Self-hosted viewers such as 3DHOP or the Simthsonian's Voyager require storage capacity and server hosting, but as open source solutions they may be more sustainable in the long term. We are currently looking into both Sketchfab and open source self-hosted options.

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MORPHOSOURCE: CREATING A 3D WEB REPOSITORY CAPABLE OF ARCHIVING COMPLEX WORKFLOWS AND PROVIDING NOVEL VIEWING EXPERIENCES

Doug M. Boyer, Director of MorphoSource / Associate Professor of Evolutionary Anthropology, Julie M. Winchester, Lead Developer & Product Manager of MorphoSource, Department of Evolutionary Anthropology, Duke University; Edward Silverton, Mnemoscene

Introduction

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MorphoSource (http://www.morphosource.org)™ is a public web repository where 3D object experts, collections curators, and the public can find, download, upload, and manage three dimensional (3D) (and 2D) media representing physical objects, primarily biological specimens. Soon the site will support cultural heritage and other object types as well. Compared to other online resources, the strength of MorphoSource is in its support for the specific, emerging needs of users for whom 3D imagery is data and evidence for research and education. Specifically, it emphasizes paradata including support for 1) describing the sometimes complex acquisition and modification narratives for 3D media, 2) deep nuanced metadata for 3D and 2D imaging modalities, and 3) efficient tracking and managing of media by collections organizations. MorphoSource is the largest resource for biological 3D data with regard to data depth (~100,000 datasets) and diversity (30,000 specimens and 12,200 species). As a result, it has extensive adoption by its research community (~11,000 active users, 200,000 downloads, and 3.7 million views) and growing impacts for scholarship (~550 citing publications) as well as education. Once upgraded with cultural heritage object support (est. Fall 2020), the repository will run on a Ruby on Rails web application. The MorphoSource Rails application is a specialized data management platform dedicated to providing deep support to independently operated collections organizations for archiving, curating, and managing access to 3D and 2D media representing, based on, or related to physical objects and data.

Challenges and Benefits of 3D Data Representing Physical Objects

3D digitization of physical objects provides an enormous opportunity to accelerate advances in and access to knowledge related to natural and cultural history, biodiversity, geology, geography and culture. Compared with access to a physical object, access to a 3D digital object can allow a user to examine more quantitative (and often otherwise inaccessible) information related to shape, materials, or internal structure. Additionally, 3D digital objects provide unparalleled accessibility, because users are not hindered by geographic distance or the number of other individuals and/or machines simultaneously examining that same virtual object.

For academic use cases, there are also significant challenges associated with purely virtual examination of physical objects. Principally, there is a risk that the virtual object is not a reliable representation of the physical object, or that the virtual object becomes inaccessible or misrepresented over the long term due to data corruption, lack of context, or file format obsolescence. This risk must be addressed and minimized as much as possible. There are several key components to mitigating such risks: 1) granular documentation of 3D image creation and modification (i.e., paradata); 2) use of open and supported file formats; and 3) use of standardized data models and metadata terms by repositories as much as possible.

Parenthetically, we note that these challenges are much less of a problem for 3D imagery that is not intended to accurately represent a physical object of natural historical or cultural relevance (e.g., a 3D painting of a toy unicorn), or in cases where the imagery is meant to summarize interpretations based on physical objects in order to express academic concepts (e.g., a 3D animation of a beating heart). In other words, we are focused on issues associated with 3D imagery that are meant, in some sense, as data for analysis or evidence of something that exists/existed in the real world. MorphoSource Rails as a repository platform has been created specifically to address the particular challenges associated with these 3D data, which differentiates it from other available web 3D resources.

