Mathematical morphology and applications in automated sunspot detection

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Mathematical morphology : the basics

Mathematical morphology in image processing allows the shapes and structures in images to be used as tools in analysis. It was developed with binary images by Matheron (1975) and Serra (1982) but has been extended to include grayscale and colour. The two most basic operations are erosion and dilation. A shape called a structuring element must be chosen to probe the image with: we use a circle in this poster.

Erosion

Removes protrusions from a shape or structure.

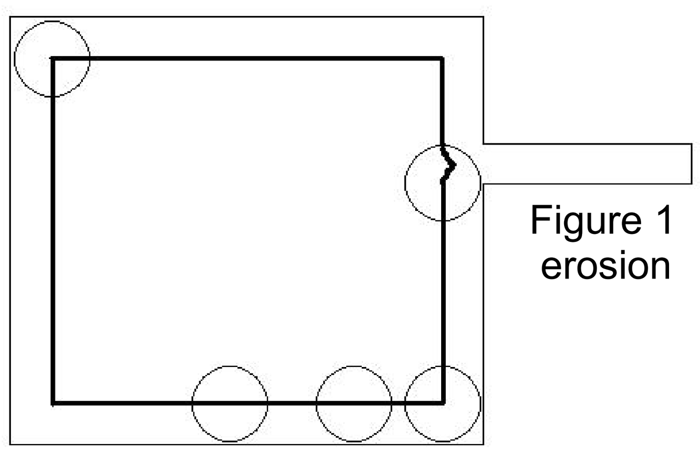


Figure 1 erosion

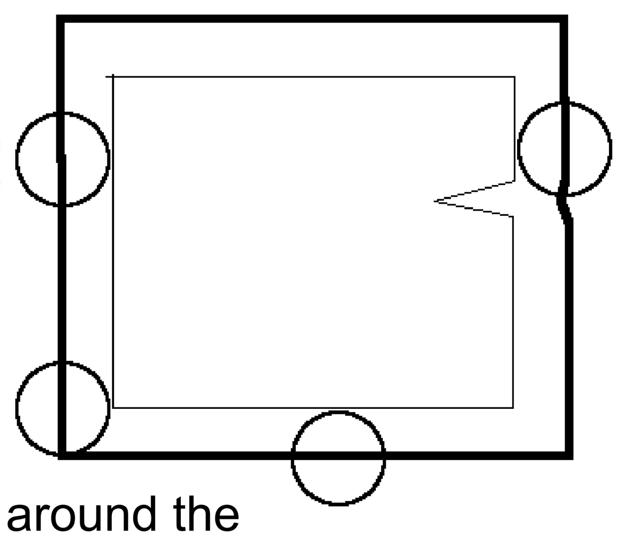


Figure 2 dilation

The structuring element is rolled around the inside of the shape given by the thin black line and produces the thick black line. This set of points traced out by the centre of the disk is the erosion of the larger square with the protrusion.

Dilation

· Dual to erosion.
· Equivalent to rolling structuring element around outside of the shape and marking centre of the circle.
· Example in Figure 2.

Sunspot detection

The problems with detecting sunspots in an automated way are more related to the surrounding areas than the spots themselves. The spots appear clearly on images as dark regions however thresholding is not an option as the Sun itself becomes dark near the limbs. So a method which can take the local background into account was required. The top-hat transformation can provide a solution and is also the subject of work undertaken by Curto, Blanca and Martinez (2008).

