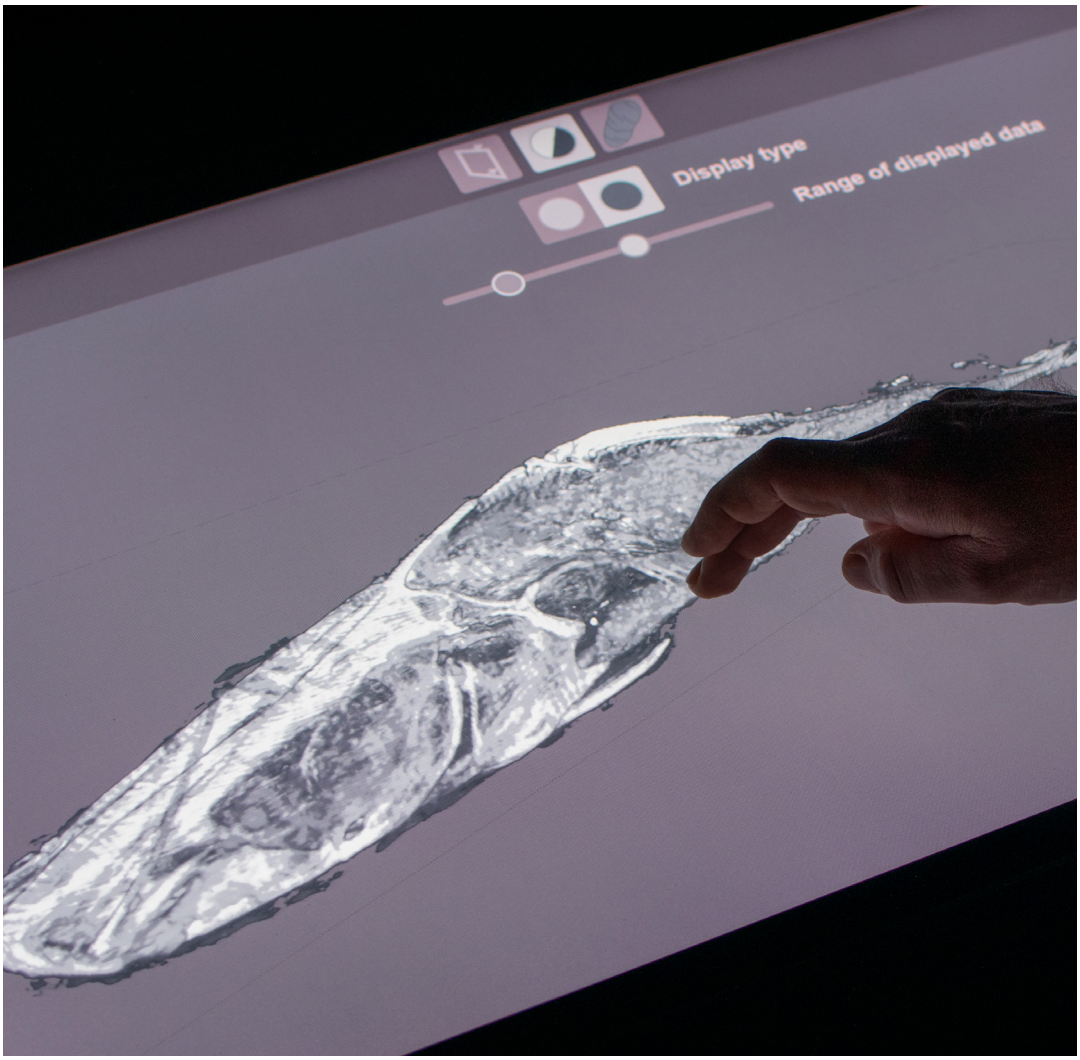

The Animal Mummy Viewer in use in the exhibition room.

