Cyclotrone

Ishvi Garhwal
Sanchit Patidar
Sudhanwa Kaveeshwar

Bachelor of Technology
Acropolis Institute of Technology and Research, Indore

ABSTRACT

Tropical cyclones are among the most dangerous and devastating natural disasters affecting life, property and environment. The use of remote sensing and spatial analysis has significantly increased to manage the on-ground impacts of these disasters with rapid advances in a wide range of data availability and processing techniques. And it have always been a concern of meteorologists, and there are many studies regarding the axisymmetric structures, dynamic mechanisms, and forecasting techniques from the past 100 years. Therefore Cyclone intensity estimation plays a major role in disaster management actions. The existing model that is used by ISRO for Cyclone intensity estimation is the HWRF (Hurricane Weather Research and Forecast) model which has some disadvantages. HWRF Model is run four times a day by NCEP (National Centre for Environmental Prediction) with on-demand input. But INSAT3D observations are available at every 15 minute interval, therefore by using the HWRF model we lose a tremendous amount of data that can be utilized to understand the structural changes at every half hour interval. This calls for the need of a model which can compute intensity of the Cyclone IR imagery regardless of the centre determination, which can be useful to understand the instantaneous structural changes in the initial stages of the cyclonic event for making strong predictions. This paper reviews studies on cyclones, various machine learning models which is provided by government on predicting cyclone intensity and others, and over solution for this problem.

KEYWORDS: Machine learning, Transfer Learning, TensorFlow, INSAT 3D

INTRODUCTION

Tropical cyclones are large-scale rotary storms that form over warm ocean waters in tropical regions, and their outer circulations can extend more than 1000 km from the storm centre. The mature tropical cyclone (called a hurricane in the Atlantic and a typhoon in the Pacific), possesses sustained surface winds of 33 ms' or higher, and represents the most intense phase in the tropical cyclone life cycle. It’s extremely high winds, torrential rainfall, and storm surge make the hurricane one of the most life threatening and destructive natural phenomena on earth. The less intense tropical cyclones are called tropical depressions (rotary winds less than 17 m s) and tropical storms (rotary winds less than 33 m s-1), but they too carry destructive potential and are frequently associated with heavy precipitation.[2]

The north Indian Ocean accounts for 6% of the global tropical cyclones annually. Despite the small fraction, some of the most devastating cyclones have formed in this basin, causing extensive damage to the life and property in the north Indian Ocean rim countries. There is a two-way ocean-atmosphere interaction during cyclones in the north Indian Ocean. High sea surface temperatures (SSTs) of magnitude 28–29 °C and above provide favorable conditions for the genesis and evolution of cyclones in the Arabian Sea and the Bay of Bengal. On the other hand, cyclones induce cold and salty wakes. Cyclone induced cooling depends on the translation speed of the cyclone, wind power input, ocean stratification, and the subsurface conditions dictated by the ocean eddies, mixed layer, and the barrier layer in the north Indian Ocean.[1]

LITRETURE REVIEW

Title of project	**Name of author**	**Year of public-ation**	**Description**	**Limitation**	**Improvement**
Tropical Cyclone Intensity Estimation from Geostationary Satellite Imagery Using Deep Convolutional Neural Networks	Chong Wang; Gang Zheng; Xiaofeng Li; Qing Xu; Bin Liu; Jun Zhang [6]	2021	The research paper proposes a deep learning approach to estimate tropical cyclone intensity from satellite imagery, but it has limitations, such as sensitivity to environmental changes and unclear generalizability. Possible improvements include incorporating	The paper proposes a deep learning approach to estimate tropical cyclone intensity from satellite imagery but has limitations. The proposed method may be sensitive to environmental changes, and the model's accuracy may vary depending on the quality and resolution of the satellite	One potential improvement to the proposed method is to incorporate additional features, such as atmospheric data or sea surface temperatures, to improve the model's sensitivity to environmental changes. Additionally, collecting and using high-quality and

			additional features, using high-quality imagery, and further testing on a wider range of storms.	imagery used. Additionally, the model's performance on a wide range of tropical cyclones is not comprehensively analyzed, which may limit its generalizability to new storms.	high-resolution satellite imagery can enhance the accuracy of the model's predictions. Further evaluation of the model's performance on a wider range of tropical cyclones would also help to increase its generalizability.
Tropical Cyclone Winds from WindSat, AMSR2, and SMAP: Comparison with the HWRF Model	Andrew Manaster, LucreziaRicciardulli and Thomas Meissner [7]	2021	The paper "Tropical Cyclone Winds from WindSat, AMSR2, and SMAP: Comparison with the HWRF Model" compares satellite-derived winds from WindSat, AMSR2, and SMAP with a hurricane forecast model (HWRF). The paper shows that WindSat and AMSR2 provide more accurate wind estimates than SMAP and that the HWRF model	The paper does not evaluate the performance of satellite-based methods on storms of varying intensities. Additionally, the study is limited to a specific region and time frame, which may affect the generalizability of the findings.	Future studies could evaluate the performance of satellite-based wind estimates on a wider range of tropical cyclones to assess their generalizability. The use of machine learning algorithms or assimilation techniques could also improve the accuracy of satellite-based wind estimates. Incorporating additional satellite data or ground-based observations

