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

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Introduction

Space weather forecasting remains a national priority in the United States due to the impacts of events like solar flares to life on Earth. High energy bursts of radiation originating from solar flares have the potential to disrupt critical infrastructure systems, including the power grid and GPS and radio communications.[1] Furthermore, understanding solar flares helps us protect astronauts in space and provides additional insights to human solar flare predictions.

Solar flare prediction models trained using machine learning have greatly improved in the past decade.[2] However, the two magnetogram datasets used for solar flare forecasting are incompatible due to differences in the cadence, resolution, and size of the data. Furthermore, many studies only use data from a single instrument, which disregards decades worth of potential training data that is necessary to understand solar cycles. **We use a class of machine learning techniques called Generative Adversarial Networks (GANs) to super-resolve the historic, lower-quality SOHO/MDI dataset to match SDO/HMI quality.**

Data

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

- the NASA Solar Dynamic Observatory/Helioseismic and Magnetic Imager (SDO/HMI), 720s cadence.[3]
- the Solar and Heliospheric Observatory/Michelson Doppler Interferometer (SOHO/MDI), 96m cadence.[4]

Research Objectives

The goal of this project is to create a combined, standardized dataset of magnetogram data. The dataset will be used to train current solar flare prediction models.

Data Processing

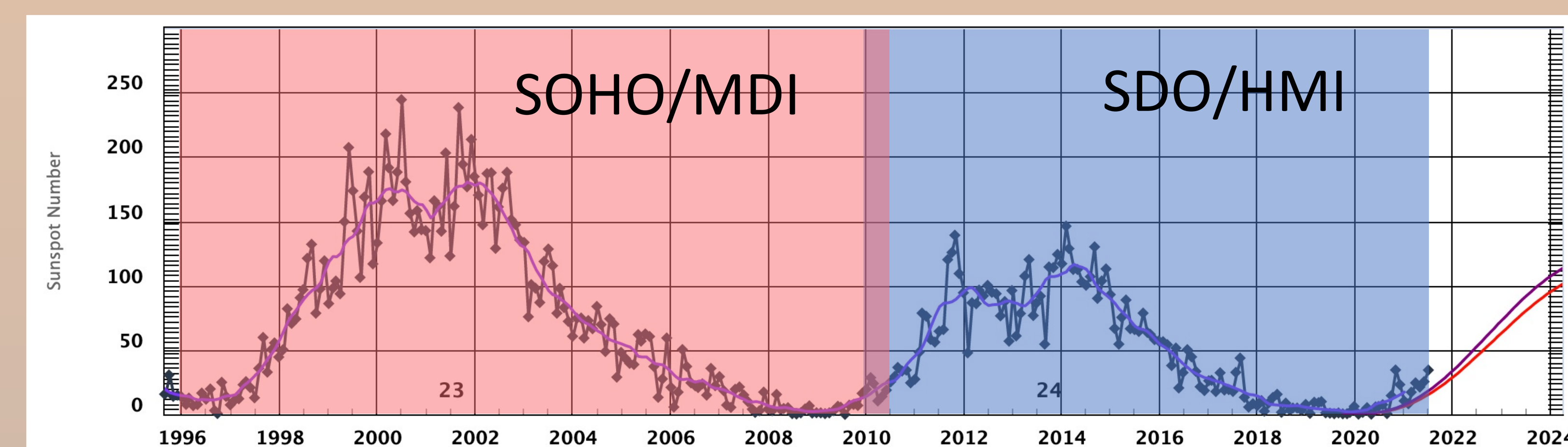
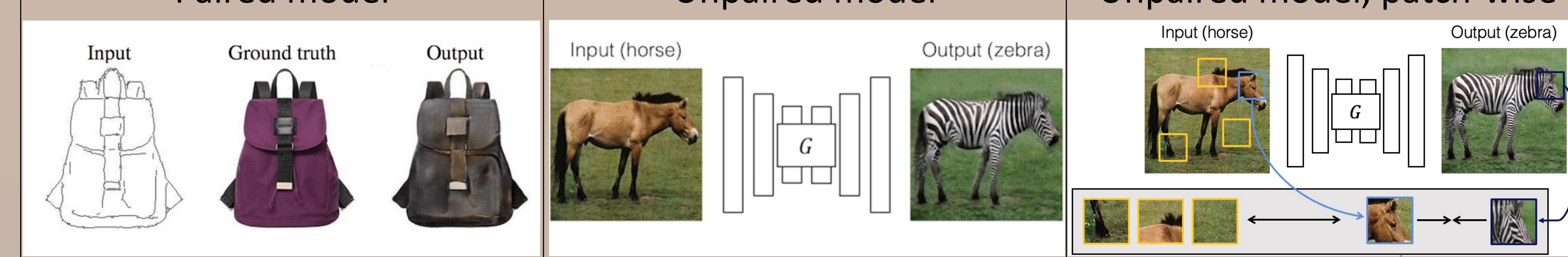


