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Spatially Resolved Soft X-ray Images to Understand the Variation of Total Solar X-ray Flux

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Abstract- **In day to day life, new technologies are emerging in the field of Image Processing, especially in the field of Astronomy and Astrophysics. The most eminent celestial body is the Sun. Through Image Processing, important features of the Sun are studied. The objective of this study is segmentation of the solar features (Active Regions, Coronal Holes, Background, and X-Ray Bright Points), estimation of intensity, and determining the individual intensity of the solar features for a period of one year (2016). The proposed methodology for Segmentation is Thresholding technique. This technique is applied to the images obtained from the Hinode X-ray Telescope (Hinode/XRT) to measure intensity variations of solar features.**

Index Terms— Hinode, XBPS, active region, coronal holes, GOES.

I.INTRODUCTION

The Sun is by far the largest object in the solar system. It contains more than 99.8% of the total mass of the Solar System. Its temperature at the surface is about 5800k and 15,600,000k in the core. The solar cycle (the magnetic activity cycle) is the amount of magnetic flux that rises up to the Sun's surface and varies with time. This cycle usually lasts for about 11 years on an average scale. The Sun's power is produced by the nuclear fusion reaction. Each second several tons of hydrogen are converted to energy in the form of gamma rays. The outermost layer of Sun is the Photosphere, which is at a temperature of 5800k and is one the visible surface also known as the Sphere of Light. The second layer is the Chromosphere which basically means the sphere of color. It is about 2,000 kilometer deep and sits directly above the photosphere. The prominent layer for this study is the solar corona which is the extended outer atmosphere of the Sun, it has a glow that is about a million times less bright than the Photosphere. The important features of this layer are the active regions, coronal holes, x-ray bright points and the background. Active regions are the brightest feature in the corona, whereas the coronal holes which are cooler regions have the least brightness [9][12]. The X-Ray bright points are the tiny features that are scattered all over the corona [10] [11]. Each feature of this layer varies according to their characteristics such as temperature, magnetic flux, area occupied etc. The objective is to successfully segment these features and apply suitable Image processing techniques to find their individual contribution to the total solar x-ray flux. The images are captured by Hinode X-ray Telescope [1] in a wavelength of 108Å. These images are calibrated (noise free) and the actual image processing techniques such as the image enhancement and the image segmentation techniques are deployed. The aim of image processing is to use data contained in the image to enable the system to understand, recognize and interpret the processed information available from the image. Several image enhancement techniques that are suitable to read the FITS data as shown in Fig1 (a), in MATLAB are applied; these techniques vary for different formats of the images and based on their applications. Later, the enhanced image is segmented to separate out the required solar features for determining their intensity. Further with the intensity that is obtained a time series (intensity versus time) is plotted which can lead to a conclusion about the intensity oscillations.

II. IMAGE ENHANCEMENT TECHNIQUES

Digital image processing plays a vital role in the analysis and interpretation of remotely sensed data. Especially data obtained from Satellite Remote Sensing, which is in the digital form, can best be utilized with the help of digital image processing. Image enhancement techniques help in improving the visibility of any portion or feature of the image. Image enhancement process consist to improve the appearance of an image or to convert the image to a form better suited for analysis by a human or a machine. Enhancement of image is one of the challenging issues in many research and application areas. Technique applied for

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enhancing is applicable for medical image processing and image processing application areas like satellite image processing, biometric image processing etc.
The enhancement methods can broadly be divided in to the following two categories:
a) Spatial Domain Methods
b) Frequency Domain Methods

In spatial domain techniques, we directly deal with the image pixels. In spatial domain for getting desired output the pixel vales are manipulated.
In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first

