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Machine Learning Based Parametrization of Solar Active Regions Using Disentangled Variational Autoencoders

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Space Weather is an important aspect of our environment as a technologically dependent society. Moreover, space weather is a system of phenomena, bounded by complex cause-and-effect relations. In the century of Big Data solar physics, there are many archives of synoptic full-disk observations from space missions and ground-based facilities (which are growing daily) of multi-wavelength data. Driven by the amount of data and task, depending on data mining and dimensionality reduction, Machine Learning (ML) is rapidly integrated into solar and Heliophysics research. We use Deep Learning (DL) algorithms, i.e., Disentangled Variational Autoencoders (VAE, such as CT-VAE, betaVAE) for dimensionality reduction and feature extraction. The main goal of the VAE is to compress a high-dimensional input into a low-dimensional space, i.e., latent space (LS), reduce it down to its basic underlying structure, and retain enough information, that can be used to reconstruct the input and, if done properly, generate new data. Furthermore, disentangled representation learning facilitates the interpretability of the LS. The utilized dataset, Spaceweather HMI Active Region Patches (SHARPs) vector magnetic field (VMF) maps, is a by-product from the Solar Dynamics Observatory (SDO) and its Helioseismic and Magnetic Imager (HMI) full-disk observations. The Disentangled VAE are incorporated into a data pipeline, used for time series analysis, visualization and classification of the LS based on the SHARP VMF maps. The pipeline include unsupervised learning methods for label discovery and classification, such as T-SNE, UMAP, and HDBSCAN. Furthermore, the SHAPR ML-feature database will be used as a complementary dataset to the empirical SHARP parameters in a supervised DL space weather forecast pipeline.

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