Tropical Cyclone Intensity Estimation by Feature Extraction Techniques Using Satellite Imagery

Chinmoy Kar
Techno International New town, Kolkata, India
E-mail: chinmoy.kar@tint.edu.in

Thesis Summary

Keywords: tropical cyclone, intensity estimation, feature extraction, machine learning classifiers

Received: July 14, 2024

This article provides an overview of the author's doctoral dissertation entitled "Intensity Estimation of Tropical Cyclones by Feature Extraction Techniques". The dissertation introduces feature extraction techniques applied to satellite images of tropical cyclones to extract meaningful features. Additionally, the dissertation explores the use of various machine learning classifiers to determine the intensity class of a tropical cyclone based on these features.

Povzetek: Predstavljene so metode za ocenjevanje intenzivnosti tropskih ciklonov z uporabo ekstrakcije značilnosti iz satelitskih slik. Uporabljene so metode strojnega učenja za razvrščanje slik ciklonov glede na intenziteto, pri čemer sta se večplastni perceptron in naključni gozdovi izkazala za najučinkovitejša.

1 Introduction

Tropical cyclones (TCs) are natural hazards that cause massive damage near the landfall area. Early warning through TC intensity assessment helps to mitigate this damage. The wind field analysis and pattern matching-based methods. Wind field attributes are combined with best track data to determine the intensity of a TC. Pattern matching-based methods, such as the Dvorak Technique [1] and Advance Dvorak Technique [2], involve analyzing TC images to find T numbers based on the cloud pattern, which are then used to assess the TC intensity and its impact. In addition to these methods, numerical weather prediction (NWP) models, which rely on geophysical properties like air pressure, wind speed, and sea surface temperature, are used for TC intensity estimation. Image processing-based approaches are also utilized to estimate TC intensity based on the cloud pattern, curved bands, and shear structure of the cloud. In recent years, limited applications of deep learning algorithms have been used for TC intensity estimation [3].

The traditional methods for estimating cyclone intensity rely on geophysical properties and require human intervention for analysis. The main goal of this doctoral dissertation was to investigate various feature extraction methods and a fusion technique for cyclone intensity estimation. Furthermore, this research focuses on studying cyclones occurring over the North Indian Ocean (NIO) basin, aiming to develop image recognition-based techniques that can mitigate the damage caused by cyclones.

2 Methods

The subsequent subsections provide a summary of the authors' contributions.

2.1 Development of unique feature vector from satellite images [8, 11]

A method has been proposed to create a unique feature vector (UFV) from TC images by using rotation-size invariant patterns. The main features of an image, such as the center of gravity [11], density, and eccentricity, are utilized to identify rotation and size invariant patterns. Any method that estimates intensity based on TC images heavily relies on rotation-size invariant patterns and region of interest (RoI) images.

2.2 TC image classification using UFV and machine learning classifiers [5,7]

The intensity of tropical cyclones (TC) is estimated using the UFV and machine learning techniques for classification. Various machine learning classifiers are utilized to categorize TC images into seven intensity levels. The Multilayer Perceptron and Random Forest classifiers showed superior performance compared to other classifiers.

2.3 TC Intensity estimation by local binary pattern (LBP) and its variant [4,10]

The Multilayer Multi-block LBP (MMLBP) method is an extension of the Completed LBP (CLBP). It extracts important features in a step-by-step manner, organizing the input image into fixed-size blocks (3×3 pixels) to create center pixels using the CLBP. These central pixels serve as the basis for the next layer, which is further divided into 3×3 blocks to generate central pixels. The central pixels from each layer are then collected and combined into a feature vector.

2.4 Fusion based technique for intensity estimation [6]

A feature fusion and machine learning-based classification techniques to estimate the intensity of Tropical Cyclones (TC). Geometric features, Haralick features, and Multi-Block LBP features from TC images.

3 Discussion

The doctoral research involved analyzing Infrared (IR), Visible (VIS), and Water Vapor (WV) TC images of seven classes: Super Cyclone Storm, Extremely Severe Cyclonic Storm, Very Severe Cyclonic Storm, Severe Cyclonic Storm, Cyclonic Storm, Deep Depression, and Depression over the North Indian Ocean basin [9]. It was found that the UFV-TC and Random Forest (RF) classifier had an accuracy of 86.66%, which is higher compared to other classifiers. The main advantage of RF classifiers is their effectiveness in multi-class classification. By combining a group of weak individual learners into one strong learner using the ensemble model classifier, the highest accuracy can be achieved. The MMLBP and Random Forest classifier achieved a classification accuracy of 84.66% for feature extraction and feature vector creation from an image. MMLBP generated 819 features, which was then reduced by up to 97.4% using the correlation-based Feature Subset Selection approach. A Min-Max normalization-based fusion method was applied to combine GLCM, MB-LBP, and geometric features. Furthermore, a small set of features was selected from a large feature vector by reducing the original feature vector by 93% using the correlation-based feature subset selection method. The fused feature vector was able to classify TC images of various classes with 93.5% accuracy.