Various techniques are used for image enhancement they are, Histogram Equalization, Adaptive Histogram Equalization, Fuzzy Logic Technique, Nuro Fuzzy System, Unsharp Masking, Contrast Stretching, Thresholding transformations, Log Transformation, Local Enhancement[3][4]. The techniques that are suitable for enhancing the Solar x-ray images are, Log Transformation, Histogram Equalization, and Contrast Stretching.
a) Histogram Equalization is widely applicable in fields such as in consumer electronics, medical image processing, image matching and searching, speech recognition and texture synthesis because it has high efficiency and simplicity. It re-assigns the intensity values of the pixels to make the intensity distribution utmost equal, but Histogram Equalization is a global operation where it tends to change the brightness of the image that means it does not try to maintain a equity in the image brightness as shown in Fig1(b).
b) Log Transformation this transformation maps a narrow range of low-level grey scale intensities into a wider range of output values as shown in Fig1(c). The inverse log transformation performs the inverse transformation of an image. Log functions are particularly useful when the input grey level values may have an extremely large range of values.
c)Contrast Stretching is to expand the range of brightness values in an image, the contrast enhancement techniques are used. The contrast level in an image may vary due to poor illumination or improper setting in the acquisition sensor device as shown in Fig1(d).

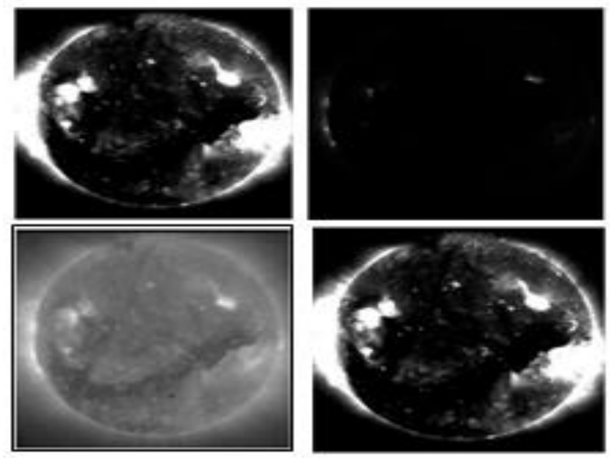

Fig 1: Enhancement output of x-ray image of July 07 2016. (a) original image, (b) Histogram Equalized Image, (c) Log Transform Image, (d) Contrast stretched image.

III. ALGORITHM

1. Read the input fits image.
2. Noise is removed using various enhancement techniques.
3. Features are segmented using enhanced image.
4. Cumulative intensity of all extracted features is calculated.
5. Time series plot of all features (AR, XBPS, CH, Background) have been done.
6. Later these results will be compared with the GOES X-Ray observation.

IV. IMAGE SEGMENTATION TECHNIQUES

Segmentation plays an important role in image processing. Segmentation is defined as the process of separation or partitioning an image into objects. The aim of segmentation is to focus on a particular region and to reduce the other region's information for easy analysis and change the representation of the image something that is more meaningful for analysis [2] [5]. Segmentation is useful for finding the area of regions that is the number of pixels contributed by that region for the given image.
Segmentation of an image can be done on the basis of some characteristics such as color, objects that are present in the entire image. The result of image segmentation is a group of different segments that mutually cover the entire image [7]. Segmentation can be done in both color image and gray image.

a) Segmentation based on color: The image with RGB model is called color image. The segmentation on color image is done by converting the image in to HSV model, this is done because the color is given based on human perception. The values of RGB will be stored in three matrices, later the conversion of RGB image to HSV, single matrix is maintained to read the RGB values in each pixel. The number of rows in the matrix is equal to number of colors in the image. The segmentation is done selecting the color [7] [8].

b) Segmentation based on gray image: In this case segmentation is done based on the pixels values. The original image is converted into gray image. The outcome of the segmented image is in binary form so the region of segmentation is mainly concentrated and remaining regions are suppressed for understanding purpose. For comparison with the original image, the outcome of segmented image is converted back to gray image. So that is useful for further analysis.