Media Preview Of 3D Models and Volumes

Though much of the rest of this article will be devoted to the use of MorphoSource Rails to preserve provenance and the details of image acquisition narratives, equally important is providing potential users with tools to quickly and easily preview and even work with the 3D data in the repository. When displayed next to essential metadata on image data format, dimensions, and resolution, these previews dramatically facilitate users' ability to determine whether a particular dataset meets their individual needs. By default, Hyrax supports the IIIF-compliant Universal Viewer **(http://universalviewer.io/)**, which provides web-embeddable media previews for a diversity of 2D media and document formats. While the Universal Viewer is an excellent open framework, the collective developing it has not yet had the opportunity to build out strong 3D support. To provide deeper support for 3D, MorphoSource has collaborated with Mnemoscene **(https://mnemoscene.io/)** and created Aleph **(https://github.com/aleph-viewer/aleph)**, a web viewer for 3D models and volumes that can be used by itself or natively as a Universal Viewer extension. This viewer leverages open source frameworks for robust 3D display, including Three.js, A-Frame, and AMI Medical Imaging Toolkit, and has been built to be extendible for future AR/VR applications. Figure 1 below shows an embedded Aleph/Universal Viewer preview of a biological specimen object which is interactable.

Figure 1. An embedded interactive 3D preview of a biological specimen object.

Representing Complex Image Acquisition Paradata

The most difficult problem we have seen data producers, repositories, and community-standards groups struggle with is how to record image acquisition paradata in a granular standardized way while also accounting for the diversity and complexity of data creation workflows. MorphoSource Rails addresses this challenge with a data model (Figure 2) that represents media, physical objects, imaging devices, and other things as a network of “entity” records that can be related to each other using “event” records (i.e., “objects” and “events” from the PREMIS Data Dictionary). Each record, whether representing an entity or an event, has specialized metadata for describing that object or action. Media files are related to both the record of the “physical object” they represent and the record of the “device” or tool used to image that object by an “imaging event” record. A complex series of derivative media can then be represented as a long chain of parent and child media entities connected by processing events.

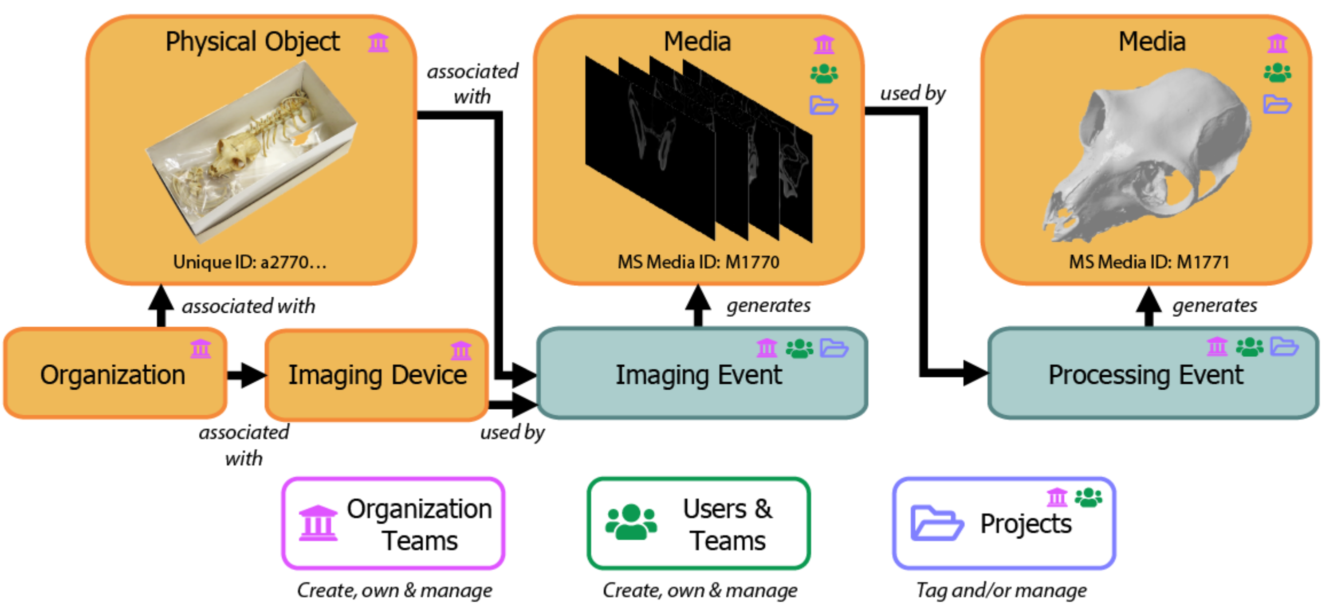

Figure 2. Schematic diagram of MorphoSource Rails data model. The workflow shown is that of a relatively simple CT scan imaging process.

