CENTER DETECTION OF TOPICAL CYCLONE IMAGES USING FIREFLY OPTIMIZATION ALGORITHM

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Abstract: *Tropical cyclones (TCs) are the most destructive weather systems that form over the tropical oceans, with about 90 storms forming globally every year. The timely detection and tracking of TCs are important for advanced warning to the affected regions. As these storms form over the open oceans far from the continents, remote sensing plays a crucial role in detecting them. Automatic weather forecasting is now achievable thanks to advancements in computer vision and satellite image technology. To prevent the loss of life and their assets, cyclone prediction is a major role because of directly related to the lives and household of human being. Satellite images provide an excellent view of clouds which can be used in weather forecasting and especially Infrared Red (IR) satellite images play in many environmental applications. To find the tropical cyclone (TC) center, the basic stage is to extract the main cloud of the cyclone. In manual segmentation, selection of the storm region is complicated, time consuming task and it also need the human experts for every time processing.in this article, NLM filter has been employed for denoising dataset. In later stage firefly optimization algorithm has been proposed to enhance cyclone center detection to mitigate loss of lives along the coastal areas of oceans. Proposed methodology has been implemented over MATLAB plateform to evaluate performance of proposed technique.*

KEYWORDS: Firefly algorithm, NL mean filter, Center detection, Tropical cyclone, Artificial intelligence.

I- INTRODUCTION:

A TC is said to be a high-speed rotating storm, characterized by a low-pressure centre with a closed low-level atmospheric movement of winds which produces heavy rain. This may cause natural disaster, death and loss of property. A matured cyclone develops a centre called Eye associated with a ring of high intensity winds around it. According to researchers about 90% of the damage is due to flood by sea water formed by high intensity winds. TC's are observed from various observation centres worldwide. Indian Meteorological Department (IMD) observes the tropical cyclones which are formed in the Arabian Sea (ARB) and Bay of Bengal (BoB). The scale is used by IMD for cyclone classification. The World Meteorological Organization Tropical Cyclone Program is assigned to set up national and regionally coordinated systems to check that the damage or loss caused by TC. Intensity of TCs is measured from these centres by a specific scale known as tropical cyclone intensity scale. Various other techniques are also established to predict the impact of a TC. Dvorak technique is a widely used method to detect cyclones using pattern recognition [1].

Since the launch of the first polar-orbiting meteorological satellite in the early 1960s, remote sensing techniques have proved to be a useful method for tropical cyclone analyses and forecasting. Satellite cloud images, acquired by passive remote-sensing instruments operating in the visible and infrared (IR) bands, vividly describe cloud-level tropical cyclone horizontal structures with large area coverage and frequently repeated observations. However, due to cloud cover and rain effects, the inner core structures and air-sea interaction near the ocean surface cannot be directly observed with visible or IR sensors. The microwave scatter meter is an active remote-sensing sensor. It works well at night and has a wide range of observation. In addition, it can simultaneously obtain wind speed and the wind direction of a wind field on the sea surface. Weather radar is a kind of active microwave radar that emits radar pulses to the sky and then receives the radar backscatter. It can identify a tropical cyclone center based on echo signal intensity [2].

As low pressure systems strongly govern our weather conditions, the ability of atmospheric models to predict cyclones is intensively studied by meteorologists and climatologists. A comprehensive overview of previous extra-tropical cyclone predictability studies focusing on short to medium-range forecasts. Nine global ensemble prediction systems (EPS) and their ability to forecast cyclones for a 6-month period was investigated. EPS produce multiple weather forecasts, which represent a sample of possible future atmospheric states. In accordance with previous findings it is shown that global deterministic models forecast the position of a cyclone with a higher accuracy than the cyclone intensity. EPS instead can add valuable information to the latter, as they show a higher skill in forecasting the strength of a cyclone [3]

The techniques have been applied to general circulation model (GCM) output. For example, Murray and Simmonds (1991a) and König et al. (1993) investigated GCM output and compared it with reanalysis data. Raible and Blender (2004) applied the method of Blender et al. (1997) to simulated data and found that cyclone tracks and their corresponding variability are a sensitive measure to detect discrepancies between simulations with different ocean representations. Other studies have presented the role of cyclone-related variability on the generation of decadal variations of circulation patterns (Raible et al. 2004; Luksch et al. 2005). In climate change scenario simulations Schubert et al. (1998) found a northward shift of cyclone tracks in a warmer climate state [4].

Most image processing problems using morphology such as merged and robust approach. Morphological pruning, thinning and filtering approaches are helpful techniques for preprocessing or post processing. The dilation, erosion, opening and closing operations are the most basic morphological operations for binary images [5].

As in the development of artificial intelligence (AI) technology in the last decade, machine learning algorithm has been successfully applied in the subjects of object detection and pattern recognition owing to its ability to efficiently extract imagery information. In the subjects of oceanography and meteorology, state-of-the-art machine-learning algorithms have been applied to recognize the circulating pattern in a spiraling fluid field. Moreover, deep convolutional neural network (DCNN) has been utilized to detect and classify objects in remote-sensing images. Based on DCNN, researchers have successfully developed object detection models for land-use and land-cover, vegetation, urban commerce, transportation vehicles, etc. Similarly, attempts are made to detect cyclones based on cloud images [6].

