

ADAPTIVE THRESHOLDING TECHNIQUE FOR SOLAR FILAMENT SEGMENTATION

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ABSTRACT

Detecting solar features become an important research study due to its important impact on forecasting space weather. Our study concerned with one important solar feature called filament. The importance of studying this solar feature comes from considering it as a significant indicator for possible occurrence of coronal mass ejections (CMEs), which is considered as the major cause of geomagnetic storms. The stage of solar image segmentation is still a challenge in the scope of adaptive detection of solar features. This paper presents an adaptive thresholding technique for solar filament segmentation from the background. The result of this technique is compared with an intensity filtering stage of an automated detection algorithm.

Keywords: Solar Imaging, Filament, adaptive thresholding, region of interest.

1 INTRODUCTION

Detecting solar features become an important research study due to its usability on forecasting space weather. One important factor that increases the opportunity to develop and design automated detection techniques for solar features is the proposed integration between image processing and machine learning techniques.

The motivations for developing such technique could be classified into three different causes. Firstly, the number of archives of digitized solar images obtained by ground-based and space-based observatories is growing gradually. Secondly, the digitized solar Images have different sizes, resolutions, dynamic ranges, and instrumental and weather associated distortions. Finally, due to the increasing demand for studying solar activity by many space weather industrial projects.

Our study concerned with one important solar feature called filament. Filament eruptions, flares and coronal mass ejections (CMEs) are important

solar events that are related to geomagnetic storms. The stage of solar image segmentation is still a challenge in the scope of adaptive detection of solar features.

In [1], an algorithm that combined thresholding and region growing methods to detect filaments as a preamble step for detecting filament disappearance was introduced. [2] had applied thresholding and morphological filtering techniques to isolate filaments from H- α images. A similar technique was applied by [3]. An edge-based algorithm had been applied for filament segmentation by [4] and [5].

Qahwaji and Colak [6] have implemented a full detection process for recognizing and verifying solar filaments and active regions from H- α images. The process involved cleaning process; segmentation phase and final region growing phase which was used to recognize filaments and gives the ability to study it by computing some statistical features to characterize the region of interest. The results of these calculations are then fed to neural

network to verify the detected regions and minimize the false acceptance rate.

Image segmentation is a very important stage in the detection process which could play a key role in recognizing and detecting the features properly. In this paper we modified the segmentation phase of the technique proposed by [6] to improve the segmentation results. We have proposed an adaptive thresholding technique for solar filament segmentation which is presented in section 2. Section 3 presents the computational experience of the proposed technique. Conclusions and discussions are presented in section 4.

2 ADAPTIVE LOCAL THRESHOLDING (ALT)

This technique depends on sliding two windows over the whole image. The windows are shown in Fig. 1. According to this technique a selection has to be made to classify the contents of the enhanced image (EI) into a potential filament pixel or a background pixel based on the following criteria [7]:

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For i=1 to m do
  For j=1 to n do
    If(EI(i,j)>TH(i,j) and RangeLWin>AverageSWin)
      then
        EI(i,j) ∈ Candidate filament area
      Else
        EI(i,j) ∈ Normal area
      Endif
    Endfor j
  Endfor i
  
```

where $m \times n$ is the size of image, and $TH(i, j)$ is an adaptive threshold value that is calculated by the following formulae:

$$TH(i, j) = Average_{SWin} - Range_{LWin}$$

and

$$Range_{LWin} = EI_{max}(i, j) - EI_{min}(i, j)$$

$Average_{SWin}$ represents the average of pixels intensity in a small neighborhood around the pixel $EI(i, j)$. $EI_{max}(i, j)$ and $EI_{min}(i, j)$ are the maximum and minimum intensity values for the windows respectively as shown in Fig. 1. Using empirical experiments, the dimensions of the large window is chosen to be 17x17 whereas the dimension of the small window is set as 3x3. The algorithm can be presented as follows:

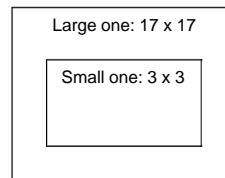


Figure 1: The window sizes