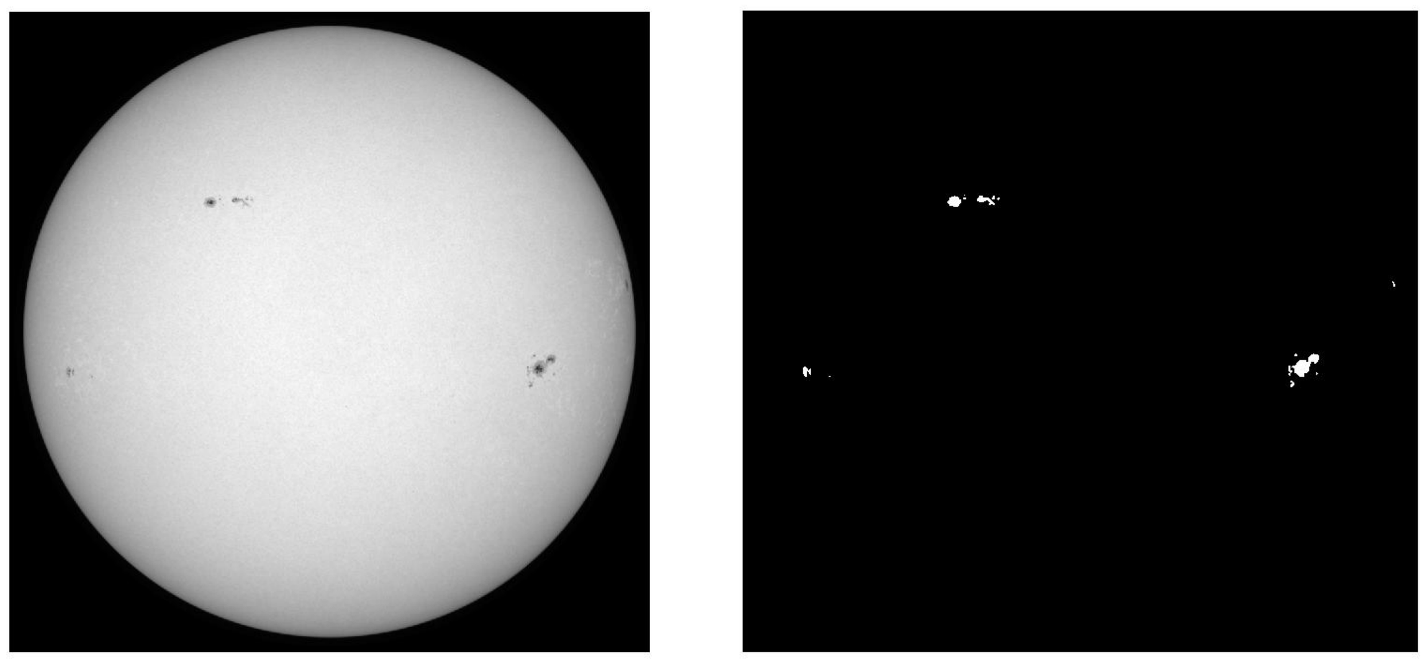
