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Dynamic 3D model for decoding archaeological complexity of funerary contexts

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***Abstract* – Archaeological contexts are extremely dynamic, undergoing changes over time that profoundly alter the archaeological record, both due to intentional human manipulation and natural degradation phenomena. These post-depositional phenomena distort our perception of ancient contexts, often making it difficult to recognize the original arrangement and to understand what the archaeologist is analyzing. This aspect especially concerns the funerary contexts, like burials, which are subject to numerous natural or anthropogenic changes. This study shows how, by analyzing funerary contexts in a processual key and reconstructing them in a 3D environment, it is possible to simulate, to isolate, and to analyze post-depositional phenomena through metrically and morphologically correct 3D reconstructions. 3D simulation can be extremely accurate when parameters such as gravitational force is taken into account. The aim is to verify changes due to transformation phenomena. The goal is to create a sequence that shows the transformative processes of the burial, from the moment of deposition to the excavation phase.**

I. INTRODUCTION

The sequence of transformative processes in a burial can be used to better understand the original arrangement in several ways. By analyzing the post-depositional phenomena that have affected a burial, it is possible to identify and isolate the changes that have occurred over time. Additionally, the sequence of transformative processes can provide insights into the cultural practices and rituals associated with the burial. For example, the accumulation of sediment or other materials within the grave may suggest that the site was revisited and used for subsequent burials. By analyzing the sequence of transformative processes, archaeologists get a deeper understanding of the cultural context in which the burial occurred and the significance of the burial practices to the people who performed them.

The fundamental premise for achieving this goal is the analytical and detailed study of the excavation sequence, to verify the temporal succession of phenomena. However, traditional study approaches do not always succeed in reconstructing all processes in their complexity, because a single post-depositional event can often generate multiple effects on the archaeological record.

By reconstructing these changes in a 3D environment, it is possible to create a dynamic model that shows the original arrangement of the burial and how it has been transformed over time.

Approaches that use 3D physical simulations are commonly used in various fields of research, like civil engineering [1], structural mechanics [2], and medical filed [3; 4]. These approaches are particularly useful for understanding the structural behavior of buildings and structures in response to different stresses [5; 6].

The statement highlights that while there are many examples of 3D reconstructions of funerary contexts in the literature, there is a lack of simulations of the degradation and transformation processes that affect these contexts over time [7; 8; 9].

Future steps may involve increasing the number of simulations to improve the visualization of the original arrangement of burials, to understand how these contexts have changed, and how these changes have affected our interpretation of the archaeological record.

II. MATERIALS AND METHODS

A. The necropolis of Piovego and its burial 22

The burial studied comes from the Iron Age necropolis of CUS-Piovego. The necropolis was frequented between the end of the 6th and the beginning of the 4th century BC, a crucial moment in the history of the ancient city of Padua, when it transitioned from a pre-urban settlement to an urban one [10; 11].

The Department of Cultural Heritage at the University of Padua has focused attention on the necropolis of Piovego in recent years; this context has been the subject of numerous archaeological and anthropological research studies [12; 13; 14].

In a previous research project, a team from the Department focused on the 3D reconstruction of some of the cremations from the necropolis based on two-dimensional graphic reconstructions of the burials and drawings of the artifacts. Among the analyzed tombs was also burial 22 [15; 16].

The burial 22 is a pit cremation. The cremated remains of the deceased were deposited inside an ossuary. The funerary assemblage was composed of several ceramic and bronze sheet vessels. All the metal objects, except for two, were placed inside the ossuary; the interior of the burial was characterized by the deposition of the funerary assemblage on two levels. The deposition on multiple levels was made possible thanks to the use of perishable materials, which allowed the objects to be placed on different levels. However, these elements were not found during the excavation, but their presence was suggested by the arrangement of the funerary assemblage itself (fig. 1).

Fig. 1. The burial 22 as it appeared at the moment of its discovery.

A 3D reconstruction of the burial has been carried out in a project with the aim of defining the position and metrics of a perishable material element inserted within the burial, as well as the correct position of the funerary assemblage. The 3D reconstruction also allowed to verify the minimum extension of the pit, which was previously unknown [17]. The typochronology of the metal objects and the bronze sheet vessels of the grave goods date the burial between the end of the 6th and the beginning of the 5th century BC.

B. Case study: the vessel 61

The research presented here aims to investigate the transformations that archaeological contexts undergo due to post-depositional processes using three-dimensional reconstructions. This study moves in this direction by applying the analysis of dynamic factors to Iron Age cremation burials, which have already been obtained through 3D modeling, using tools provided by computer graphics software integrated with physical engines.

