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Algorithm for real time flare detection

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Abstract. A real time flare searching system has been developed at the University of Tor Vergata. The system is comprised of a CMOS camera (C-CAM BCi5) which captures full disk H-alpha solar images and a detection algorithm. The system has been installed for test at the Solar Station of the Tor Vergata University. The algorithm detects in real time the onset of solar flares by analysing intensity variations in the images. The basic parameters for the definition of a flare onset (intensity gradient and threshold) are user-tunable. The algorithm has been developed in the National Instruments Labview environment. It is prepared for integration with different camera systems at different observatories, and possibily at the future EST (European Solar Telescope) and particularly at the AFDT (Auxiliary Full Disk Telescope) which will provide full disk images in three spectral bands, including H-alpha. The system has been active during the past year and a half at the Tor Vergata Solar Station. Due to the current solar minimum no flare activity was available and the algorithm is currently being tested on Solar H-alpha images taken at the Kanzelhoe Observatory.

Key words. Sun: flares - Image processing.

1. Introduction

Solar flares are local sudden increases in brightness on the solar surface, normally observed in the H-alpha band. Flares are associated with strong X-ray and plasma emissions, and as such are important in the study of solar surface activity and space weather monitoring. Flare recognition techniques have been previously developed to analyse datasets post-facto. Qu et al. (2003),(2004) have used Support Vector Machines (SVM) to characterise flares through nine different descriptors and identify them in a dataset of H-alpha images.

It is desirable, though, to be able to detect flares in real-time, that is, during the acquisition process (Veronig et al. 2000). The automatization of this process opens the possibility of using full-disk monitoring to detect flares and give an alert signal that can be used to point a high-resolution telescope on the target. Given that the impulse phase of a flare can be in the order of 1 minute, a flare-recognition algorithm that is to operate in real-time needs to use techniques that are fast enough to detect the flare inside this time constraint. We have developed a simple algorithm that controls a CMOS camera and analyses the acquired images in real-time for the onset of solar flares. The system is installed at the Solar Station of the University of Rome Tor Vergata.

2. Requirements and characteristics

When it was developed, a number of requirements were set forth for the algorithm. In the

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following we present these with a brief comment on how each one has been implemented.

1. Separate control of CMOS sensor.
   The code that controls the CMOS camera is separate from the code that analyses the images. Thus it is easier to modify the program to accept new cameras. At present a C-Cam BCi5 CMOS sensor is used.
2. Full-disk image analysis.
   The Solar Station at Tor Vergata has a 40mm H-alpha telescope that gives full-disk images of the Sun with a solar diameter of around 500 px.
3. Analysis based on intensity variation.
   The algorithm is based on the analysis of the intensity difference between successive images. This approach is simple and reduces computation time with respect to other, more sophisticated systems.
4. Two main tunable parameters.
   - Threshold on intensity differences between images, above which these differences are considered "significant".
   - Threshold for the rate of intensity increment over time.
5. Use of a buffer for images.
   To save storage space, acquired images are stored temporarily in a buffer folder. Once the buffer is full, as each new image is acquired the oldest one is cancelled. This feature can be disabled by the user and the full set of images stored.
6. Storage of flare images in a separate folder.
   When a flare is detected, the images taken from the detection point onwards are stored in a separate flare folder. A user-defined number of images previous to the moment of detection are copied from the buffer to the flare folder, to give information on the initial phases of the flare.
7. Derotation and centering of images.
   Due to the nature of the heliostat at the Solar Station of Tor Vergata, the image field rotates during the day. Also, the solar disk might not be centered on the CMOS. The algorithm provides the possibility of centering and derotating the image.
8. Developed in Labview.
   The algorithm was developed in National Instruments Labview language, to take advantage of the hardware interfacing possibilities of this software.

A screenshot of the user interface panel is presented in Fig.1.

2.1. Method

The algorithm consists of the following steps (refer to Fig. 2).

1. Images are acquired in succession by the CMOS.
2. Images are centered and derotated.
3. Starting from 4 sequential images, differences in intensities are calculated between couples of two successive images.
4. Difference images are analysed to detect areas in which there is a positive intensity gradient.
5. Areas whose intensity gradient is greater than a threshold (the first user-defined parameter) are marked as Regions Of Interest (ROIs).
6. The mean intensity is calculated inside the the ROIs in the original images.
7. The sequence of mean intensity in the ROI in each image is analysed. A linear fit is performed on these values.
8. If the slope of the linear fit is above a certain threshold (the second user-defined parameter) the algorithm returns a positive flare identification.
9. At flare detection:
   - flare time and position on the disk is stored in a log file;
   - flare images (including the ones preceding the flare) are stored in a separate folder. The user can decide how many images previous to the flare have to be stored.

One of the problems is the possible sudden passage of clouds across the field of view.

