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AUTOMATED DETERMINATION OF THE ALIGNMENT OF SOLAR IMAGES

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Abstract. To determine the heliographic coordinates of various solar features in the solar image one should know the alignment of the image. In practice, there are several methods to mark the direction of the solar image. A method that automatically finds several types of the alignment marker in the solar image is presented.

Key words: Heliographic coordinates

1. Introduction

In the Debrecen Heliophysical Observatory we compile a sunspot catalogue (Debrecen Photoheliographic Data, DPD) as a continuation of Greenwich Photoheliographic Results (GPR). The basic data in a sunspot catalogue are the heliographic positions and the areas of the sunspots. A computer program was developed to automatize the compilation of DPD. The Sunspot Automatic Measurement (SAM) program is a set of cooperative computer programs that embraces every aspect of compiling a sunspot catalogue: (1) setting up the necessary data base for the observation and the telescope, (2) determination of sunspot coordinates and area on digitized solar images and (3) making the catalogue ready for printing (Győri, 1998). This catalogue is based on our own solar observations but gaps in our observations are filled by solar images from other observatories. So there was a need to develop a method for automatic finding and proper interpretion of several alignment markers on various solar images.

2. Propagation of the alignment error into heliographic coordinates

The well known equations to transform coordinates of a point on a heliogram (solar disk) into heliographic coordinates on the solar surface are (Smart, 1977):

$$sin(B) = cos(\gamma)sin(B_o) - sin(\gamma)cos(B_o)cos(\omega), \qquad (1)$$

$$sin(L_{cm}) = -sin(\gamma)sin(\omega)/cos(B), \qquad (2)$$

or in other form

$$sin(B) = cos(\gamma)sin(B_o) - sin(\gamma)cos(B_o)cos(P - \tau), \qquad (3)$$

$$sin(L_{cm}) = sin(\gamma)sin(P - \tau)/cos(B), \qquad (4)$$

where B is the heliographic latitude, B_o the heliographic latitude of the center of the solar disk, γ the heliocentric angle, L_{cm} the heliographic longitude measured from central meridian and P the positional angle of the Sun's axis.

In the first group of the equations the polar (position) angle ω of the requested point is reconed from heliographic north direction of the solar disk. While in the second group τ is measured from geographic north direction of the solar disk. So, in any case, we should know the proper direction on the solar disk (the alignment of the solar image) if we want to determine the heliographic coordinates. The accuracy of solar image alignment has an impact on the accuracy of the heliographic coordinates. Using the Taylor series expansion the error propagation for the heliographic longitude L and the latitude B can be written as

$$\Delta L = [sin(B_o) - cos(B_o)tan(B)cos(L_{cm})]\Delta\tau, \qquad (5)$$

$$\Delta B = cos(B_o)sin(L_{cm})\Delta\tau, \qquad (6)$$

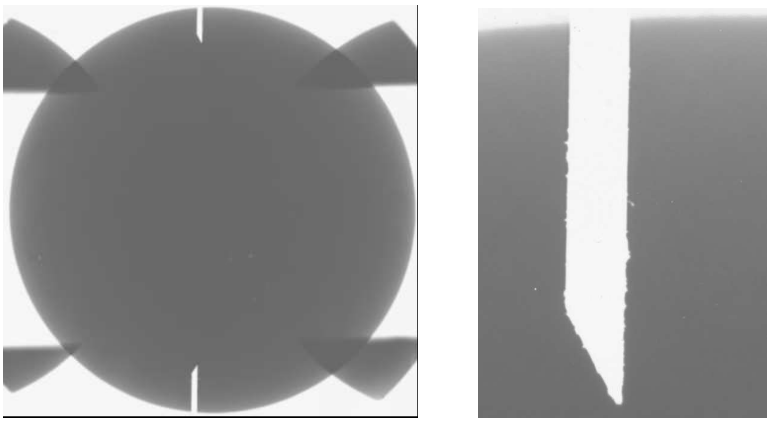
Here the second-order and higher terms are omitted but if $\Delta\tau < 1^o$ and $B < 45^o$ the accuracy of these formulae is about 0.01 heliographic degrees. From these equations we see that:

- The maximum error in the heliographic coordinates caused by the alignment error is about equal to the alignment error itself.