Creating the Animal Mummy 3D Viewer

Tijm Lanjouw, Jitte Waagen, Markus Stoffer

The Allard Pierson Animal Mummy Project aimed to study animal mummies by using high-resolution image data of the interior of the mummies. Specialists then used these data to identify the animal species and study the bones, wrapping, and any items included during the process of mummification. The 4D Research Lab (4DRL) was involved in creating a 3D viewer that allows museum visitors to interact with the scan data (fig. 1). The viewer aims to inform visitors about research methods and the results, applies gamification principles to stimulate deeper engagement with the information provided, and in addition allows users to make and communicate their own observations. This is a well-considered attempt to approach two challenges in current museological discourse: how to make scientific research processes transparent and insightful, and how to involve the general public with them.[1]

Concept

The idea of displaying the interior of mummies in a digital application that allows visitors to unwrap them layer by layer is not new. A commercial solution called the 'inside explorer' created by Interspectral has gained some recognition and is being used by various European museums.[2] The application uses a simple and intuitive user interface that allows museum visitors to virtually 'unpack' scanned mummies based on pre-processed, segmented elements of the mummy (the coffin, wrappings, or other objects). In the Netherlands, the application was used at the Rijksmuseum van Oudheden (National Museum of Antiquities) in Leiden to display some of its CT-scanned animal mummies.[3] Whereas the Interspectral software solution is interesting, it is a proprietary closed-source solution. For the 4DRL, as a university lab developing methods and techniques to allow a maximum scientific and societal impact, the goals of transparency and reusability are fundamental. Therefore, the goal has been to create such an application with the use of

1 Personal communication with Allard Pierson curator Ben van den Bercken (August 2024).

2 See https://insideexplorer.com/ (accessed 16 August 2024).

3 Raven/Weiss 2018, 58–61.

in Van den Bercken, B. J. L. (ed.), 2025, *Animal Mummies: From Research to Outreach at the Allard Pierson*, Leiden: Sidestone Press, 112–122.

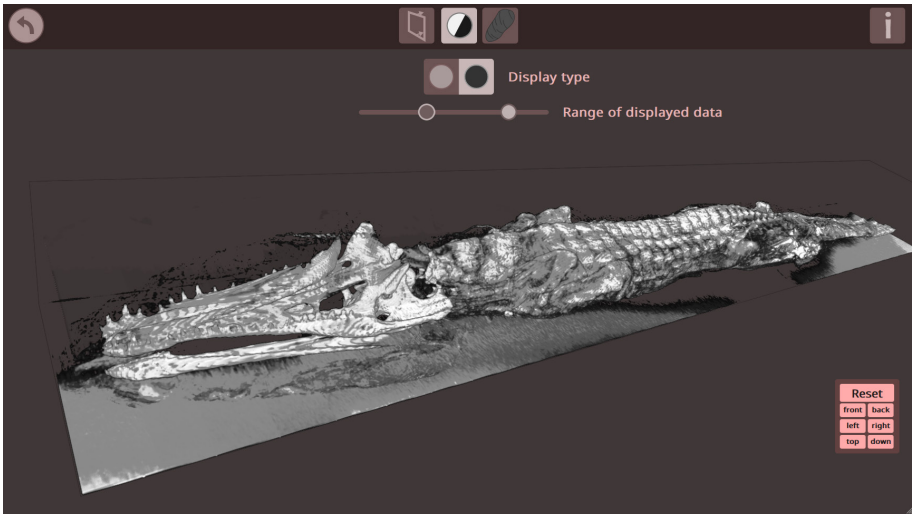

Fig. 1. Screenshot of the Animal Mummy 3D Viewer application showing the crocodile mummy CT reconstructions and the density slider tool.

freely available open-source tools. Also, given the recent discussions on effective design for visitor engagement, an explicit goal has been to test and evaluate it in order to learn more about user interaction with such applications. We also wanted to explore some uncharted conceptual angles in allowing people to directly interact with CT-scan data. Not only would this allow users to get an impression of how the data actually behave and can be used for visualisation, therefore illustrating the dynamic of expert interaction with the data, but in addition it potentially creates the thrilling prospect of users making their own discoveries. Hence, we do not segment and label the data, but present the raw data with well-explained interactive tools, as we want museum visitors to try to identify and understand certain features themselves. This application therefore places the museum visitor in the position of the researcher. In order to stimulate the user to think as a researcher, the application contains a minigame that familiarises users with CT reconstructions and the available visualisation tools, guiding them through the exploration of the data before inviting them to explore the data in detail for themselves. Eventually, we wanted to enable people to snapshot and annotate their discoveries and send them to the museum curator, who can also respond to visitors leaving their contact information. Not only does this potentially engage people with the exhibition content more, it could also lead to new discoveries along the lines of citizen science.

