Grenze International Journal of Engineering and Technology, Jan Issue

A Review Paper on Cyclone Intensity Estimation on INSAT 3D IR Imagery using Deep Learning Algorithms

Kuldeep Vayadande[1], Tejas Adsare[2], Neeraj Agrawal[3], Tejas Dharmik[4], Aishwarya Patil[5] and Sakshi Zod[6]
[1-6]Vishwakarma Institute of Technology, Information Technology, Pune, India
Email: kuldeep.vayadande@gmail.com, { tejas.adsare20@vit.edu, neeraj.agrawal20@vit.edu, tejas.dharmik20@vit.edu, aishwarya.patil20@vit.edu,sakshi.zod20@vit.edu }

***Abstract*—Due to the various dangers involved, especially tropical cyclones, they are one of the most common and deadly calamities in the world. The very important primary step in monitoring this destructive disaster is by estimating its intensity. The aim of this research is to determine intensity of cyclones. For the estimation of cyclones and determination of their intensity, various methods have been created. It is a difficult task which requires speed and efficiency. This paper shows comparison between various types of deep learning algorithms on infrared satellite imagery dataset for tropical cyclone intensity estimation. A side-by-side comparison research revealed that the detection of the tropical cyclone intensity evaluated via the models derived from different machine learning algorithms is significantly impacted by the use of various infrared (IR) channels.**

***Index Terms*— Cyclone, INSAT-3D, Deep Learning, Intensity estimation.**

I. INTRODUCTION

Cyclones are giant and spiral-moving storms that develop in the ocean, absorb energy and grow. High intensity tropical cyclones may result in destructive damages to the people. Due to the potential damage to lives, estimating the intensity or strength of cyclones is a crucial undertaking. The middle center of the cyclone is called the eye from which we can detect the exact location of the cyclone and can track where it will further move. Researchers are attempting to automate the estimation procedure such that there is minimal human participation in the intensity assessment using satellite pictures. Tropical cyclones, even in their formation stage, are among the greatest threats to life and property. Floods, high winds, tornadoes, and lightning strikes are just a few of the hazards that hurricanes can pose and can have serious consequences. The combination of these risks poses a serious threat of death or property damage. Therefore, it is important to detect and predict hurricanes in their early stages. Cyclone detection and prediction can be done using conventional means such as the practice, which includes specific parameters such as temperature, wind speed, etc.
Various recent advances use deep learning techniques such as segmentation and convolutional Bi-Directional Gated Recurrent Unit (GRU) networks. Due to the wide variation in MSW and variety of cyclone patterns, it is challenging to predict the tropical cyclone strength using pure regression approaches. By utilizing a set of pertinent rules and subjective pattern recognition, Dvorak (from 1975,1984) has created a reliable method for manually calculating intensity of Tropical Cyclones(TC)from infrared and visible satellite data. In the Dvorak

Grenze ID: 01.GIJET.9.1.330
© Grenze Scientific Society, 2023

method to reduce subjectivity, Velden et al. (1998) developed the objective Dvorak technique.[3] Three independent estimates from the Tropical Analysis Center have been demonstrated to be competitive with or superior to ODT intensity estimates.

In earlier works, attempts were made to acquire more precise TC measurements by fitting the parametric models to coarse observations. By combining the outer and inner structures of wind, Chavas et al. [11] created a comprehensive model of the radial wind structure. The observations made by the Global Navigation Satellite System of Cyclone, which consist of clusters of tracks rather than whole swathes, were fitted using the parametric model of Morris and Ruf [12]. These investigations, However, pay less attention to the signal channels' limited resolution at high wind speeds and instead concentrate on the shortcomings of the parametric models.

Furthermore, the cyclone is detected using K-means that is compared with other segmentation techniques like Detecron2 and Mask-RCNN (Recurrent Convolutional Neural Network). Applications of the proposed approach include the ability to identify cyclones and determine their paths using satellite imagery.

