Proc. VI Serbian-Bulgarian Astronomical Conference, Belgrade 7-11 May 2008,
Eds. M. S. Dimitrijević, M. Tsvetkov, L. Č. Popović, V. Golev
Publ. Astr. Soc. "Rudjer Bošković", No. 9, 2009, 207-216

TECHNIQUE FOR TRACKING AND VISUALIZATION OF MOTION IN SEQUENCE OF IMAGES OF THE SOLAR CORONA

PETYA PAVLOVA[1,2] and KOSTADINKA KOLEVA[3]

[1]*Technical University Sofia, branch Plovdiv,*
[2]*Institute of solid state physics – Bulgarian Academy of Sciences*
e-mail: p_pavlova@gbg.bg
[3]*Institute of astronomy, Bulgarian Academy of Sciences, Bulgaria*
e-mail: koleva@astro.bas.bg

Abstract. The material represents specialized methodology for tracking and visualization of the motions in sequence of pictures of the solar corona. The performance includes:

1. Preliminary processing of each frame: initial analysis and elimination of atmospheric scattering of light, image improvement using Gaussian filtering and a sharpen filtering for emphasizing of the contours;
2. Processing to the series: clipping the area from the currently processed frame, alignment of the clipping area with the same area in the initial frame, forming an image from the maximal brightness for each pixel of each picture of the sequence, calculation of the time-spatial gradient, determining of the direction of gradient changes and visualization of the motion by transfer to saturation and colour hue for each pixel.

This technique is used for development of a special computer program working with pictures in FITS and JPG graphic formats.

The results from testing the technique on the sequences of images from solar coronagraph of NAO Rozhen are shown.

1. INTRODUCTION

The term Solar prominences (SP) is used to describe a variety of objects, ranging from relatively stable structures with lifetimes of many months, to transient phenomena that last hours or less. Most commonly they are observed at the solar limb in the time of total solar eclipses or through solar telescope – coronagraph. The prominences are wonderful demonstration of that part of the local magnetic fields that affect to our life penetrating by the earth atmosphere. The form and movement of prominences trace the configuration and evolution of the local magnetic fields. During its evolution the prominences could be disturbed by external factors that affect on the plasma movement. These disturbances varied from temporal activation increasing the internal motions to big forced disturbances, which can completely destroy the whole prominence body.

The activation of the promineces includes an active phase, when the matter flows from the top of the prominence to some outlying gravity center following the magnetic field lines. That movement could stop after some hours or continues until the whole matter flows back to the chromosphere.

The SPs situated far from the active regions, during their lifetime can grow up and disappear and after that appear again. The growing obtains from slow to high velocity.

Object of this investigation are the so-called eruptive prominences (EPs). They are unusual and some times final stage of existence of SP. The eruption is visible effect of dynamical reconstruction of its magnetic configuration. Sometimes the eruptions can lead to destroying the prominence structure. In the other cases the SP appears again one or two days later keeping the form and position.

At the first phase of eruption the EP is escaped into the corona with a stable increasing velocity. Eruptions in the solar limb are with about 100 $km \cdot s^{-1}$, but the fastest observed eruption escapes with 1130 $km \cdot s^{-1}$. The matter could rise to 1.5 x 10^6 km in height above the photosphere (Tandberg-Hanssen, 1974). Some times the speed increases rapidly for less than 2 minutes time period. In the other cases – different parts of the prominence moves with a different velocities. The eruptive prominences have almost linear trajectory orientated towards a radial direction.

A sequence of registered images (frames) could display prominence motions resulting from temporal activity: raising, plasma escaping, disappearing and appearing again. However the frames registered with a terrestrial instrument keep also some destruction of the images appeared as a small distance flickering of the observed objects as effect from turbulence in the earth atmosphere.

Currently, estimation of the movement into the erupted prominences is carried out by spectral measurements.

The aim of the work is development of a technique for objective estimation of the total and internal motions of the prominence plasma and compensation of the flickering into the terrestrial registered images.

2. THEORY

2.1. Methods for tracking the movement in the images

Two typical methods for tracking of the movement are known (Tekalp 1995, Marr 1989):

1. Tracking the position of some typical morphological elements of the object and obtaining the features of the movement by time dependence of the transpositions. Obviously the method is suitable for solid-state objects or objects wit a small deviations in the form along the period of movement. The movement occurs as a passed way for a time period i.e. translation of the object in 3D space and derived vector field of the speed.