App development

This concept, the technical features, and the content were developed in close collaboration between the 4DRL, the curator, and the project manager assigned to organise the installation of the viewer in the museum galleries. The app was created in two stages: for the temporary exhibition *Animal Mummies Investigated* (December 2021–March 2022), a pilot was developed with limited functionality and content. The main aim was to get acquainted with the technology and explore the possibilities. From the beginning we opted for a web-based framework. There were two main motivations for this choice: first,

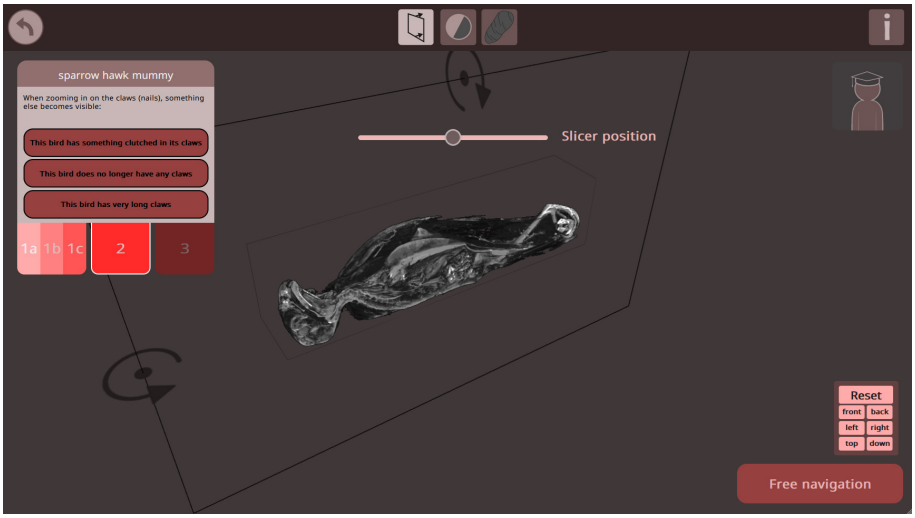

Fig. 2. Screenshot of the Animal Mummy 3D Viewer application showing the sparrowhawk mummy on a question page, with the cross-section tool activated.

we could make use of existing open-source technology to visualise CT reconstructions in the web browser; and second, it would enable optimal accessibility in potential future sharing of the data and application.

A new, fully featured version was created in the second stage and included in the permanent display of the museum in May 2024. As already mentioned, this version contains a gamified introduction to CT-scan data and animal mummy research. In short, the users move through three 'levels' of interaction with the data, each ending with a question. After answering that question, they receive an upgrade of their level of expertise and simultaneously new features are unlocked in the app to investigate the animal mummies (fig. 2). To cater for visitors who are not inclined to follow the gamified setup, it is also possible to skip this and freely explore the data. In the end, it will be very valuable to be able to study visitor interaction with the app and thoroughly evaluate the design choices made during development. Therefore, the fully featured version collects use data, which help us study and understand how users interact with the Animal Mummy Viewer. In the following paragraphs we will give further background information on the various techniques on which the application relies.

CT reconstructions and displaying volume

CT scanners generate X-rays from several sides of an object and use computer algorithms to reconstruct 'slices' (cross-sections) of an object at predetermined distances. These slices can be in the order of 70 µm (0.07 mm) to 200 µm (0.2 mm) apart, so the process generates very high-resolution data. Each slice is an image with a fixed resolution, such as 512x512 pixels. CT-reconstruction datasets are thus series of 2D images positioned in a 3D space. Unlike regular digital images, the pixel values do not represent colour values (e.g. RGB), but Hounsefield units, a standardised unit used to express material density. The CT scan thus allows us to discern materials with different densities: we can see the

difference between bone, fabric, and metal. This makes it a very powerful analytical tool for material studies.

CT reconstructions are often viewed as sequences of 2D slices through which the researcher scrolls to see them one by one, but since they contain data about the density and composition of objects, they also very suitable for volumetric 3D visualisation. To create a 3D representation, the slice images are converted and interpolated so that the model can be displayed as voxels (3D pixels). Using a range of rendering techniques, the display quality of the volume can be improved, for instance by modifying opacity and enhancing outlines or by darkening crevices and lightening protruding areas. The capacity to modify the visualisation by dynamically selecting displayed data and changing rendering modes is what gives the technology its analytical value. These are exactly the types of interactions that we wanted to have the user of the application play with, to better understand the use and usefulness of the technology.