II-LITERATURE SURVEY

Crespo *et. al* [**2023**], assessed the performance of the Regional Climate Model version 4 (RegCM4) in simulating the climatology of the cyclones near the west coast of South America. The synoptic evolution and seasonality of these systems were thoroughly investigated. The analyses were based on four simulations from the CORDEX-CORE Southern America (SA) domain, at 0.25° of horizontal resolution: one had driven by ERA-Interim and three driven by different GCMs. The reference dataset was represented by ERA5. Cyclones were detected by an objective scheme in the period 1995–2005 and classified in three different classes: (i) Coastal Lows (CLs) and cyclones affecting the coast (CAC) (ii) crossing and (iii) not crossing the Andes. In general, RegCM4 was able to reproduce the climatology of cyclones affecting the western coast of SA. In particular: (i) CLs were shown to be more frequent in austral summer although their frequency was underestimated by the simulations in this season; (ii) CAC not crossing the Andes represent 76% of all CAC and are more frequent in winter, with simulation underestimating their frequency by ~ 22% due to the differences in the simulated upper-level jets, which tend to get weaker (by ~ 5–10 m s− 1) northwards of 30°S; (iii) the frequency of CAC crossing the Andes tends to be overestimated mainly in winter, which was associated with the combination of the stronger upper-level jets and weaker SLP in the simulations, especially southwards of 40°S [7].

Kotsias *et. al* [**2023**], An objective cyclone detection and tracking analysis was performed for the Mediterranean region with the use of 6-hourly (00, 06, 12, and 18 UTC) 1° × 1° mean sea-level pressure data obtained from the ERA5 database for the period 1950–2018. At first, the main cyclogenesis and high-density areas of cyclones were identified. Next, principal component analysis and cluster analysis were performed, classifying the detected cyclone trajectories into 12 clusters. In the following step, the application of the above methodology, this time on the intra-annual variations of the 12 cyclone clusters' frequencies leads to the objective definition of four seasons, which generally correspond to the conventional ones, but they present differences in their limits and duration [8].

Wang *et. al* [**2023**],a two-dimensional objective cyclone identification method based on outermost closed isolines was used to obtain the EC-related datasets, and the summertime ECs in East Asia were classified by the relationship between ECs of different intensities and the corresponding precipitation. The results showed that compared with the cyclone mean depth, central wind and other traditional intensity indicators, the cyclone intensity index that was the maximum product of the EC-associated wind speed and specific humidity, has the highest correlation with the EC-associated maximum precipitation (r = 0.74). To simplify the definition of cyclone intensity index, the vqmax within the radius of 300 km from the cyclone center was defined as the cyclone intensity. According to the relationship between EC and precipitation intensity and the precipitation grades in China, the ECs in East Asia were classified into four levels. Accordingly, the EC-associated maximum precipitation increases substantially with the raising of cyclone level. In particular, 32.8% of heavy rain events in East Asia in summer were related to ECs of the strongest category [9].

Bourdin *et. al* [**2022**],compares four trackers with very different formulations in detail. Author's assessed their performances by tracking tropical cyclones in the ERA5 reanalysis and by compared the outcome to the IBTrACS observations database. The first section of the paper finds typical detection rates of the trackers ranging from 75 to 85%. At the same time, false alarm rates (FAR) greatly vary across the four trackers and can sometimes exceed the number of detected genuine cyclones. Based on the finding that many of these false alarms were extra-tropical cyclones, Author's adapted two existing filtering methods common to all trackers. Both post-treatments dramatically impact FARs, which range from 9 to 36% in final catalogs of tropical cyclones tracks. Article then showed that different traditional metrics can be very sensitive to the particular choice of the tracker, which was particularly true for the TC frequencies and their durations [10].

Chand *et. al* [**2022**],Assessed the role of anthropogenic warming from temporally homogeneous historical data in the presence of large natural variability was difficult and has caused conflicting conclusions on detection and attribution of tropical cyclone (TC) trends. Here, used a reconstructed long-term proxy of annual TC numbers together with high-resolution climate model experiments, Author's showed robust declining trends in the annual number of TCs at global and regional scales during the twentieth century. The Twentieth Century Reanalysis (20CR) dataset was used for reconstruction because, compared with other re-analyses, it assimilated only sea-level pressure fields rather than utilize all available observations in the troposphere, making it less sensitive to temporal inhomogeneities in the observations [11].

Stegner *et. al* [**2021**], proposed a strong cyclone-anticyclone asymmetry of the eddy detection on the altimetry products AVISO/CMEMS in the Mediterranean Sea. Large-scale cyclones having a characteristic radius larger than the local deformation radius were much less reliable than large-scale anticyclones. Author's estimated that less than 60% of these cyclones detected on gridded altimetry product are reliable, while more than 85% of mesoscale anticyclones were reliable. Besides, both the barycenter and the size of these mesoscale anticyclones were relatively accurate. This asymmetry comes from the difference of stability between cyclonic and anticyclonic eddies. Large mesoscale cyclones often split into smaller sub-mesoscale structures having a rapid dynamical evolution. The numerical model CROCO-MED60v40 showed that this complex dynamic was too fast and too small to be accurately captured by the gridded altimetry products. The spatio-temporal interpolation smoothes out this sub-mesoscale dynamics and tends to generate an excessive number of unrealistic mesoscale cyclones in comparison with the reference field [12].

III-RESEARCH METHODOLOGY

Our goal is to provide a optimizing tool which would provide a new automated technique for TC centre estimation using only the tropical cyclone satellite data The proposed technique has the added advantages of simplicity, objectivity and consistency compare to Dvorak technique. The proposed technique provided a better understanding of characteristics of satellite imagery in response to TC's intensity change; which is not well understood yet.