Agents or users are not tied directly to data creation workflows: data are contributed through a user or team MorphoSource Rails account (Figure 2, bottom row and management icons throughout). Ownership and management rights flow from and can be modified by users and teams. As part of this management functionality, users and teams determine how and by whom data are accessed or modified. Organizational teams are special certified user groups that officially represent a collection or imaging facility organization. They have default management status for all specimens associated with their organization and view access to all media associated with specimens they manage. Records associated with an imaging event and derivative chain can be owned by multiple users and teams in an ad hoc way. Any user can create projects containing media for the purpose of tagging resources used in lesson plans or research articles, for example. Users can create projects that give special access permissions for media they own to any number of other individual users.

This data model maps to virtually any image creation scenario and supports the long and complex image acquisition workflows and data relationships required for scientific and academic use cases that treat imagery as data (Figure 3). Our submission form anticipates that raw data may often be unavailable, and our processing event structure anticipates that some users will prefer to use one event to specify multiple sequential processing activities, while others might specify the same workflow through multiple events with fewer activities in order to preserve a number of intermediate media files (Figure 3A). In addition, during data submission, users are required to choose an imaging modality from a controlled vocabulary, which allows preloading of modality-specific metadata profiles and restricts allowable formats for media upload.

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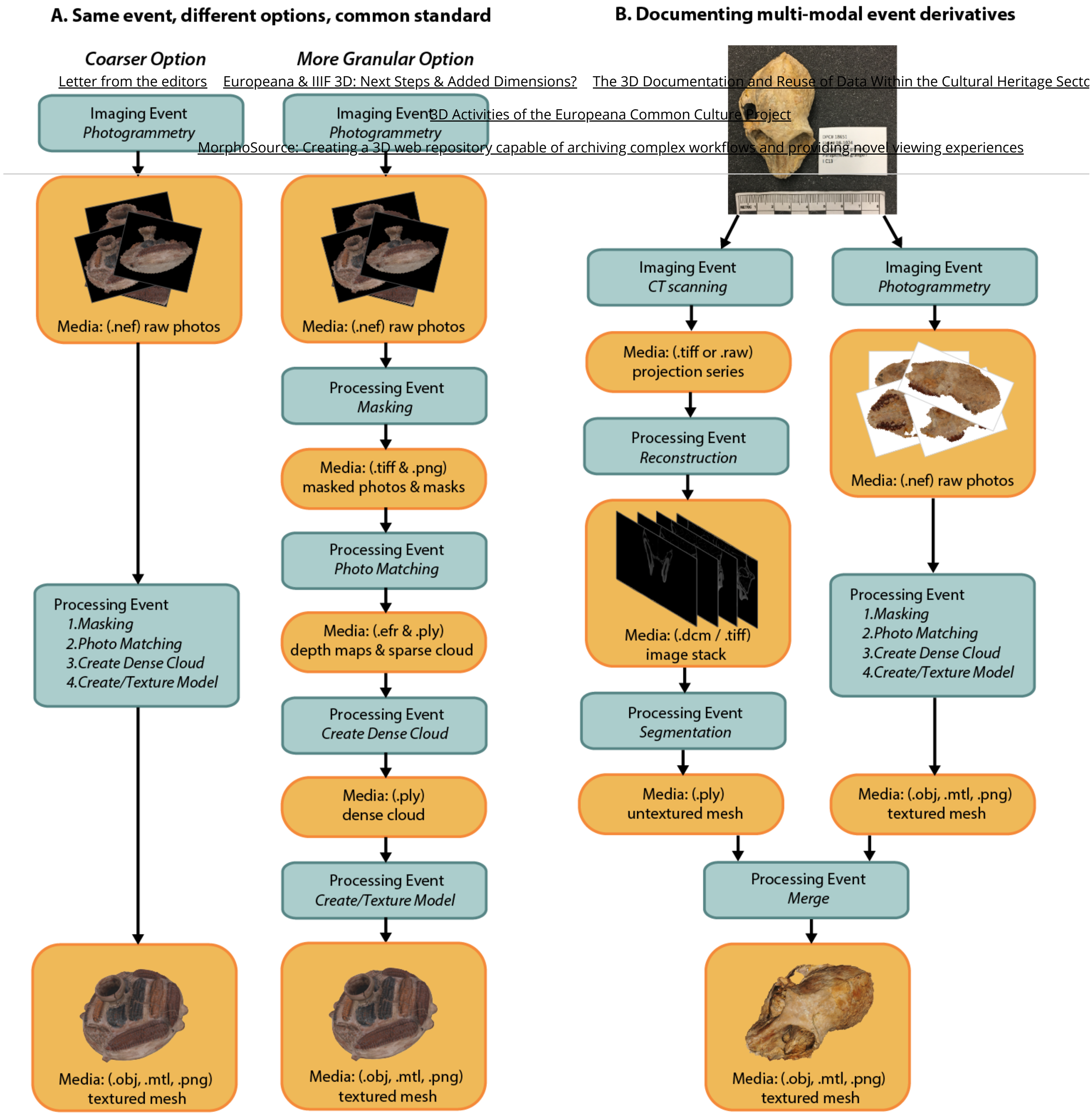

