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Tree Based Decomposition of Sunspot Images

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***Abstract*—**Solar sunspot rotation, latitudinal bands are studied based on intelligent computation methods. A combination of image fusion method with together tree decomposition is used to obtain quantitative values about the latitudes of trajectories on sun surface that sunspots rotate around them. Daily solar images taken with SOlar and Heliospheric (SOHO) satellite are fused for each month separately .The result of fused image is decomposed with Quad Tree decomposition method in order to achieve the precise information about latitudes of sunspot trajectories. Such analysis is useful for gathering information about the regions on sun surface and coordinates in space that is more expose to solar geomagnetic storms, tremendous flares and hot plasma gases permeate interplanetary space and help human to serve their technical systems. Here sunspot images in September, November and October in 2001 are used for studying the magnetic behavior of sun.

***Keywords*—**Quad tree decomposition, sunspot image.

I. Introduction

SUNSPOTS appear as dark spots on the surface of the Sun. Temperatures in the dark centers of sunspots drop to about 3700 K (compared to 5700 K for the surrounding photosphere[1]). They typically last for several days, although very large ones may live for several weeks. Sunspots are magnetic regions on the Sun with magnetic field strengths thousands of times stronger than the Earth's magnetic field. Sunspots usually come in groups with two sets of spots. One set will have positive or north magnetic field while the other set will have negative or south magnetic field. The field is strongest in the darker parts of the sunspots - the umbra. The field is weaker and more horizontal in the lighter part - the penumbra. In Fig. 1(c), the sunspot on photosphere is shown. Sunspots rotate around the sun each 27-day or monthly and their paths are like a belt around the sun sphere. In sunspots there is more intense magnetic fields, and as a result due to extra heating of plasmas on this region and then cause the Magneto Hydrodynamic instability in this region and as a result cause to solar flares and solar loops near of this region as shown in Fig. 1(a), (b) respectively, also some heated plasmas detached from sun and go to interplanetary space and have an energy approximately equivalent to 100 ton TNT explosion with tremendous explosion, this very heated and ionized gases in plasmasphere and magnetoheat region lead to electromagnetic instability and finally lead to geomagnetic storms near the magnetosheat and could disturb and harm satellites and very technical systems. A very tremendous explosion occurs in 14 March 1989 that causes the power black-out in Quebec and North America and lead to about 20 million dollar financial damages because of burning of several power transformers due to unexpected extra induced current that geomagnetic disturbance did that, and also 2 million people without electricity energy for about and 100MW power losses. Although sunspots themselves produce only minor effects on solar emissions, the magnetic activity that accompanies the sunspots can produce dramatic changes in the ultraviolet and soft x-ray emission levels. These changes over the solar cycle have important consequences for the Earth's upper atmosphere and also for global climate of the earth. Some researchers based on magnetic map of solar have shown that small changes of solar magnetic fields have major effects on coronal heating [4] that such phenomenon indicating on chaotic behavior of solar interior. Using advanced innovative methods could help scientist for further understanding about the behavior and laws of solar system. Based on image processing methods some physicists compute and functionalize the latitudinal solar wind speed as a function of magnetic observations with the aim of solar images [5]. First image fusion method is applied for September, October and November in year 2001. Based on fusing the sunspot images in these months, each separately, we deduce some remarkable concludes:

1- Although sunspot changes patterns usually have not shown any regular paths, but the total trajectory shows the regular belts like path.
2- Result of image fusion of these three months shows that sunspots with approximately same degree of intensities have the same trajectories.
3- Variation of solar magnetic fields has chaotic paths varying with time
4- Sunspots nearer to sun equator rotate faster than higher latitudinal (whose that are nearer to poles)

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[1] The photosphere is the visible surface of the Sun.