4 Conclusions

The thesis focuses on feature extraction techniques for tropical cyclone (TC) images over the North Indian Ocean (NIO) basin. The rotation-size invariant unique feature vector generation is explored, followed by a classification task to categorize TC images into various classes. Local binary patterns from cloud images are extracted using LBP and a modified LBP algorithm named Multi Block Multi-Layer LBP (MMLBP). Haralick features from TC images are also extracted, and a feature fusion technique is proposed to fuse Haralick features, Multi Block LBP (MB LBP) features, and geometric features. The proposed feature extraction techniques are applied to IR, VIS, and WV satellite images for performance analysis on various satellite images. The study also collects and checks performance towards intensity estimation over the NIO basin. The RF classifier and MMLBP achieve the highest classification accuracy compared to other tree-based classifiers.

The thesis presents several limitations, including the lack of standard TC databases for the NIO basin, difficulty in gathering accurate TC images for cyclonic seasons, and a lack of comparative analysis between similar models due to limited cyclone image feature extraction-based intensity estimation techniques. The study was tested using NIO basin images and a limited dataset of other basins. The Future work includes addressing the need for labelled TC images, using multispectral images for intensity estimation, testing the model on Pacific and Atlantic basins, and incorporating additional techniques for extracting and combining features to improve the TC estimation model for the NIO basin.

Acknowledgment

I would like to express my gratitude to my supervisor, Prof. (Dr.) Sreeparna Banerjee, Maulana Abul Kalam Azad University of Technology, West Bengal, India.

References

[1] Dvorak, V. F., Tropical cyclone intensity analysis using satellite data. In NOAA Technical Report NESDIS, 11, US Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service: Washington, DC, USA, 1–47, (1984).

[2] Olander, T. L., & Velden, C. S., The advanced Dvorak technique (ADT) for estimating tropical cyclone intensity: Update and new capabilities. Weather and Forecasting, 34(4), 905-922, (2019).

[3] Pradhan, R., Aygun, R. S., Maskey, M., Ramachandran, R., & Cecil, D. J. (2017). Tropical cyclone intensity estimation using a deep convolutional neural network. IEEE Transactions on Image Processing, 27(2), 692-702.

[4] Kar, C., Banerjee, S., Intensity prediction of tropical cyclone using multilayer multi-block local binary pattern and tree-based classifiers over North Indian Ocean, Computers & Geosciences, 154, 1-14, (2021).

[5] Kar, C., Banerjee, S., Tropical cyclone intensity classification from infrared images of clouds over Bay of Bengal and Arabian Sea using machine learning classifiers. Arabian Journal Geosciences 14, 683 (2021).

[6] Kar, C., Banerjee, S., Tropical Cyclones Intensity Estimation by Feature Fusion and Random Forest Classifier Using Satellite Images. Journal of Indian Society Remote Sensing 50, 689–700 (2022).

[7] Kar, C., Kumar, A., Banerjee, S., Tropical cyclone intensity detection by geometric features of cyclone images and multilayer perceptron. SN Applied Sciences 1, 1099 (2019).

[8] Kar, C., Banerjee, S., An image processing approach for intensity detection of tropical cyclone using feature vector analysis. International Journal of Image and Data Fusion, 9(4) 338-348 (2018).

[9] Kar, C., Banerjee, S., Intensity Estimation of Tropical Cyclone using Different Satellite Imagery and Random Forest Classifier, 2022 IEEE Region 10 Symposium Mumbai, India, 2022, pp. 1-5.

[10] Kar, C., Banerjee, S. Tropical Cyclones Classification from Satellite Images Using Blocked Local Binary Pattern and Histogram Analysis. In Advances in Intelligent Systems and Computing, vol 1248, (2021).

[11] Kar, C., Kumar, A., Konar, D., and Banerjee, S. Automatic Region of Interest Detection of Tropical Cyclone Image by Center of Gravity and Distance Metrics, 2019 Fifth International Conference on Image Information Processing (ICIIP), Shimla, India, 2019, pp. 141-145.