Machine Learning for Microstructural Characterization of Archeological Specimens from XRT

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Abstract

Concrete is the second most-consumed resource in the world, and it is currently responsible for 8 percent of all carbon dioxide emissions – one of its key ingredients, cement, produces more than 4 billion tons yearly around the globe. Research about the structural characteristics of Ancient Roman concrete has been influencing the process of designing future materials with similar complex heterogeneous structures, exhibiting exceptional durability, low-carbon footprint, and interlocking minerals that add cohesion to the final compound. Its poorly crystalline, calcium-aluminum-silicate-hydrate (C-A-S-H binder) in the cementing matrix of the mortar contributes to the long-term durability and pervasive crystallization of zeolite and Al-tobermorite minerals; in addition, the sequestration of chloride and sulfate ions in discrete microstructures of concrete further improves the crack resistance. These hydration and crystallization products compose specific microstructures in ancient Roman concrete, but identifying the structure of the cementing fabric continues to be a major challenge. By inspecting archeological samples (67 B.C. to A.D. 64) using X-ray tomography (XRT), the concrete microstructure can be quantified in terms of its different phases, their fraction estimates, and qualitatively analyzed through 3D visualization of the porous network and density gradients. These preliminary results highlight the advantages of using non-destructive 3D XRT combined with machine learning methods, e.g., Simple Linear Iterative Clustering, and Neural Networks, for systematic characterization of archeological samples. Internal structures and respective organization might be the key to construction durability as these samples come from ocean-submersed archeological findings. These samples present remarkable durability in comparison with the concrete using Portland cement and nonreactive aggregates.