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The Dynamic Collections project: providing structured online access to digital replicas.

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***Abstract* – This contribution will present the latest results of the Dynamic Collections project, highlighting the evolution of the approach, methodologies and tools. The core idea behind the project was to explore the possibilities of working online, for teaching and study purposes, with high-resolution digital replicas of archaeological artefacts, going beyond the single-object approach.**
To this aim, the project built an archive of high-resolution digital models, and designed and implemented an online platform that makes it possible to build, annotate and share a custom assemblage of the objects in the archive (a Dynamic Collection, that is). These annotated collections can be the pivot element in the definition of collaborative workflows and shared research/teaching environments.

I. INTRODUCTION

The concept of "collection" is crucial in many areas of the Cultural Heritage world, especially in archeology. Collections are used daily for teaching, as reference to support excavation and classification of materials, to study stylistic variation and chronological developments.

Collections and archives continue to rely on object classifications for their accessibility—on chronological cataloguing as well as groupings based on material, form, technical elements etc. However, modern 3D visualisation technology represents an additional opportunity for identifying and (virtually) sharing an even larger number of significant features and elements contained within the single artefacts with a broader, even global, community of stakeholders, and provide a greater holistic access to details and perspectives of the objects otherwise inaccessible due to their fragile state or to limited visibility or access [1] [2] [3].

The materiality of digital objects, and the various digital modalities through which this materiality is mediated, has furthermore the potential to counter the limitations of 2D representations [4] so common in archaeological archives and publications [5], and allow the exploration of novel analyses and interpretations [6] [7] [8] [9] [10] [11] [12]. Until now, however, much scholarly discussion has revolved around the ethics of 3D archiving, the tools and techniques available, the importance of metadata and the sustainability of this data.

Despite the large investment, at national and international level, in the mass-scale digitization of cultural heritage artefacts, and in the creation of platforms for the archival and access to digital models. These platforms, however, were not originally designed to facilitate deep interaction with digital materials or to encourage new research approaches.

Since 2009, The Petrie Museum of Egyptian Archaeology at UCL, with UCL's Department of Civil, Environmental and Geomatic Engineering and business partner Arius 3D, has been developing a programme for creating 3D models of objects in the Petrie collection UCL (https://www.ucl.ac.uk/3dpetriemuseum/). The aim is to develop a range of digital 3D applications that will engage audiences, and to undertake audience evaluations of the 3D models and applications to better understand the potential of 3D in cultural heritage. The artefacts are presented online, but with limited interaction.

Another example is the digital sculpture project (www.digitalsculpture.org/florence) carried out by the Virtual World Heritage Laboratory (VWHL, Indiana University), the Politecnico di Milano and the University of Florence. The project started in 2016, aiming to digitise in 3D the complete collection of Greek and Roman sculpture in the Uffizi, Pitti Palace, and Boboli Garden. The models are presented online, through the Sketchfab service, but there are no specific tools to work with the objects. Meta- and para-data are provided.

Also in the French context, there is a 3D collection created by an agency serving French museums

(https://www.photo.rmn.fr/CS.aspx?VP3=CMS3&VF=RMNNN6_21&FRM=Frame%3ARMNR5N_79).
The hosting and visualisation, also in this case, relies on sketchfab, without specific tools to interact with the objects.

The digital collection proposed by the Smithsonian museum in the Smithsonian 3D digitization project (https://3d.si.edu/) is a good example of a digitization campaign enriched by tools. Beside the creation of high-quality 3D data, also available for download, the Smithsonian worked on the creation of a specialised tool to interact, measure and present in an annotated and enriched form the 3D models: the Smithsonian Voyager (https://smithsonian.github.io/dpo-voyager/).
The annotation and authoring feature, are, however, restricted to the person doing the publishing (and not available to the final users), and there is not a clear support for working with a group of objects.

The 4D research lab in the Netherlands also works with the digitization of artefacts. The initial tests have been based on Sketchfab, but they are starting an activity focused at building a dedicated tool. They plan to extend the Smithsonian Voyager tool to add annotation and collaborative work capabilities, to create a shared 3D workspace for educators, researchers and students (https://4dresearchlab.nl/research/interfaces/).

Ideally, a digital collection must be something more than just a set of 3D models with some attached metadata, but should be able to include all those elements that might be used by scholars and teachers to effectively use those objects in their everyday work in a cohesive and structured way. Elements such as notes, reasoning relationships, object-specific annotations, cross-links between the entities in the collection, schemes and conceptual maps.

The COVID-19 pandemic made it even more apparent these limitations, as the digital resources became the only available sources for research, highlighting the urgent need to explore strategies to define digital collections as primary research tools and to fully support scholars working in the digital space.