```

Algorithm( )
{
  Max := maximum intensity value in the large window
  Min := minimum intensity value in the large window
  Range := Max - Min
  Average := average of intensity values in the small window
  Threshold := Average - Range
  If ((Pixel intensity > Threshold) && (Range > Average)) then
    The Pixel belongs to the region of Interest
  Else
    The Pixel belongs to a non region of interest.
  }
  
```

3 COMPUTATIONAL EXPERIENCE

The ALT technique was implemented on H- α solar images, these images could be acquired by the Solar Survey Archive at Meudon observatory through <http://bass2000.obspm.fr>. The result of the underlying adaptive detection technique has been compared with an intensity filtering stage of a complete detection algorithm developed by [6]; we called this stage Adaptive Local Thresholding and Verification (ALT&V). The segmented filaments were estimated by comparing the resultant image with the manually constructed synoptic maps shown in Fig. 2 (b). The maps contain the number of solar filaments for any given day and could be obtained from the same observatory website. The results of the above mentioned techniques are shown in Fig. 2.

The primary goal of all the solar filament segmentation techniques is to obtain well defined filaments, a low false acceptance rate (FAR) which means a high false rejection rate (FRR)

We can conclude from Fig. 2 that our ALT algorithm, as shown in Fig. 2(c), has an added value in getting unambiguous filaments and decreases the noise in comparison with the results obtained by applying the ALT & V technique, which are revealed in Fig. 2(c & d).

The performance of the detection algorithms are evaluated using the following error rates [8].

- The false acceptance rate (FAR), which is the probability of a non-region of interest (non-RoI) being detected as a RoI.
- The false rejection rate (FRR), which is the probability of a RoI not being detected because it is considered to be a non-RoI.

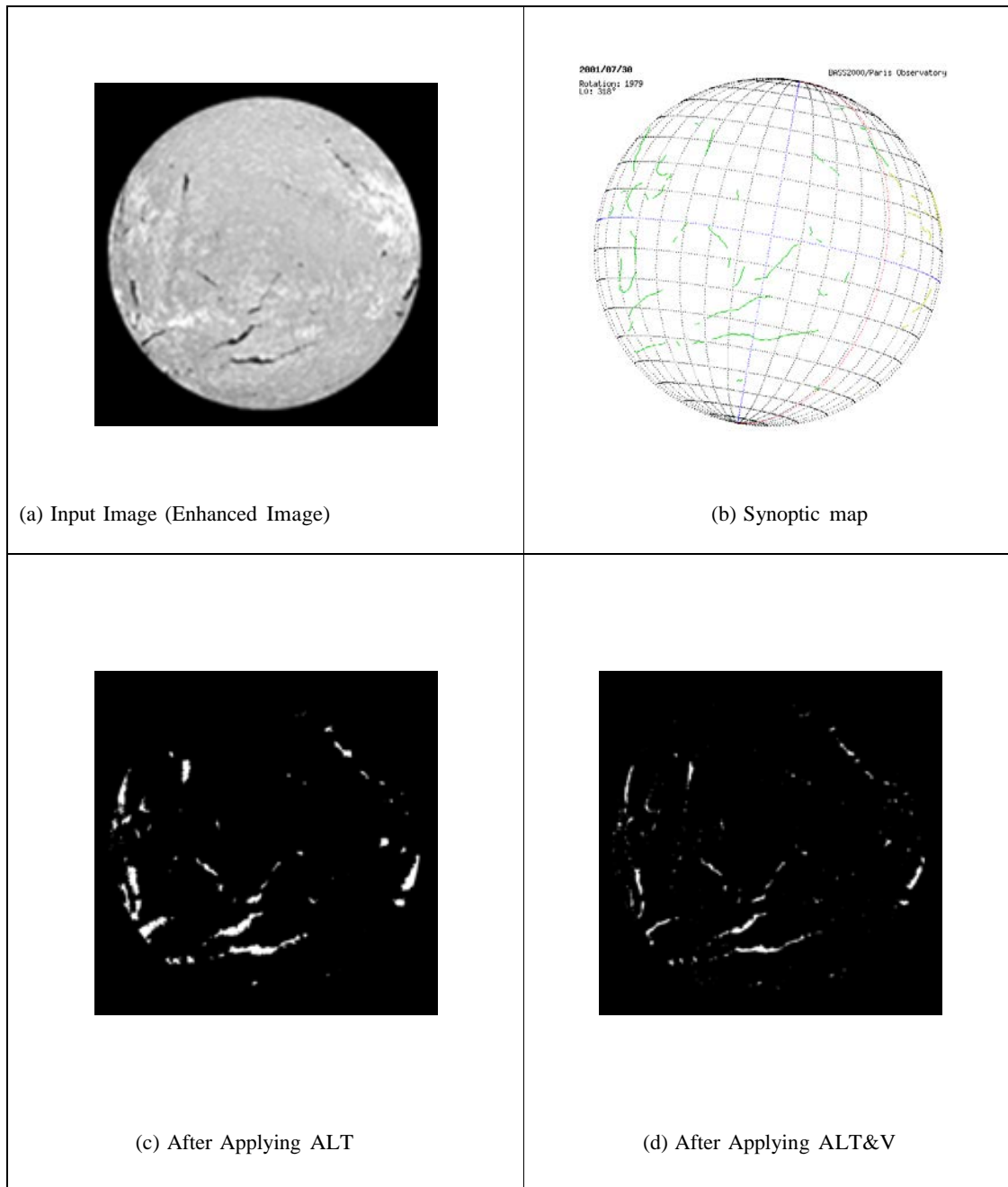


Figure 2: Results by applying the two techniques.

Table 1: FAR values for synoptic maps, ALT, and ALT&V techniques.

Problem	Synoptic maps	ALT		ALT&V	
	Filaments	Filaments	FAR(%)	Filaments	FAR(%)
02/07/2001	44	28	0	44	15
03/07/2001	45	33	0	45	5
04/07/2001	38	18	0	38	3
06/07/2001	50	43	10	50	18
