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Optimum Analysis for Tropical Cyclone Eye Fix Using Genetic Algorithm

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Abstract: ***Tropical cyclones (TCs) 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. This requires the accurate location of the circulation center, or the "eye", of the TC. This is normally done by the analysis of remote sensing data from weather radars or satellites. Weather forecasting often requires extensive computationally expensive numerical analysis on remote sensing data. For example, to determine the position of a tropical cyclone (the TC eye fix problem), computationally intensive techniques, such as the analysis of wind fields or processing of fields of motion vectors, are needed. In this, a template matching method is proposed to solve a subclass of TC eye fix problems. In this proposed work, developing an effectives and efficient algorithm that makes use of a simple template model of TC for matching. Genetic algorithm is used to speed up the search and to break out of local maxima. Genetic algorithm (GA) makes use of Darwin's idea of "survival for the fittest", the best genes (sets of model parameters) that maximizes a fitness function (a quality measure of match) are iteratively generated and selected.***

Keywords: tropical cyclone eye fix; remote sensing data; Genetic algorithm.

1. INTRODUCTION

Tropical cyclones (TCs) can cause property damage and loss of lives in affected areas. Direct economic losses can amount to billions of dollars [1]. To provide rapidly updated information to the general public regarding the movement of a TC nearby, a weather centre should issue warnings as early as possible. A key element in issuing warnings for a TC approaching land is an accurate and timely knowledge of the location of the circulation centre, or the 'eye', of the TC as detected on the radar [5].Weather radars work by sending out microwave signals to the atmosphere. The reflected signals are then preprocessed to extract the relevant slices suitable for analysis [6].

TC eye fix is often done manually in practice. Forecasters estimate the center location by tracing the movement of spiral rainbands using consecutive remote sensing images, or by overlaying spiral templates on remote sensing images for the best match [7]. However, these techniques are not completely objective. In contrast, automated TC eye fix methods, such as wind field analysis and pattern matching, employ objective measures. In wind field analysis, the TC center is found by analyzing the motion field [3, 8], which is built using the TREC algorithm [7] or by cloud feature tracking [5]. For pattern matching, the TC eye is fixed by finding the best match of a predefined TC model, whose parameters are estimated from remote sensing data. A method for ideal TCs is to identify the shear pattern [6]. Another example, [8] the spiral rainband of a TC is modeled by the equation $r = a\ e\theta \cot \alpha$, where a and α are found by transformation techniques. Templates generated by the estimated parameters are used to match against radar images at plausible latitude-longitude positions. These eye fix methods require computationally expensive operations such as motion vector field construction, parameter estimation, and extensive block or object matching. With the large volume and rate of data, this problem is often solved using mainframe computers or clusters to generate timely results.

II. PREVIOUS WORK

Firstly, Most of the methods are manual or semiautomated [1] and that based on satellite images [1, 2]. As radar data normally have a higher resolution and are updated frequently, better performance can be expected [2]. As timely and accurate estimates of the centre position and motion of TCs are essential, the focus in this is on the eye fix process using radar data, which normally have higher spatial and temporal resolution than satellite images. The radar reflectivity data at 3 km Constant Altitude Plan Position Indicator (CAPPI) and the corresponding Doppler velocity data are used simultaneously. The S-band Doppler radars used by the Hong Kong Observatory take 6 min to update both types of data [1]. This covers a radius of up to 512 km, with radial spatial resolution of 250 m. Early TC eye fix methods are completely manual. Forecasters estimate the centre location by tracing the movement of spiral rainbands using consecutive remote sensing images, or by overlaying spiral templates on remote sensing images for the best match [2].

Attempts to automate or semiautomate the TC eye fix process categories as: pattern matching and wind field analysis. In pattern matching, a TC eye is fixed by finding the best match between predefined TC models and remote sensing data. An example, where the TC centres is defined as the geometric centre of the TC eye wall. By using airborne radar data, the forecaster first subjectively determines a centre point. From the selected point, the inner edge of the eye wall is found.

The centre of the circle that best fits the location of the inner edge of the eye wall gives an objective estimate of the centre.

Secondly, Rinehart developed the Tracking Radar Echoes by Correlation (TREC) method for motion field construction using radar images [2, 3]. In TREC, two scans of Plan Position Indicator (PPI) reflectivity data measured at the same elevation angle, separated a few minutes apart, are used. The analysis proceeds by dividing the first scan into a number of equal-sized two-dimensional arrays of pixels. Each array is correlated with the possible arrays of the same size in the second scan to find the best match. The location of the second array with the highest correlation determines the end point of motion vector.

