Development of a Rapid Detection Method for A Particle Tracks in Nuclear Emulsion Using Machine Learning

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Introduction

Nuclear emulsion is a radiation detector composed of silver bromide crystals dispersed in gelatin that records charged-particle tracks as sequences of silver grains with submicron spatial resolution. Although tracks recorded in emulsion can be analyzed with Nagoya University's Ultra-High-Speed Track Selector (HTS2), fast and precise detection of α-particle tracks has remained limited. In this study we aim to precisely determine the distributions of uranium and thorium in rocks. We expose emulsion to α particles emitted from rocks and apply the YOLO (You Only Look Once) object-detection framework to HTS2 images to accelerate track finding. This approach automatically and accurately identifies α tracks, shortening analysis time relative to manual visual inspection and enabling visualization of the spatial distribution of α-emitting minerals in granite. Quantitative evaluations of detection efficiency and false-positive rate are in progress. While machine-learning–based methods for nuclear emulsion have been reported, to our knowledge this is the first application that targets stand-alone detection of α-particle tracks [1,2].

Methods

We adopted supervised object detection with YOLO (You Only Look Once) [3] to automatically identify α-particle tracks. A 4.0 × 4.5 cm granite specimen was placed in contact with a nuclear emulsion for 120 days. Using HTS2, we acquired 4,032 images, which were curated into training data for YOLO. Model training and inference were then performed to generate per-image detections of track candidates.

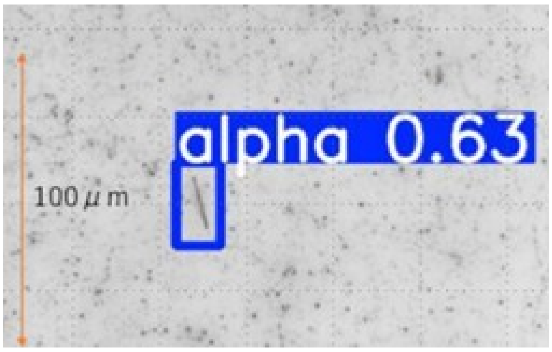

Figure 1,Example of α track detection using YOLO.

Results

Using YOLO, we successfully automated α-track detection (Fig. 1). A default confidence threshold of 0.25 was used unless otherwise noted, and the detector reproduced visually evident tracks with high recall. Because the granite exhibits mineral-dependent variations in U and Th concentrations, we created a two-dimensional map of the spatial distribution of detected α tracks based on the per-image counts (Fig. 2).

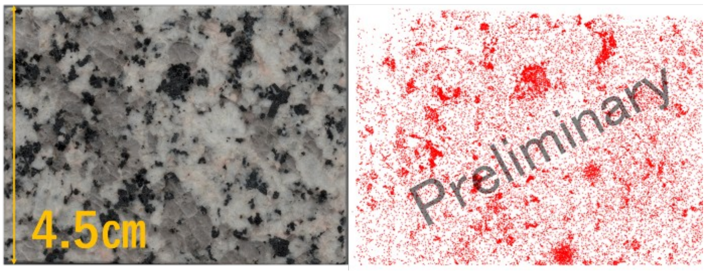

Figure 2: Two-dimensional mapping of the spatial distribution of α-particle counts detected in this study, together with a photograph of the granite sample.

Outlook

At this stage, outstanding issues include a detailed evaluation of detection efficiency and the establishment of detection accuracy in regions where α particles are densely clustered. To address this, we are currently quantifying the detection efficiency by combining experiments using samples with known U and Th contents with simulations, and we plan to apply these results to rock analyses. These outcomes are expected to enable visualization of the distribution of radioactive elements in the Earth's interior and to play an important role in constructing geoneutrino emission models [4].

References

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