National Aeronautics and Space Administration

Detecting Wildfire Plumes in Multi-Resolution Satellite Observations via Deep Multiparameter Persistence Learning

Principal Investigator: Huikyo Lee (398); Co-Investigators: Nicholas Lahaye (398), Baris Coskunuzer (University of Texas at Dallas), Yulia Gel (University of Texas at Dallas)

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Objectives:

We enhance deep learning (DL) architectures for onboard learning with the most salient time-conditioned topological information of observed smoke plumes caused by wildfires. This enhancement will be achieved by integrating a fully trainable topological layer into time-aware deep neural networks (DNNs).

Background:

To the best of our knowledge, NASA's Earth Science missions do not apply any topological and geometric DL that integrate multi-resolution observations for onboard detection of anomalies. The ultimate goal of the project is to develop efficient, systematic, and reliable learning mechanisms for the onboard exploration by explicitly integrating both space and time dimensions into the knowledge representation at multiple spectral and spatial resolutions.

Approach and Results:

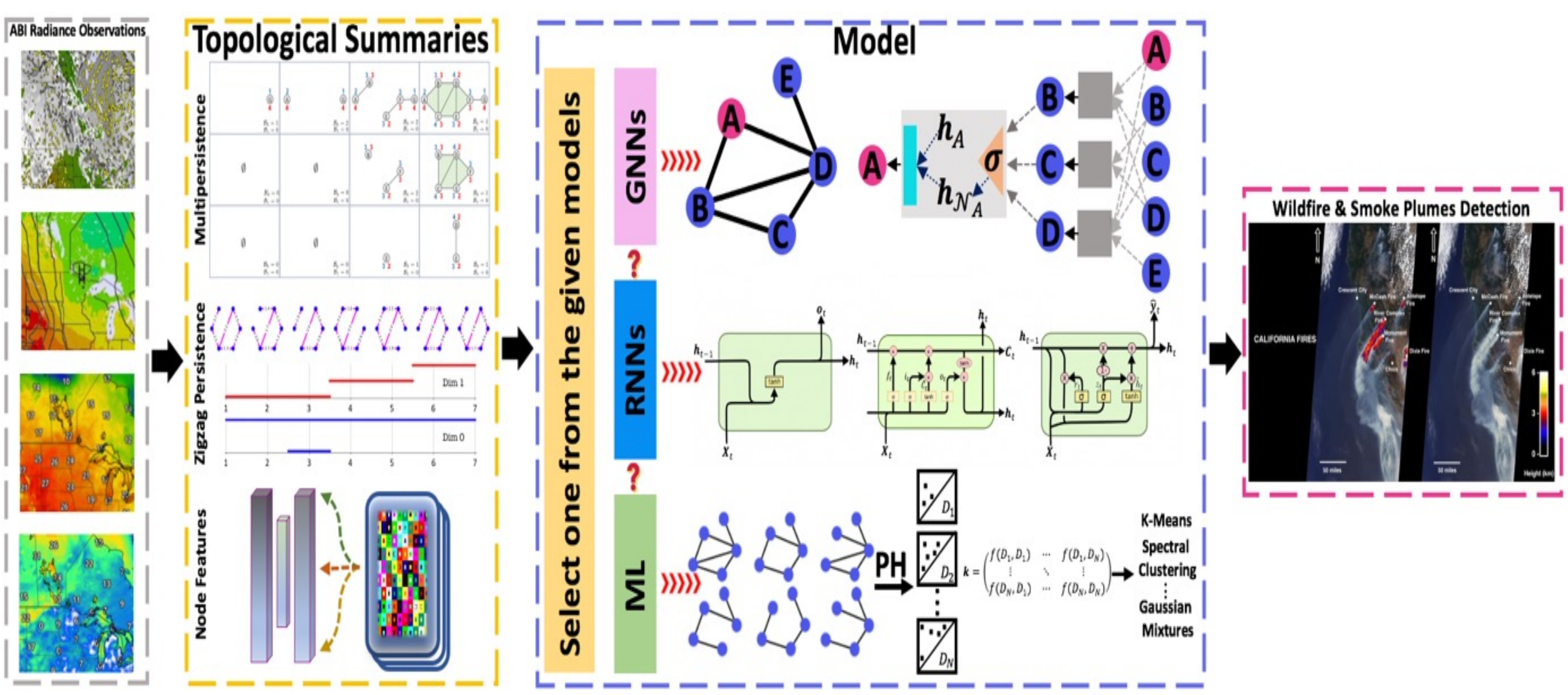

Illustration of topology-based representation learning architecture. Given the Advanced Baseline Imager (ABI) radiance observations, we first apply various TDA tools and obtain the corresponding topological summaries (e.g., multipersistence and zigzag persistence). Then we feed these topological summaries into the model; specifically, we provide three options as examples, including GDL (e.g., GNN-based models), recurrent neural networks (e.g., RNN, LSTM, and GRU), and ML algorithms (e.g., K-Means, spectral clustering, and Gaussian mixtures). Finally, we can utilize the output of the selected model for tracking and detecting smoke plumes.

Significance/Benefits to JPL and NASA:

To date, there are currently no topological and geometric DL applications that integrate multi-resolution observations for onboard detection of anomalies. By leveraging the team's achievements from previous and ongoing projects, we will develop an innovative and efficient DL architecture "beyond current state-of-the-art machine learning (ML)". Training of this architecture shall scale linearly with the resolution of the data and the number of images. We will also conduct "uncertainty quantification" in the proposed DNNs.

Making better use of NASA's satellite observations is our top priority. The Geostationary Operational Environmental Satellite (GOES) program is managed by NASA's Joint Agency Satellite Division. Eventually, the GDL-based anomaly detection will be applicable to detect high levels of aerosols due to wildfires using other observations from NASA's satellite and suborbital missions in the future, such as the Multi-Angle Imager for Aerosols (MAIAand Tropospheric Emissions: Monitoring of Pollution (TEMPO).

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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Dixon et al. (2023), Application of topological data analysis to multi-resolution matching and anomaly detection, in preparation

PI/Task Mgr. Contact Information:

Email: Huikyo.Lee@jpl.nasa.gov