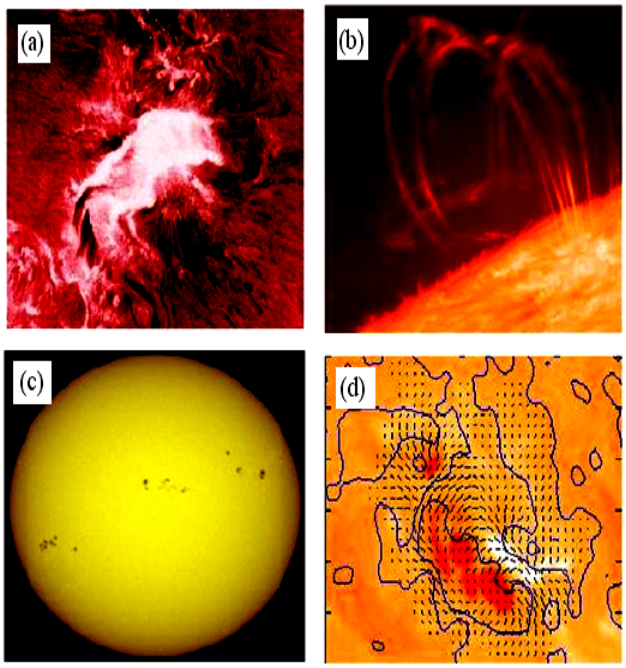

Fig. 1 (a, b) Solar flares (c) sunspots (d) a simulated feature of direction of magnetic field near the sunspots

II. Image Fusion Method

Fusion method is based on the minimum value selection of pixel (i,j) of image 1 and image 2:

$$P_{i.j}^{Fused} = \min(P_{i,j}^{image\ 1}, P_{i,j}^{image\ 2}) \quad (1)$$

Where $P_{i,j}^{Fused}$ denoted the value of pixel at coordinate (i,j) of fused images. The fused images is a color image that in each coordinate, the darker pixel between the same-coordinate pixels of two images would be selected as the fused pixel. This fusion method is illustrated for two color images in Fig. 2 according to equation 1.

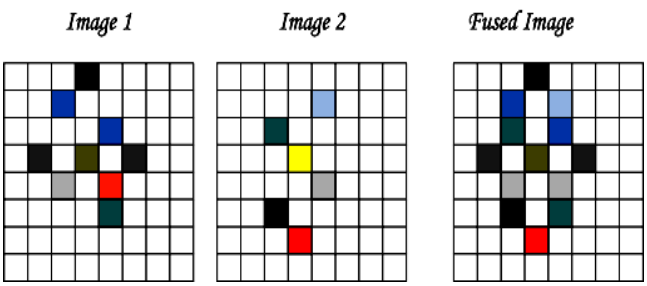

Fig. 2 Block Diagram of fusion method for fusion of two images based on equation 1

III. Quad Tree Decomposition Algorithm

Quad tree decomposition is an analysis technique that involves subdividing an image into blocks that are more homogeneous than the image itself. This technique reveals information about the structure of the image. Some researchers had contribution of using quadtree decomposition method for robot motion planning [2], and also this method had successfully applied for image modeling and for inverse modeling problems [3]. The quadtree is constructed by recursively decomposing the image into four equal-sized quadrants in top-down fashion. Given an $N \times N$ image (N = 2d for some d), the quadtree representation of it is a tree of degree four which can be defined as follows. The root node of the tree represents the whole image. If the whole image has only one color, we label that root node with that color and stop; otherwise, we add four children to the root node, representing the four quadrants of the image. Recursively we apply this process for each of the four nodes, respectively. If a block has a constant color, then its corresponding node is a leaf node; otherwise, its node has four children. Recently, Lee and Horng et al. [1] addressed a constant time quadtree building algorithm for a given image based on a specified space-filling order. Let the data structure of a quadtree node consist of four fields r; c; I and S_z, respectively. The row and column coordinates of the top-left corner of a quadtree node are represented by r and c, the image color of it is represented by I and S_z represents the index of the block size of a quadtree node; if the block size is 4^s then S_z is s. For a binary image, the third field I can be omitted. In Fig. 3, two-step of quad tree decomposition is depicted.

