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A TECHNIQUE FOR AUTOMATIC IMAGE SEQUENCES ALIGNMENT

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Abstract. Many methods for processing a series of images using algorithms for correlating two images rely on the initial alignment of the objects on the input frames. Tracking the processes in the solar corona requires exact alignment in the positioning of the sun in the analyzed images. The question remains of the greatest importance when the images are obtained using terrestrial instruments - a coronagraph. This is mainly due to the fact that manual positioning of the coronagraphs can lead to a relatively large deviation in the position of the objects in two consecutive frames, which in turn will require manual image alignment during processing or analysis. The main task of this study is to create a technique for arranging two images of the solar corona that are obtained by a coronagraph. The problem relates to process of normalization of the objects view. That means - finding and fixing points inside of the image that allow calculating geometrical features. In addition the progress in registration technology has resulted in improved spatial and time-resolved data. Consequently, increases the amount of information to be processed by increasing the resolution of the images and by reducing the intervals between the records of two consecutive images. That's why we target the implementation of the algorithm by applying advanced image processing technologies, including parallel computing.

1. INTRODUCTION

The mathematics defines the differences between two images of one object to parameters of planar, affine or perspective transformation (Birchfield, 1998). A comparing of these objects supposes a preliminary alignment. The main question at this stage of processing is how to find invariants that allow calculate correctly the transformation parameters. There are two common approaches: feature – based approach and pixel –based approach (Zuliani, 2006),(Nese, 2011). In the first case some geometric features as corners, lines, curves and so on are fixed in the images by their positions and sizes. The values of parameters of transformation are calculated after comparing the chosen features. In the second case the values of parameters are calculated by finding maximal correspondence between whole images, fixed regions or random samples from the model of the object (Zuliani, 2006). The methods for extracting features depend on particular task. For example – in medical image processing (Kumar et all, 2010), (Ching-Wei et al., 2013) are used the both approaches. The free astronomical image processing software –Siril (https://free-astro.org/index.php/Siril), supposes automated alignment for global star alignment (rotation + translation) and translation using DFT (discrete Fourier transformation) centered on an object - more suited for planetary and bright nebula images, and PSF (point spread function) of a single reference star, for deep sky images.

The main task of this study is to create a technique for arranging two images of the solar prominences on the solar limb that are obtained by the Lyot-type coronagraph at NAO Rozhen.

2. THEORY

2.1. Preliminary analysis

The images of the solar corona obtained from the terrestrial instruments consist of two parts - part of the core area of the corona with prominences and a black area of a permanent artificial moon (fig. 1), and the position of the artificial moon variate in the difference images of one sequence.

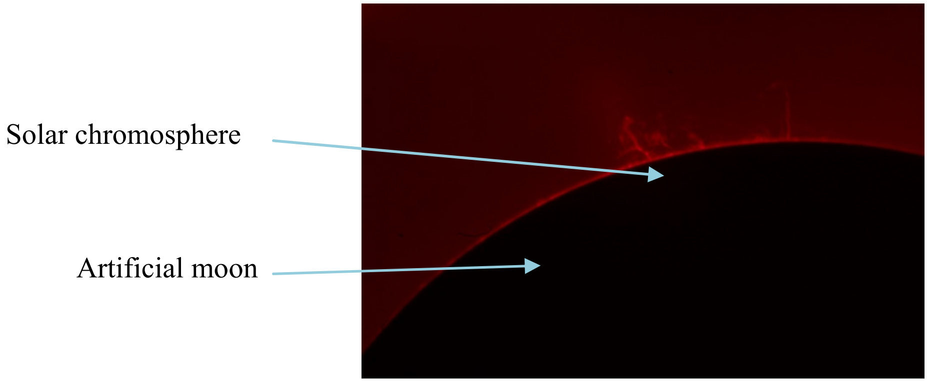


Figure 1: A common view of solar chromosphere and prominences image.

From the point of view of geometry the consecutive frames present planar projections of one variable object. It means that each pair of images could be aligned by parameters of similarity: scaling factor, rotation angle and displacements (Birchfield, 1998). The order of applying the needed transformations is very important and results are real if the center of the object coincides with the center of coordinate system. It means that the first operation must fix a center of the object. The size of the disk of artificial moon for particular instrument is constant. This makes the scaling factor insignificant, and it could be used for calculation the center of coordinate system, displacements of translation and be a center of rotation. Another special peculiarity of the sequences of solar images is dynamics of changes of the analyzed object. It complicates finding the angle of rotation.