The proposed research addresses the following challenges for estimating the intensity of a TC. First, discover features and patterns in satellite images that are relevant to current intensity of the storm. Second, working with ambiguous satellite images due to noise make the estimation difficult. Third, since limited reconnaissance data are available especially for weak and intense storms, make the validation and training procedures incomplete.

MOTIVATION

Tropical cyclones are the most dangerous and extreme weather phenomena. Landfall TCs accounts for an average of $10 billion in damage annually in United States (Pielke et al., 2008). For example Hurricane Katrina (2005) took more than 1800 lives and caused about $81 billion in damages. Despite large decreases in tracking forecast errors over the past three decades, hurricane estimation and prediction errors have not reached estimated predictability limits (McAdie and Lawrence, 2000) and there has been little improvement in forecasting of storm intensity (Camp and Montgomery, 2001). Long-term planning like evacuation, costal development or route capacity is certainly important in mitigating the economic damage and loss of the life due to the TCs, but it is the prediction of a TC's future characteristics that determines the short term response of communities to decrease the threat of TC landfall. TC forecasts serve as input to those public officials who make decisions regarding preparations for TC landfalls (Regnier, 2008).

3.2.1- OBJECTIVES:

- To detect the center of the tropical cyclone.
- To improve the detection accuracy using Firefly optimization algorithm.
- To introduce optimization algorithmic approach in solving center detection in tropical cyclone.

3.3-RESEARCH METHODOLOGY In this research article, tropical cyclone center detection has been proposed using firefly optimization algorithm. Dataset with 60 images has been employed to determine performance of our proposed technique.

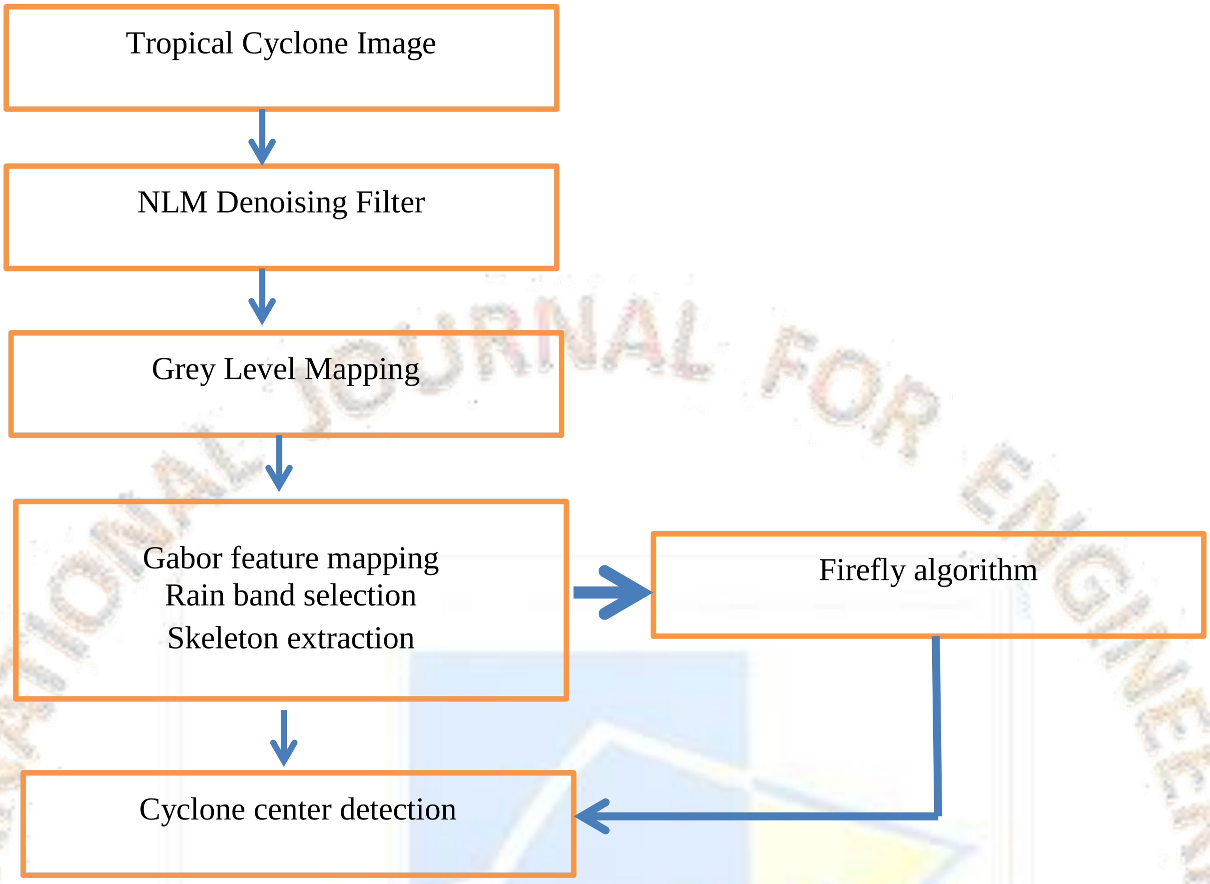
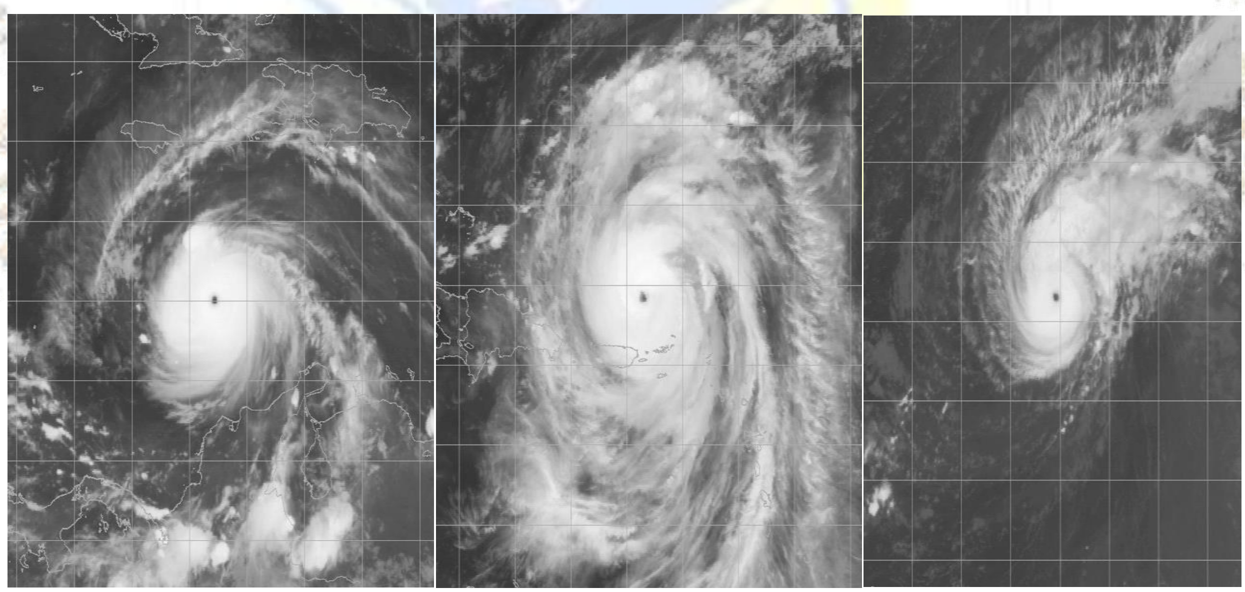