IV.1 Types of segmentation

There are many segmentation methods have been proposed. The choice of a segmentation technique over one another and the level of segmentation are decided by the particular type of an image and characteristics of the problem being considered. The different types of segmentation are edge based, region based, watershed based, thresholding based, clustering based, PDE based and Ann based. All this techniques has their own importance.

a) Edge based segmentation: In this technique, the edges are detected in an image that are assumed to represent object boundaries, and used to identify these objects.

b) Region based segmentation: Is the method that segments the image into various regions having similar characteristics.

c)Watershed based segmentation: This technique represents the basins having hole in its minima where the water spills [8]. This method considers the gradient of image as topographic surface.

d)Threshold based segmentation: The commonly used method for segmentation is thresholding method. This technique works by separating the pixels into group by the intensity levels of an image [6]. There are three types of in thresholding: they are simple, multiple, adaptive [6]. The features of x-ray images can be segmented by these one of the thresholding technique. The multiple thresholding technique is more suitable for gray images. The segmentation is based on threshold values for the range of pixels. The x-ray images of sun have four regions (features) active region, coronal holes, background, XBPS.

The input image considered for segmentation has all these features as shown in Fig 2(a). The active region has high intensity ranging from 240 to 255. These pixels are segmented as shown in Fig 2(b). The coronal holes which is due to sunspots has very low intensity value zero grouped together as shown in Fig 2(c). The remaining regions are considered as background and segmented as shown in Fig 2(d).

The XBPS are scattered in all the regions of full disk X-Ray images, so they share wide range of intensities because these XBPS wander around within the neighboring features from two hours to two days unlike other features, hence they are segmented by edge detection. The canny edge detection is more suitable method for detecting any edges when compared to Sobel, Roberts, Prewitt. Since canny is sensitive to small edges also as shown in Fig 2(e).

Later on this outcome are filled through holes as shown in Fig 2(f).

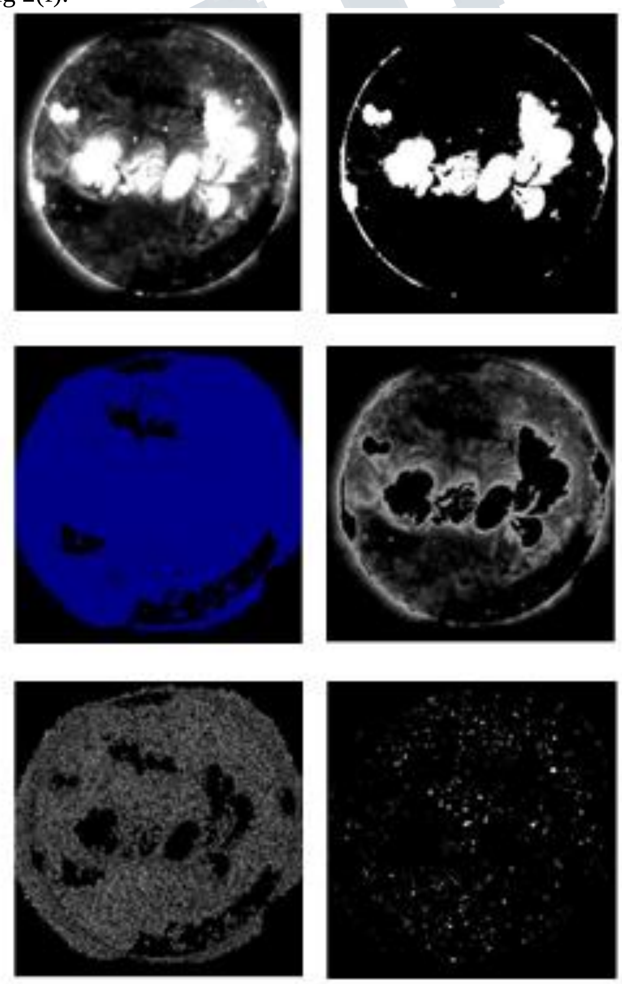

Fig 2: Segmentation output of x-ray image of July 15 2016. (a) Original image, (b) Active region, (c) Coronal holes, (d) Background, (e) Canny edge detection, (f) x-ray bright points.