- The error depends on the heliographic position, especially on the central meridian distance, thus it can cause an incorrect proper motion of the solar features.

3. Alignment markers and what they represent

There is a number of methods to mark the alignment of solar images. A marker can represent: (1) heliographic direction; (2) geographic direction. The type of the direction can be: (1) south-north direction; (2)east-west direction; (3) both of them (cross-hair). Also there is a wide variety of the shape of the markers. Figure 1 to Figure 4 show some of them.



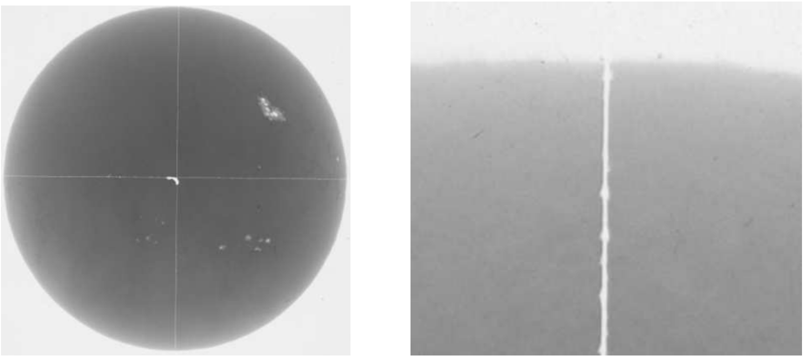
(a) Photoheliogram (b) Upper marker

Figure 1: Gyula watch hand marker.

4. Automated marker finding technique

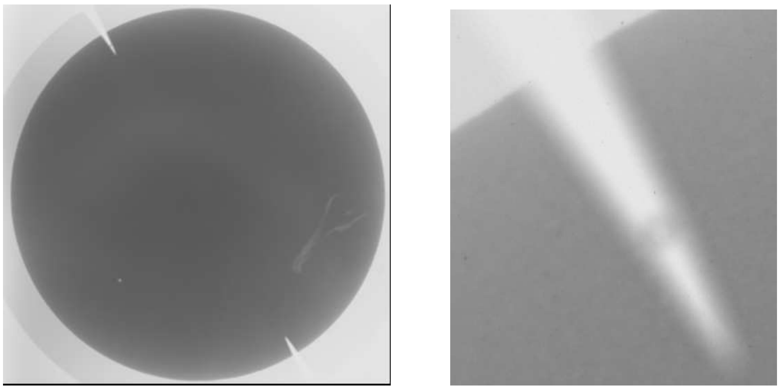
4.1. Markers with axial symmetry

The markers, as a consequence of their purpose, are relatively sharp (well defined) features and therefore a gradient (edge) filter seems to be well suited to find the shape, regardless which discrete gradient operator is used



(a) Photoheliogram (b) Spider line

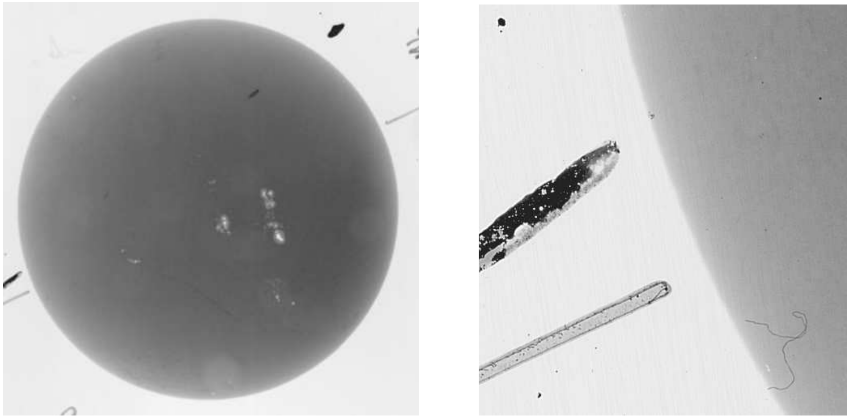
Figure 2: Gyula cross spider lines.



