# ACCELERATED NEUTRON TOMOGRAPHY AND AI-ASSISTED RECONSTRUCTION FOR THE STUDY OF ARCHAEOLOGICAL ARTIFACTS FROM THE VOLNA 1 NECROPOLIS

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The Volna 1 necropolis on the Taman Peninsula is one of the key archaeological sites associated with Greek colonization in the Northern Black Sea region. Metal artifacts discovered there are of particular importance for the study of ancient craftsmanship, cultural contacts, burial practices, and corrosion processes. At the same time, such objects are often unique and fragile, which makes non-destructive analytical methods essential for their investigation. Previous work has shown that neutron and X-ray tomography complement each other well in the study of archaeological finds from Volna 1: neutron imaging is highly informative for detecting internal corrosion products, hidden voids, and features associated with light elements, whereas X-ray tomography provides high-quality visualization of dense metallic regions. Their combined use makes it possible to characterize both preservation state and technological features of ancient objects without physical intervention.

A major practical limitation of neutron tomography, however, is the long acquisition time required to collect a sufficiently dense set of radiographic projections. This reduces throughput, complicates the study of series of artifacts, and is especially undesirable for valuable archaeological material. In earlier work, convolutional neural networks were explored as a tool for reconstruction of neutron tomography from incomplete projection sets, showing that the number of required projections could be reduced substantially while preserving acceptable reconstruction quality. This direction is especially promising for cultural heritage studies, where measurement time, activation concerns, and access to beam facilities are critical constraints.

In the present study, we develop this approach further by addressing the reconstruction problem in a form that is more suitable for sparse-angle neutron tomography. Instead of treating the task as a classification or segmentation problem, we formulate it as image-to-image completion of the sinogram followed by reconstruction in image space. The input consists of a sparse sinogram acquired on a reduced angular grid, while the target is the full sinogram corresponding to a standard acquisition geometry. To improve physical consistency, the measured angular rows are preserved explicitly, and the neural network predicts only the missing information. This hard data-consistency strategy helps prevent degradation of experimentally measured projections and stabilizes training.

The model combines two stages. In the first stage, a convolutional network reconstructs the missing angular information in the sinogram. In the second stage, a refinement network operates directly in reconstruction space and corrects residual artifacts after filtered backprojection. This dual-domain strategy is motivated by the fact that global consistency is easier to recover in projection space, while local fine details and object morphology are more naturally corrected in image space. To improve the fidelity of internal features, the training procedure includes object-focused supervision in reconstruction space, with increased emphasis on the artifact region and its internal structure rather than on the empty background.

The proposed pipeline is aimed not only at improving visual quality, but also at preserving archaeologically relevant information: internal cavities, corrosion patterns, density heterogeneities, cracks, and technological traces that may reflect manufacturing history or post-depositional alteration. This is especially important for finds from Volna 1, where the interpretation of metal composition, preservation state, and production technology depends strongly on the reliability of internal structural data. In practical terms, accelerated tomography based on sparse-angle acquisition and neural reconstruction may make it possible to investigate larger numbers of artifacts, shorten beam time, and reduce the burden on unique museum and excavation materials.

The results obtained so far indicate that AI-assisted reconstruction from incomplete projection data can significantly improve the efficiency of neutron tomography while retaining physically meaningful internal structure. In the context of the Volna 1 necropolis, this opens new possibilities for systematic, non-destructive study of ancient metal artifacts and for integrating advanced imaging methods into archaeological research, conservation planning, and the reconstruction of ancient technological traditions. The combination of neutron tomography, X-ray tomography, and neural-network-based reconstruction therefore represents a promising interdisciplinary framework for the investigation of cultural heritage materials from the Classical world.

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