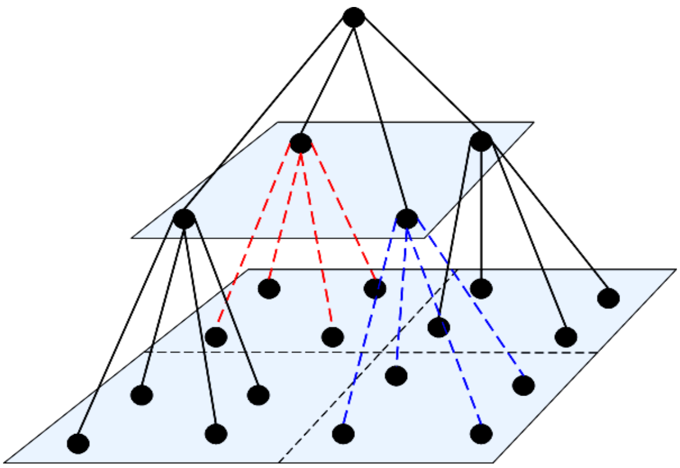

Fig. 3 Block Diagram of Quad Tree Decomposition Structure

IV. Simulations

Use Daily sunspot images[2] of each month is fused based on equation (1) and the result of image fusion is shown in Figs. 4, 5, 6 for September, November and October 2001 respectively. These results indicate the existence of some bands of sunspots on both sides of sun meridional in each month. It is obvious from this figures that sunspots with different degree of intensity are lying with different latitude; also sunspots with

[2] Sunspot images is taken with SOHO satellite and is downloaded from address: www.spaceweather.com

higher latitude have less intensity. Also sunspots with approximately same degree of magnetic flux intensity lying in a certain belts. To obtain quantitative information about these trajectories latitudes, we applied quad tree decomposition that mentioned above. The decomposition result of fused image of September, November and October 2001 is shown in Figs. 7, 8 and 9 respectively. Analyzing the Figs. 9, 10 and 11 give us the qualitative insight about the speed of sunspots nearer to sun meridional that rotate faster around the sun. With analysis of these plots; someone could compute the rotation speed of sunspots with different latitudes and obtain a quantitative insight and curve about sunspot speeds. In Fig. 7 the magnetic structure around sun is depicted that is based on faster rotation of sunspots nearer to equator and also lack of sunspot on meridional line; because the magnetic field with apposite direction could neutralize effect of each other. Also in this plot (Fig. 7(b)), the magnetic structure of sunspots is depicted schematically that shows magnetic field of a sunspot in a hemisphere is outward and enters to other sunspot on other hemisphere downward.

Using data collected by astronomers at the U.S. National Solar Observatory on Kitt Peak, the Sun's average magnetic field, day by day, is plotted as a function of solar latitude and time from 1975 through the present in Fig. 8. The result is a sort of strip chart recording that reveals evolving magnetic patterns on the Sun's surface. It is called butterfly diagram, because sunspots make a pattern in this plot that looks like the wings of a butterfly. In this plot, yellow regions are occupied by south-pointing magnetic fields; blue denotes north. At mid-latitudes the diagram is dominated by intense magnetic fields above sunspots. During the sunspot cycle, sunspots drift, on average, toward the equator; hence the butterfly wings. The uniform blue and yellow regions near the poles reveal the orientation of the Sun's underlying dipole magnetic field.