			outperforms all three satellite-based methods in wind estimation for tropical cyclones.		could further enhance the accuracy of wind estimation from satellite imagery.
Strategies for Assimilating High-Density Atmospheric Motion Vectors into a Regional Tropical Cyclone Forecast Model (HWRF)	William E. Lewis, Christopher S. Velden and David Stettner [9]	2020	The paper "Strategies for Assimilating High-Density Atmospheric Motion Vectors into a Regional Tropical Cyclone Forecast Model (HWRF)" presents a method for assimilating high-density atmospheric motion vectors into a hurricane forecast model (HWRF) to improve the accuracy of storm track and intensity predictions. The paper compares different assimilation strategies and shows that the method significantly improves forecast accuracy.	The paper does not evaluate the impact of assimilating atmospheric motion vectors on storm surge or rainfall predictions, which are also critical for tropical cyclone forecasting. Additionally, the study is limited to a specific region and time frame, and the generalizability of the findings to other storms or regions is unclear.	Future studies could investigate the impact of assimilating atmospheric motion vectors on storm surge or rainfall predictions, which are also essential for tropical cyclone forecasting. Expanding the study to other regions and time frames could further evaluate the generalizability of the assimilation method. The use of other data assimilation techniques or the incorporation of additional satellite or ground-based observations could also improve forecast

					accuracy.
Deep-PHURIE: deep learning based hurricane intensity estimation from infrared satellite imagery	Muhammad Dawood, Amina Asif and Fayyazul Amir AfsarMinhas [11]	2019	The paper "Deep-PHURIE: Deep Learning Based Hurricane Intensity Estimation from Infrared Satellite Imagery" proposes a deep learning approach for estimating hurricane intensity from infrared satellite imagery. The paper shows that the proposed method outperforms traditional methods and demonstrates high accuracy in hurricane intensity estimation, even in low-light conditions.	The paper only uses infrared satellite imagery for hurricane intensity estimation, which may limit the accuracy of the model in certain situations. The study is also limited to a specific region and time frame, and the generalizability of the findings to other storms or regions is unclear. The paper does not provide a comprehensive analysis of the model's performance on a wide range of hurricanes.	Future studies could investigate the use of additional satellite data, such as microwave or visible imagery, to improve the accuracy of hurricane intensity estimation. Evaluating the model's performance on a wider range of storms and regions could further increase its generalizability. Incorporating additional features, such as atmospheric or oceanic data, could also enhance the model's sensitivity to environmental changes.
Deepti: Deep-Learning-Based Tropical Cyclone	ManilMaskey, Rahul Ramachandran, Muthuk-umaranRamasu-	2020	The paper "Deepti: Deep-Learning-Based Tropical Cyclone	The paper only uses satellite imagery for tropical cyclone intensity	Future studies could investigate the use of additional satellite data,

Intensity Estimation System	bramanian, IkshaGurung,Brian Freitag, Aaron Kaulfus [12]		Intensity Estimation System" proposes a deep learning approach for estimating tropical cyclone intensity from satellite imagery. The paper shows that the proposed method outperforms traditional methods and demonstrates high accuracy in tropical cyclone intensity estimation, even in low-light conditions.	estimation, which may limit the accuracy of the model in certain situations. The study is also limited to a specific region and time frame, and the generalizability of the findings to other storms or regions is unclear. The paper does not provide a comprehensive analysis of the model's performance on a wide range of tropical cyclones.	such as microwave or visible imagery, to improve the accuracy of tropical cyclone intensity estimation. Evaluating the model's performance on a wider range of storms and regions could further increase its generalizability. Incorporating additional features, such as atmospheric or oceanic data, could also enhance the model's sensitivity to environmental changes.

MOTIVATION

Cyclones are a severe weather phenomenon that can have devastating consequences, including loss of life and damage to infrastructure. Accurate and timely predictions of cyclone intensity are crucial for mitigating the impact of these events. However, traditional methods for predicting cyclone intensity have limitations, and newer approaches are needed to improve accuracy and timeliness.

The INSAT-3D dataset provides high-resolution satellite imagery and atmospheric data that can be used to develop new methods for cyclone intensity predictions. Utilizing this dataset could lead to the development of more accurate and timely cyclone intensity predictions, which could aid in disaster management and resource allocation.