II. THE DYNAMIC COLLECTIONS PROJECT

The Dynamic Collections started as a result of a collaboration between the Visual Computing Lab of ISTI-CNR (Italy) and the Digital Archaeology Laboratory at Lund University (Sweden) [13].
The project has developed an online system that hosts a number of digitised artefacts coming from university and museums reference collections, and provides functionalities to create, annotate and share custom assemblages of the available objects (hence, the name dynamic collections).

The online system (freely accessible from the page https://www.darklab.lu.se/digital-collections/dynamic-collections/) hosts a wide set of digitised high-resolution 3D models of artefacts, enriched by simple meta- and para-data (Fig 1, top).
The entire archive of objects can be explored with a standard web interface and simple searching/filtering functionalities.

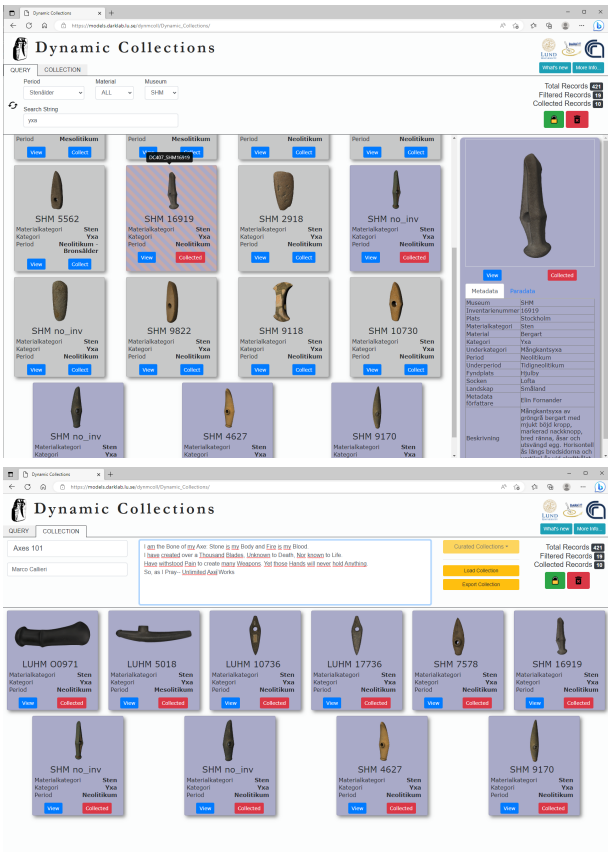

Fig 1. The online platform, showing all the objects in the archive, with details and metadata (top) and an annotated collection (bottom)

The users can then explore all the objects in full detail, using a customised navigation and visualisation interface built on top of the 3DHOP tool (https://www.3dhop.net/) [14]. Thanks to its multiresolution engine, the high-resolution textured models are stored in a compressed, streaming-friendly format, making it easy the transmission and efficient realtime visualisation of the digitised datasets at their full detail.
To cope with the need of the project, the 3DHOP viewer has been fully customised to enable a deep interaction with the 3D models (Fig. 2). The navigation interface is simple to use but able to reach every part of the object, it uses a turntable + pan + zoom interaction, with

doubleclick-to-recenter function, it offers predefined canonical views and a navigation cube to help in understanding the positioning of the object. The rendering options makes it possible to perceive the structure and details of the surface, offering a variable light direction, and options to toggle between texture and pure geometry, make the object translucent and see the inner structure, toggle illumination on/off, and add specular reflections to enhance the surface details. The object can be interactively sliced using cut-through sections. The measurement tools can be used to do on-the-fly geometrical analysis on the model, using point-to-point distance, coordinates point picking, angle measurement.

A core component of the viewer is the possibility to annotate each digital model. It is possible to add free-text notes to the object. The user can save "bookmark views" that contain the current view direction and all the rendering and measurement parameters, effectively saving the current state of the viewer, and associate to these views some text notes. Finally, it is possible to add custom hot-spots located on specific points of the geometry, thus adding notes to specific areas of the digital model.

Object annotations can then be saved and exported as JSON files for later use or sharing.