Figure 3. Schematic diagram demonstrating the ways in which the MorphoSource Rails data model allows the platform to have a UI supporting complex image acquisition narratives. 3A shows how the processing event model can reflect the creation of a photogrammetry model with only initial and terminal media archived, a variety of intermediate media, or any point between these extremes. 3B shows how the data model can describe media resulting from multiple imaging events or even multiple imaging modalities.

An Example Photogrammetry Deposit

To demonstrate the flexibility of this approach, we present an example deposit of a cultural heritage object imaged with photogrammetry (Figure 4). The cultural heritage object here is *Pacha with ears of corn* **(https://nasher.duke.edu/artwork/2213/)**, an Inca vessel dated to 1438 – 1532 in the collection of the Nasher Museum of Art at Duke University and imaged by the Wired Lab for Digital Art History & Visual Culture, Duke

University. Figure 4 below is a screenshot of how this model is represented on MorphoSource Rails. The upper portion shows the initial top page view of this media object. A short description of the media, including its status as a cultural heritage object and the physical object which it represents, is indicated in the header banner. Below this, the media can be previewed and interacted with to the right. To the left, primary media metadata is provided, including title, creator, file format, and relevant data resolution properties such as the number of points and polygons for this 3D model. Though it is not shown, immediately below this page view a user would find metadata relating to licensing, citation, ownership, and other similar information, as well as other media related to the current media.