2.2. Feature extraction

The simple way to calculate displacements at directions x-dx and y-dy is finding the difference between two positions of one point in consecutive images (fig.2). The technique described below uses a center of circle for this calculation.

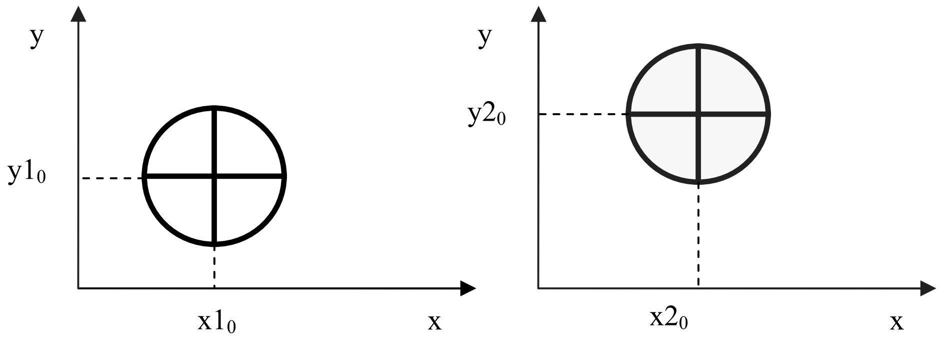


Figure 2: Displacements between two centrums.

$$dx = x2_0 - x1_0 \qquad dy = y2_0 - y1_0 \tag{1}$$

If we have three points $A(x_a,y_a)$, $B(x_b,y_b)$ $C(x_c,y_c)$, the coordinates x_0,y_0 of the centrum of the circle could be calculated by equation (2) (http://mathforum.org/dr.math/):

$$x_0 = \frac{1}{2}.\frac{(y_c - y_b).(x_c^2 + y_c^2 - x_a^2 - y_a^2) - (y_c - y_a).(x_c^2 + y_c^2 - x_b^2 - y_b^2)}{(x_c - x_a).(y_c - y_b) - (x_c - x_b).(y_c - y_a)} \tag{2}$$

$$y_0 = \frac{1}{2}.\frac{(x_c - x_a).(x_c^2 + y_c^2 - x_b^2 - y_b^2) - (x_c - x_b).(x_c^2 + y_c^2 - x_a^2 - y_a^2)}{(x_c - x_a).(y_c - y_b) - (x_c - x_b).(y_c - y_a)}$$

The radius from the points is calculated by equation (3).

$$(x_i - x_0)^2 + (y_i - y_0)^2 = r_i^2 \qquad i=A,B,C \tag{3}$$

The points A, B and C lay on the borders of the artificial moon. That is why the borders in the image have to be outlined. This could be obtained by gradient of the light distribution (Gonzalez et al., 2002). The processing also includes calculation of directional gradients for the central pixel- b_9 under the 3x3 pixels window. The b_i denotes pixels values from the image, and m_i denotes coefficients of gradient operator (4).

$$gr(b_9(x,y)) = \sqrt{gr_x^2 + gr_y^2}$$

$$gr_{x/y} = \sum_{k=1}^{9} m_{i(x/y)}.b_i \tag{4}$$

The gradient image is discrete function and that decrease the accuracy of calculations. That is why the technique applied for finding border points includes tracking the contour by Canny edge detection method (Hoggar, 2012) and calculation the center coordinates by three –pass procedure.

3. IMPLEMENTATION

The algorithm was implemented by parallel processing technique including GPGPU (General Purpose GPU computing) and OpenCV library (http://opencv.org/) for image processing. Figure 3 represents the algorithm used for images alignment.

The algorithm can be described in four common steps:

- Extraction of points over the visible the edge of artificial moon;
- Finding of possible centers of the arc;
- Finding of the real center;
- Alignment of the images.

Alignment of two images is performed with use of affine transformation translation matrix, which can be represented with (5):

$$T = \begin{bmatrix} 1 & 0 & d_x \\ 0 & 1 & d_y \end{bmatrix} \tag{5}$$

Parameters d_x and d_y are calculated as a displacement between the centers of circles in two images.

