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Deep Learning based Cyclone Intensity Estimation using INSAT - 3D IR Imagery

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Abstract: The discovery of unknown regularities in the existence of cyclones intensity and abnormalities in previous observations. This could help humans interpret changes in the intensity of tropical cyclones. The ideology has inspired us to detect the tropical cyclone using satellite imagery. The system uses deep learning studies and hurricane satellite data to provide an automated technique for cyclone estimation. The existing system requires a longer time complexity to produce tropical cyclone intensity estimation.

Keywords— Deep learning research, Intensity, Estimation, and less timing complexity.

I. INTRODUCTION

Rapidly rotating storms known as Tropical cyclone are characterized by low pressure centers, little low-level atmospheric wind motion, and significant rainfall. Natural disasters, casualties, and property destruction could result from this.

A mature cyclone has an "eye" in the center that is surrounded by a strong wind ring. According to studies, powerful winds causing seawater inundation are responsible for nearly 90% of the damage. Multilayer Perceptron uses the model presented here to train and test the feature values of TC images (MLP). MLP is a supervised learning approach. MLPs are feedforward artificial neural network subsets with at least one hidden layer and input, output, and output layers. with the exception of the input nodes, each node in MLP is modelled as a neuron with a nonlinear activation function.

The backpropagation algorithm is a supervised learning method for training and testing models.

II. SCOPE

This might make it easier for people to understand how tropical cyclone intensity changes. The system offers an automated method for cyclone estimation using deep learning studies and hurricane satellite data.

III. PROBLEM STATEMENT

Tropical cyclones pose one of the biggest risks to property and human life, even in the early stages of development. These dangers vary greatly, and each one has the potential to seriously harm both people and property. Thunderstorms, storm surges, high winds, flash floods, and tornadoes. These dangers, when combined, greatly increase the possibility of fatalities and property damage.

IV. RELATED WORK

Some related research in estimating wind speed from satellite images is discussed here, along with existing portals that provide real-time tropical cyclone information. In addition, we provide background information on the convolutional neural network, which serves as the foundation of our deep learning model.

1. Dvorak Technique

The Dvorak method is a cloud pattern recognition method that is based on a model of tropical cyclone development and collapse. It was developed and tested for the first time in 1969 to monitor storms in the western North Pacific. This methodology makes use of satellite imagery obtained from polar satellites.

Orbits to characterize tropical storm development (hurricanes, cyclones, and typhoons). Using visible spectrum images, observe the sea during the thermal images during the day and daytime images at night. The technology uses satellite imagery to identify patterns in observed storm structure, assisting in the location and measurement of eyes. Storm ferocity. It does not measure or predict wind, pressure, or other hurricane-related weather parameters, but rather

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serves as a guide for assessing storm intensity and potential intensification. It also helps to be close to the authorities when it comes to evacuation plans. Local residents are crucial.

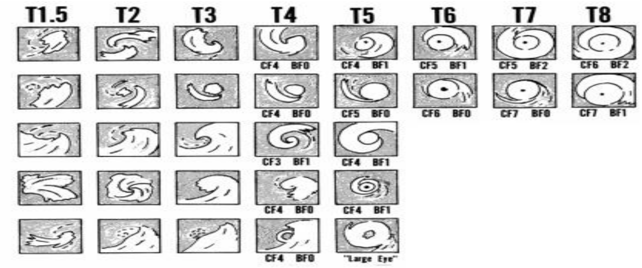

Fig. 1: Dvorak's illustration of common development patterns and corresponding intensities.

2. Advanced Dvorak Technique

The Advanced Dvorak Approach, developed by Olander and Velden as an extension of the manual Dvorak technique, uses satellite imagery as input to an automated algorithm that returns a T-number. ADT has also been improved with the addition of passive microwave data, aircraft observations, and improved tropical cyclone centering, all of which are critical components of the automated process. Although the ADT outperforms the manual Dvorak technique, model performance suffers with smaller storms with more erratic cloud distribution. Empirical thresholds are thus maintained to limit how much cyclone strength shifts over time.

3. Convolutional Neural Network

Convolutional Neural Network, is a type of artificial neural network that has revolutionized the field of computer vision and image processing. It is widely used in various applications such as object recognition, image segmentation, face detection, and many others. The CNN architecture is based on the biological structure of the visual cortex of the human brain. It comprises of several layers, including the input layer, convolutional layer, pooling layer, and fully connected layer. The input layer takes the raw data in the form of an image, and the convolutional layer applies a set of filters to it. The filters are used to detect various features in the image, such as edges, corners, and shapes. The output of the convolutional layer is then passed through the pooling layer, which reduces the dimensionality of the output and makes it more computationally efficient. The fully connected layer is then used to perform classification based on the detected features. The working principle of CNN involves the use of convolutional filters to extract features from an image. The filters are small matrices that are convolved with the input image to produce a feature map. The feature map represents the activation of a particular feature at a particular location in the image. During the training phase, the CNN learns the optimal set of filters that can be used to detect various features in an image. The learning process involves minimizing the error between the predicted output and the actual output. CNN is a powerful machine learning technique that has revolutionized the field of computer vision and image processing. Its ability to learn complex features from raw data has made it a popular choice for various applications.