Recently, the model was subsequently improved to have six parameters to limit the extent of rainbands [5, 6], allowing the eye to vary in size during the TC's lifetime, and modeling the eye wall as well. It used a genetic algorithm (GA) to speed up the search of the parameter set for the best match. Templates are thus generated as candidates of the GA, and a fitness function is defined. There is an order of magnitude of improvement in terms of efficiency with respect to that makes use of transformation techniques. To further improve the speed and accuracy, we also make use of temporal information in the GA-based eye fix algorithm [5, 6] This method gives an improvement of 35% in speed and 20% in accuracy compared to the one without the use of temporal information.

III. PROPOSED APPROACH AND ALGORITHM

Proposed solution establishes TC eye fix method using genetic algorithm which is useful for the affected tropical areas lives. Genetic algorithms (GAs) are search methods based on principles of natural selection and genetics developed by Fraser, Bremermann; Holland.

Another important concept of GAs is the notion of population. Unlike traditional search methods, genetic algorithms rely on a population of candidate solutions. The population size, which is usually a user-specified parameter, is one of the important factors affecting the scalability and performance of genetic algorithms. Genetic algorithm is used to find the template that best fits the image. To evolve solutions by using the following steps:

1. Initialization.

The initial population of candidate solutions is usually generated randomly across the search space. However, domain-specific knowledge or other information can be easily incorporated.

2. Evaluation.

Once the population is initialized or an offspring population is created, the fitness values of the candidate solutions are evaluated.

Fitness Function $f(x, y) = yx^2 - x^4$.

	0 0 1 1 1 1	Bit String (Gray Coded)
Degray ↓		
	0 0 1 1 0 1	Base 2
	1 5	Base 10

$F(001111) = f(1, 5) = 5 * 1^2 - 1^4 = 4$

Fig. 3.1: Bit-string encoding

3. Selection.

Selection allocates more copies of those solutions with higher fitness values and thus imposes the survival fittest mechanism on the candidate solutions.

4. Recombination.

Recombination combines parts of two or more parental solutions to create new, possibly better solutions (i.e. offspring). There are many ways of accomplishing this and competent performance depends on a properly designed recombination mechanism.

5. Mutation.

While recombination operates on two or more parental chromosomes, mutation locally but randomly modifies a solution.

6. Replacements.

The offspring population created by selection, recombination, and mutation replaces the original parental population. Many replacement techniques such as elitist replacement, generation-wise replacement and steady-state replacement methods are used in GAs.

7. Repeat steps 2–6 until a terminating condition is met.

8. After generating the cyclone image, evaluate the effective and efficient performance and then it gives the optimum predicted tropical cyclone image.

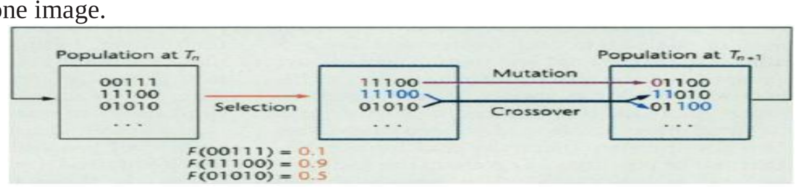


Fig. 3.2: Operation of the Genetic Algorithm

A population of three individuals is shown. Each is assigned a fitness value by the function F. On the basis of these fitnesses, the selection phase assigns the first individual (00111) zero copies, the second (111000) two, and the third (01010) one copy. After Selection, the genetic operator are applied probabilistically; the first individual has its first bit mutated from a 1 to a 0, And crossover combines the second two individuals into two new ones. The resulting population is shown in the box labelled Tn+1.

IV. SYSTEM DESCRIPTION

Figure shows a forecasting model to predict the tropical cyclone intensities. This model uses a Genetic algorithm to estimate the significance of every features of tropical cyclone from observation. A time series adjustment used to improve the similarity calculations among tropical cyclone samples based on their observation sequence.

