Data-driven segmentation and tracking of solar filaments using ground-based instrument data

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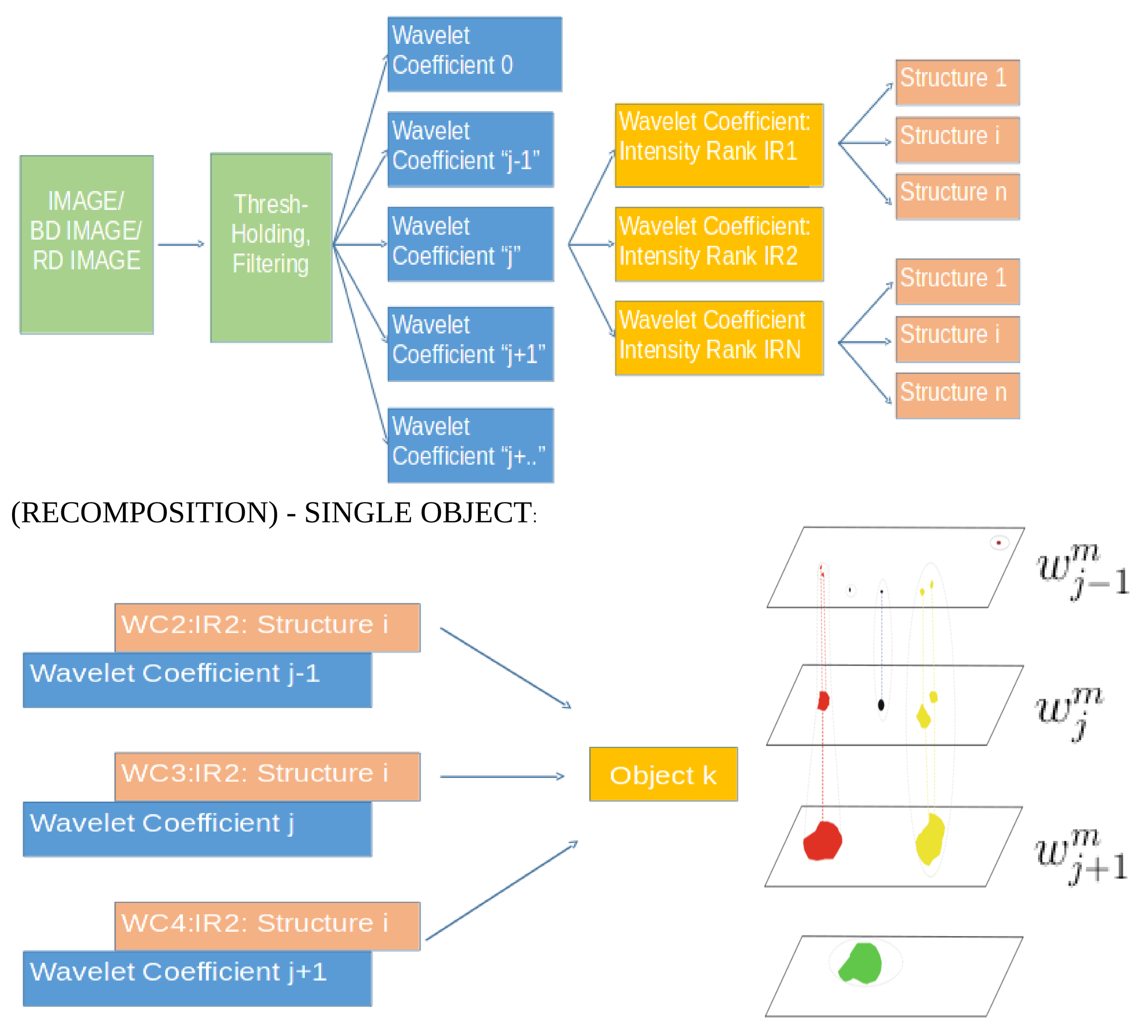
Background, Motivation

Analysis of the morphological changes and destabilization processes of filaments and prominences, captured in observational datasets, can help identify early warning signs of potential eruptions, . Previously, we developed algorithmic multi-instrument solar eruptive feature recognition and tracking methods and applied them to tracking coronal bright fronts and CMEs from the low corona out to 30 solar radii, using ground- (COSMO K-Coronagraph) and space-based (SDO/AIA, SOHO/LASCO C2 and C3) telescopic observations, followed by demonstration of data-driven image segmentation of CBF's based on SDO AIA data. In this work, we extend this approach for on disk image segmentation using H-alha Kanzelhohe Observatory data (https://gitlab.com/iahelio/helios_cnn*)



General image processing approach for objects recognition (shock waves, filaments, active regions) and tracking in solar physics.