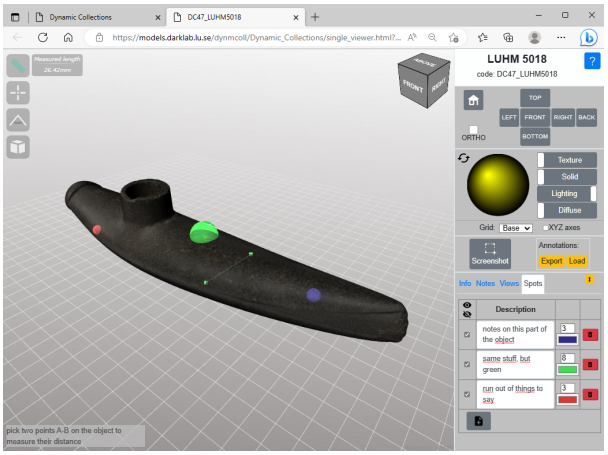

Fig 2. The single-object viewer, showing an annotated high-resolution 3D model.

The most interesting aspect of the system is going beyond the single-object paradigm. The users can assemble a custom collection (a *dynamic collection*, that is) from the available digital objects, according to their needs and purpose (Fig 1, bottom). This collection can be then enriched: by adding notes and information at the collection level, but also by annotating each individual object in the collection using the aforementioned tools, thus creating an *annotated dynamic collection*. This annotated collection can be then exported as a JSON file for later use or to be shared with colleagues and students, to pursue a collaborative working/teaching environment.

The idea is that the annotated collection might be used to build complex interaction and collaboration schemes between scholars and students. An annotated collection may be used to represent the working notes shared between the authors of an oncoming paper. It might contain the candidates for the identification/classification of a newly excavated specimen, with comments localised on the different parts of the candidates that are relevant for the identification.

Assembled by a teacher, an annotated collection may be used as a course material, distributed to students or used as slides during lessons. Compiled by the students, it might be lecture notes taken directly on the 3D models, or even over the same collection distributed by the teacher (as annotations can be added over existing ones). Or it might become an assignment to be compiled by the student and sent back to the teacher.

This setup maintains a clear distinction and separation between the data created by the users (the list of chosen objects, the notes and the annotations are stored in the collection data structure) and what is the official, institutional data (all the 3D models and their relative meta- and para-data are stored only in the online system).

This separation also causes an additional level of privacy: the user data is always under the full control of its creator, as the creation of the annotated collection happens client-side and it is not stored on the remote server.

This detail was initially caused by a limitation of the system, but has become a relevant feature of the system, as the target audience values this kind of privacy. Although we will add server-side capabilities in the next step of the project (see next section), we still will strive to maintain the possibility of working completely client-side, to support this kind of use, well received by the community.

III. AN ONGOING EFFORT

Since its initial release, in December 2020, the project has been steadily growing. Scholars from different universities currently use the online system to support research activities, and various courses have used the annotated collections as teaching material and for tests.

In order to obtain meaningful results, it was necessary to reach a critical mass of 3D objects to interact with [15]. For this reason, the project established a plan for the digitizations, complete with guidelines and conventions for the data creation and processing, allocated hardware and software for the task, and recruited a specialist to carry out the data collection.

The FAIR principles [16] were carefully considered when setting up the archive and its procedures, to enable the reuse of the digital models and of the original data.

Digitization was carried out using various techniques and devices, depending on the objects characteristics: 3D

scanning devices (ARTEC Spyder, Eva and Leo); photogrammetry, through the Agisoft Metashape software (often using macro lenses or cross-polarization setup); or using a combination of both scanning and photogrammetry. The 3D models were often subject to further processing (cleaning, orienting, local repairing), using MeshLab.
The data was archived as raw data plus the master 3D model, and then converted to the NEXUS multiresolution format used by 3DHOP for the online publishing and streaming.
3D models coming from previous campaigns or external sources were checked and, when necessary, made compliant with the conventions of the project (mostly: reoriented and scaled to the preferred measure unit).
The archive of digital models continues to grow and currently includes 420 high-resolution 3D models of archaeological artefacts, ranging from the Stone Age to the Middle Ages, coming from the Historical Museum of Lund University, the Blekinge Museum and the Historical Museum in Stockholm.

The connections between the project and other research initiatives across Europe (e.g. BItFROST, Ariadne+) proved to be extremely helpful in the and it was an opportunity for the growth of all the involved parties.
More recently, the Dynamic Collections project has become part of the newly established Swedish National Infrastructure in Digital Archaeology SweDigArch, and it is used as a raw model by different institutions for publishing their data. The Dynamic Collections platform is also being used to support ongoing experiments within the activities of TETRARCHs (Telling Stories with Archaeological Data, https://www.tetrarchs.org/).

The system has been used in teaching courses, and the feedback from the users has been collected through the course evaluation questionnaires. While mostly positive, the students found it difficult to use the 3D interface on mobile devices, and we are thus updating it to be more responsive and compatible with tablet-like devices.

