Commentary on “Algorithms for Solar Active Region Identification and Tracking”

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SDO and Solar Statistics

The Solar Dynamics Observatory (SDO) was launched on February 11, 2010 with the goal of better understanding the Sun’s influence on Earth and near-Earth space. Image Credit: NASA

- Compared to older generation observatories, SDO generates an enormous volume of high cadence solar data.
- The continuous science data downlink rate is 130 Mb/s, enough to fill a typical CD every 36 seconds.
- Sophisticated, robust, and automatic analysis procedures are needed to supplement/replace manual techniques.
Sunspot classification is typically done manually by experts. Impractical for massive data streams. Inconsistencies stemming from human observer bias. Classification may not be reproducible.
Mount Wilson Classification Scheme

Figure: Four classes of sunspot groups according to the Mount Wilson scheme: (left to right) $\alpha$, $\beta$, $\beta\gamma$, $\beta\gamma\delta$

- $\alpha$: a single unipolar spot which may be linked with plage of opposite magnetic polarity.
- $\beta$: pair of spots with opposite magnetic polarity (bipolar), but with a simple and distinct spatial division between the polarities.
- $\beta\gamma$: a bipolar group sufficiently complex that a straight line cannot divide the two polarities.
- $\beta\gamma\delta$: a bipolar $\beta\gamma$ group with umbrae of opposite polarity inside a single penumbra.
Steps Towards Automated Classification

1. Locate active region pixels in magnetograms and identify polarities.

2. Identify umbrae/penumbræ in white-light images.

3. Extract science-driven numerical features to use as attributes in a supervised learning algorithm. (See my poster for details!)
Our current method of sunspot classification is “semi-automated.”

- The active regions come “pre-cut.”
- Difficulties arise when there are multiple active regions in the same cutout.

**Image:** (Left) Two active regions that are easily distinguishable; (Right) Multiple active regions not easily distinguishable
Multiple Merging Active Regions
Multiple Merging Active Regions $\rightarrow$ Bad Classification

- Sunspot classification is based around the morphology of individual active regions.
- Erroneously treating two (or more) active regions as a single active region introduces artificial complexity that will lead to obviously incorrect classification (i.e. $\alpha \rightarrow \beta \gamma$).
Partial Solution: Grouping and Tracking

We can use group labels to filter out pieces of magnetic flux that are not associated with the sunspot/active region of interest.
By tracking active regions over multiple frames, we can sometimes distinguish separable regions before (or after they merge) and make judgements about the number of distinct regions in a given location.

Classification according to the Mount Wilson scheme may not be ideal for merging active regions, but recognizing those situations has been non-trivial.
Our ultimate goal is to capture evolutionary patterns in sunspot groups and predict energetic events such as solar flares and CMEs that are known to be associated with sunspots/active regions.

This will require a massive amount of data (not a problem in the era of SDO) and the ability to track particular sunspots/active regions.
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For Further Reading I

- Turmon, Pap, Mukhtar
  “Statistical Pattern Recognition for Labelling Solar Active Regions: Application to SoHO/MDI Imagery”

  “Statistical feature recognition for multidimensional solar imagery
  *Solar Physics*, 04/2010

- Stenning et al.
  “Morphological Image Analysis and Its Application to Sunspot Classification.”