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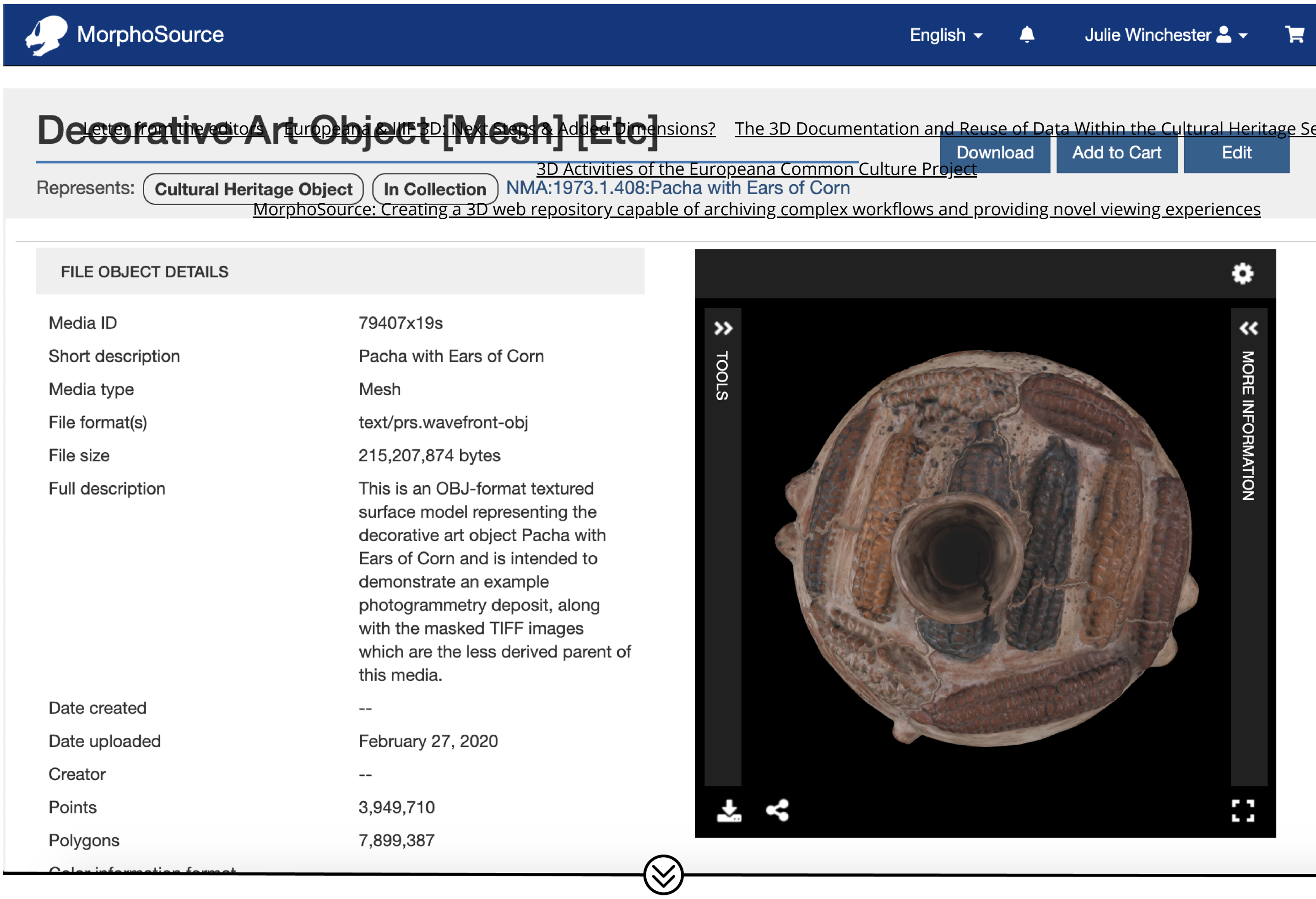