2. Pixel based tracking – the movement features are calculated using the temporal-spatial gradients extracted on the base of first spatial derivations of the images and their time derivation. The method could be used for objects that shapes and forms are inconstant deformations along the movement. That supposes estimation of each type of deviation independent of reason bearing it either from movement, deformation or variation in the lightening.

One of the possibilities to obtain time-spatial gradient is to use area from four neighbor pixels on the same positions in the sequenced frames as it is shown with formulas 1 and in Fig. 1 .

$$\begin{aligned}
\frac{\partial B(x,y,t)}{\partial x} &= \frac{1}{4}.[B(n_x+1,n_y,k)-B(n_x,n_y,k)+B(n_x+1,n_y+1,k)-B(n_x,n_y+1,k)+\\
&+B(n_x+1,n_y,k+1)-B(n_x,n_y,k+1)+B(n_x+1,n_y+1,k+1)-B(n_x,n_y+1,k+1)]\\
\frac{\partial B(x,y,t)}{\partial y} &= \frac{1}{4}.[B(n_x,n_y+1,k)-B(n_x,n_y,k)+B(n_x+1,n_y+1,k)-B(n_x+1,n_y,k)+\\
&+B(n_x,n_y+1,k+1)-B(n_x,n_y,k+1)+B(n_x+1,n_y+1,k+1)-B(n_x+1,n_y,k+1)]\\
\frac{\partial B(x,y,t)}{\partial t} &= \frac{1}{4}.[B(n_x,n_y,k+1)-B(n_x,n_y,k)+B(n_x+1,n_y,k+1)-B(n_x+1,n_y,k)+\\
&+B(n_x,n_y+1,k+1)-B(n_x,n_y+1,k)+B(n_x+1,n_y+1,k+1)-B(n_x+1,n_y+1,k)]
\end{aligned} \tag{1}$$

Where the $B(x,y,t)$ is processed image (frame),

$\frac{\partial B(x,y,t)}{\partial x}, \frac{\partial B(x,y,t)}{\partial y}, \frac{\partial B(x,y,t)}{\partial t}$ - first derivative by space directions and time,

n_x, n_y – indexes of the pixels into the digital presentation of the image

κ – ordered number of the frame

κ			κ+1	
n_x, n_y	n_x+1,n_y	+	n_x,n_y	n_x,n_y+1
n_x,n_y+1	n_x+1,n_y+1		n_x,n_y+1	n_x+1,n_y+1

Figure 1: Areas of neighbor pixels in sequenced frames.

2.2. Visualization

The spatial gradients correspond to variations of the whole area pixels values from frame to frame. The temporal gradient corresponds to variation of each pixel's values in the areas from frame to frame. These three gradients form direction given as an angle – Θ, calculated by formula 2 and magnitude of the vector of the speed given as a temporal gradient.

Features of the color have a simple visualization of the speed if they are presented in a HSV/L/I (hue, saturation, value/lightness/intensity) color models (Gonzalez 2002, Rogers 1989). The parameter Hue –H is measured as angle, with corresponding hue, the achromatic parameter corresponds to magnitude of the normalized vector of the speed. Fig. 2 shows common scheme of the hue and directions and the magnitude for a fixed angle.

$$\Theta = arctg(\frac{\partial B / \partial y}{\partial B / \partial x}) \qquad (2)$$

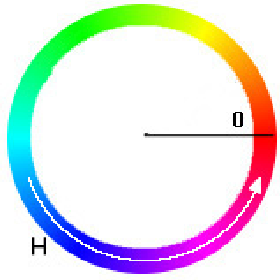


Figure 2: Hue scale with a maximal saturation.

2.3 Flickering and it's compensation

The "flickering", result from atmosphere turbulence leads to shifting and return to the previous position of some point from scene to their projection in the image. It means that if the direction of movement is constant at the period of shifting, these direction changes in the fixed pixel from the image. And the direction for that pixel becomes opposite along the return from shifting and "collision' for the sequenced directions. Pixels with "collisions" should be reconstructed adding some value (with an appropriate sign) from the previous frame.

3. EXPERIMENTAL WORK

We used sequences of images acquired from two different instruments:

1. Small Coronagraph (130/3450 mm) at the Astronomical Institute of Wroclaw University, Poland. The images were taken through a 3Å Hαα filter and recorded to plates. The plates were digitalized with the automatic Joyce-Loeble MDM6 micro-densitometer at NAO Rozhen, Bulgaria. The two-dimensional scans have resolution of 20 μm per pixel and step 20 μm in both directions. Spatial resolution is a little larger than 1 arc sec. The images derived from the film are formatted in FTS format with limits of the value from 0 to 4095.