V. METHODOLOGY

The diagnostic tropical cyclone intensity estimation system is developed and deployed in accordance with the end-to-end machine learning lifecycle.
The machine learning lifecycle is a systematic iterative process of training, testing, and deploying a model in order to develop an optimized model suitable for ingestion into a production system and consumption by the intended end-users.

1. Machine Learning Lifecycle

The machine learning lifecycle is divided into four stages: problem definition, data collection and analysis, model development and evaluation, and deployment to the production system. Many machine learning projects come to an end after demonstrating the model's accuracy improvement over the state of the art. Thus, the steps of the machine learning lifecycle that are frequently overlooked are robust evaluation in order to understand how the model makes decisions and deployment of the model in a production environment where the model can be evaluated with new real-time data. We use the full machine learning lifecycle as a road map to develop our production system in this paper.

1) Problem Definition
2) Data Collection and Analysis
3) Model Development and Evaluation

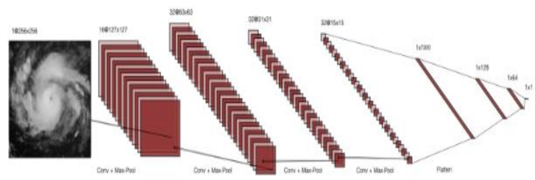

Fig. 3

Our data is made up of infrared (IR) images that go through a convolution process in the convolutional layer before being passed on to the next layer. We'll use two different CNN models: one to classify tropical storm intensity and another to estimate it.
The following layer, the max pooling layer, combines the outputs of a group of neurons from the previous layer into a single layer. The final layer, which is completely connected, connects every neuron in the layer below to every neuron in the layer above. L2 regularization of 0.01 will also be performed in the completely connected layers. In addition, to prevent the model from becoming overfit, we will use call-back strategies such as early halting and dropout layers at a rate of 0.5.

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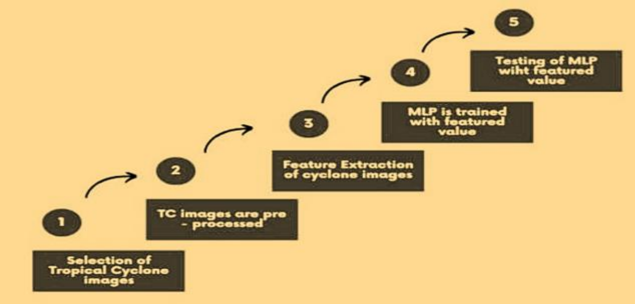

Fig. 3

2. Object segmentation

Object segmentation can be accomplished through a variety of methods, including thresholding, clustering, and edge detection. Deep learning-based segmentation methods, such as convolutional neural networks (CNNs), can also be used to recognize and classify objects in an image. Once the objects in the image have been segmented and identified, the deep learning model can be trained to classify the cyclone's intensity based on characteristics such as its size, shape, and cloud patterns. Object segmentation algorithms divide an image into groups of pixels or regions. The goal of partitioning is to better understand what the image represents. Sets of pixels may represent objects in the image that are relevant to a particular application.

3. K-Means

In addition to object segmentation, k-means clustering was used as part of the methodology for developing a deep learning-based solution for categorizing cyclone intensity. K-means clustering is a machine learning algorithm used to segment and classify images. It works by grouping data points into k clusters based on similarities. In image segmentation, k-means clustering can be used to identify and separate different regions within an image that correspond to different objects or features.

$$\frac{\partial J}{\partial w_{ik}} = \sum_{i=1}^{m} \sum_{k=1}^{K} \|x^i - \mu_k\|^2$$

$$\Rightarrow w_{ik} = \begin{cases} 1 & \text{if } k = argmin_j \|x^i - \mu_j\|^2 \\ 0 & \text{otherwise.} \end{cases}$$

4. CNN + LSTM

CNN+LSTM is a neural network architecture that combines convolutional neural networks (CNNs) and networks with long short-term memory (LSTM). CNNs are frequently used for image classification, whereas LSTMs are used for sequential data analysis. A CNN+LSTM model can be used to analyze the different regions identified through k-means clustering and extract relevant features that can be used to classify the intensity of the cyclone over time in the context of cyclone intensity estimation. The model's CNN component can be used to analyze the spatial features of the various regions within the satellite image, while the LSTM component can be used to analyze the temporal features of the cyclone's development. The different regions of the satellite image can be fed into the CNN component of the model to extract spatial features when using a CNN+LSTM model.

