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Cyclone Intensity Estimation System using Satellite Images

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Abstract: *Tropical cyclones are big storms that can cause a lot of damage. Cyclone intensity estimation plays a vital role in disaster preparedness, response, and mitigation strategies. This paper introduces a novel approach to estimating cyclone intensity using satellite images through a Convolutional Neural Network (CNN) model. Unlike previous methods, we employ advanced techniques such as histogram analysis for feature extraction and adaptive thresholding for image segmentation using mean, Gaussian, and Otsu methods. The model also predicts potential coverage distance. Additionally, we present a user-friendly visualization portal, a pioneering effort in this field, which displays the deep learning output along with contextual information for end-users*

Keywords: Satellite Images, Convolutional Neural Networks, Cyclone Intensity Estimation, Deep Learning

I. INTRODUCTION

Cyclones are powerful, swirling storms that form over warm ocean waters and can cause widespread destruction when they make landfall. Natural disasters, casualties, and property destruction could result from this. [1] These storms start as tropical disturbances, which are clusters of thunderstorms over warm ocean waters. As these disturbances move across the ocean, they can intensify into tropical depressions, then tropical storms, and eventually into cyclones, hurricanes, or typhoons, depending on their location.

From 1998 to 2017, storms had an impact on about 726 million people. According to a recent analysis, the main reason for at least 10,000 fatalities in Odisha in 1999 was a cyclone. Cyclone detection will therefore benefit remote sensing organizations and give them plenty of time to prepare for and handle such a dangerous circumstance.[1] Being properly able to accurately diagnose the intensity of a tropical cyclone is essential for disaster preparedness and response.

In this paper, we present a novel approach for cyclone intensity estimation using satellite imagery and machine learning techniques. Leveraging convolutional neural networks (CNNs) and advanced machine learning algorithms, our model aims to objectively identify the intensity of tropical cyclones based on features extracted from satellite images. By analyzing patterns and structures within the imagery, the CNN model can provide real-time estimates of cyclone intensity. With our method, we can give fast and accurate estimates of cyclone strength, which can help people in charge of emergency responses make quick decisions. Basically, in our system, we employ a systematic preprocessing approach to ensure accurate model predictions. The preprocessing steps involve converting the input satellite images to grayscale, resizing them, and then normalizing the pixel values also extracting the features using thresholding and histogram analysis. This preprocessing step is crucial for standardizing the input data and improving the efficiency of our convolutional neural network (CNN) model. Once the preprocessing is completed, we feed the processed images into our CNN model for training to teach our system how to guess cyclone intensity from these images. We use all parts of CNN to make our guesses more accurate, and we keep track of how well it's learning. This helps us build a system that can predict cyclone intensity reliably, which is important for keeping people safe during storms.[2,3,4]

In assessing the performance of our cyclone intensity estimation system, we primarily focus on evaluating the accuracy of our model. Accuracy serves as a key metric to measure how well our system performs in correctly predicting cyclone intensity levels.

We introduce an innovative web-based interface that allows users to input geographical coordinates and retrieve real-time cyclone intensity information for a specified location. This user-friendly platform aims to enhance accessibility to vital information for stakeholders, including emergency responders, policymakers, and the public. By providing easy access to accurate cyclone intensity estimates, we empower individuals and organizations to make informed decisions and take proactive measures to mitigate the impact of cyclones on vulnerable communities.

The study also evaluates the system's cost-effectiveness and scalability. The scalability of the system is evaluated by testing the system's ability to handle a large number of data inputs.This paper presents a comprehensive approach to cyclone intensity estimation, combining state-of-the-art CNN models with a user-friendly website interface for cyclone classification. By leveraging cutting-edge technology and user-centric design principles, our system aims to enhance cyclone monitoring and response efforts, ultimately contributing to the resilience of communities vulnerable to cyclonic events. Furthermore, chapters include a literature survey, proposed system, flowchart, future scope, results and conclusion for the system.