Software

Various open-source applications already exist in the medical domain that allow visualisation of CT or MRI scan data, but since we wanted a completely customised user interface while not only displaying CT-scan data but also regular 3D mesh models and high-resolution textures of the exterior, we needed a more general approach. A code library, i.e. a collection of functions or routines that can be used in writing applications, and a base application with an application programming interface (API) provides such flexibility without having to reinvent the wheel. For 3D display there are several widely used libraries, but not all have sufficient options for displaying volumetric 3D data. In the end we settled for X3DOM, a Javascript-based viewer developed to display various kinds of scientific 3D data, which showed some promise with regard to volumetric 3D visualisation.[4] In order to cater for all functionality we wished, we used an adaptation of the X3DOM volumetric codebase, created by Michael Hofmann of Bonn University[5]. This adaptation creates sharper 3D visualisations of CT reconstructions than the default X3DOM viewer. This approach requires a modified version of X3DOM 1.7.2, whereas the up-to-date version is now 1.8.3. It also means that the app requires a specific browser, as certain DOM (Document Object Model) actions are not available in up-to-date versions of browsers such as Google Chrome.

To increase the degree of interactivity, we have used Vue.js (version 3.0.2), a framework that allows reloading content without refreshing the entire web page. This allows more dynamic switching of the models, text, game 'levels', and tools (fig. 3).[6]

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4 Arbelaiz et al. 2014; Arbelaiz et al. 2017.

5 See http://web.archive.org/web/20230613060550/http://131.220.133.140/VNHM (accessed 16 August 2024). Dr Hofmann generously gave us permission to use his adapted code.

6 Additionally, some tools implemented in the app are:
- html2canvas version 1.4.1 from https://html2canvas.hertzen.com/ (accessed 16 August 2024), used for screenshot functionality;
- marker.js from https://markerjs.com/ (accessed 16 August 2024), used for annotation functionality;
- simple keyboard from https://github.com/hodgef/simple-keyboard (accessed 16 August 2024), used to enable on-screen keyboard input.

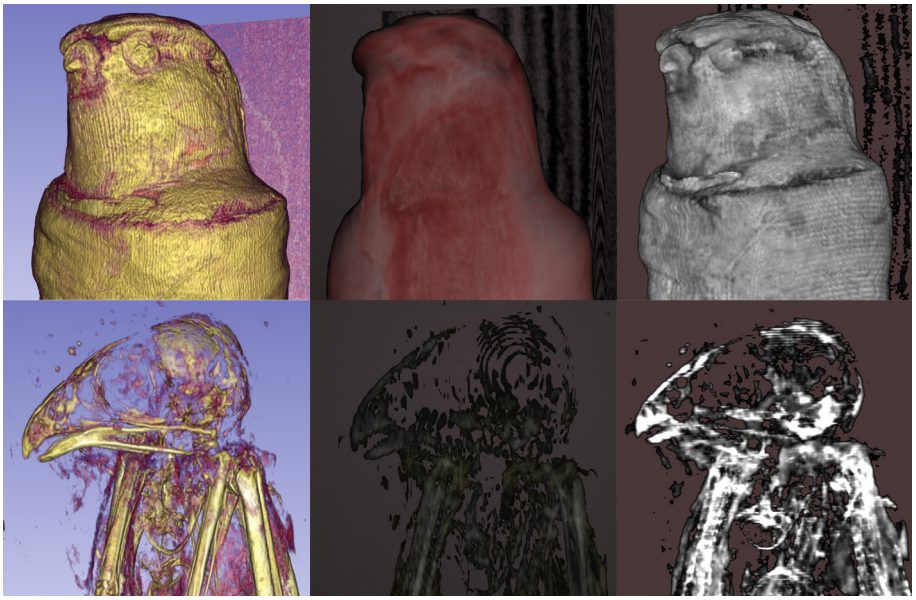

Fig. 3. Comparison of data visualisation in full resolution rendered in 3D-slicer software (left top and bottom), using the default volume-rendering mode in X3DOM (middle top and bottom) and the modified volume-rendering mode adapted from the Virtual Natural History Museum by Michael Hofmann (right top and bottom).