Figure 1. The data overlap of SOHO/MDI and SDO/HMI over solar cycles 23 and 24
Source: SWPC

Methods

We compare the performance of three GAN models:

Pix2Pix[5] Paired model	**CycleGAN**[6] Unpaired model	**CUT**[7] Unpaired model, patch-wise



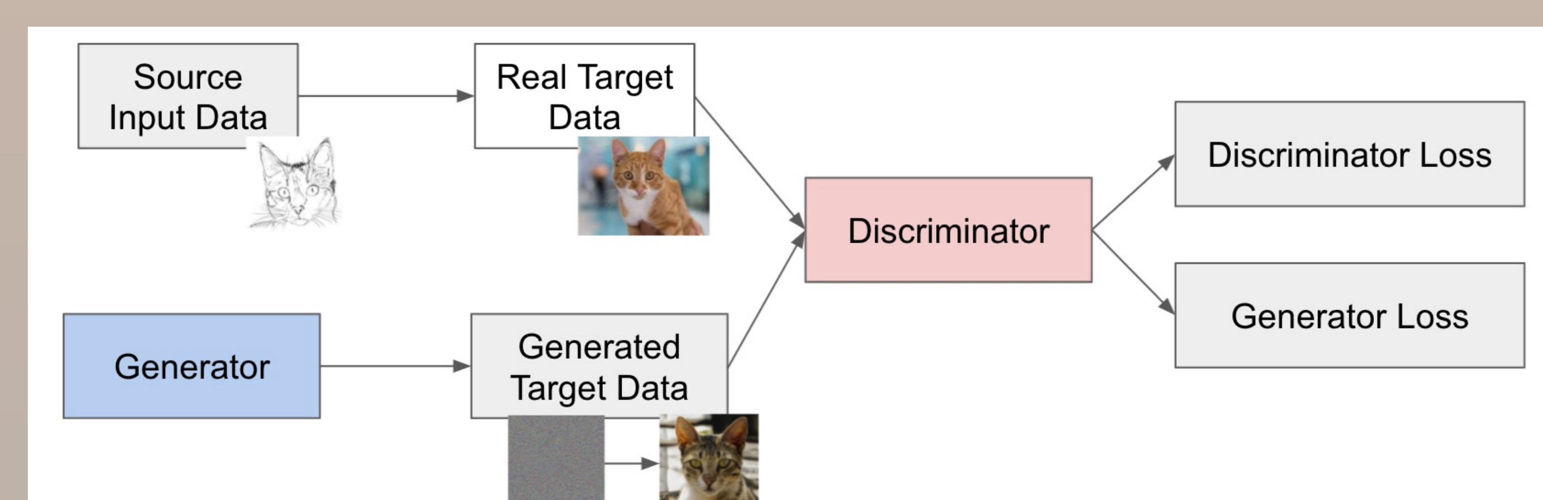


Figure 2. An overview of the architecture of a Pix2Pix GAN model.