II. LITERATURE SURVEY

Deepti: Deep Learning Based Tropical Cyclone Intensity Estimation System, Manil Maskey ,Rahul Ramchandran, Mutthukumaran Ramasubramanian ,Iksha Gurung , Brian Freitag ,Aaron Kaulfus ,Drew Bollinger,Daniel j. Cecil, Jeffrey Miller, 2020

This study introduces a groundbreaking deep-learning model for accurately estimating tropical cyclone intensity using infrared satellite imagery. With a root mean squared error of 13.24 knots, the model surpasses existing techniques, enhancing disaster preparedness. A unique visualization portal provides real-time outputs and contextual information for end users. The deployment, following an end-to-end machine learning lifecycle, ensures scalability on Amazon Web Services, contributing to improved disaster readiness. The model's transparency is enhanced through in-depth decision analysis using class activation maps. Overall, this research represents a significant advancement in tropical cyclone intensity estimation, with implications for future disaster management improvements.[5]

Deep learning Based Cyclone Intensity Estimation Using INSAT-3D IR Imagery: A Comparative Study, Harshal Dharpure ,Tejal Mohod, Radhika Malani,Janhavi Chandak, Atharva Belge, Preet Ambadkar, Prof Ankita Pande,2023

This paper compares deep learning methods with traditional ones for predicting tropical cyclone strength using satellite images. Deep learning models, especially the CNN-RNN combo, perform better. Data from INSAT-3D and IMD (2014-2019) are used. CNNs are explained briefly, along with AlexNet's potential for better accuracy. Overall, the goal is to enhance early warning systems for severe weather using advanced image analysis.[6] By leveraging geometric features in cyclone images and employing multilayer perceptron, CNN, and AlexNet models, the system seeks to automate cyclone estimation processes, reducing timing complexities and increasing efficiency.

Cyclone Intensity Estimation Based on Deep Learning Utilizing INSAT-3D Data, Deshna Jain, Esha Mathur, Garima Mathur, Priti Shukla, Praveen Bhanodia, 2022

This proposed system uses infrared(IR) images, which are subjected to two separate models: one for classifying tropical storms and the other for estimating them. In this project typhoon satellite imagery is analysed using deep learning(CNN)[7] This paper introduces an innovative deep learning solution for accurately estimating wind speeds of tropical storms in real-time. An essential aspect of this research involves the creation of a comprehensive and reliable training dataset comprising images and corresponding wind speeds.

Tropical Cyclone Intensity Classification and Estimation Using Infrared Satellite Images With Deep Learning ,Chang-Jiang Zhang, Xiao-Jie Wang, Lei-Ming Ma, and Xiao-Qin Lu,2021

This proposed system uses a new model, TCICENet, for classifying and estimating the intensity of tropical cyclones (TCs) using infrared satellite images. TCICENet has two modules Intensity Classification (TCIC) module: classifies TCs into three categories.TC Intensity Estimation (TCIE) module: estimates the intensity of a TC based on the results from the TCIC module and the satellite images.The model was tested on 1001 TCs from 1981 to 2019 and achieved good performance with an overall root mean square error of 8.60 kt and a mean absolute error of 6.67 kt.[8]

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An effective tropical cyclone intensity estimation model using Convolutional Neural Networks, M. Swarna, N. Sudhakar and N. Vadaparthi, 2020

This paper presents a novel convolutional neural network (CNN) architecture for tropical cyclone (TC) intensity estimation from satellite images. The proposed CNN architecture, called CNN-TCIE, is specifically designed to address these challenges by automatically learning features from the satellite images that are relevant to TC intensity. The authors evaluated CNN-TCIE on a dataset of satellite images of TCs from the North Atlantic basin. They compared their model to several other existing methods, including statistical models, physical models, and other CNN-based models. CNN-TCIE achieved superior accuracy on all metrics, including mean absolute error (MAE) and root mean square error (RMSE). Additionally, CNN-TCIE was significantly faster than other methods, making it suitable for real-time applications. Overall, this paper presents a novel and effective CNN architecture for TC intensity estimation from satellite images. CNN-TCIE achieves high accuracy with reduced computation time, making it a promising tool for operational forecasting.[9]