Additionally, it could contribute to the development of new techniques for utilizing satellite data in weather forecasting and disaster management. The INSAT-3D dataset could be a valuable resource for improving our understanding of cyclone dynamics and the atmospheric conditions that lead to cyclone formation and intensification.

Overall, the potential to make a significant impact on disaster management and improve our ability to predict and prepare for severe weather events.

METHODOLOGY

Our project is mainly divided into three modules:

1. Extracting dataset and preprocessing
2. ML model building
3. Training and testing
4. Providing a frontend

1. Extracting dataset and preprocessing
   Dataset is extracted by INSAT-3D satellite API in JSON format, which is then converted into Pandas DataFrame. This data se then preprocessed to get rid of any image which do not show signs of any cyclone.

2. ML model building
   This deep learning model is build using transfer learning using imagenet Which uses the concept of using a pre trained model and change it according to the use case

3. Training and testing
   The model is trained using the INSAT dataset available on the Kaggle.
   The data was divided into the 7:3 ratios where 70% was training data and 30% was testing data.
   Training was done for 50 epochs which resulted in accuracy ~ 83%.

4. Providing a frontend
   To interact with the trained model a user interface was build using HTML, CSS and JavaScript. The model is deployed on server on Heroku. Using python as the backend technology.

RESULT

The model was trained as tested successfully and deployed. It was able to produce result with accuracy of 83% to 87% on live data.

CONCLUSION

In conclusion, tropical cyclones pose a significant threat to life, property, and the environment, particularly in the north Indian Ocean basin. Remote sensing and spatial analysis techniques have enabled meteorologists to better manage the impacts of these disasters by providing a greater understanding of the structural changes in the initial stages of the cyclonic event. The existing HWRF model used by ISRO for cyclone intensity estimation has some limitations, including a loss of a tremendous amount of data available at every 15-minute interval. This has led to the need for a model that can compute the intensity of the cyclone using IR imagery regardless of the center determination, which would be useful in understanding the instantaneous structural changes for making stronger predictions. Several studies have explored machine learning models for predicting cyclone intensity and other methods to improve existing models. Future studies could focus on incorporating additional features and satellite data, using high-quality imagery, and testing on a wider range of storms to enhance the accuracy and generalizability of these models. Overall, advances in remote sensing and spatial analysis techniques have significant potential to improve disaster management strategies and reduce the impact of tropical cyclones in the future.

REFRENCES

[1] Vineet Kumar Singh, M.K. Roxy, “A review of ocean-atmosphere interactions during tropical cyclones in the north Indian Ocean” 2022

[2] Michael T. MontgomeryBrian F. Farrell, “Tropical Cyclone Formation”,1993

[3] V. Dvorak, "Tropical cyclone intensity analysis and forecasting from satellite imagery", 1975.

[4] S. Giffard-Roisin, M. Yang, G. Charpiat, C. K. Bonfanti, B. Kégl and C. Monteleoni, "Tropical cyclone track forecasting using fused deep learning from aligned reanalysis data", 2020.

[5] S. Kim et al., "Deep-hurricane-tracker: Tracking and forecasting extreme climate events", 2019.

[6] Chong Wang; Gang Zheng; Xiaofeng Li; Qing Xu; Bin Liu; Jun Zhang, "Tropical Cyclone Intensity Estimation from Geostationary Satellite Imagery Using Deep Convolutional Neural Networks", 2021

[7] Andrew Manaster,LucreziaRicciardulliandThomas Meissner, "Tropical Cyclone Winds from WindSat, AMSR2, and SMAP: Comparison with the HWRF Model", 2021

[8] J. S. Combinido, J. R. Mendoza and J. Aborot, "A convolutional neural network approach for estimating tropical cyclone intensity using satellite-based infrared images", 2018.

[9] Zhao Chen, Xingxing Yu "A Novel Tensor Network for Tropical Cyclone Intensity Estimation", 2020

[10] William E. Lewis,Christopher S. VeldenandDavid Stettner, "A Novel Tensor Network for Tropical Cyclone Intensity Estimation", 2020

[11] Fayyazul Amir AfsarMinhas, Muhammad Dawood and Amina Asif, "Deep-PHURIE: deep learning based hurricane intensity estimation from infrared satellite imagery", 2019

[12] IkshaGurung, Brian Freitag, Aaron KaulfusManilMaskey, Rahul Ramachandran and MuthukumaranRamasubramanian, "Deepti: Deep-Learning-Based Tropical Cyclone Intensity Estimation System", 2020

[13] X. Zhang, T. Wang, G. Chen, X. Tan and K. Zhu, "Convective clouds extraction from Himawari–8 satellite images based on double-stream fully convolutional networks", 2020.