(a) Photoheliogram (b) Upper marker

Figure 3: Mt Wilson marker.

to create the gradient image for this purpose. In order to get rid of the background gradient we found that a threshold of 4 *sigma* of the mean gradient will produce proper results. Moreover, as the markers are located near the limb, we can omit edges outside the annulus at the limb with a width of about the characteristic length (it's value is not critical) of the



(a) Photoheliogram (b) Left marker

Figure 4: Wendelstein marker.

marker. In Figure 5 we plotted the gradient pixels for the Mt. Wilson marker (Figure 3) after this filtering in a Cartesian coordinate system. Here we can see that the marker is a high concentration of the gradient pixels around a direction of the image. In the following we make use of this fact.

In case of a sharper marker (e.g., Gyula watch hand marker) we can apply a more aggressive filtering so that practically only the edge pixels will remain. But the method works even if the marker is not extremely sharp.

Let's divide the x axis of the image into bins, in such a way that the width of a bin will be a little larger than the largest width (not critical) of the marker and create a histogram for the x coordinates of the gradient pixels. A guess to the angle of inclination of the marker can be produced by maximizing the peak of the histogram by rotating the coordinate system. Figure 6 shows the result of this maximizing procedure. Using this preliminary direction and the width (it's exact value is not critical) of the marker, the pixels that don't belong to the marker can be filtered out. A line fitted to the remaining edge pixels represents the appropriate (depending on what the marker represets) direction of the solar disk. Figure 7 shows the line fitted to the Mt. Wilson alignment markers.

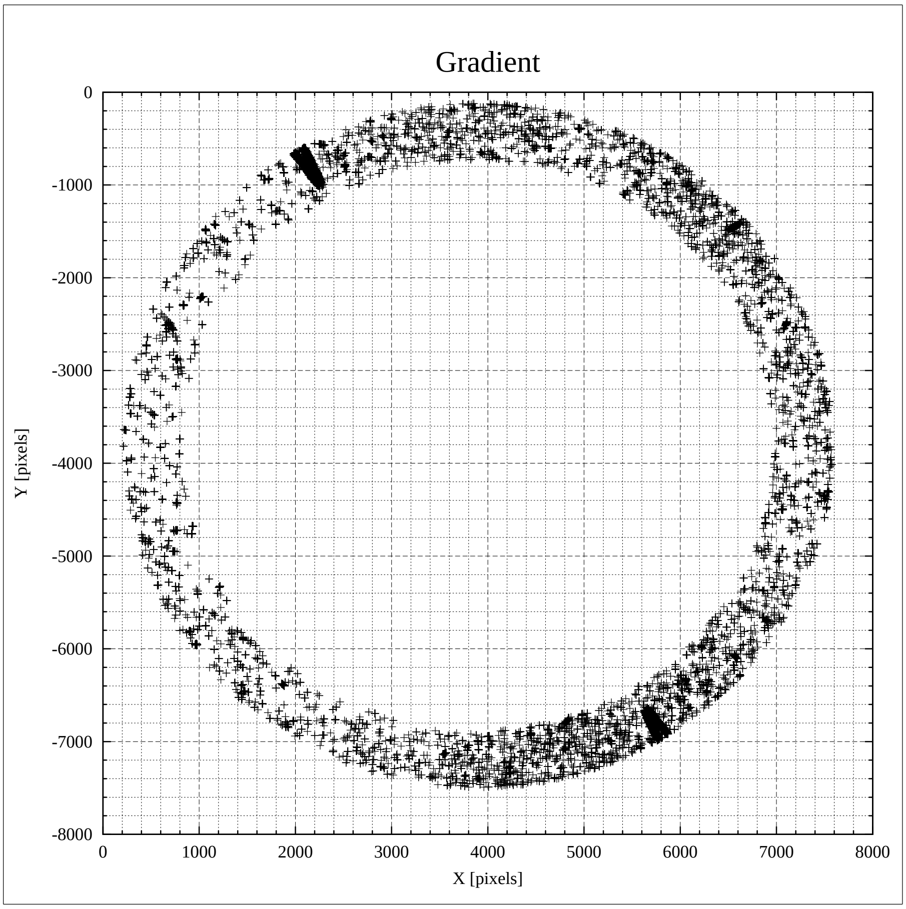


Figure 5: Coordinates of gradient pixels.