Figure 1: Proposed implementation flow diagram

3.3.1 TROPICAL CYCLONE DATASET



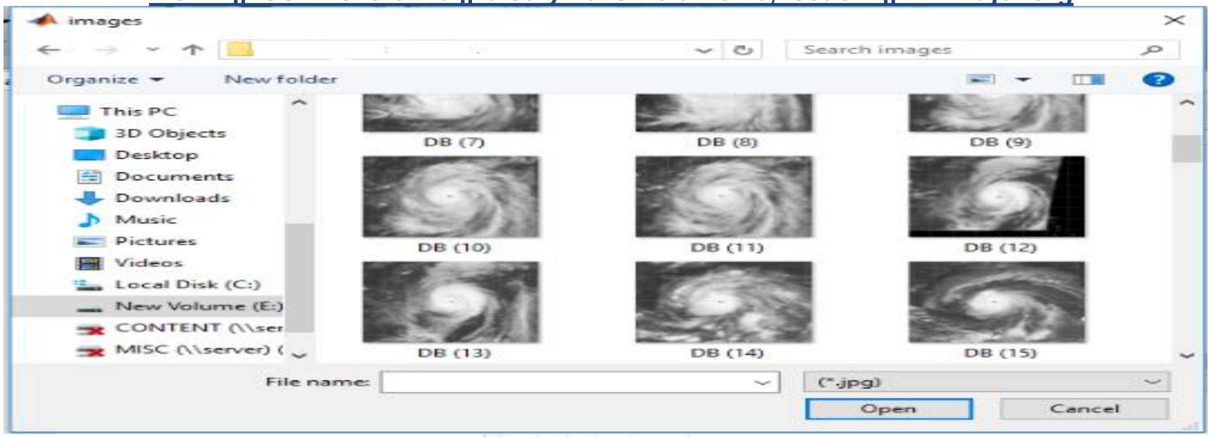


Figure 2: Input images of dataset

3.3.2 NL-MEANS ALGORITHM principle of NLM filtering algorithm The NLM filtering algorithm performs image denoising to calculate the similarity of pixel points in units of image blocks. A so-called image block is a square neighborhood centered on a certain pixel point.

Given a discrete noisy image $v = \{v(i) | i \in I|\}$ the estimated value $NL[v](i)$,for a pixel i, is computed as a weighted average of all the pixels in the image,

$$NL[v](i) = \sum_{j \in I} \omega(i, j) = 1$$

Where, the family of weights $\omega(i, j)$ depend on the similarity between the pixels *i* and *j*, and satisfy the usual conditions $0 \le \omega(i, j) \le 1$ and $\sum_j \omega(i, j) = 1$.

