Classifying Active Regions Using Machine Learning

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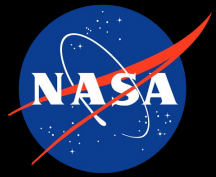
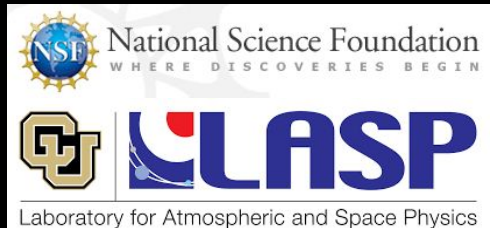
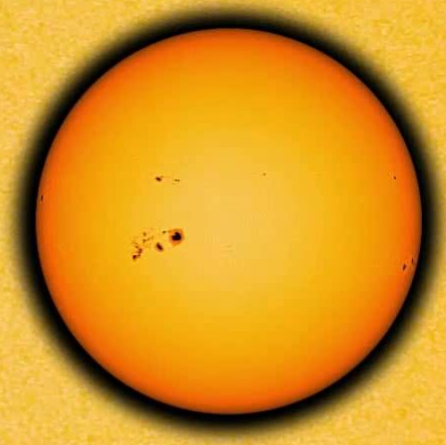


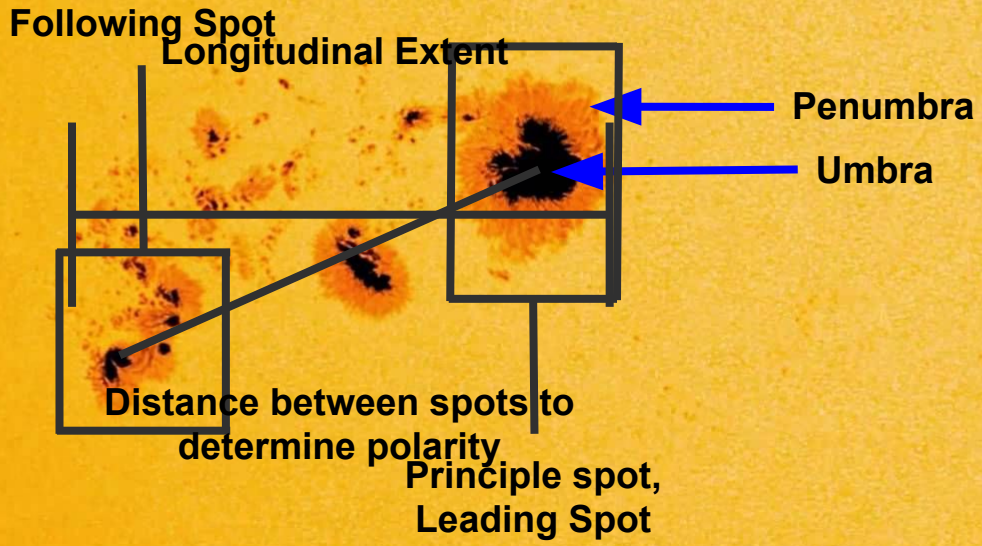


Motivation

- The McIntosh Classification system was created to use sunspots to predict solar flares
- Classifications are only published once per day
- Classifications are not precise
    - The definitions of classes are not all objective, some use words such as ‘large’, ‘small’, and ‘few’, which leaves room for disagreement on the classification of some spots