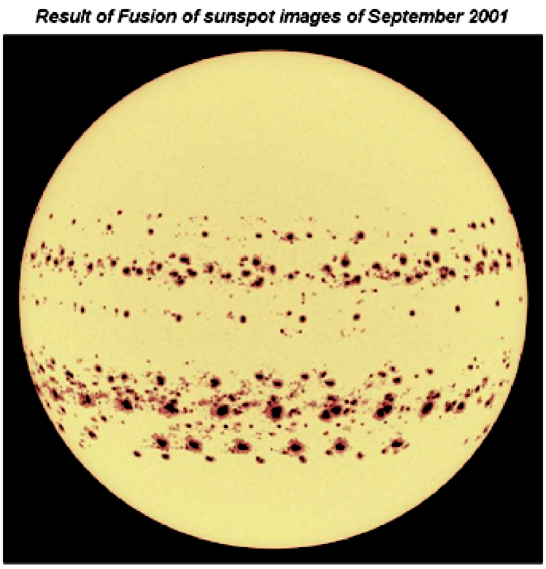

Fig. 4 Sunspot image fusion in September 2001

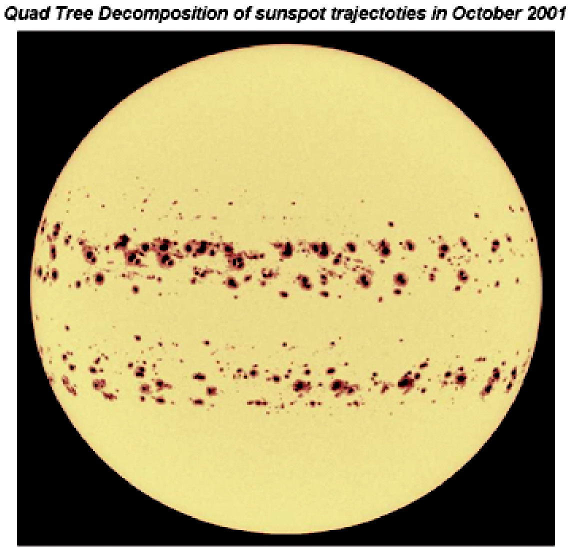

Fig. 5 Sunspot image fusion in October 2001

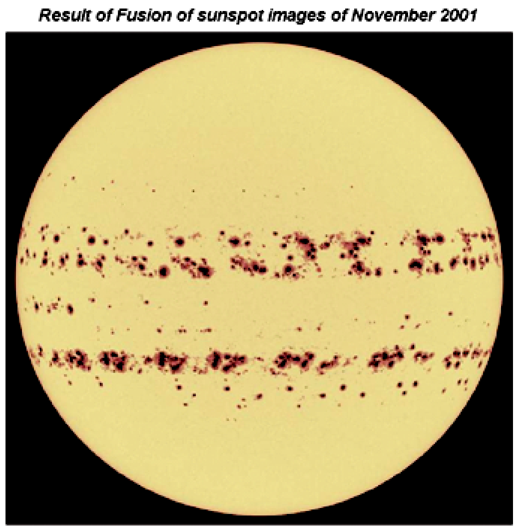

Fig. 6 Sunspot image fusion in November 2001

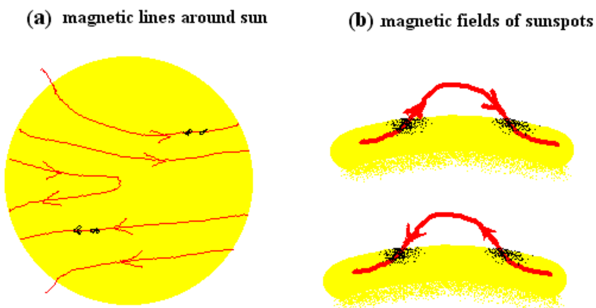

Fig. 7 (a) Magnetic field structure around the sun (b) structure of magnetic lines that form the sunspots

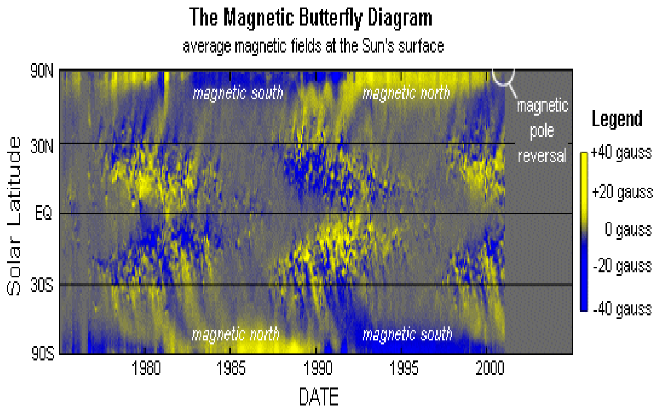

Fig. 8 Magnetic butterfly diagram of sun from year 1975 to present

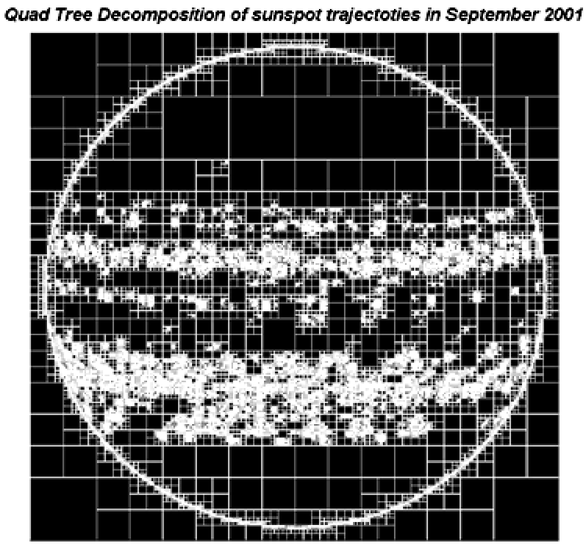

Fig. 9 Quad tree decomposition of sunspot trajectories of September 2001

Based on Fig. 9; three trajectories in September 2001 are classified into latitudes:

(A) One trajectory on top of meridional:
$(0^0) \rightarrow (33.75^0)$

(B) Two trajectories on bellow of meridional:
$(0^0) \rightarrow (-11.5^0)$ and $(-21.2^0) \rightarrow (-56.25^0)$

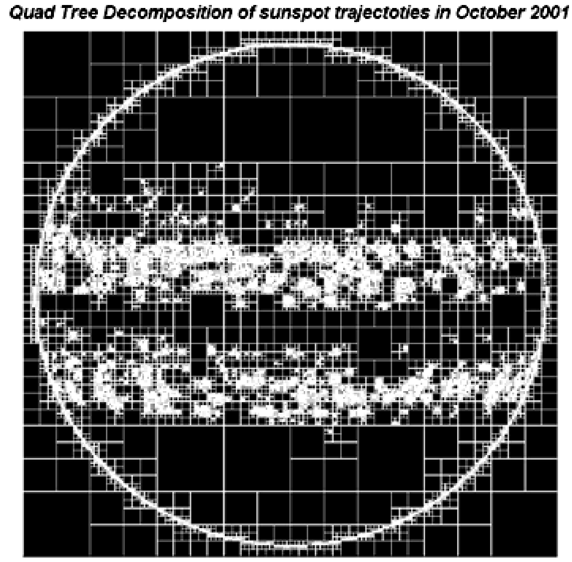

Fig. 10 Quad Tree decomposition of sunspot trajectories of October 2001

Based on Fig. 10; two trajectories in October 2001 are classified into latitudes:

(A) One trajectory on top of meridional:
$(-2.25^0) \rightarrow (33.75^0)$

(B) One trajectory on bellow of meridional:
$(-11.25^0) \rightarrow (-45^0)$

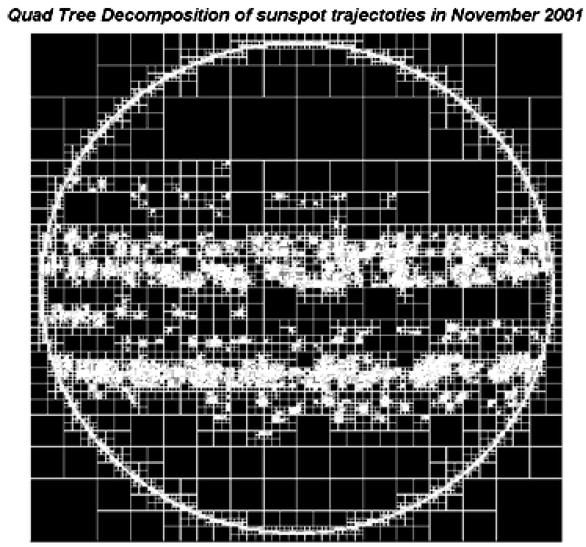

Fig. 11 Quad Tree decomposition of sunspot trajectories of November 2001

Based on Fig. 11; two trajectories in November 2001 are classified into latitudes:

(A) One trajectory on top of meridional approximately is:

$(0^0) \rightarrow (22.5^0)$

(B) One trajectory on bellow of meridional: $(-6.25^0) \rightarrow (-50.62^0)$

V. Conclusion

In this study a combination of image fusion method and quad tree decomposition method was applied for detecting the trajectories of sunspots over one month and then computing the latitudes that sunspots are rotate along them. In continue it is worth full to using the method for several months and by computing the latitude band of sunspot belts on sun photosphere and gathering this information and use this information for black-box. Modeling of variation of these trajectories and finally the prediction of next month trajectories latitude for alert the technical systems. Also it is worthful to using this combined method for every two day sunspot images for computation of variation of sunspots in direction of latitude and longitude of sun sphere and using this information for modeling and prediction of co-ordinates of sunspots for next day in order to alert satellites from regions in space that solar wind and plasma gases would attack. For this purpose a black-box model like neurofuzzy or neural network could be used for modeling of latitude and longitude variation of sunspots.

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