The starting point was therefore the static 3D model of burial 22 of the Piovego necropolis, specifically analyzing the fall of an object from a higher to a lower level within it.

This work is focused on the reconstruction of the dynamic of the fall of vessel 61. During the excavation phase, the collection of data was excellent because it was done from a genetic-processual perspective, aimed to define the formative genesis of the archaeological deposit [18; 19; 20]. During the post-excavation phase, its position could not be established, but it was known that some fragments of the vessel were found in the pit and on the shoulder of the ossuary. Previous 3D simulations showed that there was not enough space to place vessel 61 on the floor of the pit (fig. 2).

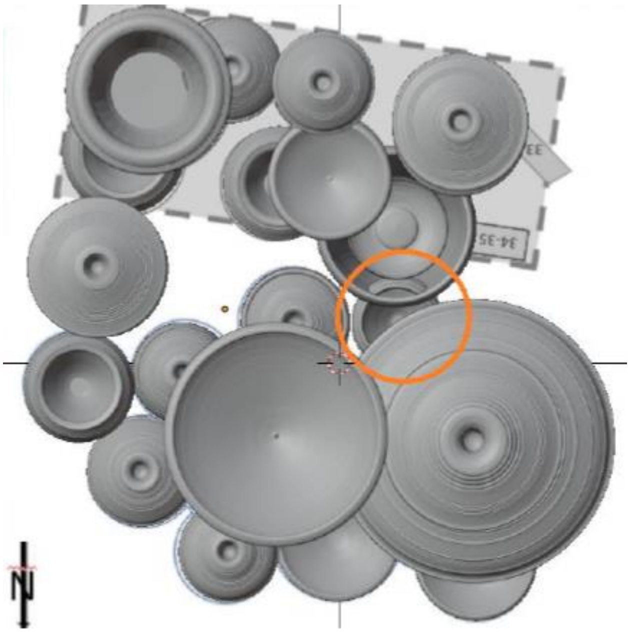

Fig. 2. Evidence from previous simulations has shown that it is impossible to position vase 61 between vase 1 and vase 59.

Thus, vessel 61 was placed on a surface made of perishable material located along the south side of the pit. This position is the only one that is compatible with the locations where the fragments of the vessel were found. The vessel fell from a height of about 22 cm, impacting the shoulder of the ossuary (causing fragments to be released) while others fell into the pit, between vessel 1 and vessel 59 (fig. 3). Probably the fall of the vessel occurred when the surface made of perishable material was still entirely or partially intact.

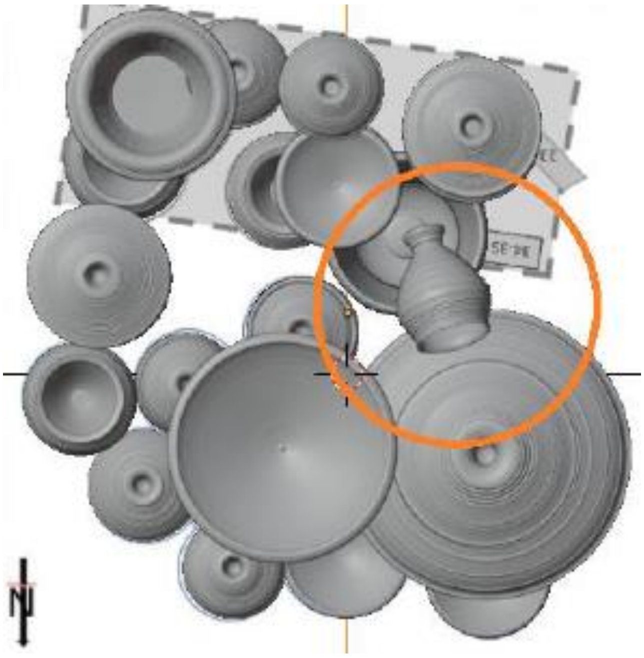

Fig. 3. Static simulation of the direction of the fall of vase 61.

C. Physical simulations in Blender

The complexity of these phenomena that accumulate over time on the archaeological deposit is such that it cannot be managed in its entirety. The first step is to recognize a hierarchy of phenomena to identify the relative sequence of the dynamics of fall and/or transformation. Secondly, it seemed useful to simulate them individually at the beginning and then bring them together in a general framework. The aim is to simulate the changes that have occurred in a diachronic sequence.

This is a methodology applied *a posteriori*, that is, when the deposit has already been excavated, which is why the dataset for this research is made up of excavation data. For this reason, it is necessary that the collected data be complete and detailed enough to be able to accurately recognize the formative genesis of the archaeological deposit.