2. The second one is 15-sm Lio-coronagraph for observation of prominences and the low part of the solar corona mounted at NAO Rozhen completed with low-band Hαα filter with 1.8 Å interval of transmittance. The images are registered using 8-Mp digital camera CANON 350D in JPG file-format with 24 bits per pixel, which describe red, green and blue reproducing signals.

The images show several elements – an artificial moon visible as a black half circle, the solar corona with bright prominences appears above the moon and near them is background of a shining earth atmosphere. All these elements are shown in Fig. 3.

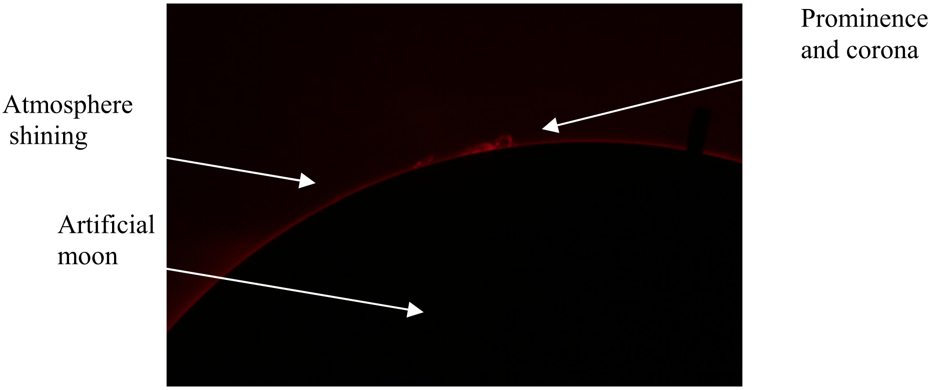


Figure 3: Common description of the image.

Since the object of interest is only movement of the prominences it is better to eliminate this background shining before main processing. Another problem in the frame sequence is the displacement between the images effect from the earth rotation.

A three steps algorithm with a computer program was developed for image processing and analyses of the collected sequences of frames. The algorithm is described below:

I. **Preliminary processing of the images**:
I.1 - Selection of the first image for the sequence.

The first image is the basic frame accordingly to which all the other images are alighted.

I.2 - Filtration of the noises (optional)
a) – elimination of the atmosphere shining

For this aim the upper three and lower three rows and left three and right three columns are analyzed. The hypothesis supposes that all pixels in the border rows and columns present signal only for the dark area of the artificial moon and background shining. The sum of the average value and deviation gives threshold for selection.

b) – image enhancement

The single pixels remaining after previous processing are treated by Gaussian and sharpening filter for scanning mask 3x3 (Gonzalez 2002, Rogers 1989). The coefficients are as follow:

0.1	0.5	0.1
0.5	1.0	0.5
0.1	0.5	0.1

multiplied by 3.4 for Gauss filter and

0	-1	0
-1	5	-1
0	-1	0

for the sharpening filter.

Since the identical information presents with different number of digital values in fts and jpg files applied filtration depends on the type of graphic format. An additional filtering by magnification of the green signal is included for the jpg files.
I.3 - Interactive alignment the positions of the all next images

Output:
1. A sequence of aligned images
2. ASCII file with the names of the output image files

II. **Processing of the sequence**
II.1- Crop the needed area
Only the area of eruptive activity is selected for sequenced analyses for movement.
II.2 – Forming the image collecting the max values of the pixels from the every single image in the sequence. That summary image gives an imagination about area of the plasma spreading.
II.3 - Calculation of the gradients and visualization of the pixels' directions using equations (1), (2) and transformation HSV – RGB.

Output:
1. A sequence of cropped images.
2. ASCII file with the files' names.
3. A file of the max values in the sequence.
4. A sequences of images with gradient levels.
5. A sequence of images of the movement between each pair of neighbor images.

III. **Processing the sequence of aligned images for elimination of the signal result from flickering**
III.1- Finding of the "collisions" in the movement.
"Collision" is defined as a change of gradient direction over than 135 deg. for a single pixel in two sequenced images in accordance with the initial one.
III.2 – Preparing a map of "collisions" for the each pair of frames,
III.3 – Correction of the additional signal, result from flickering. Correction is made subtracting the difference between the values of one pixel in two images from the pixel of the middle frame among of three sequenced frames for the pixels marked with "collision".

