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Identification and 3D morphological modeling of solar coronal mass ejections using deep neural networks

F.A. Iglesias[1,2], M. Sanchez[1], F. Cisterna[1], Y. Machuca[1], D. Lloveras[1,2], F. Manini[1,2], F. Lopez[1,2] & H. Cremades[1,2]

1.Grupo de Estudios en Heliofísica de Mendoza, Universidad de Mendoza, Argentina.
2. Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina.

Coronal mass ejections (CMEs) are a major driver of space weather and thus can have important negative technological and social implications. Given our current inability to forecast the occurrence of a CME, it is crucial to assess their geoeffectiveness once they are ejected. Particularly relevant for this task are the identification and correct assessment of the CME 3D morphology in coronagraph images. In the last decade, Deep Neural Networks (DNN) have experienced enormous improvements in solving various machine-vision-related tasks, particularly excelling at image recognition and segmentation. One issue when trying to use these deep models for CME segmentation or related tasks using coronagraph images, is that no large, curated dataset exists that can be used for supervised training. To mitigate this, we produced a synthetic dataset of CME coronagraph images by combining actual quiet (no CME) coronagraph background images with synthetic CMEs, the latter simulated using the Graduated Cylindrical Shell geometric model (GCS). In this work, we present preliminary results of two DNN-based models. The first model is used to identify and segment the outer envelope of CMEs in a single image. This is done by fine tuning the pre-trained MaskR-CNN model to produce a GCS-like mask of the CME present in a single differential coronagraph image. The second model estimates the simplified 3D structure of the CME outer envelope from 2 and/or 3 simultaneous differential coronagraph images, acquired from different vantage points (spacecrafts). This model is implemented by adding a fully-connected, linear head to a pre-trained ResNet backbone, and is trained to produce the GCS model parameters that best fit the CME outer envelope in the input images.