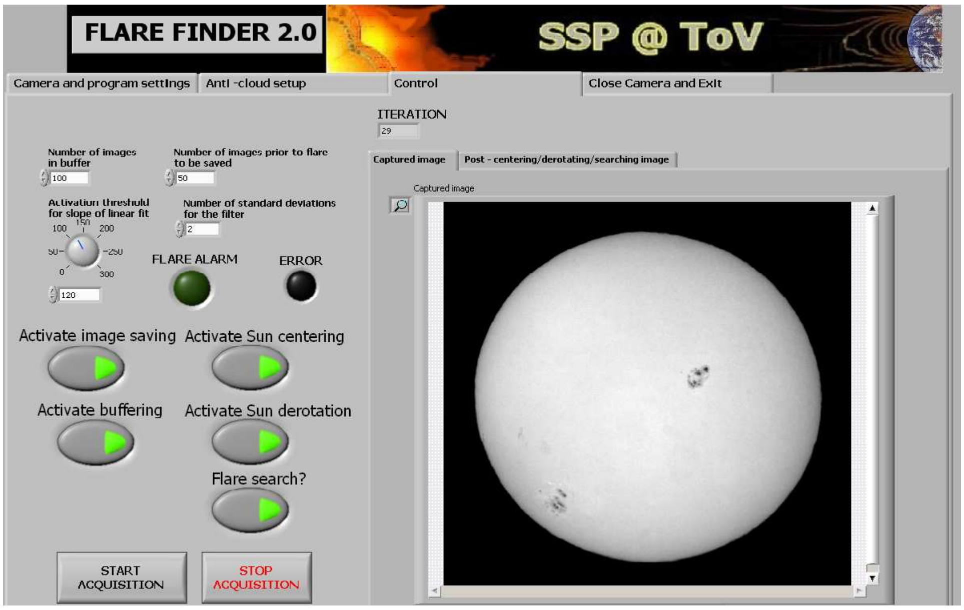

Fig. 1. User interface.

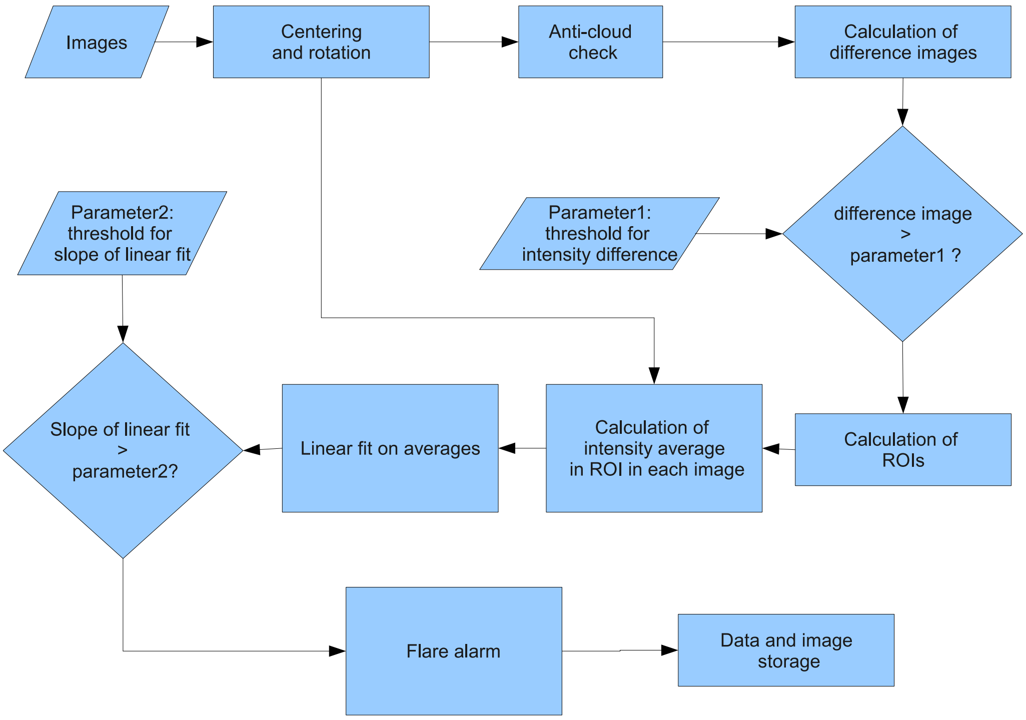

Fig. 2. The flowchart of the algorithm.

When the sky clears, a false signal originates, as the algorithm would perceive a sudden increase in luminosity. To avoid this, at the beginning of the observing run an image is acquired and used as a luminosity reference: each image is compared with the reference, and if the luminosity of the whole solar disk decreases below a certain threshold (defined by the user) flare detection is inhibited.

2.2. Results

Due to the reduced activity of the Sun in the years 2008/2009 there were no flares to test the algoritm in a live situation. The solar minimum was used to tune the parameters to find the minimum values that would avoid activation. The system is currently active at the Tor Vergata Solar Station: with the reprise of solar activity it will be possible to test the algorithm for real time flare detection. In the meantime, to test its reliability, the algorithm is being applied to solar flare images taken at the Kanzelhohe Observatory in Austria. This sequence of circa 1900 images contains a number of flare events of different intensity, interspersed with moments of cloud coverage. It provides an excellent testbed for the algorithm and will allow a true determination of its value.
Collaborations are active with both the Kanzelhohe Observatory in Austria and the Ondrejov Observatory of the Czech Republic. After the tests with the Kanzelhohe images it will be possible to implement the system at the Kanzelhohe Solar Observatory.
The Astronomical Institute of the Academy of Sciences of the Czech Republic is in charge of the Auxiliary Full Disk Telescope (AFDT) of the European Solar Telescope (EST). The AFDT will observe the Sun in full disk in three wavelengths: Ca K, H-alpha and a continuum. The H-alpha channel will be devoted also to flare searching and alerting: there is the possibility that the algorithm described here be implemented at the AFDT at EST.

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