Results

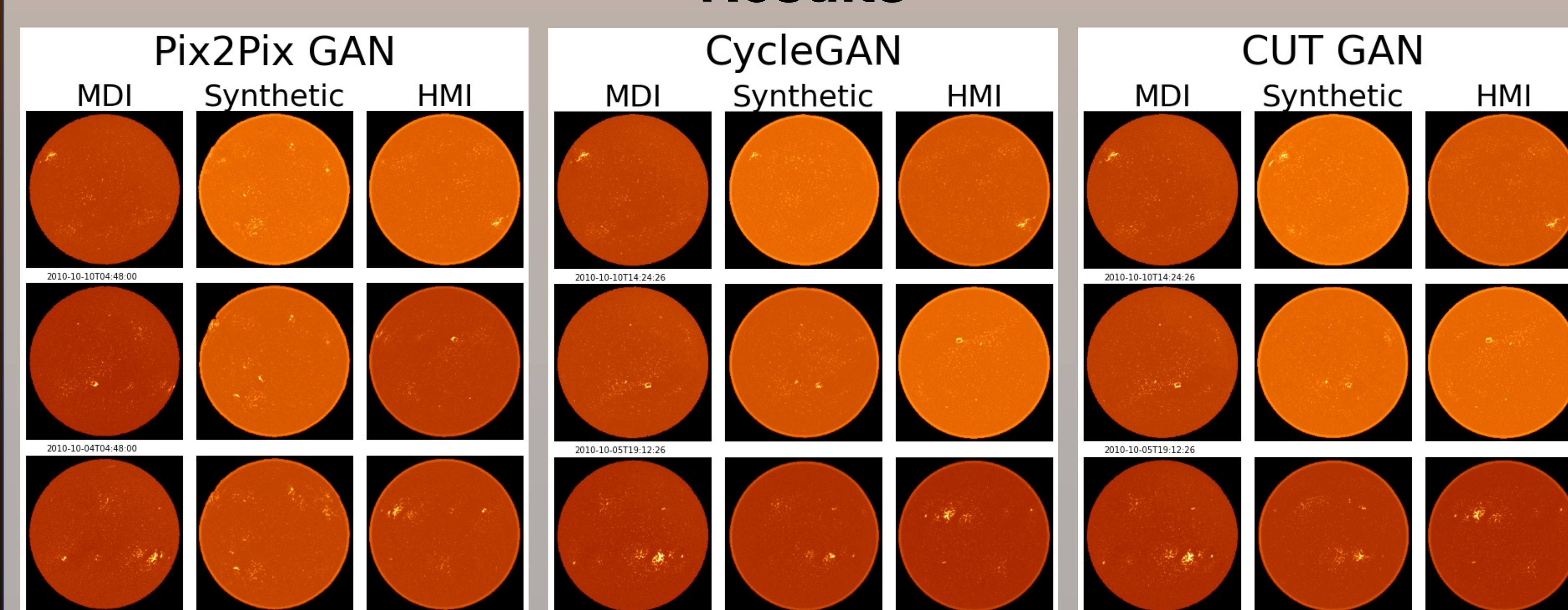


Figure 3. Synthetic images generated by different GAN models. Note that the MDI and HMI images differ in rotation angle.

Discussion

The Pix2Pix GAN model introduced some strange image artifacts. CycleGAN and CUT generalized better, with CUT capturing the dynamic range of the SDO/HMI data more accurately. This could be due to the patch-wise nature of training the CUT model. Using unpaired models allows for the use of training data that extends beyond the 1 year of overlapped SOHO/MDI and SDO/HMI data.

Conclusion

We show Generative Adversarial Networks (GANs) can be used to super-resolve the historic SOHO/MDI dataset to SDO/HMI quality to create a standardized training data set. The resulting combined, higher-quality data set will be used to improve the predictive power of current solar flare forecasting models.

Takeaways:

- Start simple
- Modify existing and well-documented models
- This technique shows promise for creating a high-quality, combined magnetogram dataset

Further Research

- Rotate MDI images in preprocessing
- Get a quantitative error calculation
- Training on a new GPU!
  - More iterations
  - Training on full-resolution images
  - Patch-wise

References

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