Image decomposition as:

$$I(x,y) = \sum_{i=1}^{n} O_i(x,y) + F(x,y) + B(x,y)$$

Structures by definition:

$$S_{j,k} = \{w_j[k_1,l_1], w_j[k_2,l_2], \ldots, w_j[k_p,l_p]\}$$

Objects by definition:

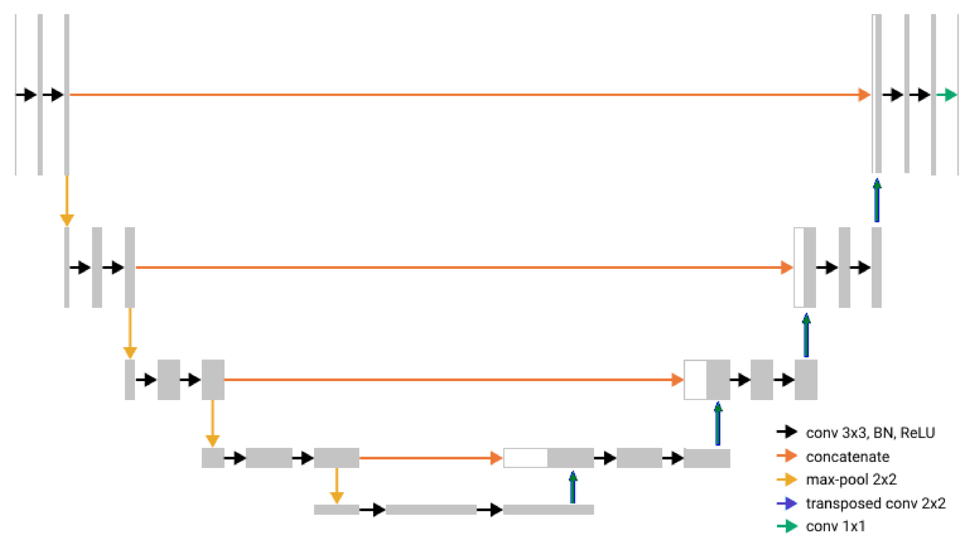
$$O_l = \{S_{j_1,k_1}, \ldots, S_{j_n,k_n}\}$$

Object condition for a structure:

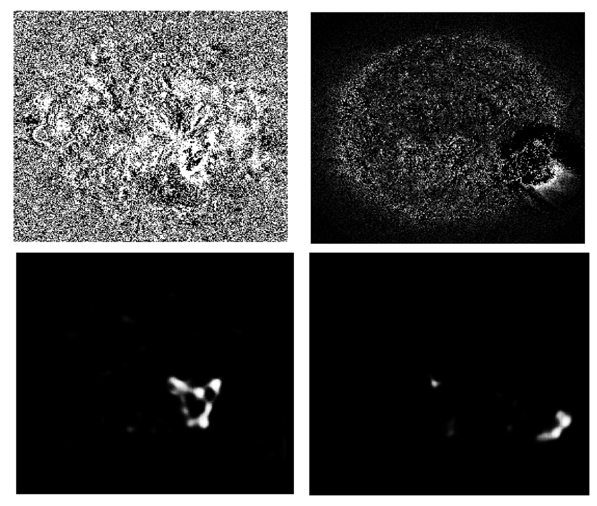
$$w_j^m > w_{j-1}^m \quad w_j^m > w_{j+1}^m$$

Where:

$$w_{j+1}^m = max\{w_{j+1,x_1,y_1}, \ldots, w_{j+1,x_n,y_n}\},$$
$$w_{j,x,y} \in S_{j,k}$$