III. PROPOSED SYSTEM

In our proposed system, we aim to develop a Cyclone Intensity Estimation System using a Convolutional Neural Network (CNN) model. The system begins by taking input satellite images, which are then converted to grayscale to focus on key features. Subsequently, the images undergo resizing and normalization processes to standardize the input. The normalized images are then converted into arrays of pixels, then we are using the histogram analysis for feature extraction (Histograms are collected counts of data organized into a set of predefined bins. A matrix containing information of an image (i.e. intensity in the range 0-255)[16] and also done adaptive thresholding for image segmentation. This enables us to refine our dataset and create a CSV file containing the preprocessed data.

After preprocessing data, we proceed with essential steps to predict cyclone intensity levels. This involves training a Convolutional Neural Network (CNN) model on preprocessed data to recognize patterns and correlations. We then evaluate the model's performance using validation datasets and analyze results through a confusion matrix. Post-training, we fine-tune the model and make predictions on new data, including cyclone intensity levels and estimated distances.

Proposed Architecture of the System

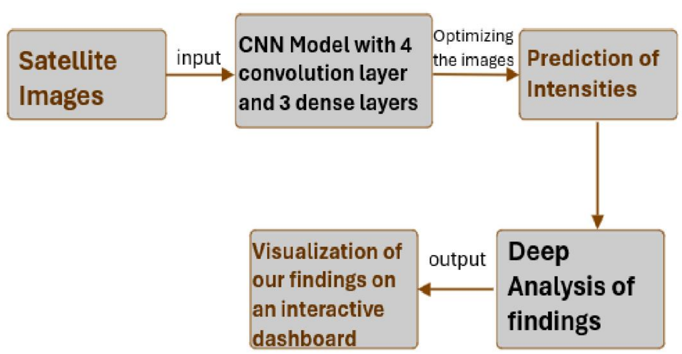

Fig 1.: working flow of proposed system.[10]

architecture designed to deliver accurate predictions and user-friendly interactions. Beginning with the accession of satellite images, the system initiates a meticulous preprocessing phase, which undergo preprocessing steps including grayscale conversion, normalization, resizing, histogram analysis, and adaptive thresholding. The preprocessed data is then converted into pixel arrays, serving as input for a Convolutional Neural Network (CNN) model. This machine learning model is trained to discern patterns and relationships between image features and cyclone intensity levels. Evaluation through a confusion matrix ensures the model's reliability. Post-training, the CNN is utilized to estimate cyclone intensity. With the trained and optimized CNN model, predictions on new or unseen data are made, encompassing cyclone intensity levels, forecasts of landfall countries, and estimates of cyclone distances based on parameters like intensity, longitude, latitude, and wind speed. Additionally, we develop a user-friendly website interface for real-time access to intensity estimations and cyclone insights. Through these processes, our system aims to provide accurate predictions for effective disaster management

Flowchart

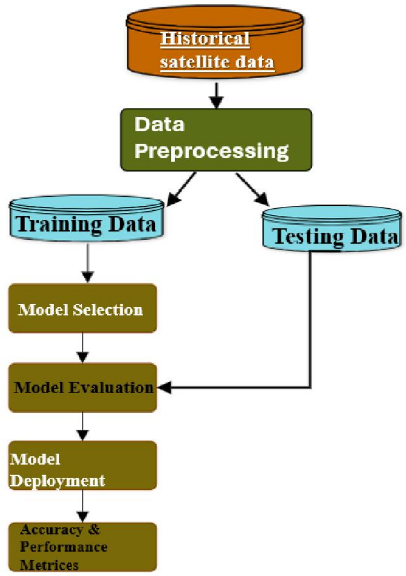

Fig 2.: Flowchart of proposed model[11]