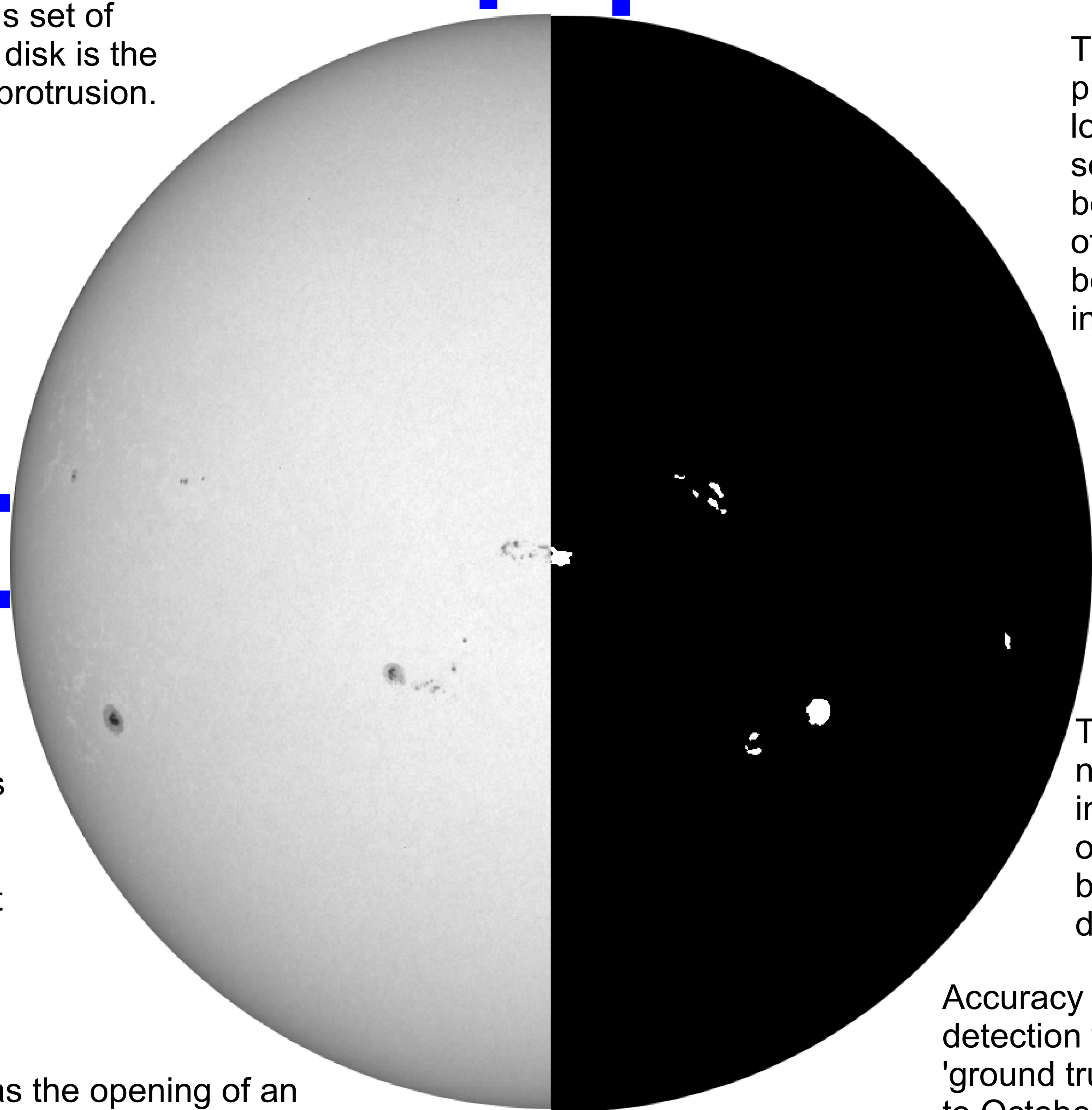