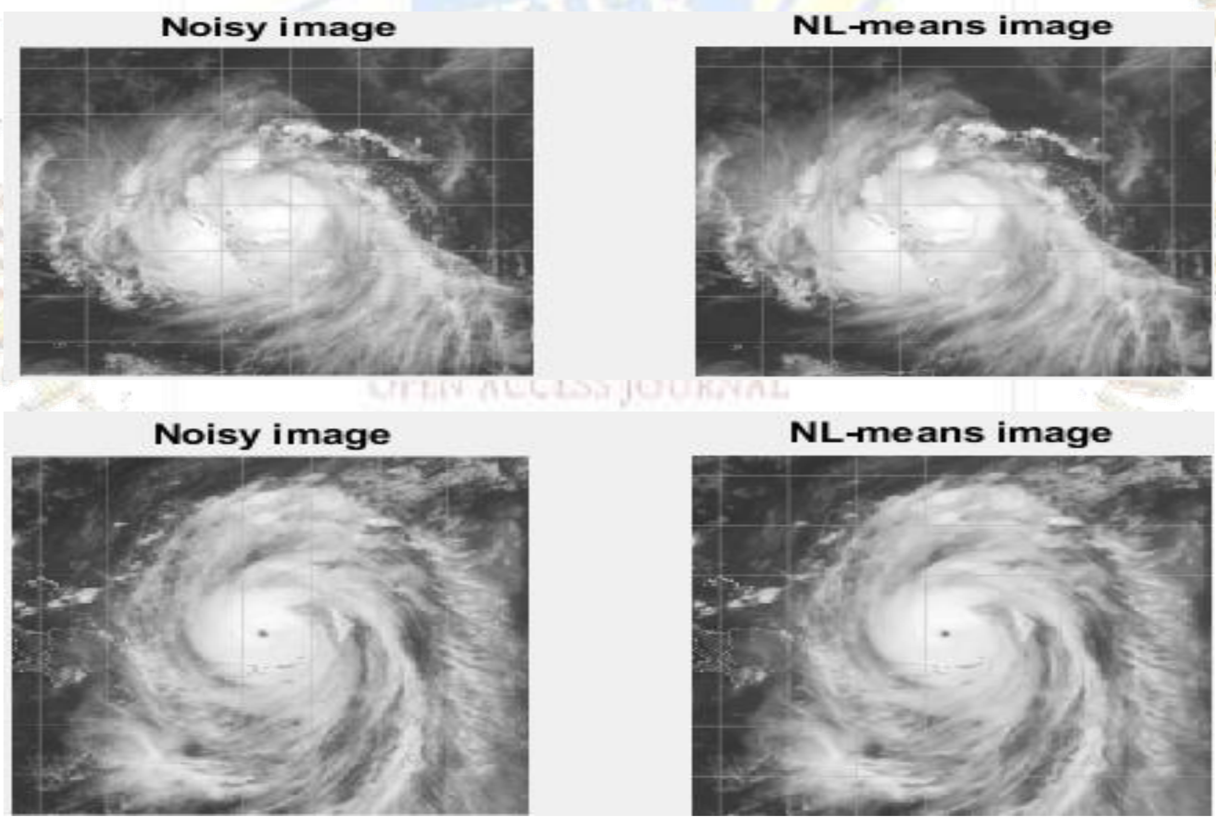


Figure 3: Filtered images by NLM filter

3.3.3 GREY LEVEL MAPPING: Gray level transformation allows the modification of pixel intensities by mapping input gray levels to various output levels, to achieve desired image enhancements. This mapping can easily be achieved through different mathematical functions.

However, the basic transformation function is given as follows:

$$O=T(i)$$

Where O stands for output pixel value, I stand for input pixel value, and T stands for the transformation function that maps the pixel values of the input image to different output gray levels.

