E2S EMBED 2SCALE

REVOLUTIONISING GEOSPATIAL DATA WITH AI COMPRESSION

Scalable Efficient Compression in Large-Scale Earth Observation

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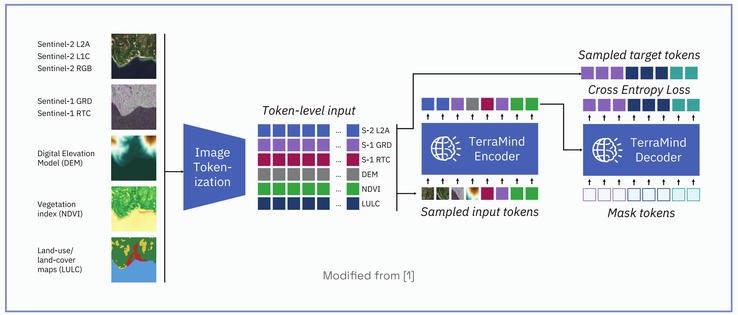
Motivation

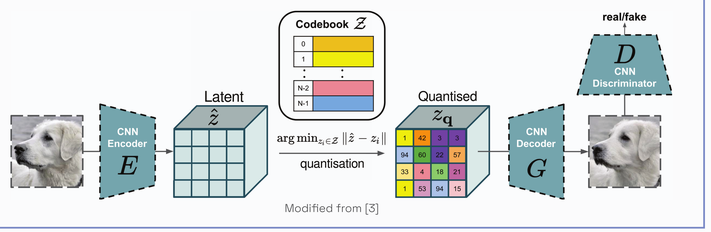
- Continuous EO acquisitions generate petabyte-scale archives
- Larger deep learning models demand more training data and I/O
- Vector-quantisation (VQ) compression stores only codebook indices, reducing size by > 450x
- Transformer backbones like TerraMind [1] already rely on a fixed VQ codebook
- Experiments use MajorTOM-Core dataset [2]



Modified from [1]

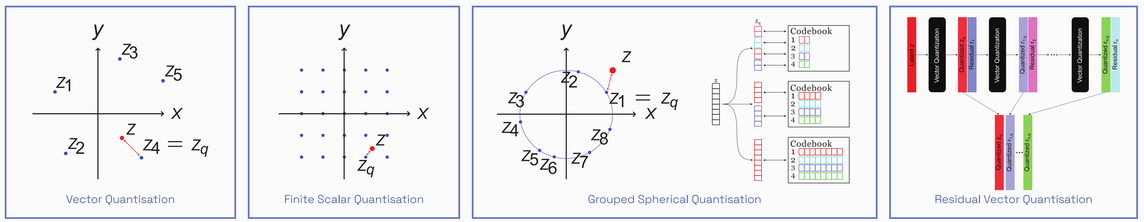
Vector Quantization

- Encoder (VQ-GAN [3]) produces latent representation
- Quantiser assigns each latent vector to its nearest codebook entry
- Decoder reconstructs the image from the quantised embeddings
- An optional discriminator influences training dynamics



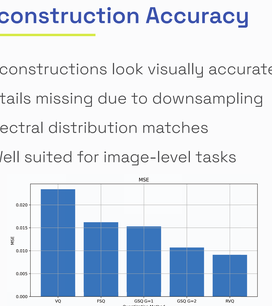
Modified from [3]

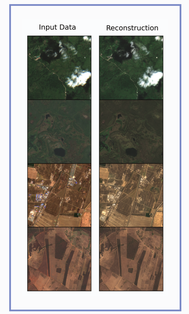
Quantization Methods

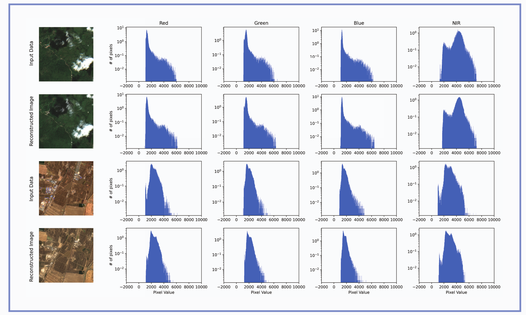


Reconstruction Accuracy

- Reconstructions look visually accurate
- Details missing due to downsampling
- Spectral distribution matches
  - Well suited for image-level tasks

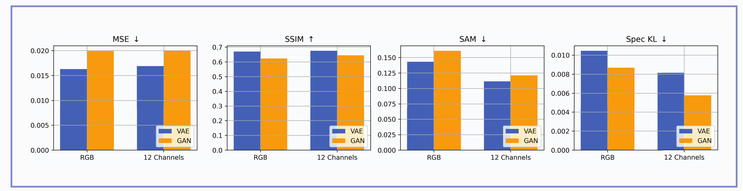






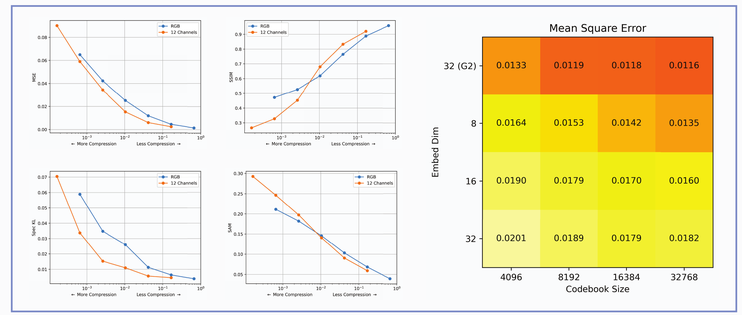
Using a Discriminator

- For non-EO data: Discriminator found to improve visual fidelity of images [4]
- For EO data: Beyond visual aspect, spectra must match, and each pixel should be as close to original as possible



VQ-VAE for Compression

- Additional correlations in multispectral data aids compression
- Larger codebook sizes improve reconstruction fidelity
- Larger embedding dimension underutilised and harder to optimise codebook
  - Decomposed VQ helps utilise large latent space [4]



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[2] Blumenstiel, B., Fraccaro, P., Marsocci, V., Jakubik, J., Maurogiovanni, S., Czerkawski, M., Sedona, R., Cavallaro, G., Brunschwiler, T., Bernabé-Moreno, J., & Long'ep'e, N. (2025). TerraMesh: A Planetary Mosaic of Multimodal Earth Observation Data.

[3] Esser, P., Rombach, R., & Ommer, B. (2021). Taming transformers for high-resolution image synthesis. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 12873–12883.

[4] Wang, J., Qin, Z., Zhang, Y., Hu, V. T., Ommer, B., Briq, R., & Kesselheim, S. (2024). Scaling Image Tokenizers with Grouped Spherical Quantization. arXiv preprint arXiv:2412.02632.

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