Figure 4 : example of the top-hat transformation. Original image on the left and processed image on the right.

The example in Figure 3 gives the processed image in Figure 4. The locations of the sunspots can be clearly seen and their location and areas can be easily recorded. A major advantage of the method is speed, with a full image being processed and all spots recorded in less than 4 seconds.



Opening and the top-hat transformation

From the erosion and dilation operators, a number of other operators can be formed. One of these is the opening operator (an erosion followed by a dilation). The benefit of this is that by using both basic operators, the general size of the original shape is preserved but certain regions can be removed.

The top-hat transformation is defined as the opening of an image *subtracted* from the image itself and it is this that is of use in sunspot detection. Figure 3 shows an example of this using a single row of pixels from a SOHO MDI continuum image.

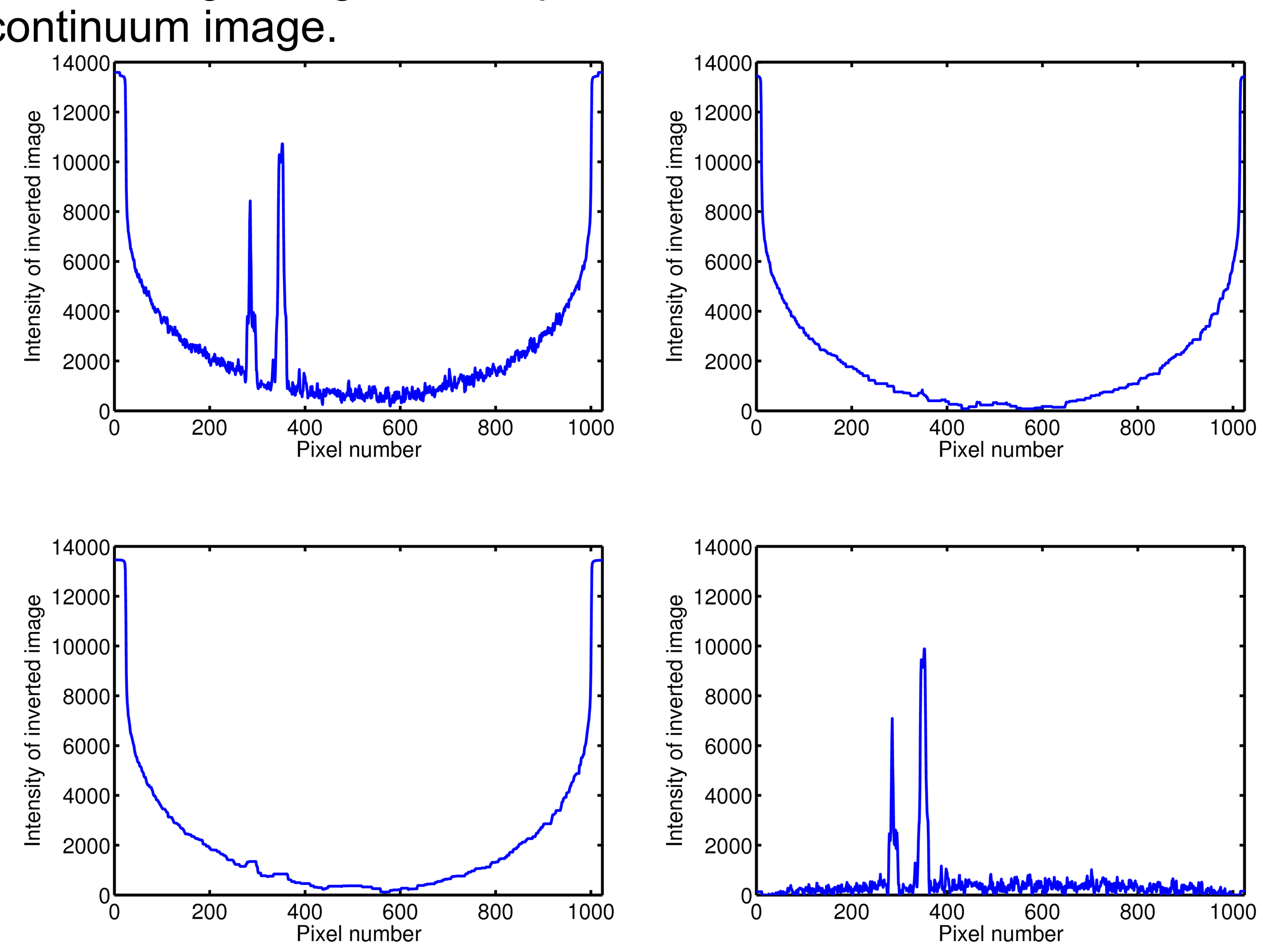


Figure 3 : (top left) original image inverted. (top right) original processed by erosion. (bottom left) opening of original image (erosion followed by dilation). (bottom right) subtraction of opened image from original image with spot peaks clearly visible. Intensity is measured pixel counts.

Discussion

The speed of the method allows large numbers of SOHO MDI continuum images to be analysed in a short space of time. The rate has been calculated at between 20,000 and 22,000 images per day given reasonable processing power.

Accuracy of the top-hat transformation in sunspot detection was determined using a series of 'ground truth' images, dated from January 1998 to October 2002, in which a human observer had marked pixels judged to be part of a sunspot.

Of the pixels marked, 77% of them were picked up by the top-hat transformation and mathematical morphology allows those areas to be used as markers to recover the whole spot area again.

Image	Pixels marked by observer	Pixels marked by top-hat transformation	False pixels
1	682	549	12
2	3700	3030	67
3	793	589	35
4	426	283	50
5	2449	1754	80
6	1014	873	88
7	2021	1434	30
8	1991	1566	38
Totals	13076	10078	400

Also, of the pixels marked by the transformation, 4% were false positives. These were enhancements to detected spots as opposed to new spot areas being incorrectly formed. Finally, 100% of sunspots present were detected.

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Curto, J.J. ; Blanca, M. ; Martinez, E. : 2008, Automatic Sunspots Detection on Full-Disk Solar Images using Mathematical Morphology. *Solar Physics*, 124. doi: 10.1007/s11207-008-9224-6
Matheron, G.: 1975, Random sets and integral geometry, Random sets and integral geometry, by Georges Matheron, pp. 261. ISBN 0-471-57621-2, Wiley, New York.
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