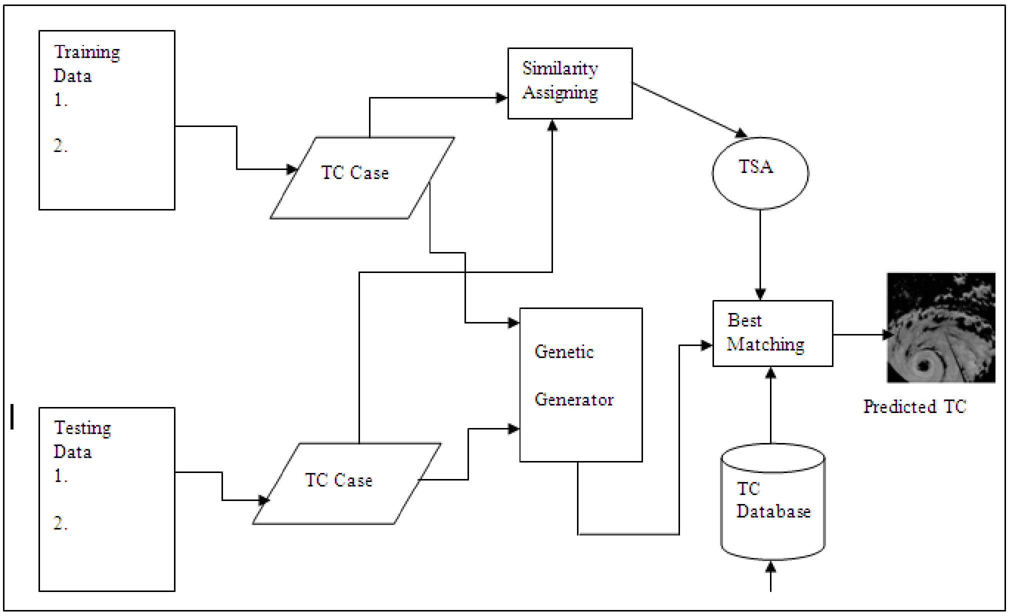


Fig. 4.1: System Architecture

For every observation sample, either from training dataset or the testing dataset it is fed into genetic generator to get a set of most appropriate weights for the attributes. The dataset used in this study is collected from Hong Kong Observatory including 10 years tropical cyclone statistics from 1994 to 2003.Five representative attributes are involved in the dataset: Time,intensity,position(longitude, latitude),speed and MSLP(mean sea level pressure),divide them into three categories as time series, positional and numerical attributes.

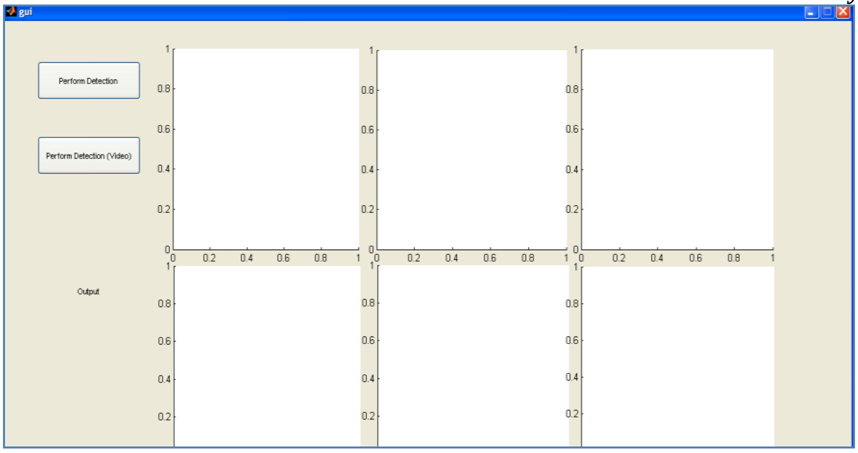
4.1 Components of System Overview

Training Data- Samples used to train the Genetic generator.
Testing Data- Samples used to evaluate the performance of the designed system.
TC Case (attribute)- A database to store tropical cyclone information according to their attributes.
Similarity Assigning - The module in which the similarity measures functions are carried out to do the retrieval.
Genetic Generator- Determine the weight of each attributes.
Time-series Adjustments- A similarity measures to indicate the time series sensitive for tropical cyclone retrieval.
Best Matching- Matching module to find most like samples from the database on the proposed similarity measures functions.
Predicted Intensity-Prediction result from the observation samples of testing dataset.