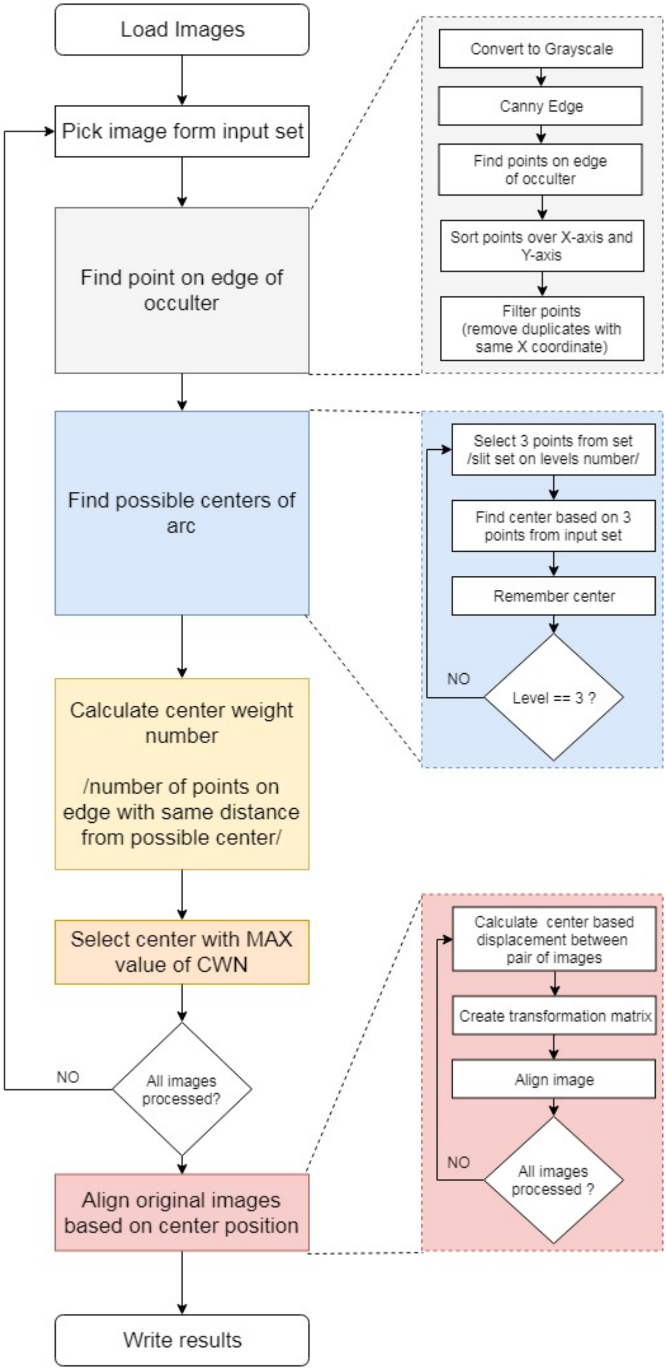
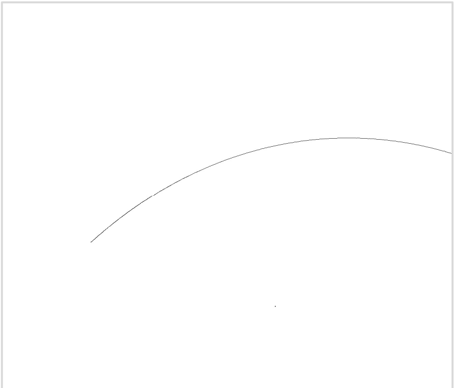


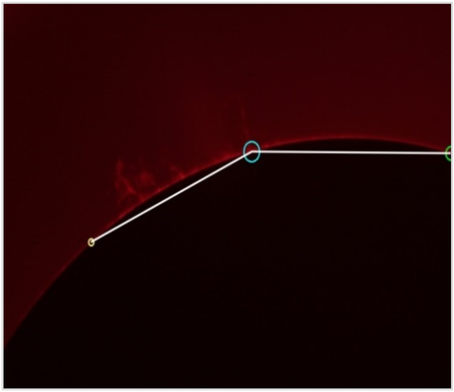
Figure 3: The images alignment algorithm.

4. EXPERIMENT AND RESULTS

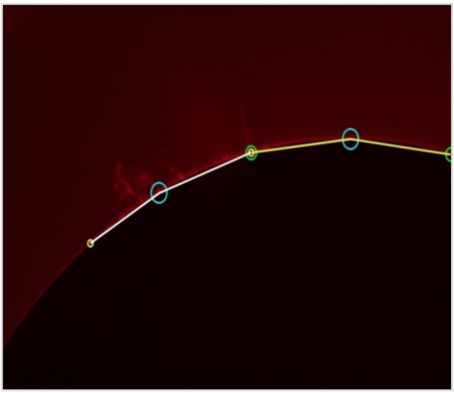
For the experiment are used sequences of images of solar corona registered by 15 cm Lyot-coronagraph mounted at NAO Rozhen. The images are 3400 x 2300 pixels. At the images below are represented different stages of the images processing. Color images below describe work of the algorithm responsible for determination of the center of arc based on first, middle and last point from group of points that represents visible part of the occulting disk.