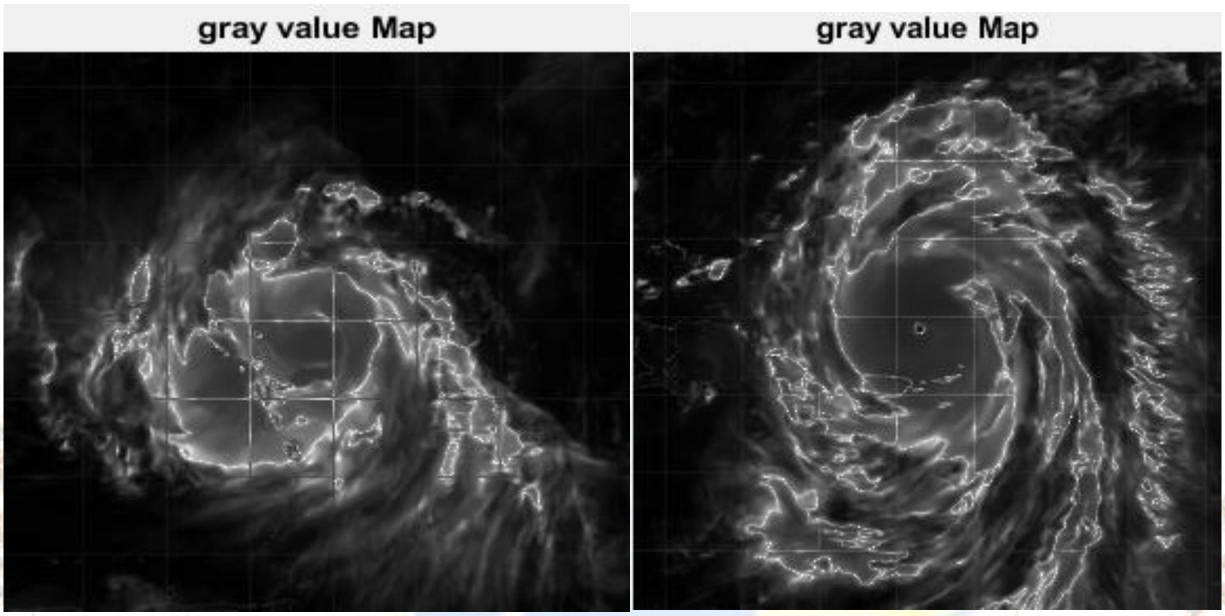


Figure 4: Grey Level Mapping

3.3.4 GABOR FEATURE MAPPING

The automatic center location of t ropical cyclones without eyes using pattern matching methods usually needs the help of rain band information. Therefore we need to obtain the spiral information of rain bands before matching. Researchers often segment satellite cloud images using a threshold segmentation method. These algorithms usually work well when the gray levels of the rain bands are obviously different from the gray levels of other regions. This is easy but not very effective when the gray levels of rain bands are more or less the same as those of other cloud clusters, which makes it hard to distinguish rain bands from other cloud clusters. Besides, influencing factors such as speckle noise, various configurations of tropical cyclone images acquired by different SAR instruments with different polarization, azimuth and spatial resolution, etc will make automatic segmentation of large numbers of rain bands more difficult. In addition, a tropical cyclone SAR image shows the sea surface imprint of a tropical cyclone with little texture information. Therefore we consider obtaining rain bands by salient region detection. In computer vision, salient regions are defined as regions that attract human visual attention at the earliest visual processing when looking at an image. Salience is based on a variety of visual stimulation, such as color, brightness, texture, shape, edge, etc. High contrast between stimuli creates space reorganization of the receptive field cells, attracting the attention of the observer. That is the occurrence of the salience. People tend to rapidly search for the most important parts and ignore the less important parts when they watch an image based on vision task and their prior knowledge. This selective attention mechanism enables people to efficiently capture the areas that they are interested in.

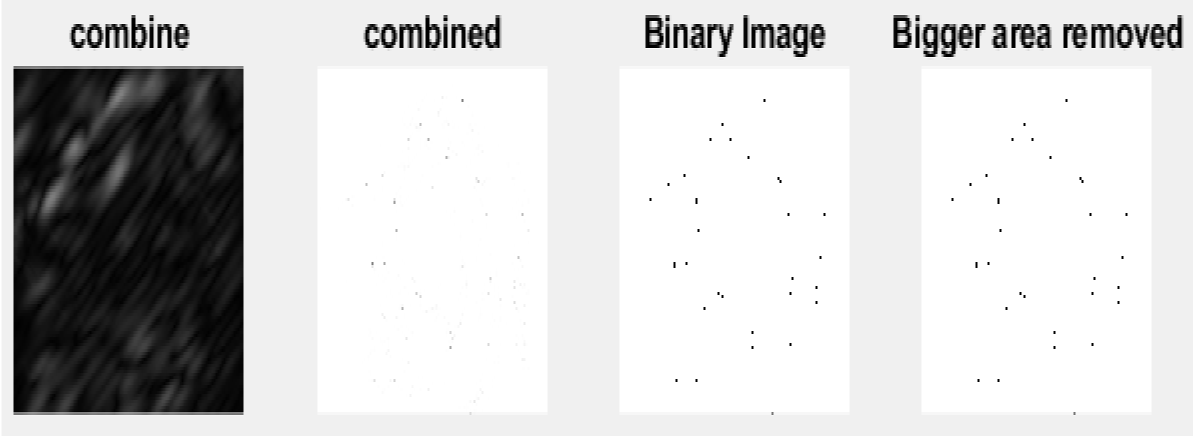


Figure 5: Gabor and rain band mapping

3.3.5: FIREFLY OPTIMIZATION ALGORITHM

Fireflies are winged beetles or insects that produce light and blinking at night. The light has no infrared or an ultraviolet frequency which is chemically produced from the lower abdomen is called bioluminescence. They use the flash light especially to attract mates or prey. The flash light also used as a protective warning mechanism to remind the fireflies about the potential predators. Firefly algorithm is a meta-heuristic algorithm that is inspired by the flashing behavior of fireflies and the phenomenon of bioluminescent communication. Firefly Algorithm has been formulated with the following assumptions:

1) A firefly will be attracted to each other regardless of their sex because they are unisexual.

2) Attractiveness is proportional to their brightness whereas the less bright firefly will be attracted to the brighter firefly. However, the attractiveness decreased when the distance of the two fireflies increased.

3) If the brightness of both fireflies is the same, the fireflies will move randomly. The generations of new solutions are by random walk and attraction of the fireflies.