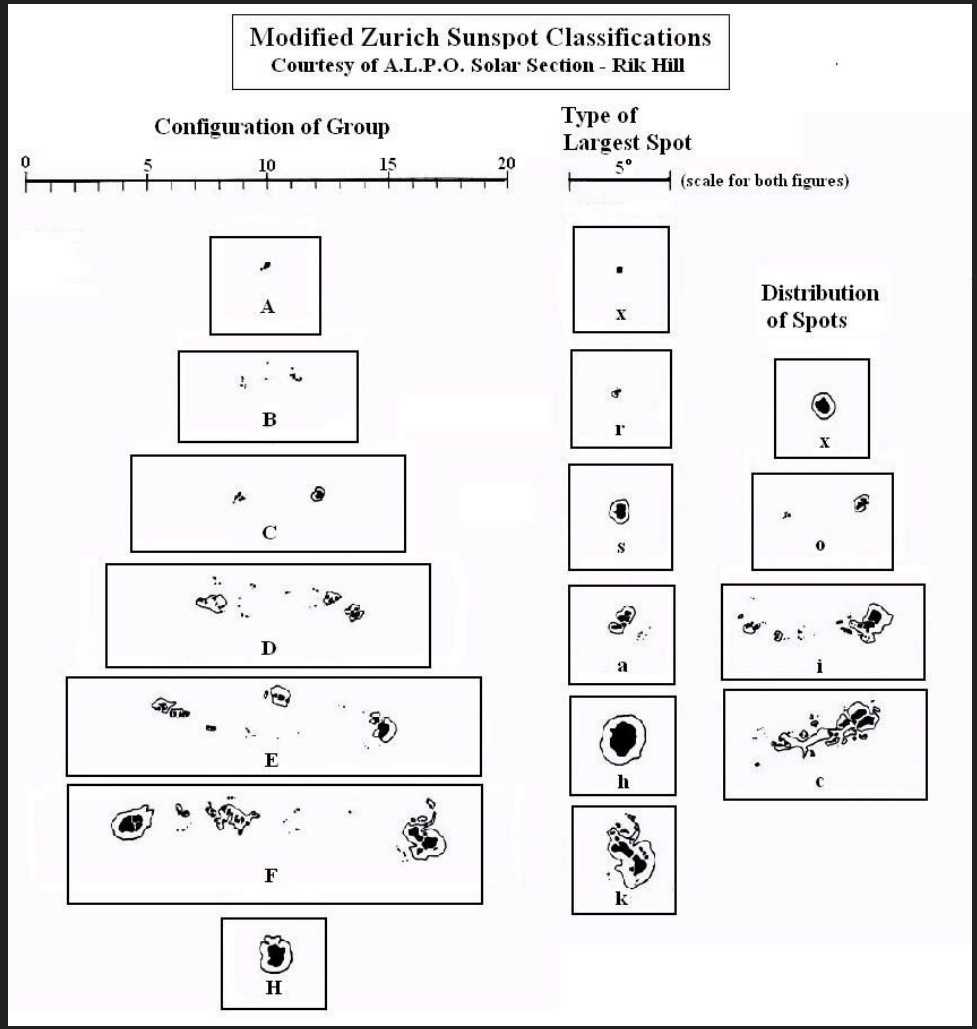
SDO/HMI Quick-Look Continuum: 20140106_073600





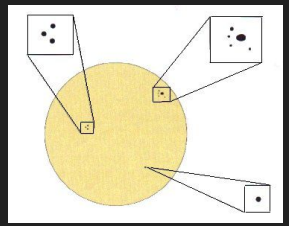
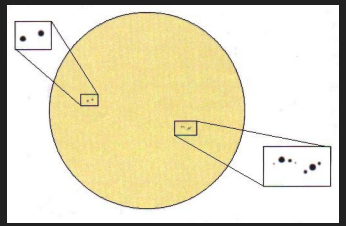
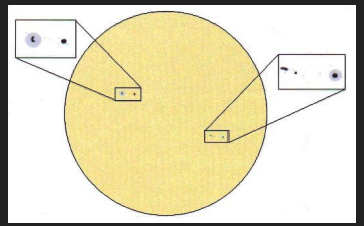
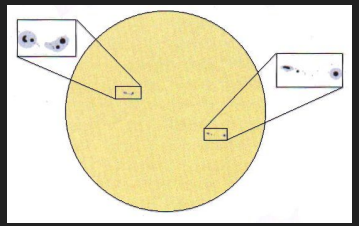
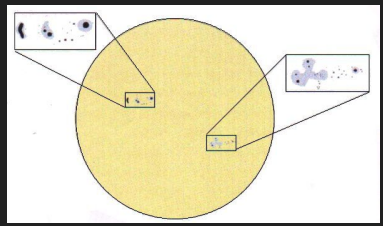
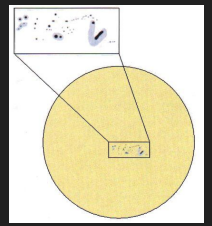
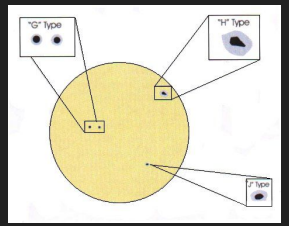
Classification

