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A FUZZY LOGIC APPROACH TO TROPICAL CYCLONE EYE LOCATION (TCEL) USING INDIAN GEOSTATIONARY METEOROLOGICAL SATELLITE IMAGERY

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ABSTRACT

This paper presents the applications of image processing specifically using Indian meteorological satellite imageries. The eye is the very important characteristics of a mature Tropical cyclone (TC) and realization their location is very difficult for weather forecast. In order to improve the objectivity and precision of the location of TC, a novel intelligent and automatic system frame work will be proposed to locate the tropical cyclone center, based on Indian Geostationary Meteorological satellite imageries. In this paper, a Fuzzy logic based algorithm presented for extraction of tropical cyclones eye location from geostationary meteorological satellite imagery. As the shapes and features of the atmospheric systems observed in satellite imagery are inherently ambiguous, fuzzy logic seems an appropriate tool for feature extraction. The proposed computing methodology produced in this paper was applied in experimental cyclone forecasting by the joint typhoon warning center (JTWC). The probability of detecting the system is effective and the performance errors are well quite acceptable for actual practical implementation.

Keywords: *Tropical Cyclone, Eye, Center Location, Satellite Cloud Image, TCEL, VHRR, VIS, TIR, WV.*

1. INTRODUCTION

Mathematical morphology, introduced initially by matheron (1975) and later by serra[1] (1982), is the study of shape or form using simple concepts from classical set theory. A novel development, fuzzy mathematical morphology (dougherty et al, 1992), is an innovative extension of traditional morphology using the tools of the fuzzy set theory [2]. Fuzzy logic is a set of multiple-valued logics, which means there are more than two true value. It has variables which approximates the value between 0 and 1 based on reasoning. The term "fuzzy logic" was introduced by Lotfi A. Zadeh in 1965. The advantages of fuzzy logic is extended to image processing by Hamid Tizhoosh and others. Many difficulties realized frequently like uncertainty and vaguness during image analysis. These can be simplified by using fuzzy mathematical morphology.

The weather forecasting centers around the world provide a comprehensive weather service, including the important warnings of events such as tropical cyclones that may enlarger life and property [3]. When a tropical low pressure system has a mean circular wind motion in all sectors between 22 and 33 knots, it is called a tropical depression; when this speed is between 34 and 63 knots or more, it is called a tropical cyclone [4]. A tropical cyclone is characterized [5], [6] by a non-frontal synoptic scale low- pressure weather system over tropical or sub- tropical waters with organized convention and definite cyclonic surface wind circulation. Conditions favorable for the formation of a tropical cyclone are i) vicinity of itcz (inter-tropical convergence zone) or near- equatorial trough, ii) sea surface temperature ≥27°c iii) arrival of an easterly wave iv)weak vertical shear of wind, less than 10ms-1 between 950 and 200 mb (hpa) v) some distance (at least 3° latitude) away from the equator.

In north indian ocean, cyclones are more frequent in the duration of april-may and in oct-nov, depressions being frequent in jun- sep but these rarely reaches cyclone intensity. Elsewhere, cyclones are most frequent during the local summer season. Due to warm structure in the troposphere, intensity of a tropical cyclone in terms of geopotential anomaly is largest at the ground, decreases upwards and the low pressure area becomes a high pressure area in the upper troposphere. Throughout the troposphere, tropical

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cyclones are warmer than their surrounding, maximum temperature anomaly (10-15°c) occurring at about 300mb (hpa) level [7]. Tropical cyclones (tc) are one of many atmospheric circulation systems, surveyed by geostationary meteorological satellites [8], [9]. Additionally, they often cause significant damage and loss of lives in affected areas. To reduce the loss, warning centers should issue warnings early based on a forecast of tc track, which circulation center, or the eye, of the tropical cyclones. This is normally done by weather radars or satellites. Tropical cyclone's inner movement is very complex and tropical hurricane theorists still argue on the cause and movement mechanism. Approximately, the life cycle of a tropical cyclone can be divided into three phases: gestate from the offing, grow up to mature and weaken to death [9]. Since its original force needed when gestation comes from the effect of corioli's force brought by the earth's rotation, tropical cyclones usually appears in latitude between-5 and +5 degree. Owing to the high variation of cloud patterns and lack of efficient scene analysis techniques for the isolation and extraction of cloud systems from satellite pictures, the tc pattern matching jobs in dvorak analysis are so far all done by subjective human justification [10].