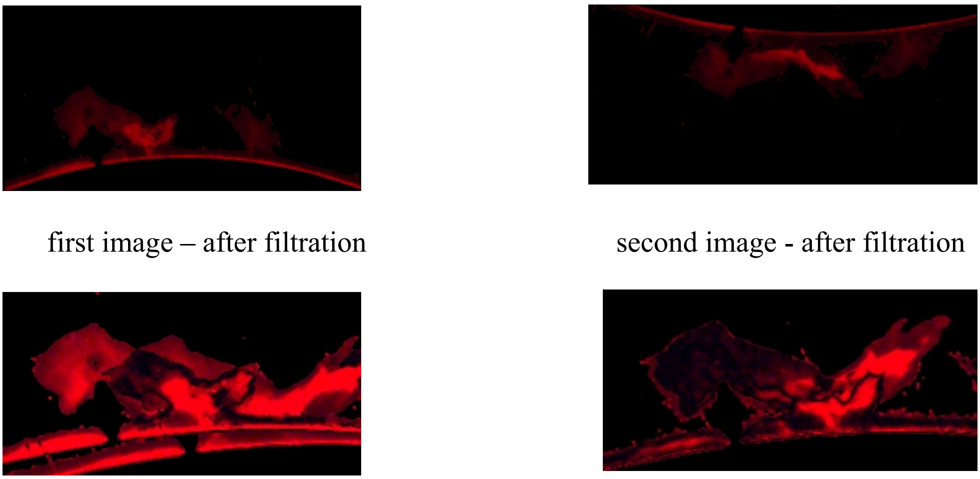
Output:

1. Images of the maps of "collisions"
2. Corrected image of the max values

The work media for the program is Visual C++ with the graphic library GDIPlus developed by Microsoft (http://windowssdk.msdn.microsoft.com/en-us/library/ms533798.aspx)

4. RESULTS AND DISCUSSION

Fig. 4 shows results from preliminary processing of the images



first image – after filtration   second image - after filtration

before alignment   after alignment

Figure 4: Results from alignment.

Results from gradients calculation are demonstrated in Fig. 5. The value of gradients is normalized to limited values between 0 and 255. These images could be used also for control of alignment of the frames in one sequence.

Fig. 6 shows an image with gradient directions and magnitude of the vector of movement. Different colours of the different part localize layers in the prominence.

Maps of collisions are given in Fig. 7. Fig. 8 demonstrates max-values images before and after correction. The results show that the level of noise increases in some images. It means that the chosen technique for turbulence compensation needs of more detail and statistical estimation.

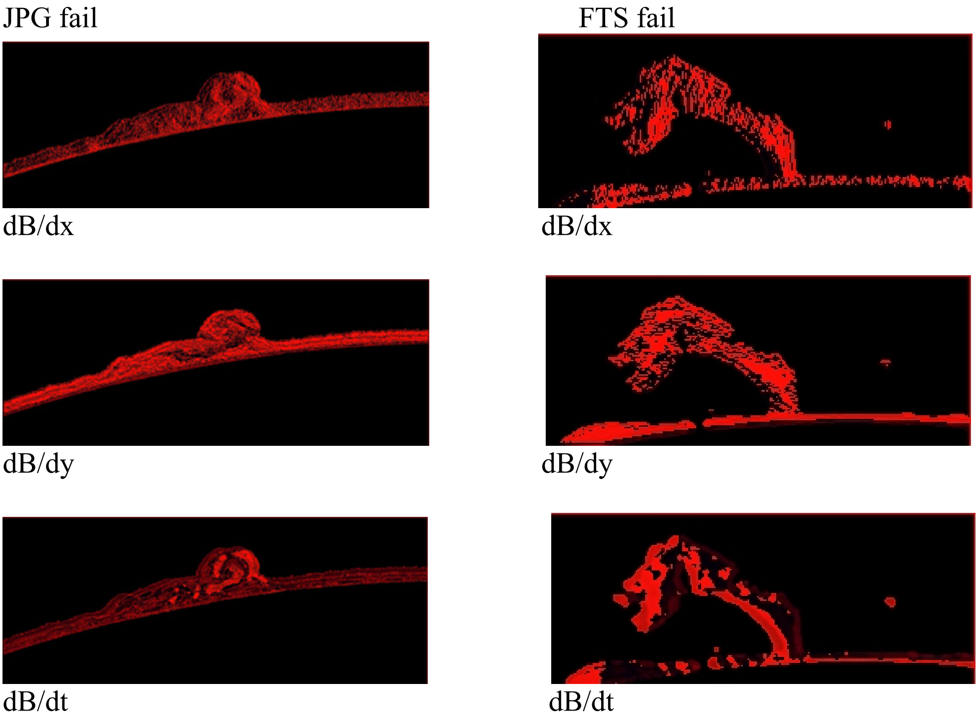


Figure 5: Gradient direction images from two types graphic formats.