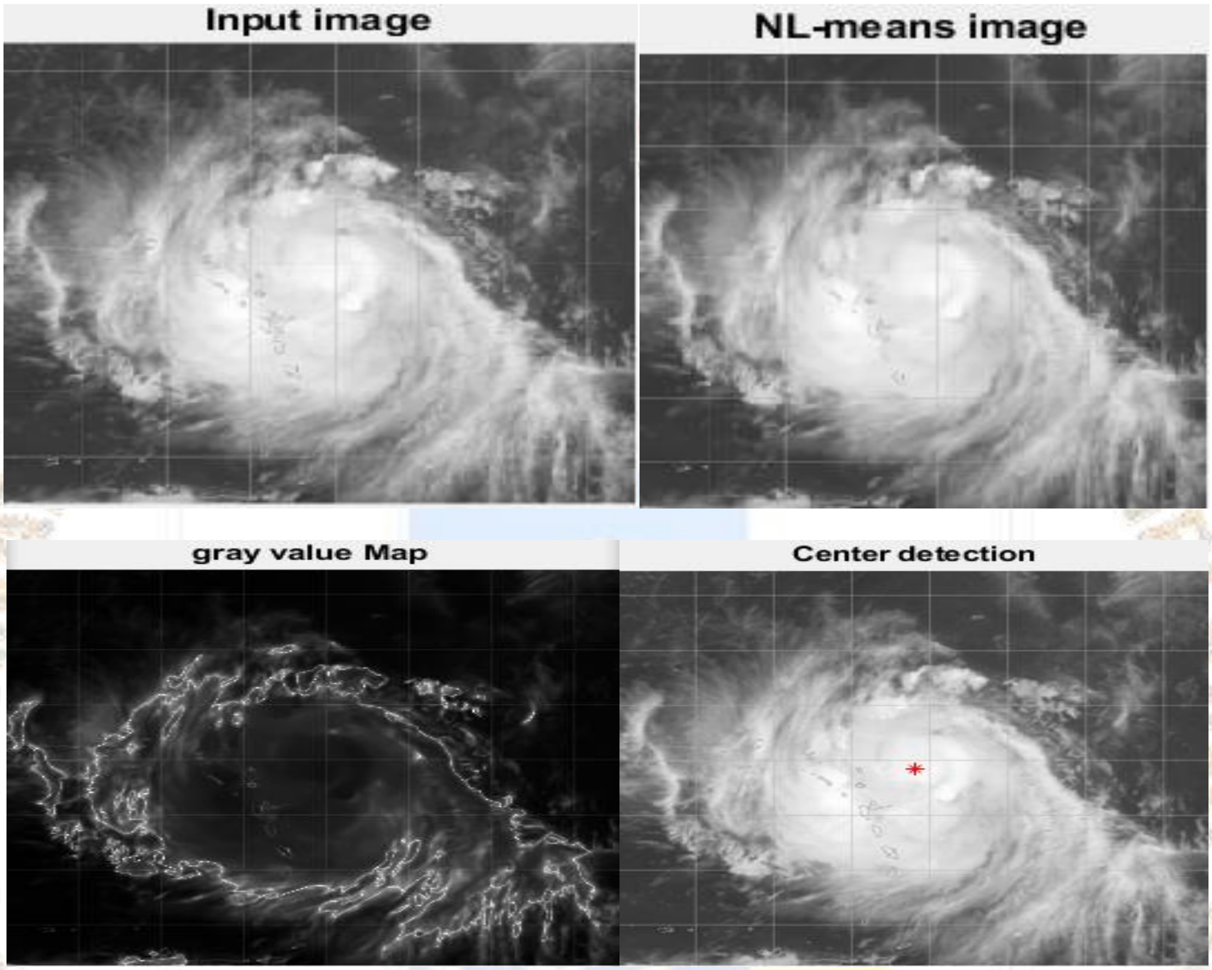
The brightness of the fireflies should be associated with the objective function of the related problem. Their attractiveness makes them capable to subdivide themselves into smaller groups and each subgroup swarm around the local models.

From the previous literatures, many researchers have stated that FA developed by Yang in 2008 is a very powerful technique to solve constrained optimization problems and NP-hard problems. Few researchers's stated that FA has widely been applied to solve continuous mathematical functions but has been rarely reported. For applied mathematics, the algorithm must be just a simple math and logic. The behavior of FA is simple and therefore it is suitable to solve the continuous mathematical functions. FA is very efficient and can outperform other conventional algorithms based on statistical performances measured using standard stochastic test functions. The algorithm works based on global communications among the fireflies. Hence, it can find global and local optimal simultaneously. FA use mainly real random numbers. Different fireflies work independently and it is suitable for parallel implementation. FA is one of the technique that recently used by researchers to solve optimization problems in dynamic environment.

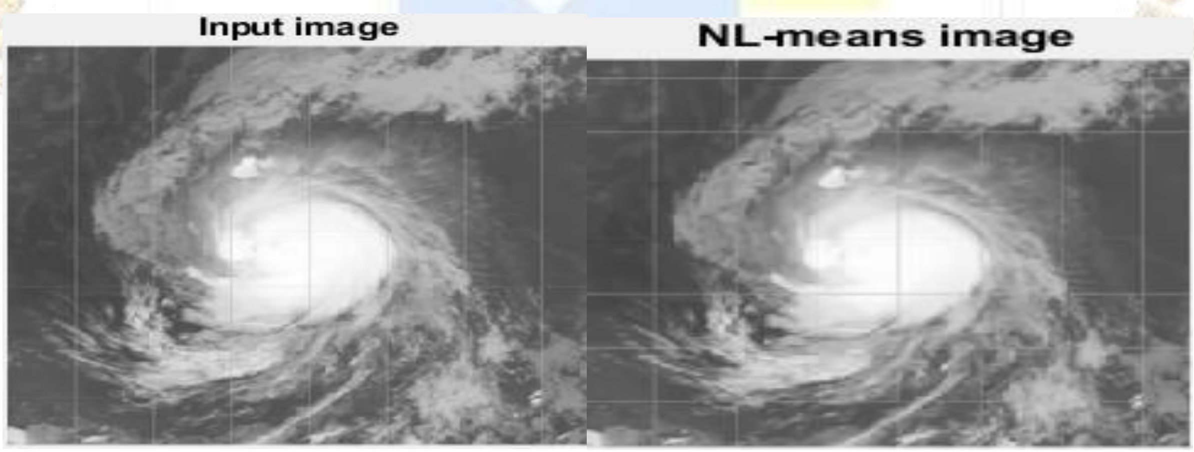
IV-RESULTS AND DISCUSSION

The flow diagram depicted in chapter 3, has been implemented over MATLAB 17b platform to evaluate the performance of proposed architecture. In the chapter, we are going to make a case study for few images in our dataset. We have tested more than 60 images in our proposed methodology for tropical cyclone center detection, only few are depicted in below cases.

