Project Details

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Project Title:
Faster, Better, Deeper: Utilizing Deep Learning to Produce Enhanced Near Real Time Inversions from HMI Data for Space-Weather Modeling

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Summary:
We propose to use a machine learning (ML) algorithm to simultaneously improve the quality and significantly speed up the production of near real time (NRT) vector magnetic field data from the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory. Our general approach will be to use convolutional neural networks (CNN), based on a U-net architecture, combined with regression-by-classification, with Stokes vectors as the input for the network, and various outputs from a Milne-Eddington inversion as the targets that the networks will be trained to produce. This approach has already been trained and validated to provide high fidelity reproductions of the present science quality inversion products of the HMI pipeline at their original resolution (Higgins et al 2021b), as well as to emulate the results of the pipeline inversions of Hinode SOT-SP data (Higgins et al 2021a).

The same type of network will be trained on the NRT Stokes spectra from HMI with SOT-SP inversions as the target. The results will enhance the present NRT HMI pipeline data product by (1) providing the magnetic field estimate for every pixel, including polar regions, (2) reducing systematic bias in the field inclination through an independent estimation of the magnetic fill factor, and (3) estimating the full physical magnetic field vector, i.e., the physically meaningful quantity used as the boundary condition for many space weather models, effectively through an ML-based resolution of the inherent 180 degree ambiguity.

These enhanced data products, produced with substantially reduced processing time, may be useful in space weather forecasting, particularly the real time modeling of eruptions that produce energetic particles, thus giving additional warning for impact on spacecraft throughout the heliosphere. This benefit addresses the third Living With a Star objective, "Human Exploration and Development: LWS provides data and scientific understanding required for advanced warning of energetic particle events that affect the safety of humans." As an additional product, the machine learning-ready data set used to train the network will be provided to the community, ready for similar or hopefully ground-breaking efforts in ML research to improve the inversion and interpretation of Stokes spectropolarimetric spectra.

The CNN to produce near-real-time full-disk vector-field data series will be implemented to run at Stanford University within 18 months of start date, with the output available through the Joint Science Operations Center, the standard repository for HMI and other NASA-mission data. Also within 18 months, the ML-ready SDO-Hinode dataset and corresponding evaluation code will be archived at the University of Michigan Library Deep Blue data repository. This system provides a DOI for the published data, and access via both browser and Globus (which facilitates inter-institutional transfers).

Publication References:

no references