V. RESULT

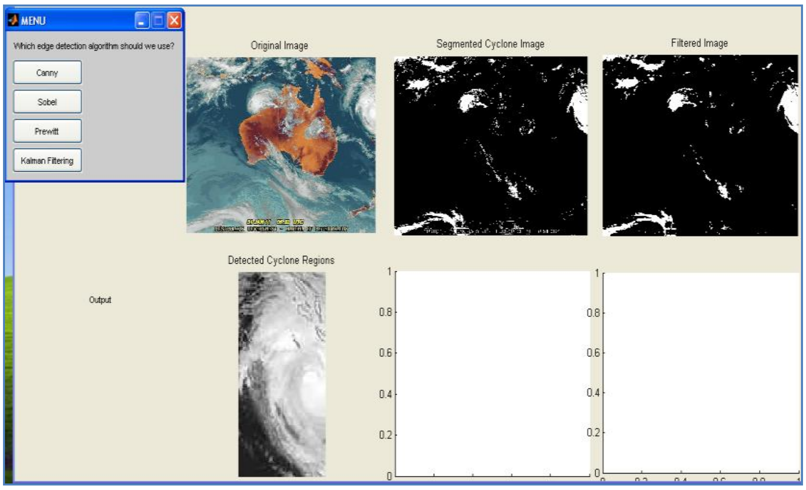
In order to determine an acceptable quality of intelligence, diverse and voluminous data have to be combined, integrated, and forecast. In this approach, we propose an efficient method for large TC database. The advantage of this method is that it transforms a initial population to generate new population by using genetic algorithm that are easier to process and fast to compute; this substantially reduces the computational complexities. Several techniques have been presented in order to illustrate the correctness of the proposed approach. Further, we perform a mechanism to enumerate the better efficiency and effectiveness of the proposed approach. We tried to focus more on time taken to response the forecast track and accuracy for TC forecast. We performed experiments to highlight some important aspects of information. We also implement this proposed scheme to different types of image such as JPEG, PNG and TIFF image formats. And again rotated TC image database which contribute the result analysis with their attribute as output.

Snapshot 5.1 shows Main GUI which is to be executed, after extracting gui.m file on matlab click on RUN and see the output which tells that either perform Detection for TC database image or Perform Detection (video) for TC video database**.**



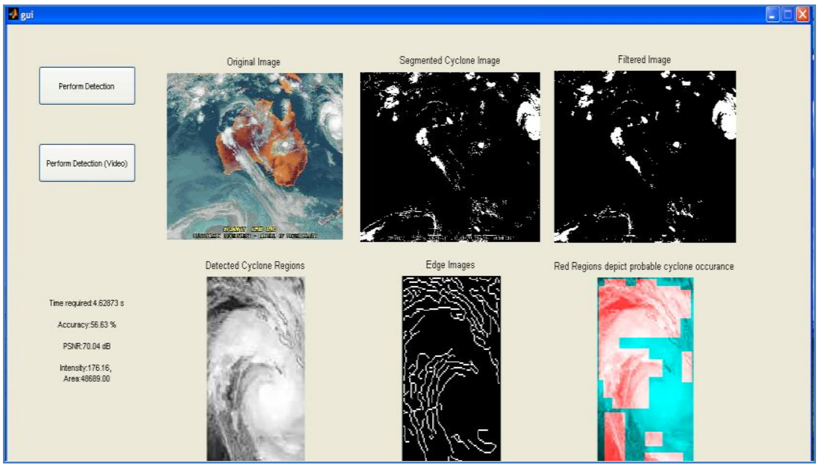
Snapshot 5.1: Displaying GUI

After clicking on Perform Detection button it tells user to pick an image file from TC database and after clicking on perform detection (video) button it tells user to pick an video file from TC database. Snapshot 5.2 shows various GUI which shows original Image, Segmented Cyclone Image, and Filtered Image with displaying menu window which ask to enter any four edge detection algorithm (one at a time).



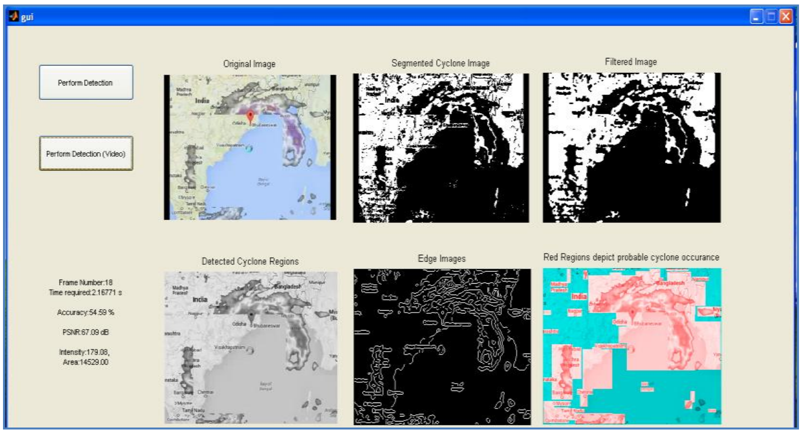
Snapshot 5.2: MENU & GUI Display

Snapshot 5.3 shows TC eye detection for TC database image. It shows different TC eye detection window with respect to edge filter which user select.



Snapshot 5.3: Perform Detection (Image)

Snapshot 5.4 shows Part of GUI to select video from TC database and shows various parameters as output**.**



Snapshot 5.4: Perform Detection (Video)

VI. RESULTS ANALYSIS

Figure shows the accuracy analysis for different types of image. We can conclude that the PNG image format has gives better accuracy than the other two.