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V EXPERIMENTAL ANALYSIS

The outcome of segmentation is used for calculating the intensity that is contributed by each region. The contribution of all the regions is summed up and compared with the input image intensity. This was carried for duration of one year. Intensity versus time(days) was plotted from the resulting outcome as shown in Fig 3 for active region, Fig 4 for background, Fig 5for XBPS, Fig 5 for input image.

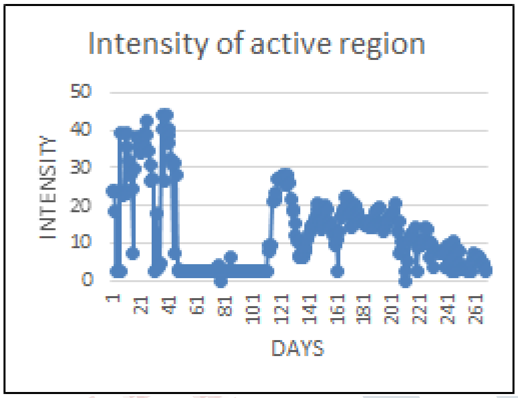

Fig 3: Intensity plot of active region.

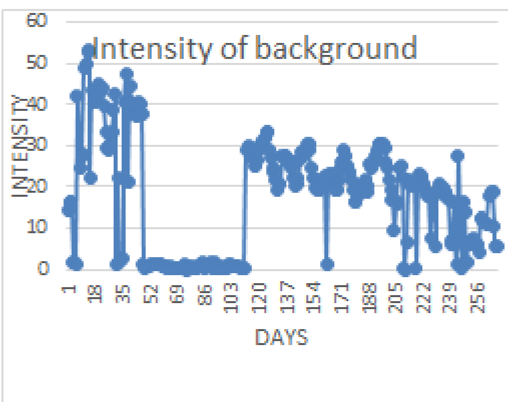

Fig 4: Intensity plot of background.

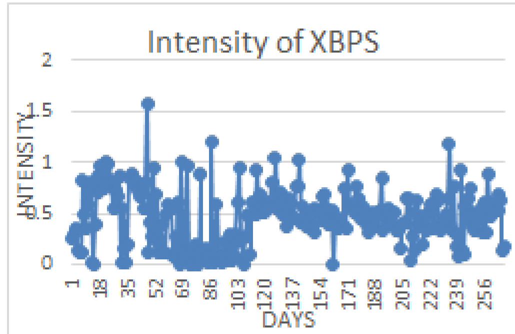

Fig 5: Intensity plot of X-Ray bright points.

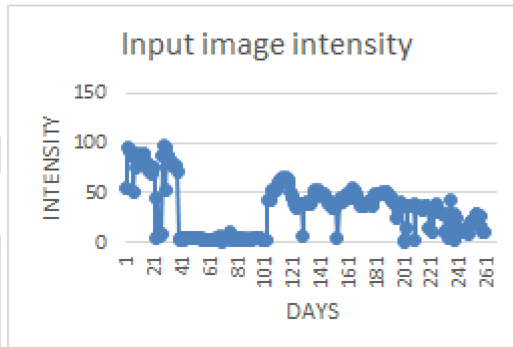

Fig 6: Intensity plot of Full disk X-Ray image.

VI.CONCLUSIONS

In this paper the data which is used in fits format, all the X-Ray full disk images have been calibrated and it is read in MATLAB. On these images several enhancement techniques are applied. The resultant images are segmented based on intensity by giving a threshold value for active region, background and coronal holes. The XBPS are tiny features that are segmented by edge detection and are filled by giving a threshold value. Later for the obtained segmented results their respective intensities are tabulated, and the time series plot of the different features show clearly the intensity oscillations. The contribution of active region is 34.4130%, background is 56.2687% and the contribution of XBPS is 1.2388% to total solar X-ray flux. Whereas the contribution of coronal hole is approximately zero. Further these results will be compared with the total solar X-ray flux(1Å-8Å) standard GOES (Geostationary Operational Environmental Satellite).

VII. ACKNOWLEDGEMENT

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Soft X-Ray images used in this paper are obtained from Hinode/XRT instrument.

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