USING AUTOENCODERS TO ASSESS SPIN STABILITY AND SPIN-RATE ON UNEVENLY SAMPLED LIGHT CURVES

Gregory P. Badura[1*], Christopher R. Valenta[1], Layne C. Churchill[1], and Douglas Hope[1];
[1]Georgia Tech Research Institute (GTRI) Electro-Optical Systems Laboratory (EOSL), 925 Dalney St NW, Atlanta, GA 30318. *[Gregory.Badura@gtri.gatech.edu]

The ever-growing volume of data collected and published to repositories such as the Unified Data Library (UDL) necessitates the development of explainable automated Machine Learning (ML) stability assessment tools to assist SDA analysts. Previous efforts to assess satellite stability using ML solutions assume idealized assumptions about the light curve data quality, such as having evenly time-sampled data, and full-night observations. Because of factors such as limited telescope tasking time and weather fluctuations, data uploaded to the UDL rarely meets these assumptions.

We developed an autoencoder-based ML framework that provides stability assessments on light curves as short as 5 minutes in duration with up to 91% balanced accuracy on UDL data from a wide sampling of UDL providers. A novel contribution in this paper is that the autoencoder is trained to reconstruct noisy light curves with explicit knowledge of the phase angle and visual magnitude uncertainty of each data point. We quantitatively and qualitatively show that the inclusion of this ancillary UDL data provides the potential for the network to overcome environmental noise and uneven sensor sampling cadences in the process of learning to differentiate typical behaviors of stable light curves (i.e. glints) from those of tumbling light curves (i.e. oscillations , aliasing). Autoencoder-derived features were then combined with expert-derived features as input to a Balanced Random Forest (RF) classifier. The Balanced RFs trained using autoencoder-derived features outperformed those trained solely using expert level features by $9\pm3.5\%$ in terms of Matthews Correlation Coefficient (MCC) and $8.5\pm3.7\%$ in terms of F1-score, with a significance level of $p<5\times10^{-5}$.

The initial development of an analysis tool for discerning the sidereal spin rate and spin axis of a space object in an earth-centered inertial frame via machine learning is also presented. This tool is derived using knowledge of the time-dependent phase angle bisector (PAB), or the direction midway between the body-to-observer and body-to-Sun direction vectors. Initial results show that the machine learning approach may provide speed and accuracy gains for discerning satellite spin rate. Our goal is to ultimately merge this tool with the stability assessment framework for seamless estimation of spin-stability, spin-rate, and spin-axis estimation.