- Z value describes the group as a whole
  - Polarity
  - Longitudinal extent
  - Presence and distribution of penumbra
- P value describes principle spot
  - Size
  - Symmetry
  - Presence and maturity of penumbra
- C value describes compactness
  - Spots in between leading and following spot
  - Penumbras between leading and following spot



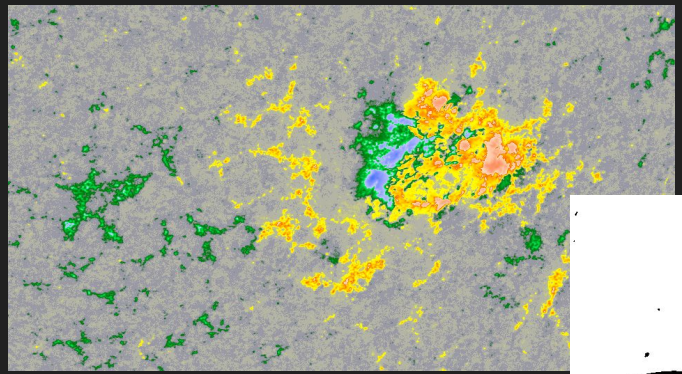
Z value

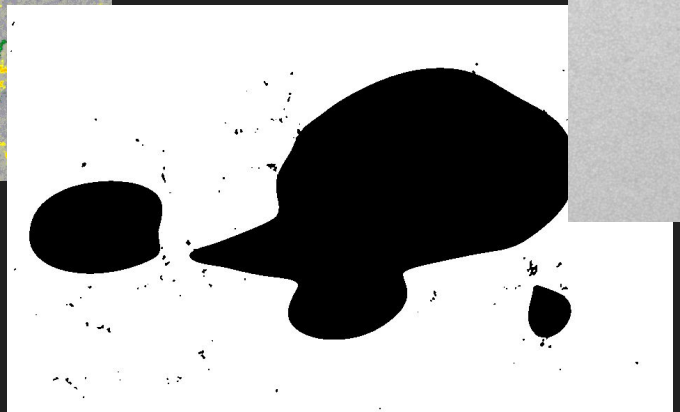
- The Z value is also called the Modified Zurich value
- The Zurich classification served a similar purpose to the McIntosh classification, but also described the history of an active region

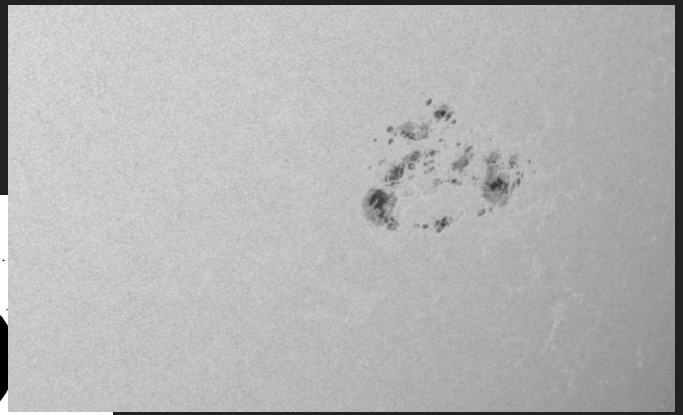








SHARP dataset

- Space Weather Hmi Active Region Patch
- Constructed using an automated process from full disk images (SDO)
- We used magnetograms, bitmaps, and intensitygrams







Parameters needed to determine Z value

- Polarity
  - Distance between the umbras of spots
- Longitudinal Extent
- Presence of penumbra
  - Which sides of region have penumbra for bipolar groups

