Time-Varying Semantic Representations of Planetary Observations for Discovering Novelties

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Anomaly and novelty detection from remote sensing observations is vital for enabling further analysis by domain experts to facilitate scientific discovery and for planning future observations by spacecraft, especially in scenarios involving natural disaster mitigation efforts and planetary exploration. These datasets are acquired by the growing number of instruments in varying modalities resulting in a massive repository for domain experts to identify anomalies from. This necessitates the need for formulating a representation of the expected attributes (properties) of planetary features (landforms) of interest and designing novelty detection techniques that can detect deviations from this representation. However, expert interpretation of novelty involves semantic analysis of a given scene that jointly considers all attributes for contextual assessment.

This work presents a semantic representation of planetary landforms with respect to attributes that include spatial association and overlap, clusters of occurrence, seasonal, and elevation properties to emulate expert-like decision making. This representation is learned from classification of past instances where initial training set is obtained from expert labels. The combination of classification followed by semantic interpretation supports contextual determination of novelties to allow retrieval of the most unusual observations from an integrated anomaly score with respect to each attribute. The novel observations are utilized to refine the semantic representation over time as more data are obtained by an instrument and the most anomalous attributes are highlighted to explain the detection. As learning representations solely from past data may fail to include domain specific preferences, expert-knowledge in the form of weights are also provided to guide the representations with domain knowledge. Case studies and future directions are presented to ultimately form a knowledge base of remote sensing data.