4.2. Markers without axial symmetry

In case of Gyula watch hand marker, a tweak is applied to the procedure described above. The reason of this tweak is twofold: (1) the marker has no axial symmetry; (2) the half distance between the tips of two marker parts is the optical point (intersection of the optical axis of the telescope with the image plane) of the image and we need this point to perform correction for the distortion of the enlarger of telescope.

The line which represents the orientation of the solar image is defined as

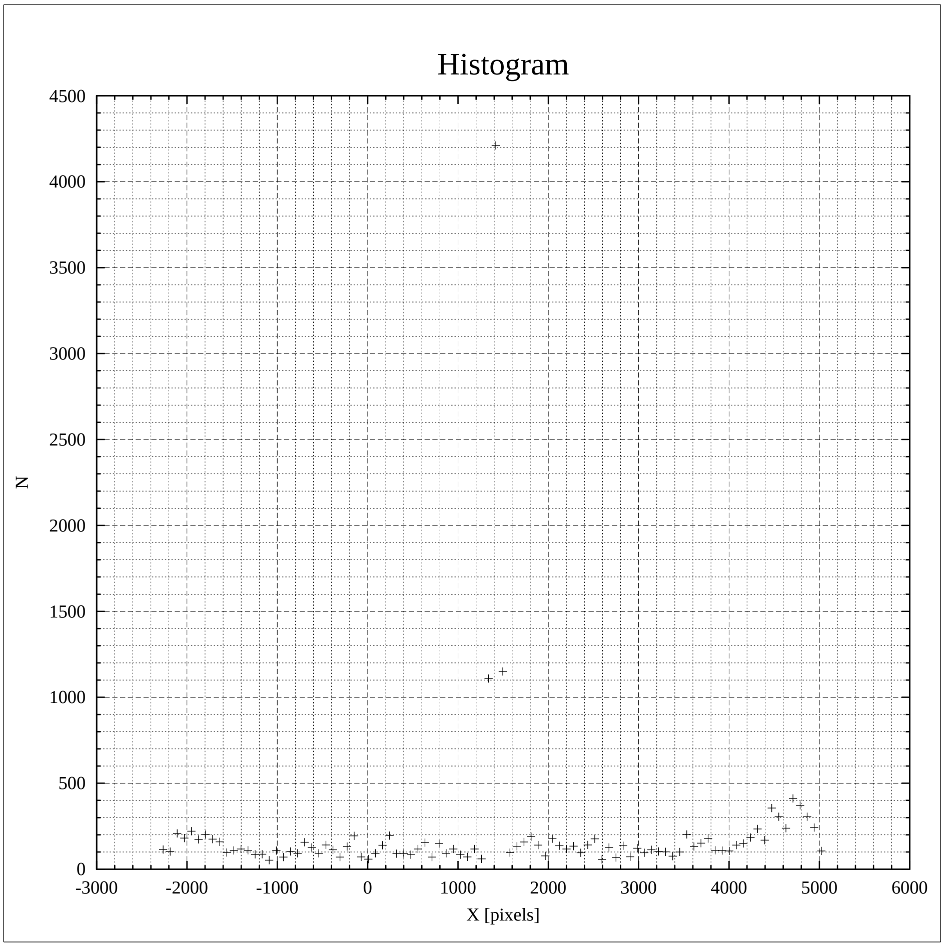


Figure 6: Histogram of the gradient pixels after maximizing the maximum of the histogram.

the connection of plateau centers C_1, C_2 of the marker tips. To determine the marker edge pixels we apply the same procedure as in the case of a symmetric marker then, using the mean intensity of the edge pixels, an intensity isocontour line of the marker is determined. This isocontour line which represents the shape of the marker is considered for any further processing. A straight line connecting the pixel pair N_1, N_2 of the opposite marker tips with the smallest distance gives an estimate for the orientation