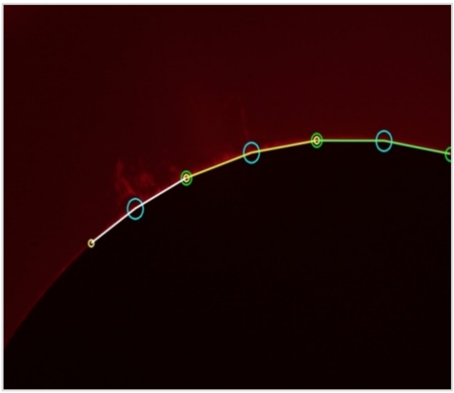
Extracted points of arc



First pass of arc center search (1 sector)



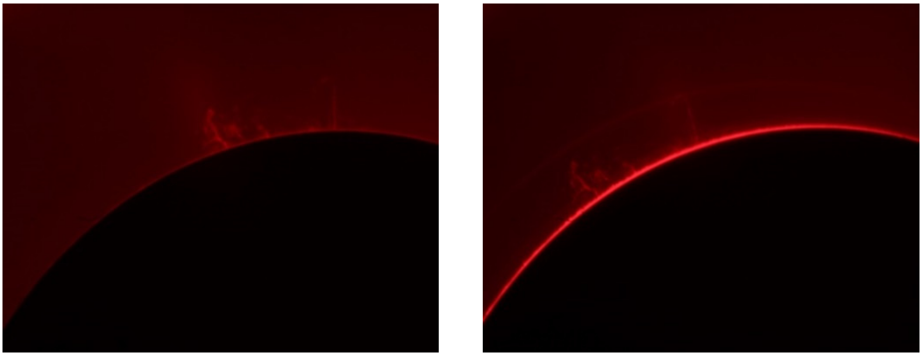
Second pass of arc center search (2 sectors)



Third pass of arc center search (3 sectors)

Figure 4: Stages of processing.

Figure 5 shows differences of two images before and after alignment.



Initial images

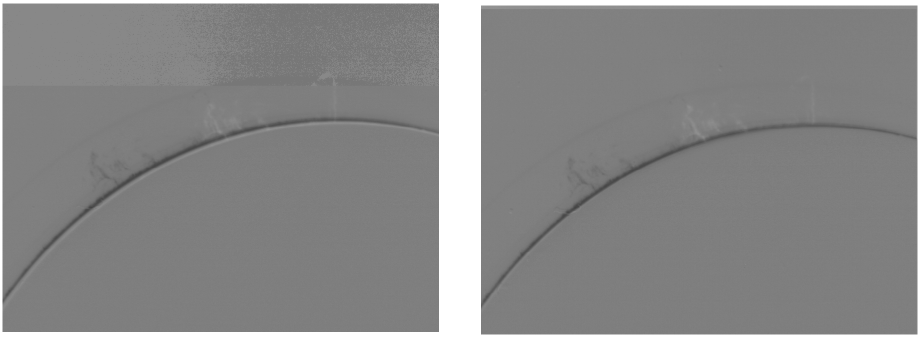


Figure 5: Images of differences before (left) and after (right) alignment.

The calculated center of the first image has coordinates x = 1331 and y = -972 (center of coordinate system is in left bottom corner of the image) and for the second image center is at x = 1339 and y = -961. It means that the second image should be moved to the left with 8 pixels and bottom - with 11 pixels before crop operation for limitation the visible field.

5. CONCLUSIONS

Developed algorithm can effectively handle images that contain less than 50% of the visible part of the occulting disk. In cases with more than 50% of the arc we can use implementation of the Hough transformation to find the circles. Since the lightness and contrast of input images variate in some cases, for optimal results (determination the edge of the occulting disk and elimination the possible false points that are not part of the arc) that insists of additional improvement of these parameters. The full compensation of distortion needs of rotation. However, finding the rotation angle depends on the changes in the picture and makes the result of automatic alignment unreliable in case of unstable solar corona. The problem could be solved using function of differences between two images calculated after step-by-step rotation around the center of the occulting disk.

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