09/07/2001	41	28	2	41	12
10/07/2001	39	21	0	39	15
11/07/2001	32	29	9	32	7
15/07/2001	32	32	19	32	31
16/07/2001	26	28	42	26	36
17/07/2001	34	20	0	34	31
19/07/2001	41	43	22	41	27
20/07/2001	36	29	8	36	24
21/07/2001	36	37	6	36	4
22/07/2001	40	46	23	40	21
25/07/2001	34	22	0	34	18
26/07/2001	37	33	11	37	9
29/07/2001	38	23	0	38	11
30/07/2001	52	36	2	30	18
31/07/2001	43	38	5	31	2
03/08/2001	46	44	22	3	29
04/08/2001	37	26	0	4	33
Average	39.0952	31.2857	9	33.86	19

Generally, the system performance requirement is specified in terms of FAR where FAR of zero means that no non-RoI being detected as a RoI. According to this criterion we can ensure the findings of Fig. 2 by observing the number of detected filaments and FAR values for all algorithms, which are shown in Table 1. The 1st column shows the date of every H- α image, while the total number of filaments that are detected manually by synopsis maps is shown in the 2nd column. The other columns alternatively show the number of detected filaments and the FAR error rates by applying ALT and ALT&V respectively. The average FAR error rates for all images are 9% and 19% by applying ALT and ALT&V respectively. Based on FAR error rate, it is very clear from the Table 1 that ALT results the lowest error rate

4 CONCLUSIONS AND FUTURE WORKS

We have developed an adaptive thresholding technique for segmenting H- α solar images to get back with a foreground segmented filaments and a non-RoI background. Based on false acceptance rate and output images, it can be concluded that our

ALT technique is the best. The well defined and visible filaments could in future be considered for further studies by characterizing the features which may give us the ability to provide work for machine vision techniques. In the near future we would like to extend this work by designing automated algorithms that can be used to detect and track evolution of filaments in real-time. We would like to design tools that could outperform the technique proposed in [3] that could also determine the chirality of filaments, filament area, length, and average orientation with respect to the equator. However, the tools we would like to develop should be real-time and fully automated and could be integrated within existing space weather prediction models.

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