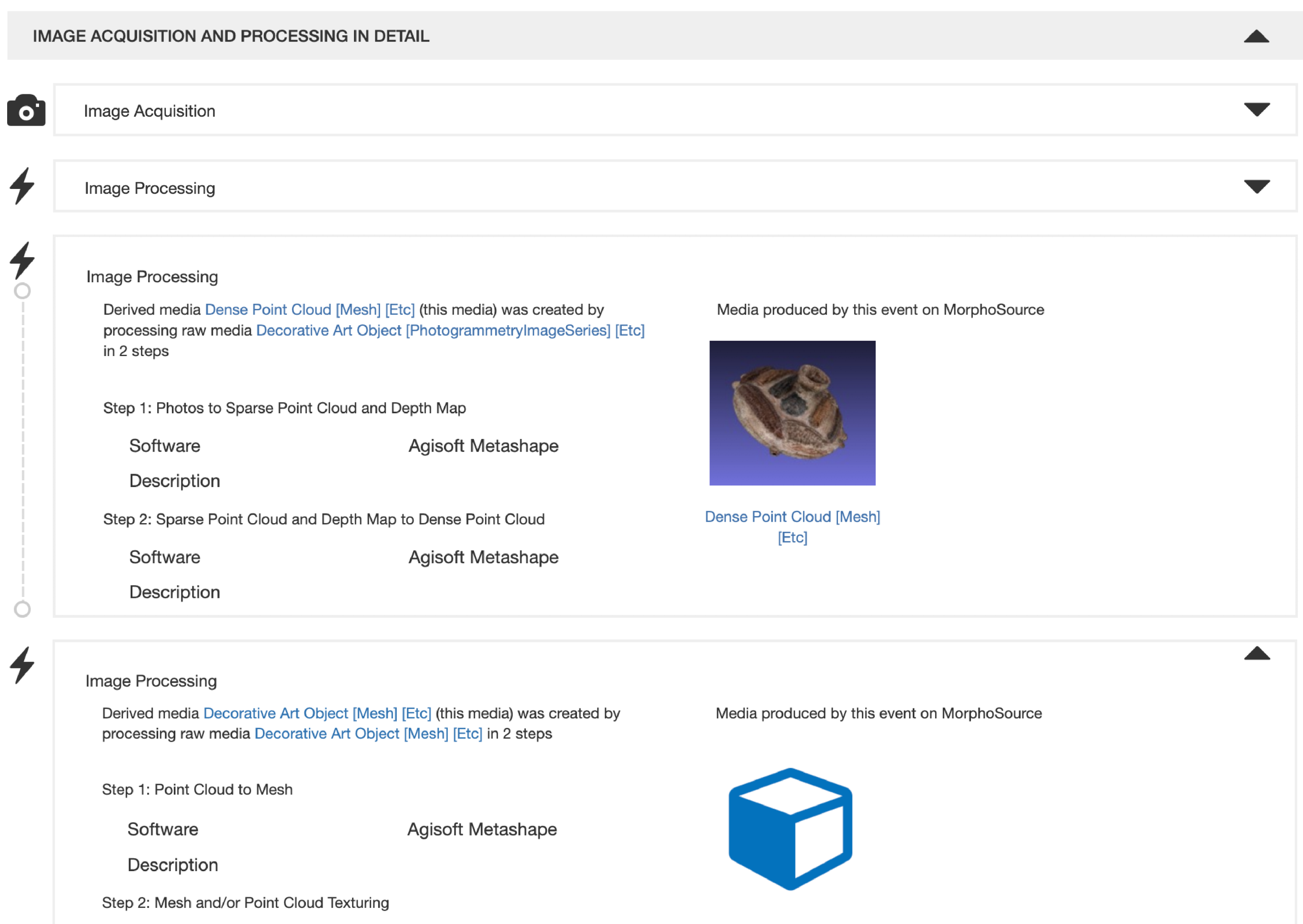

Software	Agisoft Metashape	Decorative Art Object [Mesh] [Etc]
Description		

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Figure 4. MorphoSource Rails media show page. ¬

The lower portion of Figure 4 shows the MorphoSource Rails media show page scrolled down to the section Image Acquisition and Processing in Detail. In this section, the complex image acquisition paradata that led to the creation of the current media are displayed. The first two collapsed events – Image Acquisition and the first Image processing – describe the creation of a collection of raw-format camera images and a derived collection of masked TIFF-format images generated from the raw-format images. The first expanded processing event visible here describes the creation of a dense point cloud media file from the masked images. The final processing event describes the two processing steps used to generate the current media, a textured surface model, from the dense point cloud. Each of these event sections contain a link to the media that was generated from that event.

Figure 5 is an embedded view of the decorative art object described above using the Aleph viewer, and is interactable.

Conclusions

An important priority for MorphoSource Rails is to provide extensive and customizable support for collections organizations (Figure 6). Collections with little institutional infrastructural support will benefit most from utilizing the MorphoSource web repository and cloud storage. Larger institutions with greater means to produce and host large numbers of datasets and international institutions may prefer other options. Specifically, we expect larger institutions to be interested in leveraging the tools MorphoSource has built for documenting paradata, generating interactive previews, and managing downstream use of data, while still utilizing their own storage infrastructure. We are very interested in beginning collaborations to attempt federations of locally managed MorphoSource instances. Please reach out to us!

