Supervised Learning of Complex Seabed Morphology and Pattern Discovery through Network-based Representational Similarity Analysis for Deep-Sea Mineral Investigation

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The desire to study the Earth’s deep seabed has been greatly fueled in recent years by the exploration of marine minerals, notably at mid-ocean ridge (MOR) systems where seafloor massive sulfides (SMS) are currently being investigated at hydrothermal vents. Extensive research and data collection are conducted on hydrothermally active, but also extinct SMS occurrences. Possibly, extinct SMS are more abundant than active ones, and could raise significant commercial interests for future deep-sea mining companies. However, they are difficult to locate and, for this reason, application of geophysical exploration techniques to seabed exploration is crucial. For now, these methods are mostly applied to inspect known mineral occurrences and will certainly be costly, at least in deployment time, for in-depth investigations at ridge-scale and within rough volcanic terrains. For targeting purpose, and because future deep-sea explorers will eventually focus on finding in a short timespan economically interesting SMS targets, on regional scale and at modest costs, high-resolution and high-speed multi-beam mapping with autonomous underwater vehicles (AUVs) will without doubt provide a first-order solution to seafloor analysis.

To exploit high-resolution data, innovative applications of artificial intelligence (AI) technology can support traditional techniques to automate the mapping process and study data patterns. In this study, an AI technique attempts to perform semantic segmentation of seafloor features (rock masses) on a complex topography while learning meaningful surface patterns characterizing these features. Seafloor mounds, in particular, usually describe volcanic constructions with diverse and complex sorts of morphologies, sometimes resembling and being visually confused with those of SMS mounds on a processed high-resolution bathymetry. These morphologies can be distinguished with a trained AI model and, by exploiting this capability with an adequate data processing pipeline, it is possible to determine similar (or dissimilar) surface patterns and cluster analogous seafloor features. Ultimately, clustered features constitute a database of topographic elements to be studied in space (for research purpose), or to catalogue as potential minerals targets (for mineral exploration). This research attempts to develop such database using (1) a convolutional neural network (CNN), which is trained to perform semantic segmentation of seafloor mounds by learning features of 2-m resolution bathymetric data that were collected at neo-volcanic zones of an ultra-slow spreading ridge, and (2) a data processing procedure that seeks to identify relationships among segmented objects, based on information learned by the CNN model (feature representation analysis). Final outcomes of such database are (1) to establish a risk map for undiscovered SMS, and (2) to visualize spatial relations between clustered mounds, which provide insights into geologic processes that shaped the present-day seafloor of surveyed areas

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