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Feature Stability Index (FSI): A Multi-Axis Metric for Assessing Robustness of Features in Imbalanced Fraud Detection

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In highly imbalanced domains such as credit card fraud detection, model explanations are often dominated by a few seemingly influential features. However, the importance of these features can vary considerably when data distribution, model architecture, or random initialization changes, raising concerns about reproducibility and trustworthiness. To address this, we introduce the Feature Stability Index (FSI), a unified metric that quantifies the robustness of feature importance patterns across different experimental conditions.

FSI is not a feature selection method but a diagnostic measure that evaluates how consistently a feature set maintains its relevance under three axes of variation: model choice, random seed, and temporal data window. The metric aggregates axis-specific stability components S_{model} , S_{window} , and S_{seed} into a single interpretable score, weighted by parameters α , β , and γ . Two complementary formulations are proposed: FSI-CV, which measures numerical consistency of feature importance magnitudes, and FSI-IE, which assesses the stability of feature set inclusion frequencies through entropy analysis.

Experiments using credit card transaction data demonstrate that FSI effectively distinguishes stable from unstable importance signals. Features with high FSI values exhibit consistent relevance across models and resampling, while unstable features fluctuate significantly, indicating potential sensitivity to model design or data drift.

Unlike traditional overlap-based stability indices such as Jaccard or Kuncheva, FSI captures both numeric and inclusion stability and attri-

butes instability to specific axes, providing a deeper understanding of model behavior. The proposed FSI framework supports robustness auditing of feature importance results and contributes to more reliable model interpretation in dynamic, high-risk environments such as financial fraud detection.