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Predicting Soft X-ray Emissions for Solar Flare Forecasting Using a Self-Supervised CNN Trained on Solar Dynamics Observatory Data

Predicting solar flares is crucial for communications and satellite operations. Previous Machine Learning (ML) work focused on classifying flares with labels such as M and X, overlooking the continuous nature of X-ray flux. Our approach uses Convolutional Neural Networks (CNNs) to predict X-ray flux from Helioseismic and Magnetic Imager (HMI) and Extreme Ultraviolet (EUV) images of the Sun, using a curated dataset from the Solar Dynamics Observatory (SDO). Inputs represent different layers of the solar atmosphere: HMI magnetograms (photosphere) and AIA wavelengths: 94 Å (flaring regions), 171 Å (quiet sun), 193 Å (coronal structures), and 304 Å (chromosphere). Data are processed to match SDO images and GOES X-ray fluxes. Limb-brightening correction is applied to avoid biases. We compare full-disk images versus synoptic maps as CNN inputs.

We utilise the Model Genesis self-supervised framework, originally developed for medical imaging. It consists of an encoder-decoder architecture to reconstruct artificially deformed solar images by transformations such as non-rigid deformations and pixel shuffling. The encoder part is attached to our CNN and pre-trains it. This process facilitates extracting robust features for better performance. Subsequently, we train to predict X-ray flux. We post-process outputs to associate X-ray flux predictions with flare indices to compare our work with other classifications. We benchmark this approach against state-of-the-art methods using True Skill Score (TSS) for categorical predictions and Brier Skill Score (BSS) for probabilistic predictions. Future work includes eXplainable AI (XAI) to identify which active regions and parts of the solar atmosphere contribute most to flare predictions.

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