Content creation

Currently the application contains models and information about thirteen animal mummies. It displays CT-scan data and surface scans and has bilingual (Dutch and English) narrative content. In this section, we will briefly discuss the tools and approaches used to create the content.

As for the CT scans, the data were delivered to us by the Amsterdam UMC as DICOM files, which is a worldwide standard for medical data that can be read by many applications. For processing we used the open-source 3D slicer,[7] a versatile package made for processing and visualising medical 2D and 3D data. Unnecessary parts of the CT reconstructions were cropped, after which the data was exported to new DICOM images. An online tool created by the organisation VolumeRC was used to convert DICOM images to a single image-atlas file.[8] This meant a significant reduction of data resolution, both spatially and in terms of the possible range of density data values that can be displayed, but this is required for smooth visualisation in X3DOM.

CT scans give information on the inside of objects by displaying their varying density, but they do not contain any information on the original colour of a surface. Since we wanted to give users a realistic representation of the exterior appearance to enable them to directly relate it to the contents of a mummy, we made 3D surface scans with colour textures. These scans were made on location in the Allard Pierson using two

7 See https://www.slicer.org/ (accessed 16 August 2024).

8 See http://www.volumerc.org/demos/Dicom/DicomToAtlasDragDrop/DropDICOMToAtlas.html (accessed 16 August 2024).

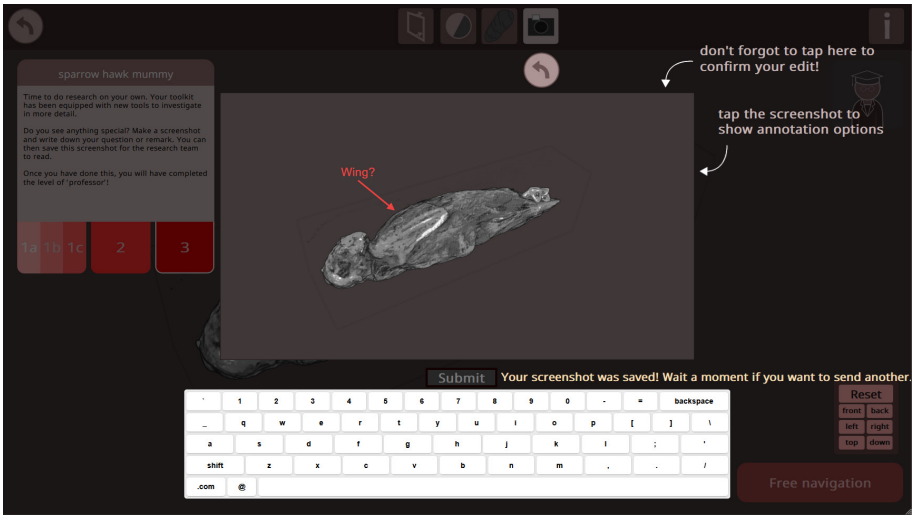

Fig. 4. Screenshot of the Animal Mummy 3D Viewer application with the annotation and screenshot tools activated.

technologies: photogrammetry and structured light. Most photogrammetry-based models were captured using a Nikon D5300 and an AR400 ring flash. The photos were processed in Adobe Lightroom for colour calibration and correction, and exported to JPEG files. These were processed in Agisoft Metashape to create textured 3D surface models. A few mummies were captured using the Artec LEO structured light scanner and subsequently processed in the Artec Studio software. Both photogrammetric and LEO models were reduced to meshes containing on average 200,000 polygons.[9] Images with a resolution of 2048x2048 pixels were created for colour textures. This resulted in high-quality models with ample detail that could still be displayed sufficiently fast in the web-based viewer.

The narrative content was largely created by museum curator Ben van den Bercken. It included insights gained from the Animal Mummy Project and information on the animal species, the mummies' history, and the contents as visible in the CT reconstructions. The content was created with the aim of illustrating current findings and research techniques, but also to encourage the museum visitor to look at these artefacts in order to gain more information from them (fig. 4).

Assessment

The next step in this research project is the study of user interaction with the application (fig. 5). Questions we have are for example: how long users spend with the application, how many people complete the gamified teaching component, and, in general, whether they use it as we hoped or expected. In addition, we have developed questionnaires as well as an interview format to learn more in depth about visitors' motivation and experience with the app. This phase of user-data collection will be initiated after publication of this

9 3D surfaces are digitally represented by a connected set of triangles, also referred to as polygons. The network of triangles has the appearance of a complex irregular latticework commonly referred to as 'mesh'. The size of these faces determines the resolution of the model, often referred to as level of detail.