The online platform is being expanded to support new interaction methods and new tools to create and share data, further enriching the possibilities offered by the annotated collection data structure.
For example, we are adding a new entity in the collection that makes it possible to compare multiple objects using a dedicated interface that enables synchronised and coherent browsing of the objects, and offers annotation capabilities. This new element builds on top of the idea of annotated collection, as it offers new ways to interconnect the entities in the collection following the reasoning of its author. This feature is currently in the testing phase (Fig. 3).
Other dedicated tools, oriented to teaching, to support the creation and management of tests and exams using the platform are currently being designed.

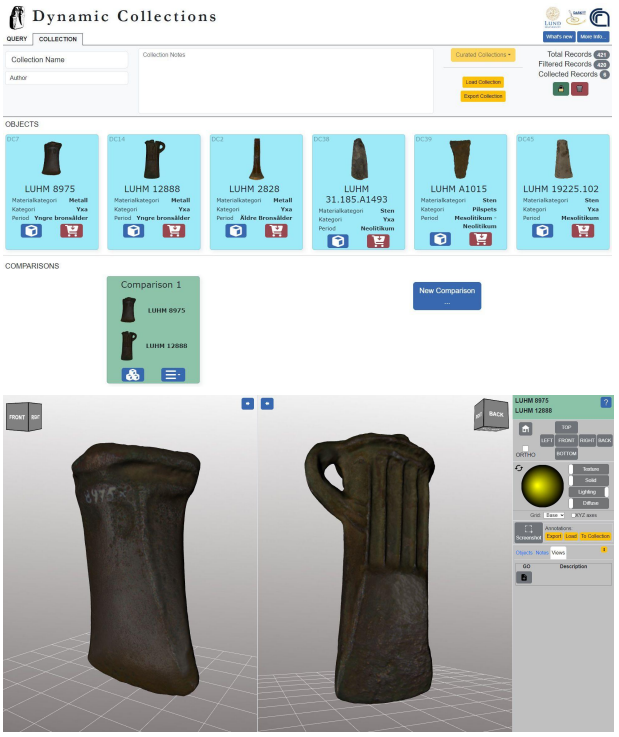

Fig 3. The new "comparison" entity in the collection can be used to create side-by-side multi-object visualisation and annotation.

The project is also improving its management of the metadata, by going towards a complete semantic approach. The new meta- and para-data definition follows established Ontologies and Vocabularies, ensuring more robustness and expressiveness to the stored data (Fig.4).
To make all the project data interoperable with other existing repositories and archives, the new version of the online system will be based on OMEKA-S, a semantic web CMS (https://omeka.org/s/). This open source platform supports modern linked data access paradigms, and is becoming more and more widespread across research bodies and public institutions.
This development increases the possibilities of Dynamic Collections to share digital content, interconnect with other open projects, and more easily reuse the information currently stored in the system.

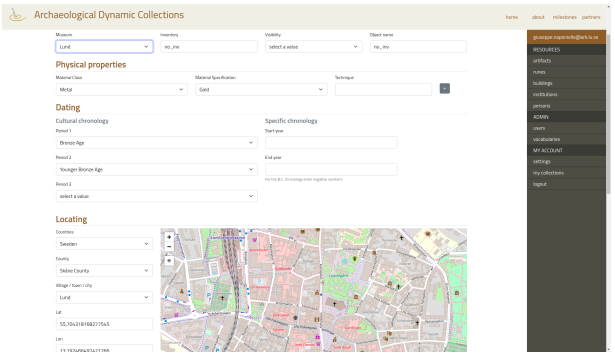

Fig 4. To support the new semantic-mapped metadata, the authoring tool make use of ontologies and vocabularies

IV. CONCLUSIONS

The Dynamic Collection project is still an ongoing effort, but has already demonstrated the potentialities of a deep, structured interaction with a digital collection, not just by proposing abstract interaction paradigms, but providing an accessible platform to experiment with these concepts.

From a theoretical point of view, the most interesting contribution of the Dynamic Collections project is related to the concept of the annotated custom collection. This structure is a simple but powerful concept that can be the basis of multiple interactions and workflows.
Its modular structure makes it easy to be extended, adding new components and nodes.
The collection data structure is stored as a JSON file, and this can help in making its components interoperable with other software tools (e.g. transfer the saved views and surface hotspots data from the Dynamic Collection viewer to rendering software like Blender; 3D editing tools like MeshLab, GeoMagic; or use them to create interactive kiosks).

All the project is based on Open Source tools, the developed technical solutions will be available to the community as reusable tools, to further stimulate the development of advanced interaction platforms online.

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