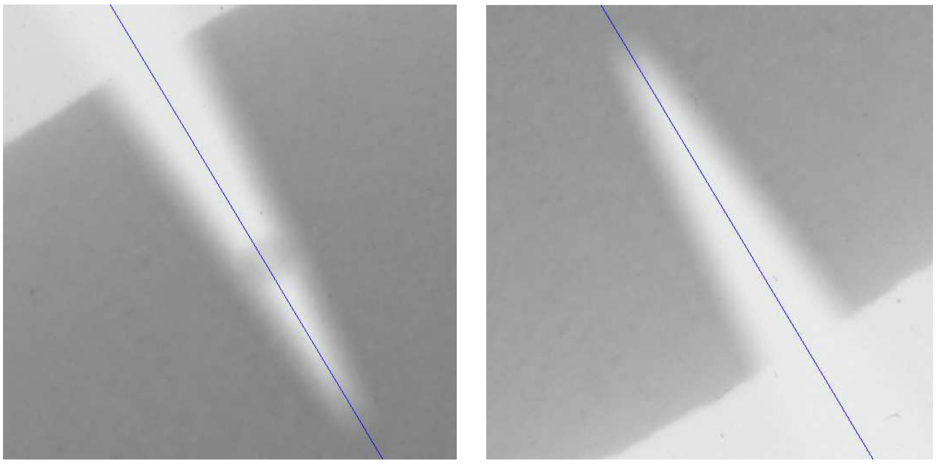


Figure 7: Two part images containing the markers, of the image in Figure 3(a) with the line representing the alignment of the solar image.

line. Along a line perpendicular to that estimate and through N_1 we check for edge pixels of the tip plateau in order to find the center of the plateau C_1. The opposite marker tip is treated analogous for C_2. Figure 8 shows the line fitted to the Gyula watch hand markers.

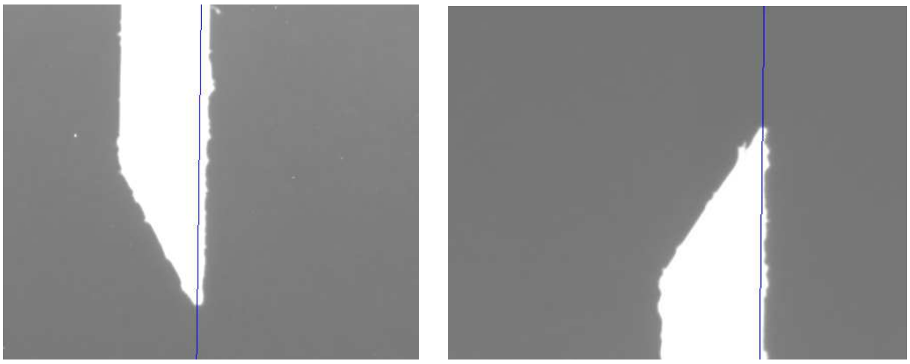


Figure 8: Two part images containing the markers, of the image in Figure 1(a) with the line representing the alignment of the solar image. Check the tip plateaus of the markers.

5. Accuracy

The accuracy of the alignment of the solar images can be broken down into two questions: (1) how precisely do we find the direction angle of the maker on the image; (2) how accurately does the marker represent the direction it is intended for.

The second item is not discussed here. It inherently depends on the method of putting the marker on the solar image. In the case of Gyula images it is about 0.05 degrees.

A way to answer the first question is as follows. Markers used to denote the alignment of the solar image have axial symmetry. Even in case of Gyula watch hand marker we can suppose this symmetry because we only use the small tip plateau to determine the direction angle of the marker, namely, the center of this plateau. So we expect about one pixel accuracy for the intersection of the fitted line with the two parts of the marker. The maximum angle error corresponding to that is $atan(2/D)$, where D is the distance between the marker parts. If $D = 7500$ pixels (as a typical value for the Gyula digitized images), the the maximum error in the angle of direction of the marker is 0.015 degrees.

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References

Győri, L.: 1998, *Solar Phys.* **180**, 109.

Smart W. M.: 1977, *Textbook on Spherical Astronomy*, Cambridge University Press, Cambridge.