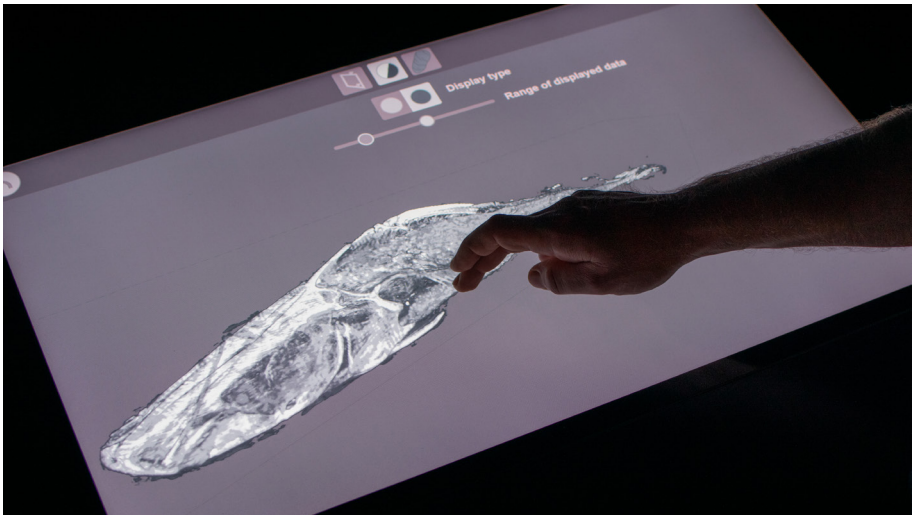

Fig. 5. The viewer in use in the exhibition room.

contribution. The assessment of the application so far therefore relies primarily on our own experience and insights.

Although the application was indeed successfully created using available open-source tooling for web-based visualisation, there are some clear drawbacks to our approach. One of these is that, although the web solution was judged to be the most useful in view of the project requirements, the display quality of the CT reconstructions had to be reduced to such a degree that visual quality and sharpness suffer from it. For instance, hundreds of CT image slices had to be merged in one 4096 by 4096-pixel atlas. This meant a significant reduction of image resolution. In addition, the DICOM images containing Hounsefield values for density had to be converted to regular RGB. Unfortunately, this means an immense compression of data as one RGB channel can only take 255 values, while the Hounsefield scale runs from -1000 (air) to +30,000 (metals). As a matter of fact, the team that is responsible for developing X3DOM has a solution available that dynamically creates the image atlases depending on a data-selection window. Due to time constraints, however, we have not been able to integrate this approach with our application.

Even though we worked with reduced data, we were confronted with long loading times or non-displaying models in specific steps of user interaction when in an online environment or on lower-end systems. The viewer in the museum is not faced with this issue, as the application is run locally on a system witch sufficient graphical processing power.

Because of the technical limitations of the current application, some of the goals are only partially reached. The reduced quality of CT visualisations makes this a less useful tool for discovery than professional applications would be, making it harder for lay people to contribute. Besides, the problems we encountered with loading these data in the browser makes this viewer less suitable to widely share the results of CT-scanning-based research on the internet. Nonetheless, as a demonstration of the concept, the project shows what is possible with relatively limited resources and available open-source tooling.

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About the authors

Tijm Lanjouw studied archaeology at the University of Groningen and the University of Leiden, specialising in the use of digital tools to analyse archaeological data from field surveys and excavation. His current focus is on the application of 3D modelling in academic research and education at the 4D Research Lab of the University of Amsterdam.

Jitte Waagen works in the fields of archaeological prospection, (UAS) remote sensing, Geo-ICT, statistics, 3D modelling, eXtended Reality and Blended Learning. In the 4DRL he examines the application of 3D technology for research and educational purposes, ranging from 3D scanning to virtual reconstruction, from an applied technological as well as a theoretical perspective.

Markus Stoffer studied archaeology and heritage at the University of Amsterdam and works as a researcher and developer at the 4D Research Lab. He specialises in making interactive apps and using XR in education and research. Through various projects at the 4D Research Lab, he gained experience in front-end development, cloud technologies, and code optimisation.