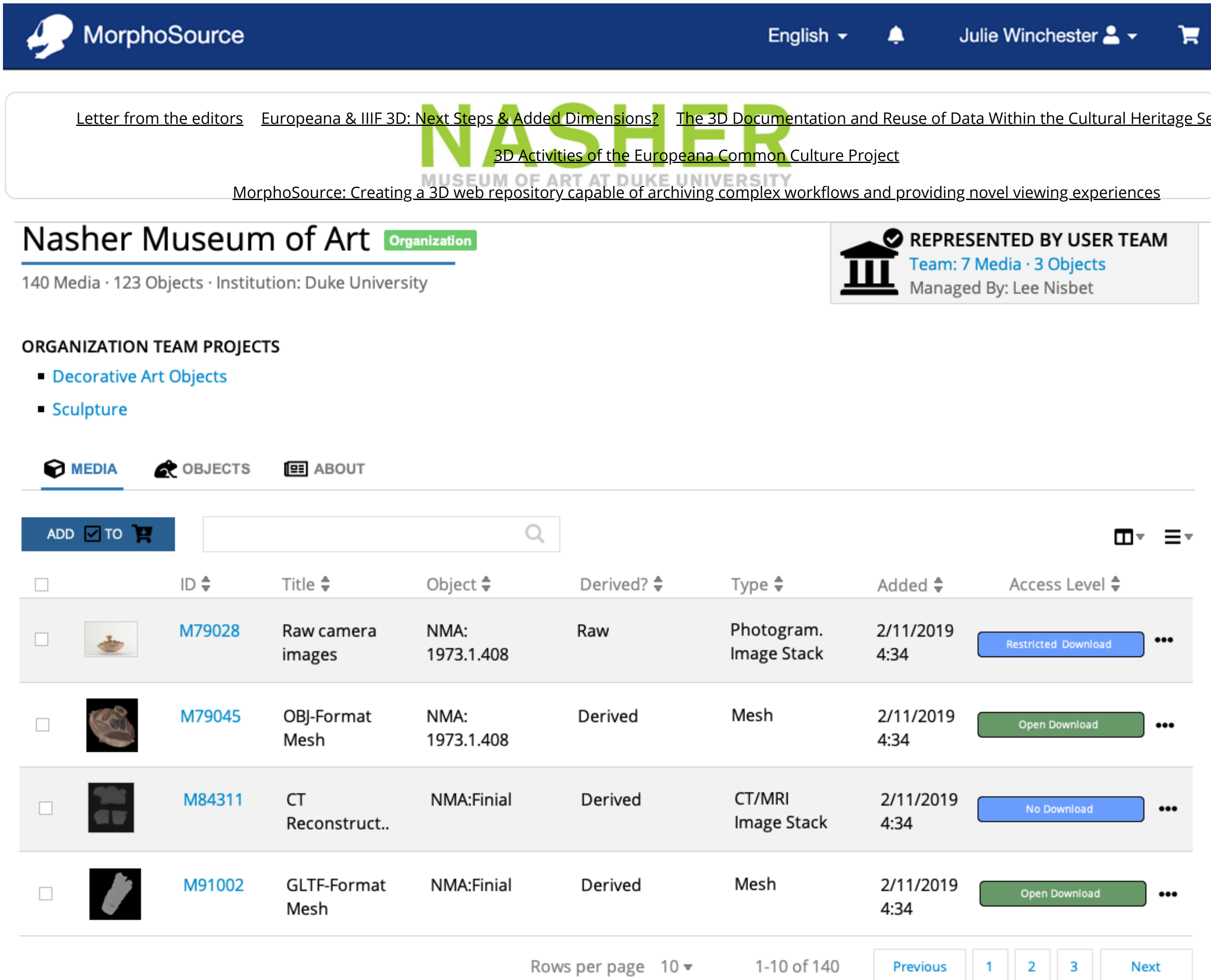

Figure 6. An example MorphoSource Rails collection organization show page for the Nasher Museum of Art at Duke University. On this page, users can find all uploaded media representing Nasher Museum physical objects. An official museum staff MorphoSource user team can be associated with this organization, and this opens additional access and management features for all MorphoSource media related to that organization.

Acknowledgements

Skip Down Icon from Figure 4 created by Marek Polakovic from the Noun Project and used here under a CC-BY license. We gratefully acknowledge the support of the Nasher Museum of Art at Duke University and the Wired Lab for Digital Art History & Visual Culture at Duke University for allowing us to use the example cultural heritage object included here. We also much appreciate the Duke Fossil Primate Center, Matt Borths, and Steven Heritage for both the creation of the textured primate skull model in Figure 3 and permission to use images of it here.

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