

Raster Structure Encoding: Computer Vision Methods for Geophysical Feature Engineering

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Many traditional machine learning (ML) methods used in the geosciences ingest gridded data as collections of spatially independent pixels, effectively prohibiting models from capturing the structural and textural context critical to geological interpretation. To address this, a modular feature engineering framework is presented for reduced-to-pole (RTP) magnetic data that encodes spatial, structural, and directional information into a multi-channel feature tensor compatible with standard pixel-wise ML workflows. The pipeline first applies local contrast normalization (LCN) [1] and global normalization to the input raster, followed by a signed Gaussian-difference bandpass decomposition [2] that separates the data into complementary high- and low-frequency responses corresponding to fault-like edges and large-scale bodies, respectively, while preserving polarity for positive/negative half-wave separation. From these responses, ten structured feature products are computed across three families: fault and structure features, including Fault Persistence [3] and Fault Density; body and regional features, including a Body-to-Fault Ratio, Multi-Scale Coherence and Coherence Density [4] derived from structure tensor [5, 6] analysis; and fabric and characteristic features, including a sin/cos-encoded Fabric Orientation and Characteristic Region Labels from unsupervised clustering of the full feature set.

Applied to RTP magnetics data from the Arabian Shield, the resulting feature products show strong consistency with manual geological interpretation, clearly delineating NW-trending fault corridors, dense fracture zones, plutonic bodies, and regions of directional fabric alignment. The framework operates entirely on the normalized input raster at native grid resolution, and as such is model-agnostic, requiring no labelled training data for feature generation. Its modular design supports adaptation to other raster types and geological settings, offering a repeatable, systematic preprocessing workflow with potential to improve the sensitivity of prospectivity models to structural controls. Future work will include quantitative evaluation across multiple datasets and geological domains, and assessment of downstream impacts on ML model performance.

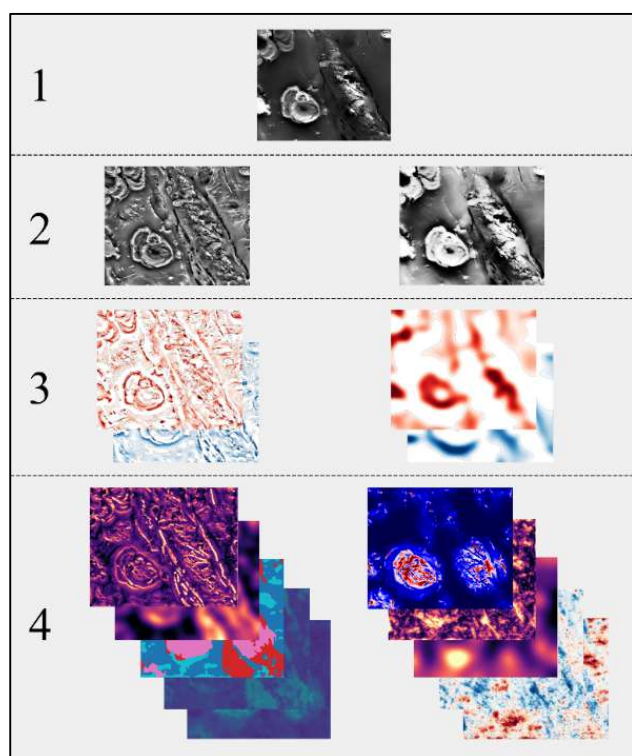


Figure 1. Overview schematic of workflow. Top to bottom: (1) input raster, (2) LCN and globally normalized rasters, (3) multi-frequency signed bandpass outputs, (4) resulting feature set.

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