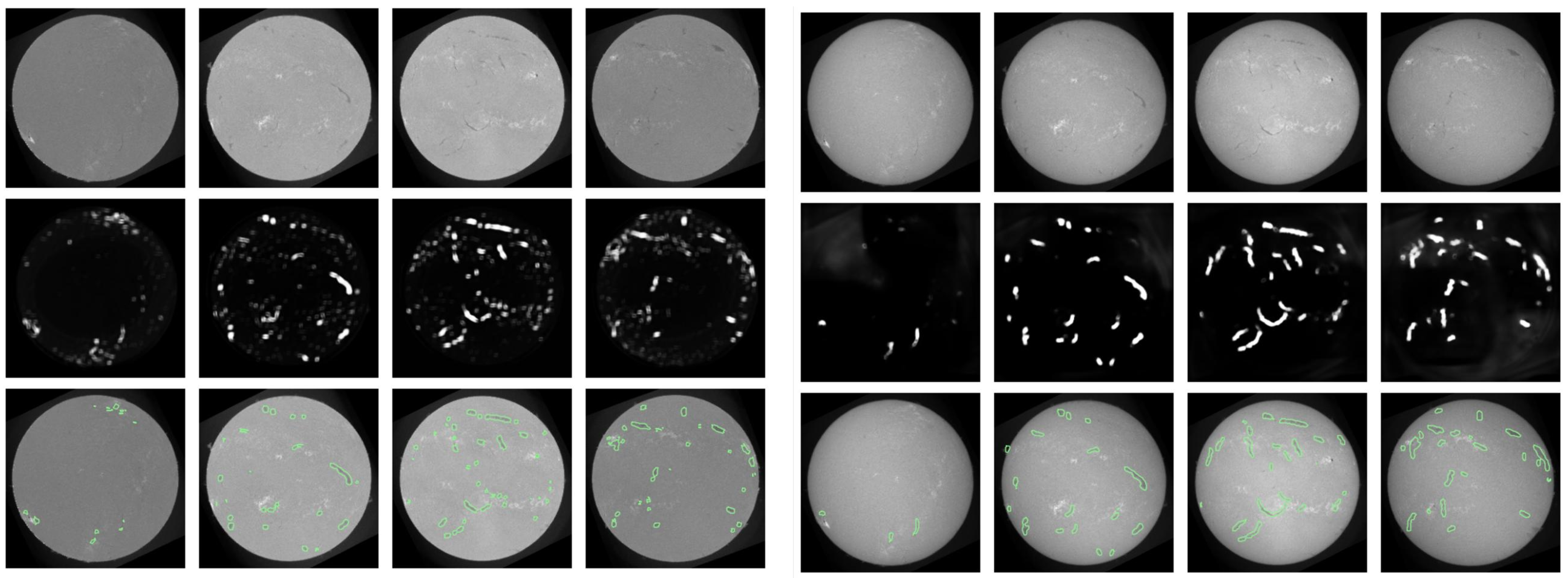
Hyperparameter search over U-NET architecture with added dropout and batch normalization. Exact network width/depth and filters/kernels count and sizes are determined dynamically depending on the grid algorithm decision.



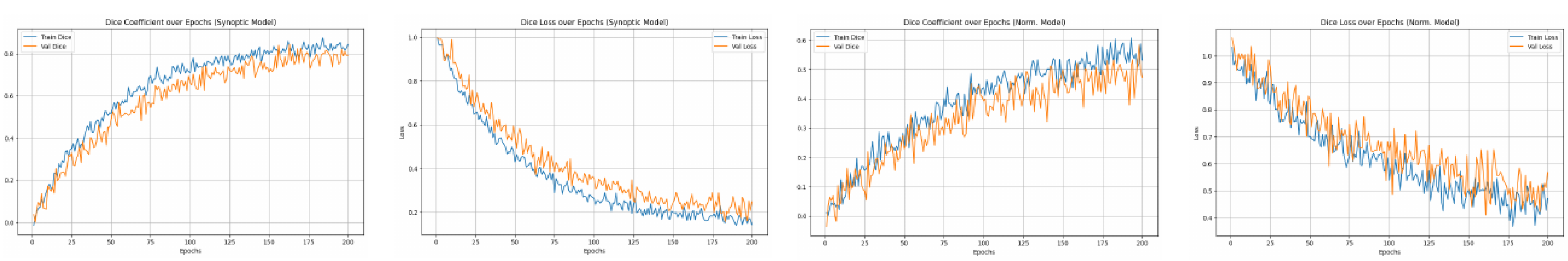
SDO AIA 193A
On-disk and on-limb Filament segmentation. For the two random events from the validation set

We previously tested this techniqe on segmentation of SDO AIA, K-Cor and LASCO C2, C3 data and in the current work we extend this approach to Kanzelhöhe observatory H-α Data.

Kanzelhöhe H-α Data: Data-driven image segmentation



U-Net image segmentation outputs for a models trained and evaluated on normalized (left) and synoptic(right) solar data. Top row: Input synoptic full-disk images of the Sun in grayscale, displaying slightly more pronounced linear features than normalized counterparts. Bottom row: Corresponding binary segmentation masks, highlighting detected features (distinctively filaments) in white on black, with improved continuity and detail



Synoptic and Normalized models. Training/validation dynamics and detection quality for two segmentation models. Intersection over Union (IoU) and DICE loss coefficients

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