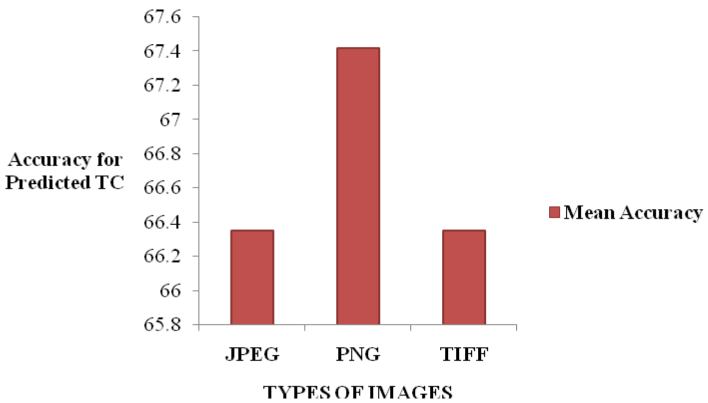


Fig. 6.1: Accuracy Analysis

This section gives the performance evaluation between proposed method and various Schemes by using different input satellite images of TC against Time Cost. We can conclude that proposed scheme is better and efficient in term of Execution time required.

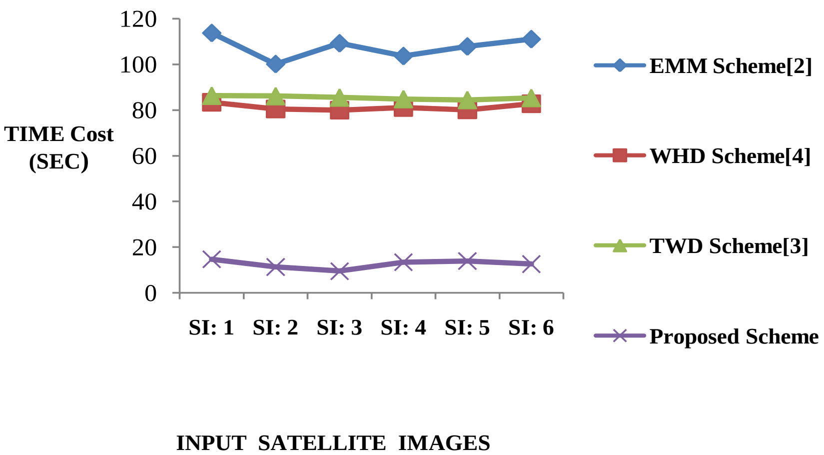


Fig. 6.2: Time Cost Comparison

This section shows detailed experiment using a selection of six satellite images from official website and calculates average matching accuracy. It is observed that Proposed Scheme being more accurate than AFM/TWD Scheme, WHD Scheme.

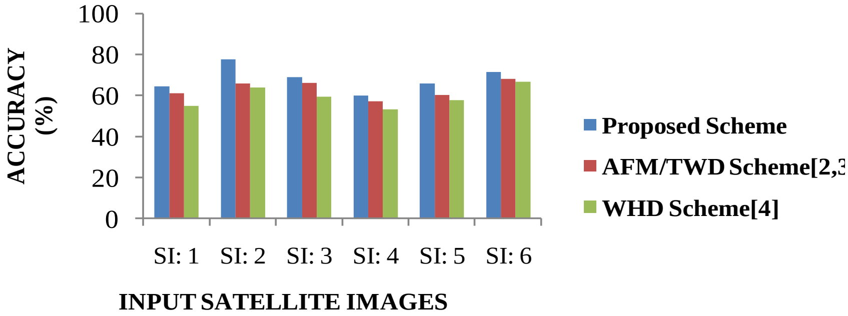


Fig. 6.3: Accuracy (%) Comparison

VII. CONCLUSION

Experimental results show that the implemented algorithm gives satisfactory performance for Speed and Accuracy. The contributions and characteristics of the proposed approach are summarized below:

1. Efficiency: Easy to implement and fast to compute.

2. **Higher PSNR:** Proposed approach provides higher PSNR and Accuracy as compared to the algorithm Implemented by YIP & WONG Scheme and other several schemes.

3. Improvement in **Speed** and **accuracy.**

4. Flexible platform for all suitable images.

5. Best (optimum) TC detection (eye) process.

6. Discovering new approaches in designing reformative forecasting models to predict the intensity of tropical cyclone using methodologies at different levels that are more reliable for the collected data types, more efficient and effective in term of predicted accuracy & computational cost, and more scalable to future system expansion.

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