Environmental Computational Science and Earth Observation Laboratory

Master thesis subject

Foundation Model for Hyperspectral Imagery

Context:

In recent years, foundation models have reshaped the processing and interpretation of Earth Observation (EO) data. Already existing EO foundation models [1]-[4] demonstrate that large-scale pretraining can capture rich cross-sensor information and support a wide range of downstream tasks. A central idea behind these models is the ability to learn shared representations that align multiple modalities, enabling robust performance even when data sources differ in spatial resolution, spectral characteristics, or acquisition conditions.

A key open challenge is how to incorporate hyperspectral imagery into such multimodal foundation models. Hyperspectral data form a distinct class of EO observations, typically consisting of more than one hundred contiguous and narrowly spaced spectral bands [5]. While this high spectral resolution provides detailed information, it also introduces difficulties: the dimensionality is substantially higher than that of standard RGB or multispectral sensors, and conventional computer vision architectures are not designed to process such large channel counts efficiently.

In this project, you will build upon an existing foundation model, which has demonstrated the ability to process multi-channel inputs of up to approximately 45 bands. Its architecture can be adapted to manage the higher spectral dimensionality of hyperspectral imagery, making it a strong starting point for extending foundation models to this modality. In addition to architectural adjustments, the project will investigate strategies for integrating physical priors into the model. These priors may include spectral characteristics such as bandwidth and wavelength, which can provide physically grounded constraints and improve the model's ability to capture meaningful hyperspectral signatures.

Requirements:

- Strong interest in machine learning and multimodal reasoning
- Experience with transformers, and foundation models is a plus
- Experience with Pytorch and relevant libraries
- Strong willingness to learn and ability to work independently

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Literature:

[1] Sumbul, Gencer, et al. "SMARTIES: Spectrum-Aware Multi-Sensor Auto-Encoder for Remote Sensing Images." *arXiv preprint arXiv:2506.19585* (2025).

[2] Jakubik, Johannes, et al. "Terramind: Large-scale generative multimodality for earth observation." *arXiv preprint arXiv:2504.11171* (2025).

[3] Brown, Christopher F., et al. "Alphaearth foundations: An embedding field model for accurate and efficient global mapping from sparse label data." *arXiv preprint arXiv:2507.22291* (2025).

[4] Feng, Zhengpeng, et al. "TESSERA: Temporal Embeddings of Surface Spectra for Earth Representation and Analysis." *arXiv preprint arXiv:2506.20380* (2025).

[5] Hong, Danfeng, et al. "Hyperspectral imaging." *arXiv preprint arXiv:2508.08107* (2025).

Additional Literature:

Hong, Danfeng, et al. "SpectralGPT: Spectral remote sensing foundation model." *arXiv preprint arXiv:2311.07113* (2023).

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