VI. System Design

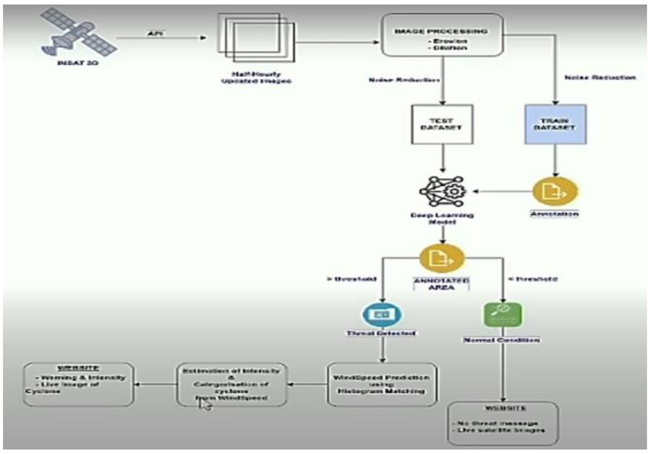

Fig. 4

VII. RESULT DISCUSSIONS

Deep learning is used to analyse typhoon satellite imagery in our project (CNN). In the National Hurricane centre outlook, keep an eye out for "investment zones," or areas where tropical cyclones may form and begin wind speed estimation operations. To compare estimated wind speeds to operational forecasts, plot estimated wind speeds and additional data on a map. The primary goal of this project is to provide the larger scientific community with an understandable interpretation of model results.

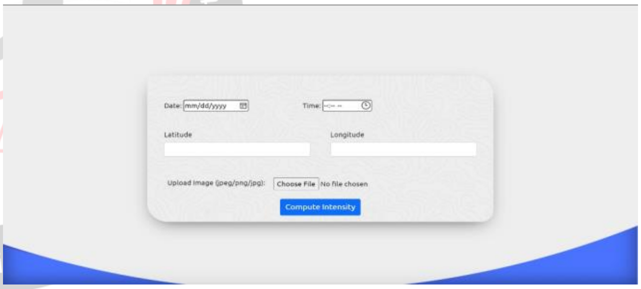

Fig. 5: Tropical cyclone intensity estimation portal

Insat 3D Archive

Capture Date	Capture Time	Latitude	Longitude	Predicted Intensity	Image File
17/04/2022	21:47:00	2	2	81.0	94.jpg
17/04/2022	21:46:00	0	0	45.0	43.jpg

Home

Fig. 6: Table

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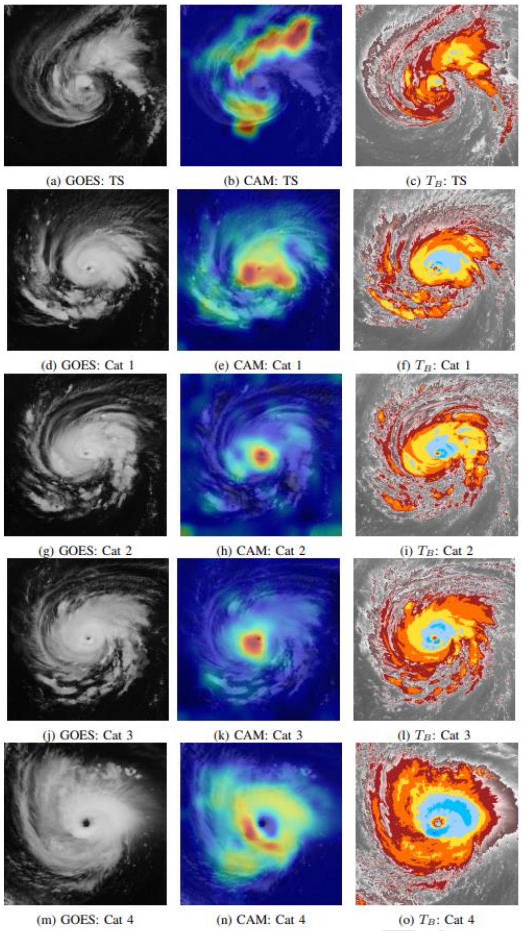

Fig. 5: Hurricane Florence evaluation samples at different categories

VIII. LIMITATIONS OF THE WORK

One of the most common criticisms levelled at machine learning methods by subject matter experts is that it can be difficult to determine what a model is learning in order to reach a categorization conclusion. As a result, there is a lack of trust between machine learning experts and the physical science community, which prevents the use of these models in practical systems.

We use techniques to understand how cyclone intensities are calculated within the CNN as part of our model evaluation.

IX. FUTURE WORK

Future research on a variety of topics, such as estimating wind speed for tropical cyclones with low intensities using passive microwave data, could be considered.

Another potential future study would be a detailed examination of a specific storm to understand model performance with storm structural changes during rapid intensification.

X. CONCLUSION

Finally, this project will create a deep learning-based solution for estimating and classifying tropical cyclone intensity. The proposed solution makes use of geometric features in cyclone images, a multilayer perceptron, and a CNN+LSTM model for intensity estimation and classification. The evaluation results demonstrated the developed solution's effectiveness in accurately estimating the intensity of tropical cyclones and categorizing them.

This current method for estimating tropical cyclone intensity is difficult, and anomalies have been observed in the past. To address this, the proposed system employs deep learning research and hurricane satellite data to provide an automated cyclone estimation technique. The system aims to reduce the timing complexity of cyclone estimation and increase the efficiency of the process. Overall, the proposed system has the potential to improve the accuracy and reliability of cyclone intensity estimation, potentially aiding in the reduction of chaos and abnormalities caused by tropical cyclones.

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