Blender [21] is commonly used to perform physical simulations [22; 23]. In addition to that, if necessary, the mass of the individual objects involved can be modified based on the size of the objects and the material they are made of, to achieve a dynamic simulation that is as realistic as possible.

III. DISCUSSION AND RESULTS

The first step is the preparation of the scene in which the dynamics of the fall take place with all the objects involved. The second step consists of calculating the path of the vase along the vertical axis of the scene. This path has its starting point where vase 61 was originally placed, and it ends when the fall of the object is ended, at the base of the pit of the burial.

Fig. 4. Simulation of the different degrees of breakage of vase 61. From top to the bottom: 10, 20, 30 fragments.

Another aspect to consider is that vase 61 is found in fragments. For this reason, it was necessary to work on the degree of fragmentation of this object to achieve a plausible breakage and to realistically reproduce the clusters where its fragments were found (fig. 4).

To generate a simulation, it is necessary to determine whether the objects present in the scene are active or passive (fig. 5).

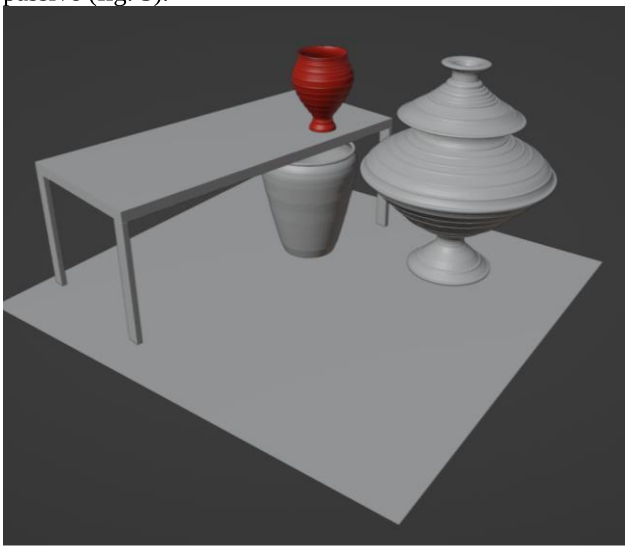

Fig. 5. Final scene setup: active object in red; passive objects in gray.

Active objects refer to those that are affected by the fall phenomena, for example in this case the vase 61. This object, in fact, falling from above, impacts on the shoulder of ossuary 1, spreading some of its fragments on it, while other fragments fall and disperse on the ground. On the other hand, the passive elements of the scene are the objects from which the fall originates and ends (the support, the perishable material, and the floor of the pit) and those that act as an "obstacle" to vase 61 (ossuary and vase 59).

To activate the fall, it is necessary for an external object outside of the scene to initiate the movement. A very small object, modeled from a primitive and which will be an active object, is added. This trick is necessary when simulating phenomena separately, as not all transformation factors are considered in isolation from each other.

Finally, when all parameters have been set, the scene can be started by playing the timeline in the interface. The small object outside the scene will hit vase 61 and cause it to fall along the path that has been set.

IV. CONCLUSIONS

The potential of virtual tools allows for a broadening of perspective in archaeologic research and provides the necessary means to carry out dynamic simulations.

The research presented represents a first attempt to analyze and reproduce a dynamic physical simulation in a 3D environment within an archaeological context. Within the overall dynamics that affect burial 22, a single event was isolated and analyzed: the fall from above of vase 61. In this specific case, data collect during excavation was carried out with an approach aimed to recognize transformative dynamics.

However, not all archaeological contexts are excavated with care and with an approach aimed at recognizing the formative processes of the deposits. This could be a limitation in terms of application, and for this reason that the progress of research in this field could implement the applicative contexts.

The dynamic simulations thus carried out could become a research tool even for those contexts that have already been excavated and do not have such precise data. The aim is to define a workflow applicable to different case studies, not necessarily excavated with a genetic-processual approach.

The next steps will be to analyze the other transformative phenomena that occurred in tomb 22 and establish a relative chronology to recognize which processes occurred before others. The aim is to understand which was the first phenomenon (or the first ones) to have acted on the archaeological deposit, in order to create a diachronic sequence of transformations.

Subsequently, it will be necessary to simulate these actions in a 3D environment to obtain a global reconstruction of burial 22. This reconstruction will show the transformation and degradation phenomena that occurred from the moment of tomb closure to its excavation.

These initial experiments could also be conducted in environments other than Blender. In particular, the research could be implemented using other physics engines such as Project Chrono, COMSOL Multiphysic, Bullet. Increasing the number of simulations would lead to multiple results that could be compared to isolate workflows that are adaptable to the specific characteristics of the contexts under examination.

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