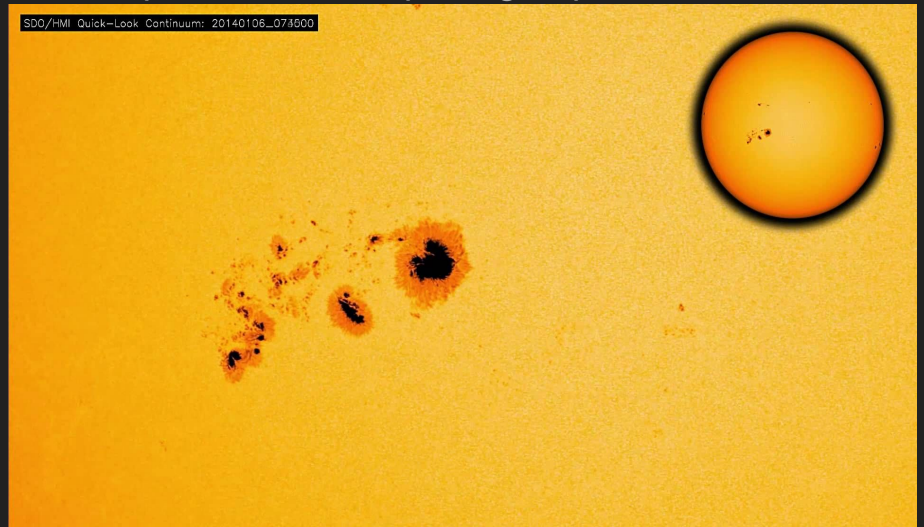
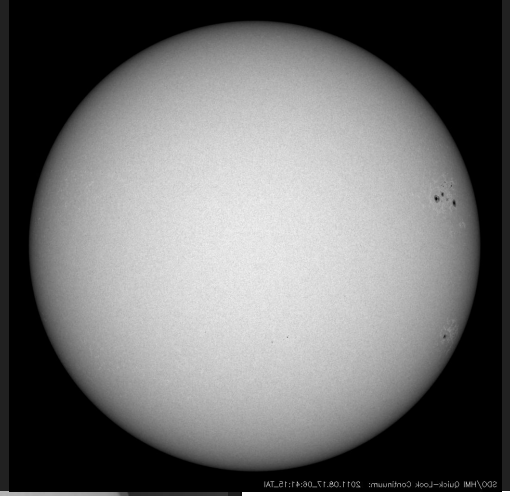
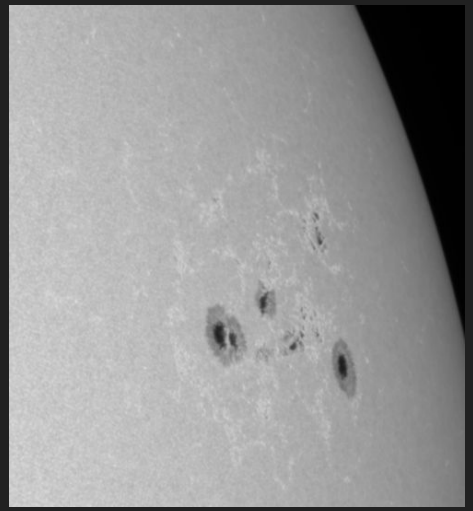
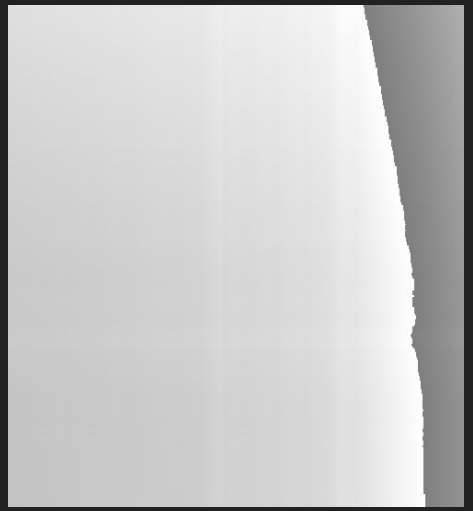