INSAT series and METSAT (KALPANA-1) satellites have provided the most consistent operational services to the nation for more than three decades. INSAT spacecrafts with metrological payloads being operated at geostationary orbit provides a stable platform to monitor and study the generation and growth of cyclones, i.e., cyclogenesis weather forecasting systems and to measure the meteorological parameters. The VHRR[6] is also called as imaging instrument of the meteorological space craft. The VHRR has a basic telescope and scan mechanism for imaging in three spectral bands (channels) namely VIS- visible band, TIR- thermal Infrared band and WV- water vapor band. Two dichroic beam splitters achieve the separation of the three bands. This scan mirror is mounted on a two axis gimbaled system to generate a two dimensional image by sweeping the instantaneous field of view (IFOV) of the detectors across the earth surface in east-west (called fast scan) and north – south called slow scan directions. North –south scanning is carried out by stepping the scan mirror placed in front of the entrance aperture of the telescope. The spatial Resolution of the INSAT VHRR satellite is 2km x 2km for VIS Band, 8km x 8km for TIR and WVP Bands. The spectral Bands for Visible band are 0.55 – 0.75µm, Thermal Infra Red band is 10.5 – 12.5 µm, Water Vapor is 5.7 – 7.1 µm .

The methodology proposed in this paper is mainly based on image processing theories and fuzzy mathematical morphology. The data received by ground station is initially processed for visual enhancement using simple filtering. This data is input to the synchronized segmentation system that extracts the tropical cyclone regions. This paper is organized as follows: section 2 introduces several pre processing methodologies to make filtering, smoothing, and segmentation on satellite images in section 3, algorithm design and implementation will proposed to detect the center of tropical cyclone. Section 4, finally a brief conclusion and discussion on the finding and future targets of our work is provided.

2. IMAGE PRE- PROCESSING

The data used in this paper is taken from VHRR payload raw data, which is obtained by normal mode scan. The data collection platform decides to start performing preprocessing procedure according to the scan line numbers. After segregation of the video data, the data is collected in to three separate buffers which are identified for each of the spectral bands. The collected data is also processed for over sampling and servo errors. Generally, cloud movement information is collected by meteorological satellite and represented through multiple modalities of images. An example on original image is shown in Figure 1. Satellite cloud image is 256 grey-scale digital images, with 1 pic/hour sampling frequency. Geostationary satellite images are easy to deformed and polluted by ambient interferences. These is a relatively range for the tropical cyclone gas temperature, which is demonstrated by pixel grey-level value. Various temperature ranges can be utilized to locate the sensitive cloud that represents the cyclone warning center.

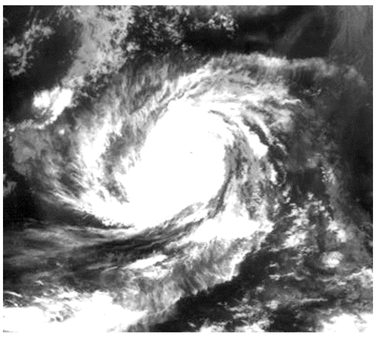

Figure 1: Original Satellite Image.

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3. ALGORITHM DESIGN TECHNIQUE AND IMPLEMENTATION

To locate eye of tropical cyclone (TC) by fuzzy algorithm implementation, the first step should be data acquisition and pre-processing of the raw data which is obtained from MET-SAT. The pre-processing step gives three data products, VIS (Visible), TIR (Thermal Infrared) and WV (Water Vapor). Among the three data products TIR image product and structural element (S.E.) are given as the inputs for the proposed method. The proposed method is shown in figure 2.