Case I:



Case II



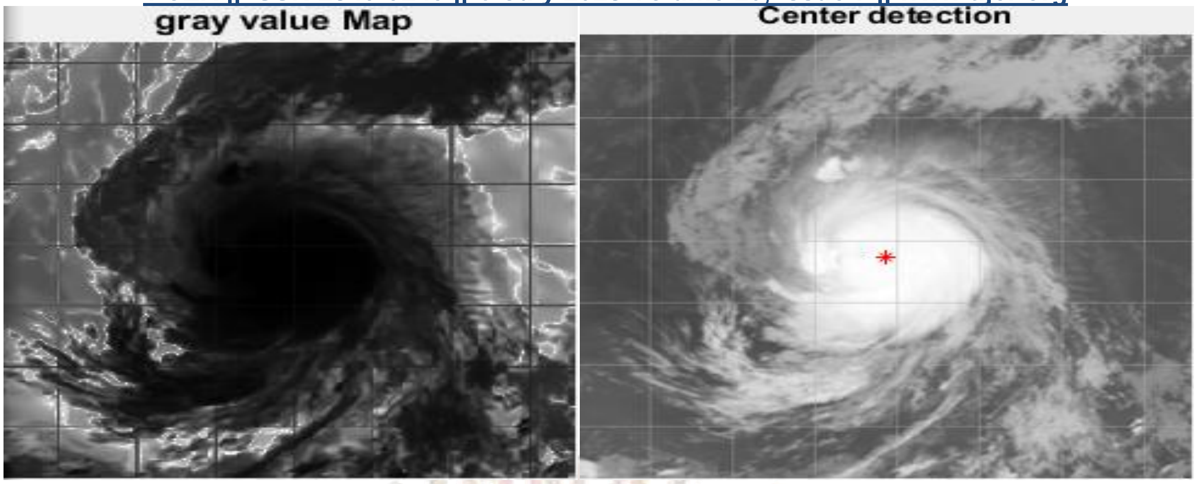


Figure 6: CT centre detection

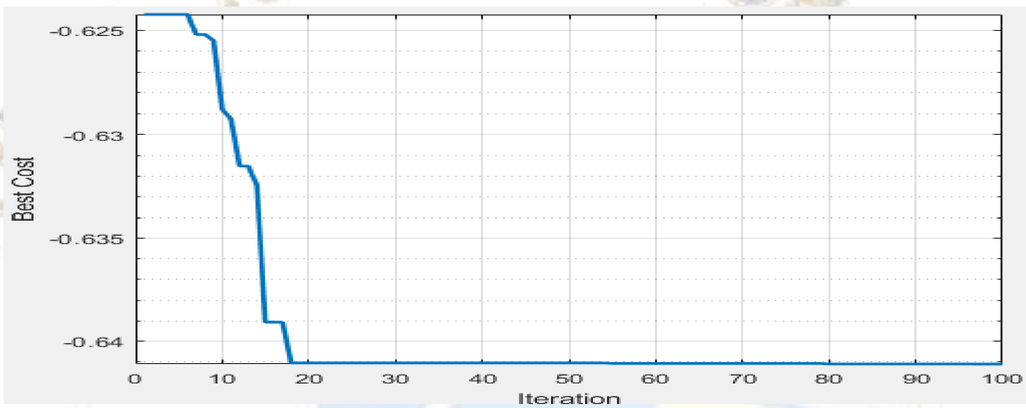


Figure 7: best value optimization by Firefly Algorithm

Serial No.	Denoising by NLM filter (PSNR value)
Image 1	69.542
Image 2	67.5849
Image 3	68.0370
Image 4	66.0409
Image 5	69.0258

Table 1: PSNR value by NLM filter

V-CONCLUSION AND FUTURE SCOPE

As in the development of artificial intelligence (AI) technology in the last decade, machine learning algorithm has been successfully applied in the subjects of object detection and pattern recognition owing to its ability to efficiently extract imagery information. In the subjects of oceanography and meteorology, state-of-the-art machine-learning algorithms have been applied to recognize the circulating pattern in a spiraling fluid field. Moreover, deep convolutional neural network (DCNN) has been utilized to detect and classify objects in remote-sensing images. Based on DCNN, researchers have successfully developed object detection models for land-use and land-cover, vegetation, urban commerce, transportation vehicles, etc. Similarly, attempts are made to detect cyclones based on cloud images. Lee and Liu classified the appearance of tropical cyclones in remote-sensing images into eight possible categories, and then trained the neural network based on this classification.

In this research article, cyclone tropical images have been employed for cyclone centre detection using firefly optimization algorithm. Sharpe centered cyclones are more likely to produce high frequency tides in the oceans. In this article, NLM filter have been used to denoise input images, firefly optimization employed to predict best value for center detection of cyclone image. Resulted images are depicted in above section.

This research can be taken to next stage by using enhanced optimization algorithm for cyclone pattern and frequency to estimate damage that can be caused by generated cyclone. Future projects can save lives of people living in coastal area by informing them prior to cyclone reach to them as with the combination of multiple cyclones result in Tsunami.

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