Automated region detection and sunspot analysis using GONG imagery

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Abstract. I describe the methods for automatically reporting magnetic regions from GONG magnetograms and sunspot area and extent from GONG white light images. The magnetic region detection involves the sun being gridded into small boxes and finding adjacent boxes that have significant field. The sunspot analysis uses gradient changes in the cumulative histogram to find dark pixels in a region. This is a variation on the method described by Pettauer and Brandt\textsuperscript{1}. Both of the methods are reasonably simple to implement and have produced good results for regions in the early part of cycle 24. Automated Sunspot areas were plotted against USAF/NOAA daily sunspot areas for the whole disk and produced a correlation co-efficient of 0.89. Future work with GONG H-alpha imagery will be described briefly.

1. Data
The data used in this project was from the GONG\textsuperscript{2} site at Learmonth, Western Australia. White light and magnetogram images are acquired every hour from the GONG instrument between sunrise and sunset, giving between 8 and 12 images per day depending on time of year and weather. The data in this report spans from September 2009 to May 2010. Sunspot numbers were obtained from the SWPC website in the form of the Daily Activity Reports supplied by USAF/NOAA\textsuperscript{3}.

2. Magnetic Region Detection
Each magnetogram is processed in order to find active regions. There are five steps involved in this process:

1. Calculate the standard deviation for the field strength of pixels whose absolute field is less than 100 Gauss and within 0.95 solar radii (Rv).
2. Grid the magnetogram into 20 by 20 pixel boxes.
3. Find boxes that contain pixels with absolute field strength greater than 12 standard deviations. This is typically between 80 and 120 Gauss.
4. Combine all adjacent boxes and find the total width and height of the combined boxes.
5. Adjust the box so that the magnetic field is in the centre of the box.
After finding each region, the algorithm checks that there is at least 20 millionths of the solar hemisphere (20 $\mu h$) of coverage of significant field and that the region has both positive and negative field. This means that some small regions will be missed. The box parameters are stored in a text file:

**Table 1.** Region file for regions found on the 17 December 2010.

| MJD:03675.539074074011296 |
|-----------------------------|
| DATE:2010/01/24 00:56:16    |
| RGN ID | LAT   | LON   | WIDTH | HEIGHT |
|--------|-------|-------|-------|--------|
| L10012300 | -24.79 | -33.93 | 0304  | 0162   |
| L10012301 | +20.82  | +42.15  | 0132  | 0112   |

The latitude and longitude are in degrees, and the box height and widths are in seconds of arc (Solar Diameter is ~1900 arcsec).

In addition, once per day magnetic parameters for each region are obtained. This is usually done near 0100 UT, weather permitting.

**Table 2.** Magnetic Parameters for the two regions found on the 24 January 2010.

| MJD:03675.539074074011296 |
|-----------------------------|
| DATE:2010/01/24 00:56:16    |
| MAX    | MAX    | MAX   | MIN   | MIN   | MIN   | TOTAL           | GRAD |
| RGN    | LAT    | LNG   | GAUSS | LAT   | LNG   | GAUSS FLUX     | GRADIENT | DIR |
|--------|--------|-------|-------|-------|-------|----------------|-----------|-----|
| L10012300 | -25.24 | -31.33 | +0747 | -25.44 | -39.28 | -0566 163542937 | -00122.38  | 89  |
| L10012301 | +19.78 | +41.38 | +0292 | +19.86 | +44.88 | -0588 061861396 | -00182.96  | 89  |

Max Lat and Max Lng defines the location of the maximum field strength. Max Gauss is the maximum field strength. Min Lat, Min Lng and Min Gauss defines the position and field strength for the minimum field. Total flux is the total absolute flux in the region in units of Gauss-$\mu$h. The Gradient is the field gradient between the max and min Gauss values in units of Gauss/degree. The Grad Dir is the orientation from north of the line between the max and min Gauss Values.

The values for the positions and the sizes of the regions are then used to do an automated sunspot analysis once per day (usually around 0100 UT).

3. **Limb Correction**

Before a region can be analysed for sunspots, the white light image needs to be corrected for limb darkening. The pixels in the white light image are 8 bit (0 to 255). The average brightness of pixels at 20 different radii are obtained and a cubic spline fit is made to find brightness as a function of radius (Figure 1). This is normalised and inverted. Each pixel is multiplied by this function to obtain a limb corrected image.

4. **Sunspot Detection**

Once the image has been limb corrected, a cumulative histogram is generated for each region. In order for a spot analysis to be performed on a region, the histogram for that region must span more than 55 intensity bins. This avoids small gradient variations in the region being detected as sunspots. A sunspot threshold is found by finding where the slope of the histogram changes by an average of 10 counts/bin over four bins (Figure 2). Only pixels within 0.95 Solar Radii are included in the sunspot search to avoid problems near the limb. This does distort sunspot area values for regions near the limb. Figure 3a shows a limb corrected sunspot region and figure 3b shows the spot detected areas for the same region. The program outputs the sunspot area, extent and position for each sunspot region. Table 3 shows sample sunspot analysis output.
Table 3. Output of automated spots analysis for 24 January 2010.

| REGION   | LAT | LNG | EWEXT | NSEXT | AREA  |
|----------|-----|-----|-------|-------|-------|
| L10012300 | -26 | -35 | 010   | 002   | 00230 |
| L10012301 | +21 | +43 | 006   | 004   | 00214 |

Figure 1. Normalised Brightness vs Solar Radii. The brightness curve for a white light image on 24 January 2010.

Figure 2. Cumulative Histogram for Region L10012300 on 24 January 2010. The threshold for sunspot detection is at bin 200.
4. Analysis
The sunspot areas calculated by the automated analysis were compared to those reported by NOAA/AFWA. One hundred individual regions were compared from September 2009 to April 2010. Figure 4 summarises these results.

Figure 4. NOAA/AFWA Sunspot Area vs GONG Automated Sunspot Area

There is a strong co-relation between the NOAA/AFWA sunspot area and the automated sunspot area. However, the automated area is 60% higher than the NOAA/USAF area. Visual inspection of the areas seems to confirm that the automated procedure works well except for those regions very close to the limb. These results are similar to those reported by Pettauer and Brandt².

5. Future Work
The introduction of GONG H-alpha provides a good opportunity for automated flare and solar feature detection. Combined with sunspot and magnetic region information, this should lead to a consistent set of solar parameters to aid in space weather prediction.

References
1. Pettauer T and PN Brandt, *On Novel Methods to Determine Areas of Sunspots from Photoheliograms*, Solar Physics, 175, 197-203 (1997)
2. Global Oscillation Network Group (http://gong.nso.edu)
3. Space Weather Prediction Center Website (http://www.swpc.noaa.gov)