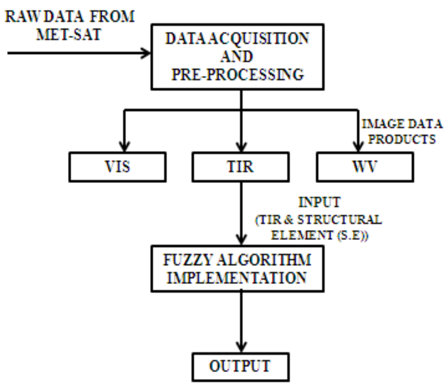

Figure 2: Flow Diagram Of Proposed Methodology.

The pre-processed TIR image is fuzzified in order to locate eye from lot of messes in original image. The fuzzified image is shown in figure 3. After fuzzification the low density cloud removal can be done by setting the below mean value range to zero in the fuzzified image, shown in figure 4.

Let i be the image matrix. The mean value m determined by histogram method, this is used as a structuring element (S.E).

Step: 1 perform fuzzification on original satellite image.

Step: 2 perform low density cloud removal using S.E.

$$i_1 = Ç\,(\hat{O}\,(i, m), m)$$

Step: 3 then perform logical *AND* with *i.*

$$i_2 = i \text{ AND } i_1$$

Step 4: Finally the resultant data is defuzzified and converted to grey scale image, which gives the eye location.

4. RESULT AND DISSCUSSION

The proposed algorithm was applied to the MET-SAT VHRR cyclone images of Bay of Bengal region and most of the image eye locations were automatically detected successfully. Figure 1 original satellite image which was scan by VHRR on 11-Oct-2013 at 20:30 UT. Figure 3 shows the fuzzified image and the Figure 4 shows the defuzzifized resultant image .The proposed algorithm considered mean value of 88.5 in grey scale. Approximately 30 to 40 % of low density clouds are eliminated. After the repetitive AND operations with the original image, successfully results the structure of eye of the mentioned tropical cyclone. Obtained results indicate that proposed algorithm exhibits significant improvement in performance and detect the TCEL more accurately than existing methods.

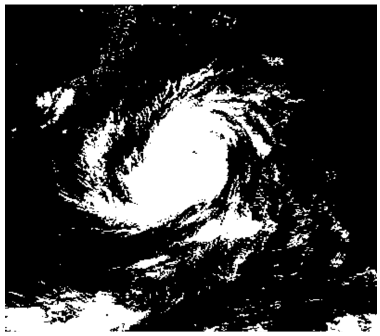

Figure 3: Fuzzified Image.

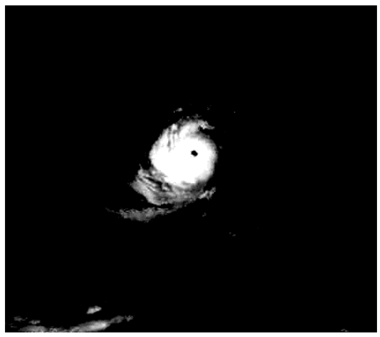

Figure 4: Defuzzified Result Image

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5. CONCLUSION

The paper proposes a novel extraction method for locating the eye position of tropical cyclones from geostationary meteorological satellite imagery by fuzzy mathematical morphology method. The proposed algorithm has been tested with five sets of multiple cyclone images during the years of 2009-2013 in the BOB (Bay of Bengal) region. Experimental results are best matching with the JTWC (Joint Typhoon Warning Centre), and errors are quite acceptable. The proposed method is very necessary input to the cyclone track prediction more accurately; at the same time it is possible to define the mature characteristics of TC. Further this research results are very use full for weather forecasting, nowcasting and rocket launch pad for during the period of launch activities, the satellite put in to desired orbits.

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