Spatial-Temporal Super-Resolution of SOHO and SDO Observations via Deep Learning

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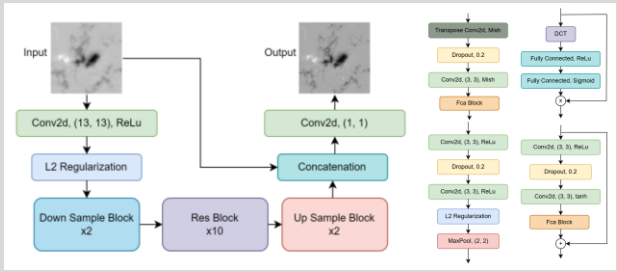
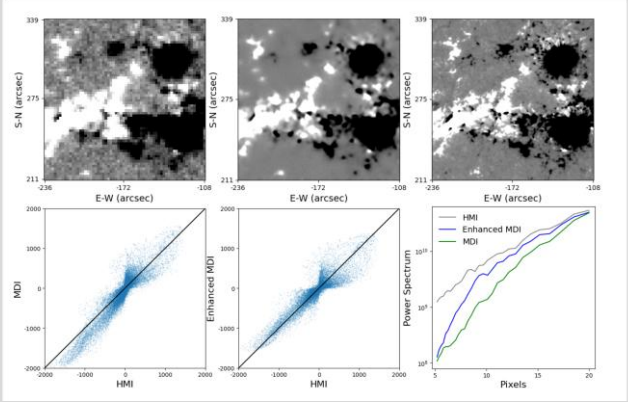
Overview: High-resolution magnetograms of solar active regions (ARs) are critical for studying fine-scale magnetic structures and their dynamic evolution, which are essential for understanding solar eruptions. While SOHO/MDI, a space-based instrument, provides continuous, full-disk magnetograms, its low spatial-temporal resolution limits its use. SDO/HMI, the successor of SOHO/MDI, provides higher spatial-temporal resolution observations. On the other hand, GST/NIRIS, a ground-based instrument with large apertures, provides much higher spatial resolutions, with limited FOVs and selected time windows. Here, we propose three deep learning models for super-resolution of solar ARs images: SolarCNN and GenMDI to enhance the spatial and temporal resolution, respectively, of line-of-sight (LOS) magnetograms of SOHO/MDI, and DeepHMI to improve LOS and transverse magnetograms of SDO/HMI guided by the observations from GST/NIRIS.

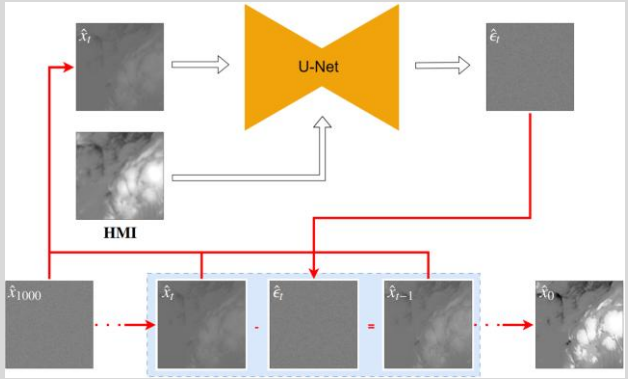
1. SolarCNN: SolarCNN is an attention-aided convolutional neural network for spatially super-resolving solar active region (AR) magnetograms. It enhances SOHO/MDI data to match the quality of higher-resolution SDO/HMI observations.



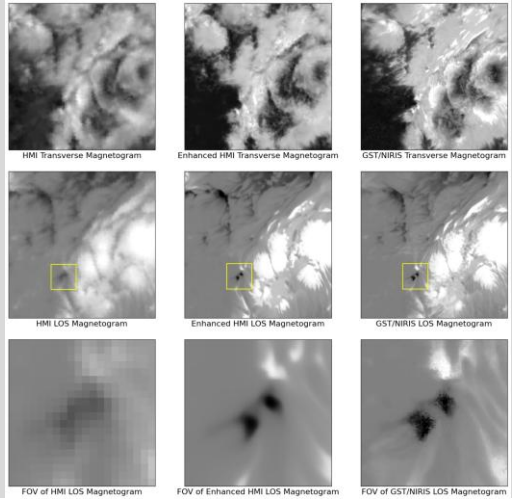
2. Spatial Super-resolution of SOHO/MDI LOS Magnetogram Using SolarCNN: Case study on NOAA 11117 at 00:00:00 25 October 2010.



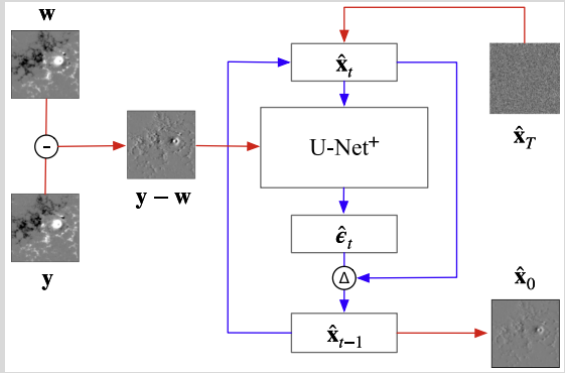
3. DeepHMI: DeepHMI is a conditional diffusion model for spatially super-resolving solar AR LOS magnetograms and transverse magnetograms. It enhances SDO/HMI data to match the quality of higher-resolution GST/NIRIS observations. The forward-diffusion process repeatedly adds Gaussian noise to a target image until pure noise is obtained. The model is trained with the backward-diffusion process. During testing, DeepHMI calculates a super-resolved result from a Gaussian noise.



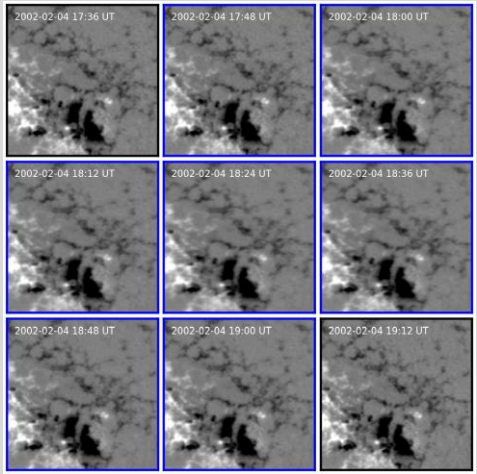
4. Spatial Super-resolution of SDO/HMI LOS Magnetogram Using DeepHMI: Case study on NOAA 12371 at 16:48:00 UT on 22 June 2015.



5. GenMDI: GenMDI is a conditional diffusion model for temporally super-resolving solar AR LOS magnetograms. It enhances the temporal resolution of SOHO/MDI data from a 96-min cadence to a 12-min cadence.



6. Temporal Super-resolution of SOHO/MDI LOS Magnetogram Using GenMDI: Case study on NOAA 09802 from 17:36:00 UT to 19:12:00 UT on 04 February 2002.



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