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Magnetogram Generation by Deep Learning

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All solar activities happening in solar atmosphere are manipulated by its magnetic field. Thus, magnetogram is regarded as the most direct evidence to indicate a solar activity. However, only photospheric magnetograms can be directly measured, while the broad chromosphere and coronal layers which are more closely associated with solar bursts, such as solar flare and CME, cannot be measured directly. Traditionally, we employ numerical simulation methods to compute solar coronal magnetogram. For example, we leverage classical magnetic field extrapolation to compute solar coronal magnetogram. However, magnetic field extrapolation has strict limitations since the requirement of boundary conditions. In addition, it has high computational complexity.
Deep learning provides a powerful tool for translation between images of different domains. It has been successfully adopted in magnetogram generation. Kim et al. [1] proposed a deep learning model for generating far-side magnetogram from UV/EUV images of STEREO for the first time. Alexandre et al. [2] validated deep learning models for learning the mapping from EUV narrowband images to spectral irradiance measurements using data from NASA’s Solar Dynamics Observatory (SDO). The magnetogram generation has been well investigated in the literatures. However, the existing models are all static models. Although they explored image translation well, they cannot make full use of spatio-temporal information effectively from the provided time series observations.
The proposed dynamic model consists of a typical U-Net and a GRU module as shown in Figure 1. It is with the input of EUV image sequence and output one magnetogram each time. The advantage of a dynamic model is that it can adjust the rhythm of input video streaming so that the output complies with the rhythm of our target. In our case, an EUV image sequence has a much faster rhythm than a photospheric magnetogram sequence, resulting in a serious problem that the polarity of generated magnetogram fluctuates as it is displayed in sequence. The proposal utilizes a GRU module to address this problem. The experimental results demonstrate that the polarity problem is greatly improved as shown in Figure 2, where the two small patches (a) and (b) are well consistent with the ground-truth.

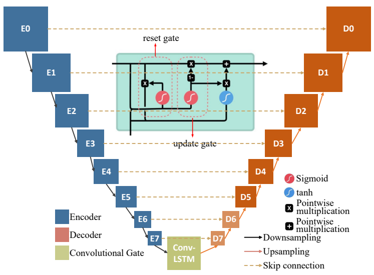

Figure 1. Network structure

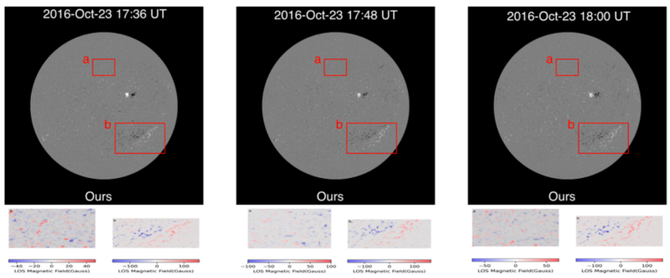

Figure 2. Three consecutive magnetograms generated by our model (the color maps of the two small patches labeled by “a” and “b” are illustrated from three consecutive magnetograms.)

References

[1] Alexandre Szenicer, et.al., A deep learning virtual instrument for monitoring extreme UV solar spectral irradiance, Science Advances, 2021.

[2] Kim, Taeyoung, et.al., Solar farside magnetograms from deep learning analysis of STEREO/EUVI data, Nature Astronomy, 2019.

[3] W. Sun, L. Xu, et al., A dynamic deep learning model for generating magnetogram sequence from SDO/AIA EUV image sequence, The Astrophysical Journal Supplement Series, 2022.