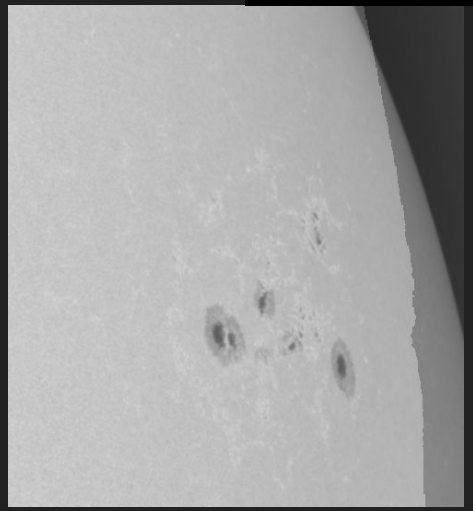
Image processing

- Correct Limb effect









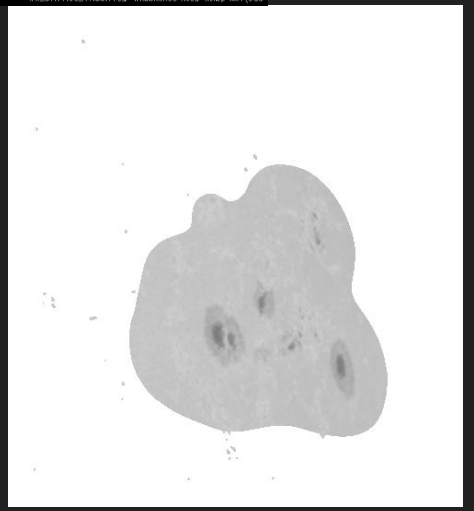


Image processing

- Find spots
  - Threshold image
  - Find contours of spots

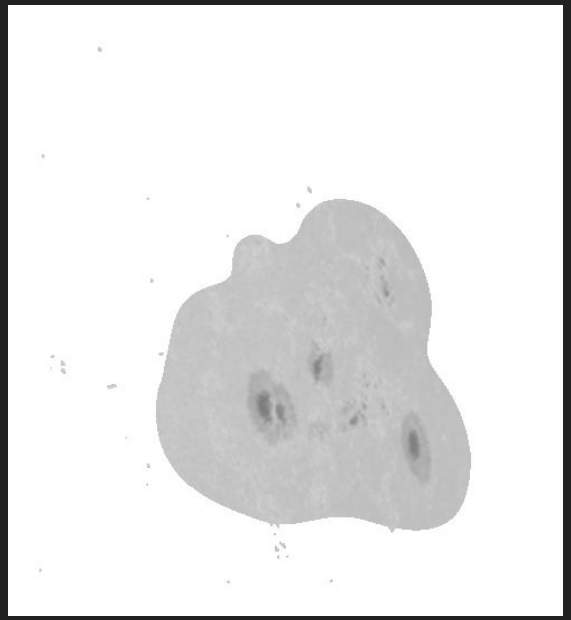


Image processing

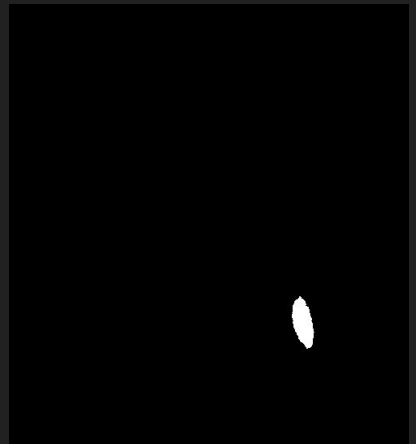
- Longitudinal extent
  - Find furthest left and right spots
  - Find edges of extreme spots
  - Find distance between furthest edges of extreme spots
  - Multiply by scale factor

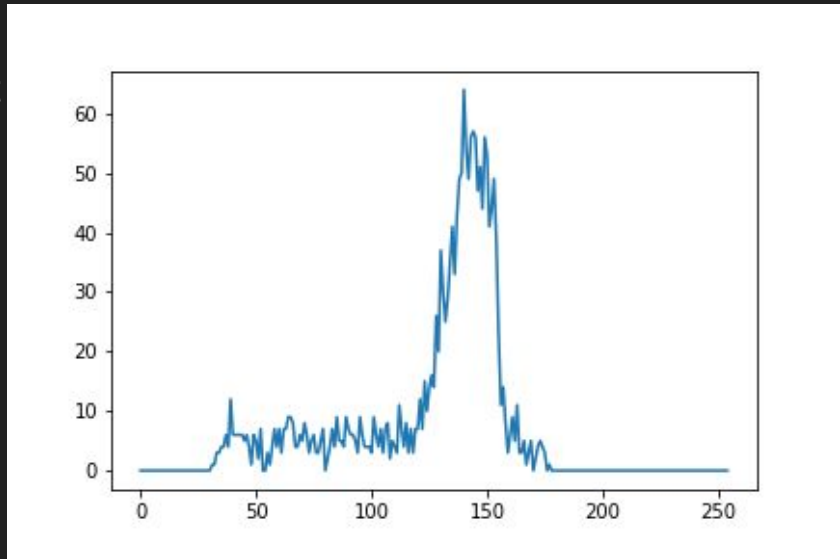
Image processing

- Polarity
  - Defined as bipolar if the greatest separation between spots is greater than 3 degrees
- Method:
  - Find furthest left and right spots
  - Find centers of extreme spots
  - Find distance between centers of extreme spots
  - Multiply by scale factor

