SURAJ NEELAKANTAN received his Bachelor's degree in Electronics and Communication Engineering from Visvesvaraya Technological University (VTU), India, in 2016, and his Master's degree in Embedded and Intelligent Systems from Halmstad University, Sweden, in 2020. In 2021, he joined Örebro University as an industrial doctoral student at the Centre for Applied Autonomous Sensor Systems (AASS), in collaboration with Orexplore AB, Sweden.

Geological exploration increasingly relies on data acquired through advanced sensing technologies. X-ray computed tomography (XCT), X-ray fluorescence (XRF), and imaging provide different views of geological materials, from their internal structure and elemental composition to their visual characteristics. However, applying machine learning to such data presents several challenges. Labelled geological data are often scarce, information is distributed across different sensing modalities, and the quality of acquired images can limit subsequent analysis.

This thesis addresses these challenges through three complementary directions: adaptation, integration, and enhancement. Adaptation investigates how machine learning can be applied when labelled real-world data are limited. Synthetic data are used together with adversarial domain adaptation to bridge the gap between artificially generated training data and real XCT measurements. Applied to the identification of euhedral pyrite in drill cores, the results demonstrate the potential of transferring knowledge from synthetic data to real geological imagery.

Integration investigates how complementary geological measurements can be combined. XRF provides elemental information, while XCT captures attenuation characteristics associated with the internal structure of the material. By integrating these two modalities, machine learning models can exploit complementary information for lithology classification rather than relying on a single source of data.

Enhancement addresses the quality and usability of image data through super-resolution. A dual-branch deep-learning architecture is developed to recover image details using complementary representations of the input. This is further extended through human-in-the-loop super-resolution, allowing users to adjust the contribution of the network branches at inference time and influence the reconstruction without retraining the model.

Together, these contributions demonstrate how machine learning can be developed to adapt to differences between data domains, integrate information across sensing modalities, and enhance data for subsequent analysis. The thesis provides a set of methods for making machine learning more applicable across the diverse forms of data encountered in geological analysis.

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