SEGMENTATION OF SELECTED SOLAR CORONA STRUCTURES USING DEEP LEARNING

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Introduction

This work addresses the critical need for automated methods to analyze solar imagery, focusing on the segmentation of coronal holes and active regions in solar EUV images. These structures are key indicators of solar activity and are essential for space weather prediction. Building on the U-Net-based SCSS-Net architecture, the work evaluates its performance and explores modifications and improvements of original SCSS-Net model.

Main development steps

A core contribution is the development of a new data pipeline using images from both SDO/AIA and GOES/SUVI, incorporating detailed preprocessing, automated quality checks, and a chronological data splitting strategy to enhance reliability and prevent data leakage. Combining theoretical background with practical modeling, the work details three experiments: implementing SCSS-Net with the new data, exploring an altered attention U-Net, and applying dynamic data augmentations to SCSS-Net. Augmentations such as flips, rotations, blurring, and distortions were used to improve model generalization, particularly for less obvious features.

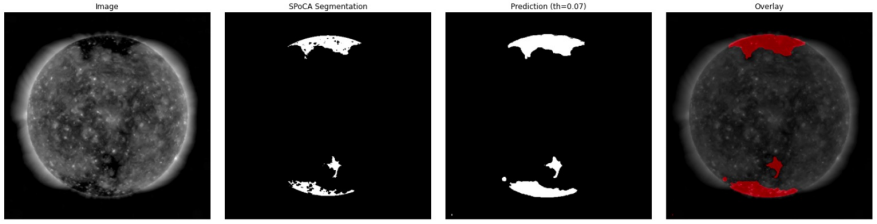
Data

Important step in data preparation for ML for independent evaluation: representative split of data form SDO/AIA and GOES/SUVI instruments. We used 60 months of data for each space telescope, with following split:

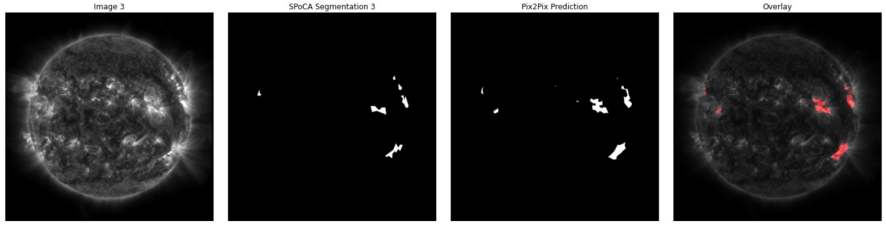
- Training set - 35 Months (For each year: 1 January - 15 March, 15 May - 15 August, 15 November - 31 December of each year)
- Validation set - 5 months (April of each year)
- Testing set - 10 months (September and October of each year)

Models

We first tested some of the selected architectures, like YOLO, U-Net and Pix2Pix. In training of final models we used U-Net with two different thresholds (A and B = less and more conservative threshold) and Pix2Pix architecture.



Example of coronal holes segmentation using Pix2Pix model



Example of active regions segmentation using Pix2Pix model

sorted by TPR	TPR	FPR	Other
CHMAP	98.8%	49.3%	82.6%
WWWBCS	97.7%	38.0%	89.7%
CHORTLE	91.9%	84.5%	100%
SPOCA-HEK*	87.5%	25.4%	44.4%
U-net B	**87.2%**	**11.2%**	**27.6%**
SYNCH	87.2%	62.0%	62.1%
ACWE04	86.0%	29.6%	41.4%
CHIPS	86.0%	53.5%	65.5%
CATCH	84.9%	0.0%	3.4%
CHRONNOS	84.9%	12.7%	41.4%
SPOCA*	84.2%	4.3%	23.1%
ACWE03	82.6%	7.0%	6.9%
Pix2Pix	**82.6%**	**12.7%**	**17.2%**
CNN193	81.4%	35.2%	37.9%
CHARM	79.1%	21.1%	13.8%
CHIMERA	77.9%	0.0%	37.9%
TH35	76.7%	21.1%	13.8%
U-net A	**73.2%**	**0.0%**	**0.0%**

sorted by FPR	TPR	FPR	Other
CATCH	84.9%	0.0%	3.4%
CHIMERA	77.9%	0.0%	37.9%
U-net A	**73.2%**	**0.0%**	**0.0%**
SPOCA*	84.2%	4.3%	23.1%
ACWE03	82.6%	7.0%	6.9%
U-net B	**87.2%**	**11.2%**	**27.6%**
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Evaluation of coronal holes segmentation – comparison to other approaches

Evaluation and Future Work

Evaluation using IoU, Dice, TPR, and FPR on internal and external datasets demonstrated that deep learning provides a reliable and scalable solution for solar structure segmentation, emphasizing the crucial role of thoughtful data handling and model design in achieving robust performance amidst domain-specific challenges like ambiguous boundaries. Our intent for the future is to provide the SCSS-Net as a service which can be used to support the space weather research and applications.

Acknowledgment

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