Image processing

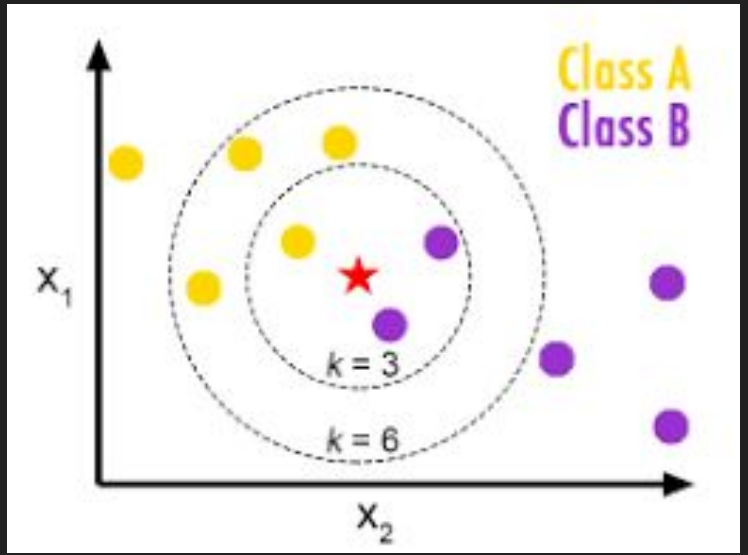
- Presence of Penumbra
  - Isolate one contour of a spot
  - Create a black image and draw contour in white (create mask)
  - Make a histogram of pixel value for spot
  - Analyze peaks of histogram
    - 2 peaks means penumbra is present
    - 1 peak means that no penumbra is present





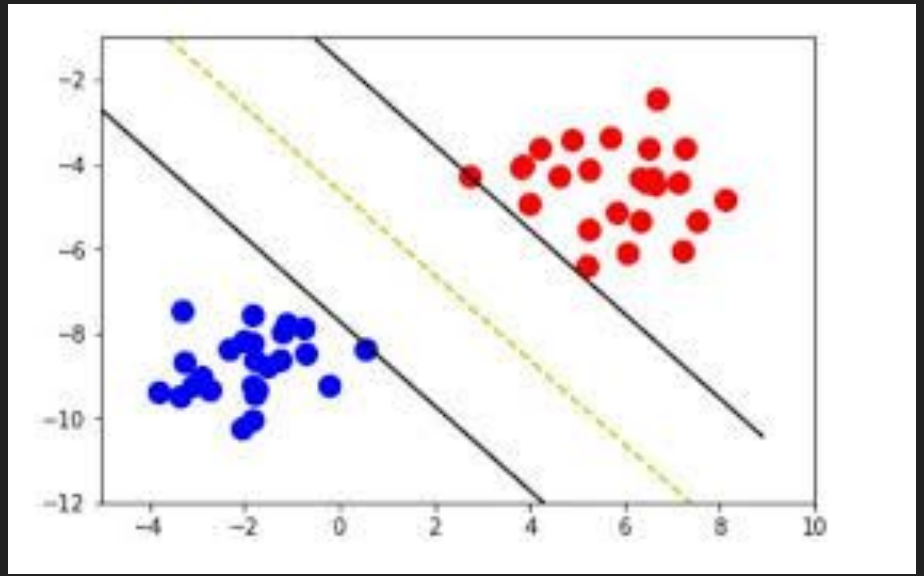
Machine learning techniques

- K Nearest Neighbor
  - Training
    - Graph all training points and their labels
  - Classifying
    - Graph point to be classified
    - Find k closest points
    - Between closest points, which label occurs the most