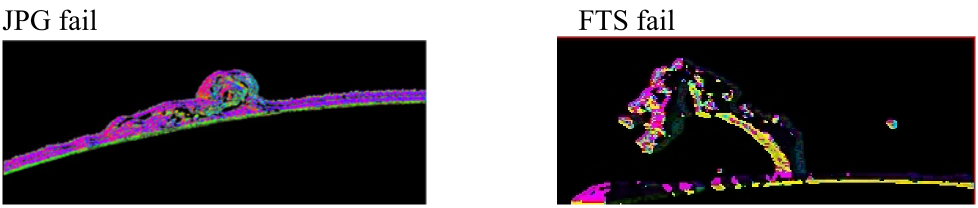


Figure 6: Gradient direction visualization for two types graphic formats.

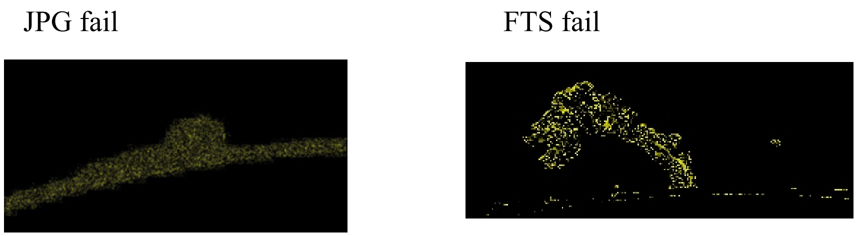
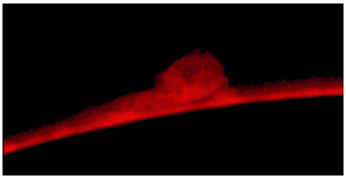
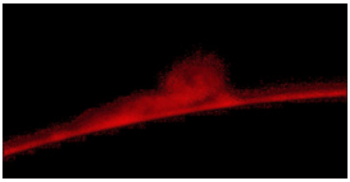


Figure 7: Map of “collisions” for two types of graphic formats.

JPG fail

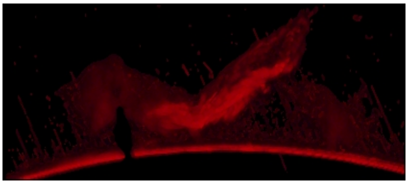


before correction



after correction

FTS fail



before correction

after correction

Figure 8: Max values images for two types of graphic formats.

5. SUMMARY

• The tests carried out have shown a good ability of the developed technique for imaging and objective estimation of the movement direction;
• The images of spatial gradients help in image alignment pointing exactly to the “displaced” frame.
• The estimation of the atmospheric turbulence according to initial direction of movement and correction by the value of temporal gradient adds a noise to some pixels in the active phase of prominence. The turbulence could be estimated better if the prominence is at inactive phase.

There are two main critical points of investigation that must be subject for testing:
- number of pixels that take a part in area of gradient calculations. It is known as an “aperture problem” and
- temporal interval between the frames that affect directly to the registration of flickering result from turbulence.

Our work hypothesis for a future work using developed technique supposes that each of searched changes have its own spatial-temporal frequencies of repetition and it gives an opportunity for their separation. An investigation of the gradient changes for a different temporal intervals between frames saved at the period of activity of the phenomenon could accept or refuse these assertion.

Acknowledgements

This work is partially supported by project TN 1523/05 of NSFB "Influence of the Atmospheric Turbulence on the Quantitative Characteristics of the Optical Systems Used in: ree- space Laser Communications, Optical Remote Control and Radiometric Systems for Environment Eco-monitoring, System for Investigation of Optical Images of Natural Objects".

References

Gonzalez, R., Woods, R.: 2002, *Digital Image Processing*, 2nd Edition, Prentice Hall.
http://windowssdk.msdn.microsoft.com/en-us/library/ms533798.aspx
Marr, D.:1989, *Vision: A computational investigation into the human representation and processing of visual information*, Moskow: Radio i svyaz Mir;. (tr.)
Rogers, D.: 1989, *Procedural elements for computer graphics*, Moskow: Mir. (tr.)
Tandberg-Hanssen, E.: 1974, *Solar Prominences*, D Reidel, Dordrecht.
Tekalp, M.: 1995, *Digital Video Processing*, Prentice-Hall, Inc.