The flowchart of our Cyclone Intensity Estimation System outlines the sequential steps involved in predicting cyclone intensity levels. Firstly the satellite images are provided to model as dataset. at a time we are working with cluster of 498 images. The acquired satellite images undergo preprocessing to enhance their quality and usability. This preprocessing includes grayscale conversion, normalization, resizing, histogram analysis, and adaptive thresholding. The selected model for cyclone intensity estimation is a Convolutional Neural Network (CNN), chosen for its effectiveness in image recognition tasks. we utilize popular libraries such as TensorFlow and Keras to implement the CNN architecture. Additionally, libraries like OpenCV are employed for image preprocessing tasks, enabling seamless grayscale conversion, normalization, and histogram analysis. CNN recognizes patterns and correlations relevant to cyclone intensity levels. Through an iterative training process, the CNN produces a robust model capable of precise predictions. After training, the CNN's performance is evaluated using a validation dataset. Evaluation metrics such as accuracy, precision, recall, and F1-score are calculated to assess the model's effectiveness in predicting cyclone intensity levels. The model is then deployed, and ongoing enhancements are made to refine its accuracy further.

On virtulization platform made, users can input longitude and latitude data, and the system will seamlessly estimate the cyclone intensity also the distance can covered . The system uses a predefined threshold to categorize cyclones into different types based on their intensity levels

IV. RESULTS & DISCUSSIONS

Fig 3.: historical satellite image

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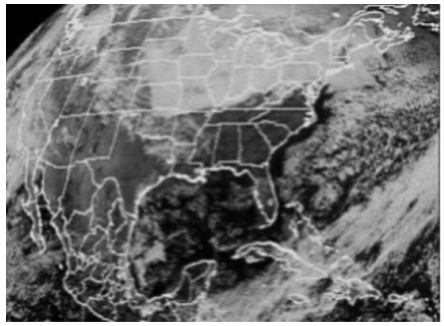


Fig 4.: satellite image after normalization ,gray scaling, resizing

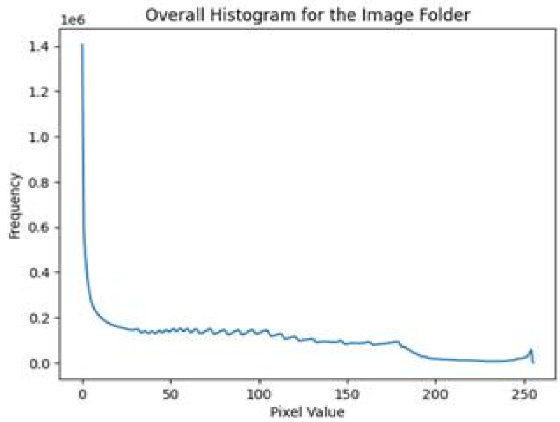
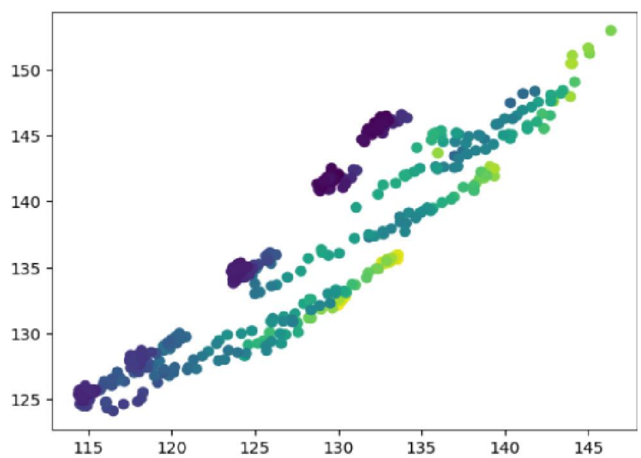


Fig 5.: overall histogram for slelected image folder

Our Cyclone Intensity Estimation System preprocesses satellite images, reducing their size and graying down colors. Additionally, histogram analysis is performed on the overall selected dataset to gain insights into the distribution of pixel intensities, aiding in data understanding and potential feature extraction. Furthermore, various types of thresholding techniques, including mean, Gaussian, and Otsu methods, are applied to segment the images and highlight significant areas of interest. our system provides a user-friendly visualization platform, accessible through a website interface.