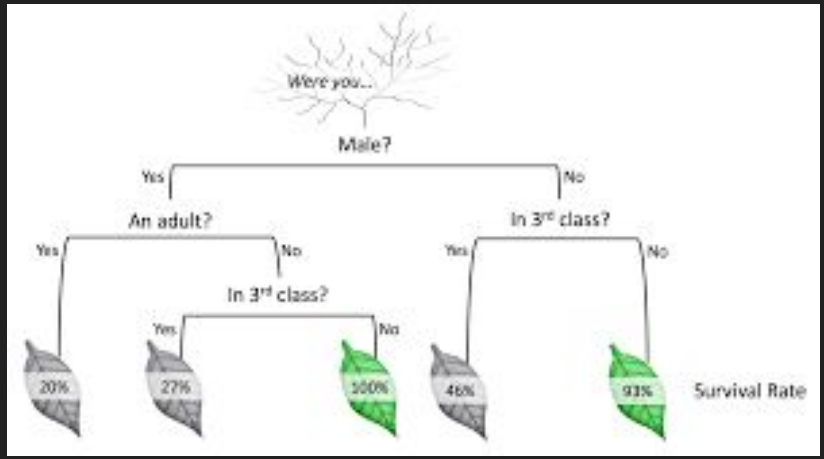
Machine learning techniques

- Support Vector Machine
  - Training
    - Graph all training points
    - Find line in between labels that is the farthest away from any point
  - Classifying
    - Graph point to be classified
    - Determine which side of the line it is on



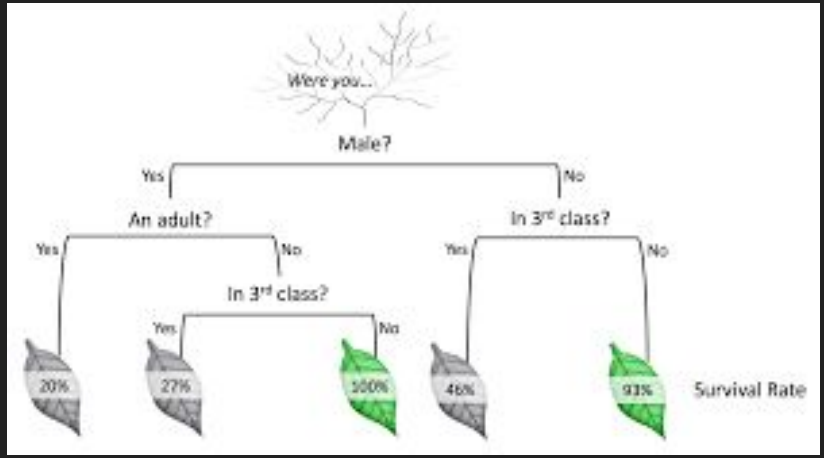
Machine learning techniques

- Random Forest
  - Training
    - Creates a random decision tree with a random subset of training points
    - Continues to make trees until the specified number is reached
  - Testing
    - Puts point to be classified through each decision tree
    - Averages the results of the trees to yield a classification



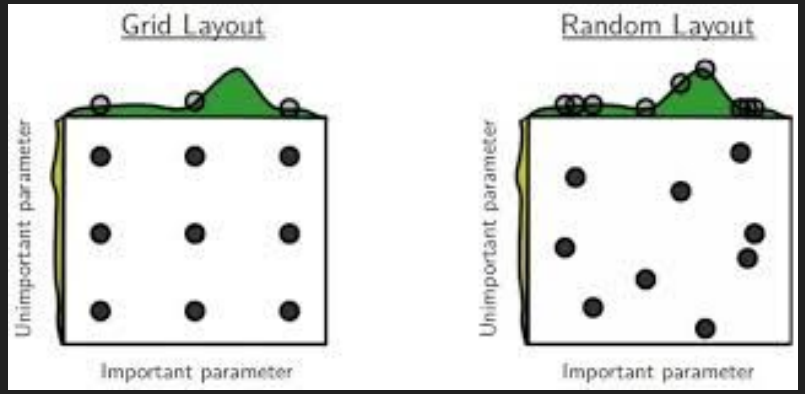
Machine learning techniques

- AdaBoost classifier
  - Training
    - Makes a random decision tree with random subset of data
    - Finds which training points the tree misclassified
    - Trains new decision tree with more weight on incorrectly classified points
    - Repeats until it has created the specified number of trees
  - Classifying
    - Finds result of point to be classified from each decision tree
    - Weighs the probabilities returned by each tree to yield a classification



