Data Augmentation of Magnetograms for Solar Flare Prediction using Generative Adversarial Networks (GANs)

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Many solar flare prediction models disregard decades worth of training data because the magnetogram datasets used are incompatible.

We produced a higher-quality magnetogram dataset for solar flare prediction using generative adversarial networks (GANs).

Motivation

Solar flares – high energy bursts of radiation from the sun – have the potential to disrupt critical infrastructure systems on Earth, including the power grid and GPS and radio communications. Understanding solar flares also helps us protect astronauts in space from harmful radiation. The two magnetogram datasets used for solar flare forecasting are incompatible due to differences in the cadence, resolution, and size of the data.

Data and Preprocessing

We use line-of-sight, full-disk magnetograms from

1. the NASA Solar Dynamic Observatory/Helioseismic and Magnetic Imager (SDO/HMI), 720s cadence
2. the Solar and Heliospheric Observatory/Michelson Doppler Interferometer (SOHO/MDI), 96m cadence

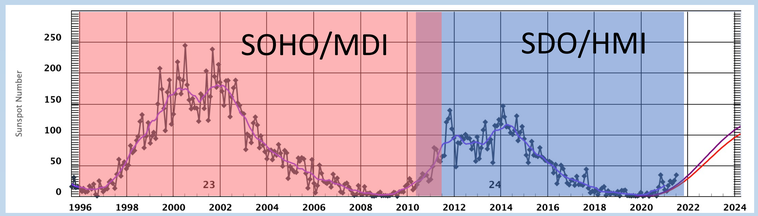


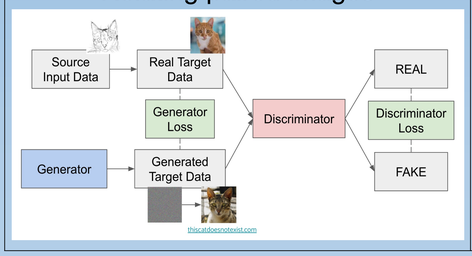
Figure 1. The data overlap of SOHO/MDI and SDO/HMI over solar cycles 23 and 24
Source: SWPC

Training and testing images were paired based on approximate time, then checked for missing pixels. Images were then rotated and centered.

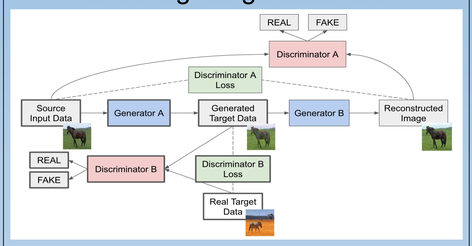
Methods

Goal: Image-translation. We want to learn a mapping between input and output images
We compare the performance of three GAN models:

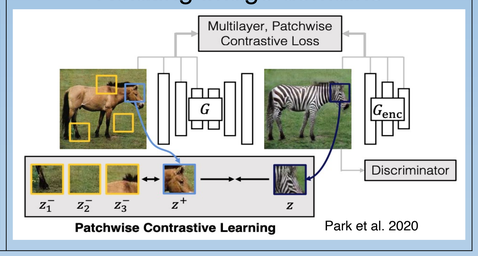
Pix2Pix
Relating paired images



CycleGAN
Relating image domains



CUT
Relating image domains



Park et al. 2020

Results

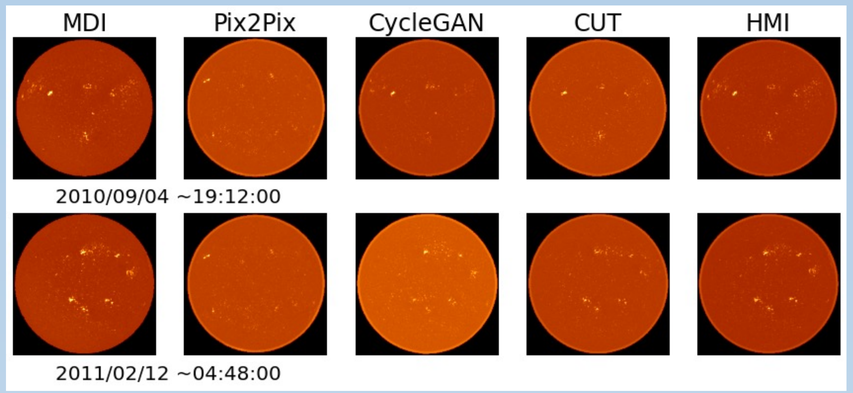


Figure 2. Synthetic images generated by different GAN models.

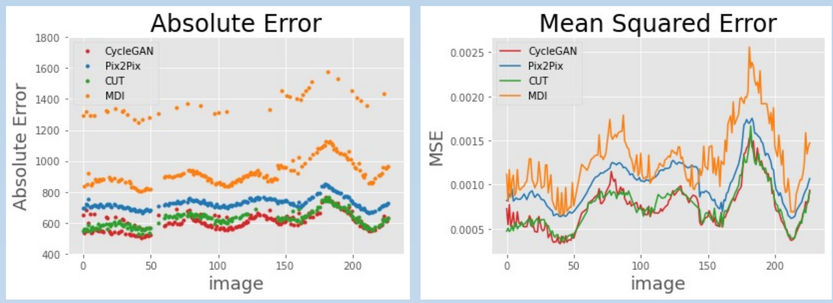


Figure 3. Plot of absolute error (a) and mean squared error (b) per image.

Model	Mean Abs Error	MSE
Pix2Pix	728.1717	0.001027
CycleGAN	608.7130	0.00745
CUT	623.8944	0.00074
Baseline	1007.9503	0.001288

Table 1. Average values of absolute errors and mean squared errors for each model

Takeaways

We have demonstrated that GANs can be used to upconvert the historic SOHO/MDI dataset to SDO/HMI quality. **We obtained best results from unpaired models CycleGAN and CUT, which generalized the best and allow for a training dataset that extends beyond the one-year overlap of SOHO/MDI and SDO/HMI data.**

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This work was supported by the SWx TREC Deep Learning Laboratory and the National Science Foundation REU Program, award #1659878

For references and more information:

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