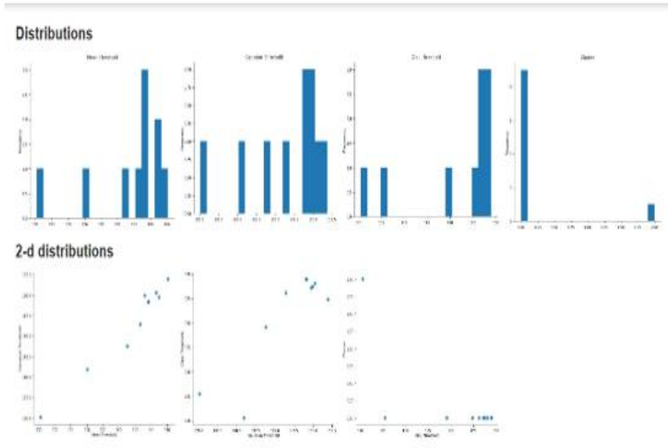


Fig 6.: threshold types present in dataset

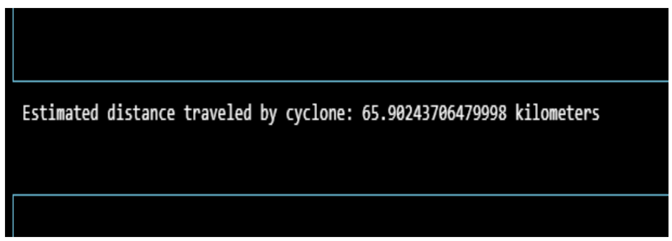


Fig 7.: estimation of distance covered by cyclone

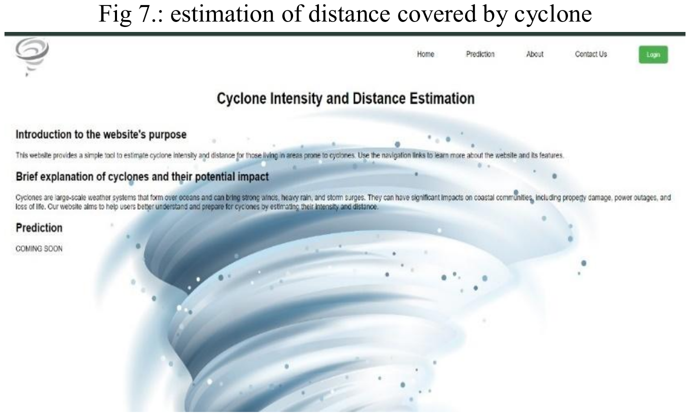


Fig 8.: website dashboard

V. CONCLUSION

In conclusion, this paper aims to find accurate Cyclone Intensity leveraging Convolutional Neural Networks and satellite imagery. Through meticulous preprocessing and a user-friendly interface, the system provides real-time intensity estimations based on geographical coordinates. The CNN model demonstrates effectiveness in learning intricate patterns, resulting in accurate cyclone intensity predictions. With cyclone categorization, our system stands as a valuable tool for disaster management. This research paper contributes a reliable and timely approach to cyclone intensity estimation, by advancing meteorological prediction and enhancing disaster preparedness.

VI. FUTURE SCOPE

In the future, our Cyclone Intensity Estimation System can get better by using more advanced techniques and real-time data. Furthermore, expanding the system's capabilities to include the prediction of other cyclone-related parameters, such as storm surge and precipitation patterns, would provide a more comprehensive understanding of cyclone behavior. we can work with estimation of direction of cyclone.

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