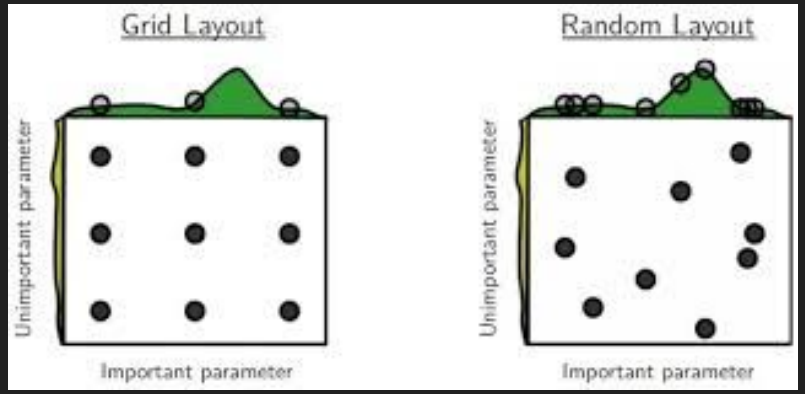
Randomized hyperparameter search

- Runs a given estimator (machine learning method) on given data a specified amount of times
  - examples
- Each time it randomizes the parameters
- Returns the parameters that yielded the best results.



Hyperparameter Grid Search

- Runs a given estimator with each possible combination of parameters that it is given
- Returns parameters that yielded the best results
- Slower than randomized parameter search



Performance of Classification using SVM

Overall score:
51.2% accurate

	A: Unipolar, no penumbra	B: Bipolar, no penumbra	C: Bipolar, penumbra on one side	D: Bipolar, penumbra on both sides, <10°	E: Bipolar, penumbra on both sides, >10°, <15°	F: Bipolar, penumbra on both sides, >15°	H: Unipolar, possesses penumbra
# of Samples	157	193	423	443	192	44	341
# Matched	58	56	225	285	85	5	204
Accuracy	36.9%	29.0%	53.1%	64.3%	44.3%	11.8%	59.8%

Performance using SVM, oversampling

	A: Unipolar, no penumbra	B: Bipolar, no penumbra	C: Bipolar, penumbra on one side	D: Bipolar, penumbra on both sides, <10°	E: Bipolar, penumbra on both sides, >10°, <15°	F: Bipolar, penumbra on both sides, >15°	H: Unipolar, possesses penumbra	Total:
# of Samples	157	193	423	443	192	44	341	
# Matched	86	75	183	259	102	10	206	
Accuracy	59.8%	38.9%	43.1%	61.2%	53.1%	20.4%	60.4%	51.4%

Comparison with literature

	A: Unipolar, no penumbra	B: Bipolar, no penumbra	C: Bipolar, penumbra on one side	D: Bipolar, penumbra on both sides, <10°	E: Bipolar, penumbra on both sides, >10°, <15°	F: Bipolar, penumbra on both sides, >15°	H: Unipolar, possesses penumbra	Total
# of Samples	157	193	423	443	192	44	341	
# Matched	86	75	183	259	102	10	206	
Accuracy	59.8%	38.9%	43.1%	61.2%	53.1%	20.4%	60.4%	51.4%
# of Samples	19	24	38	51	36	17	76	
# Matched	14	10	21	25	18	13	63	
Accuracy	73.7%	41.7%	55.3%	49.0%	50.0%	76.5%	82.9%	63%

Moving Forward

- Improve Z value
  - Find polarity using magnetogram
    - Current metric for polarity is 78% accurate
  - Improve contouring for penumbra
- Find c value
  - Number of spots between leader and follower
  - Presence of penumbra on spots between leader and follower
  - Maturity of penumbra on spots between leader and follower

Moving Forward

- Eliminate error in dataset
  - Eliminate pictures with too low of a range of pixel values
  - Limb effects
    - Write code to transform angled data to flat data
- Eliminate error in classifications
  - Comparison with mount wilson magnetic classification
  - Remove points by classifiers that are less accurate
  - Compare to flaring activity instead of classifications (McIntosh, P., 1990)
- Uses
  - Perform classification on all points in SHARP dataset to be used for research in the future

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