The paper is divided into following sections, Section 2 describes the dataset used in this study, Section 3 summarizes previous approaches and recent developments, Section 4 gives the conclusion to the paper and speaks about future scopes of the methodology.

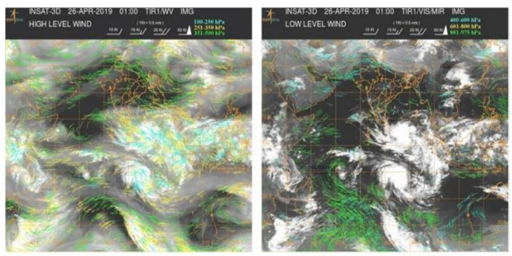

Fig 1: The live images captured by INSAT-3D Satellite were retrieved [19]

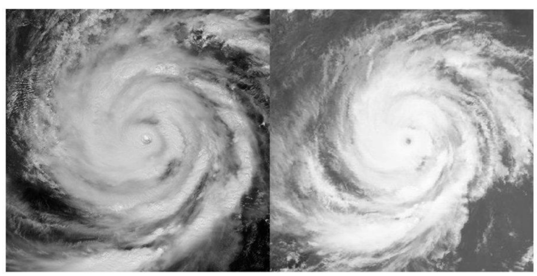

Fig 2: Cyclone INSAT 3D IR Satellite images[18]

II. LITERATURE REVIEW

Various methodologies and ideas had been implemented to categorize the behaviour of this disaster.

[1]. Kar Chinmoy , Kumar Ashirvad ,Banerjee Sreeparna summarizes "Tropical cyclone intensity detection by geometric features of cyclone images and multilayer perceptron". In this paper Multilayer perceptron (MLP) algorithm used. By using this algorithm, authors predicted the intensity of cyclones. Image based geometric properties of Tropical Cyclone (TC) are the key factors for the approach given in this research. TC intensity is estimated based on the images obtained from satellites using Dvorak technique. Properties or feature values of cyclone images are trained and tested by the model proposed in this paper through a multilayer perceptron.

[2]. Buo-Fu Chen, Russell L.Elsberry, Hsuan-Tien Lin, Boyo Chen contributed to "Estimating Tropical Cyclone Intensity by Satellite Imagery Utilizing Convolutional Neural Networks". The CNN-TC is able to determine the intensity by making changes to the CNN. Ability to design different models of CNN for prediction of the formation of tropical cyclone on the basis of different factors and images from satellite.

[3].Muthukumaran Ramasubramanian, Dan Cecil, Aaron Kaulfus, JJ Miller, Rahul Ramachandran, Brian Freitag, Drew Bollinger, Manil Maskey, Iksha Gurung contributed in "Deep Learning-based Tropical Cyclone Intensity estimation system". In this study, the authors provide models that are substantially evaluated and systematically transferred to manufacturing via comparing CAM-recognized functions to Dvorak T-wide variety

pics. The version is trained using neighbourhood servers to avoid the excessive fee of necessities for the duration of training. After the training of the model, it's uploaded in the production system. The website advanced the usage of React and Redux technology for the view and state management framework.

[4]. Anil Kumar Singh, M. Sateesh,Amit Kumar, J. N. Tripathi and Virendra Singh contributed to "Evaluation of INSAT-3D-derived Hydro-Estimator and INSAT Multi-Spectral Rain Algorithm over Tropical Cyclones", In this paper, analytical and rating of skill study is performed each over a thirty minute scale with admiration to different degrees of cyclone characteristics like intensity.

[5]. Min Yan, Chen Wang, Jun Shi, Hao Su Shunjun and Wei Xiaoling Zhang contributed to "Object Detection and Instance Segmentation in Remote Sensing Imagery Based on Precise Mask R-CNN". In this paper, for VHR remote sensing images, it helped in increasing accuracy of detection of object and instance segmentation. It can calculate the two-order integral in order to increase the accuracy directly.

[6].Aravind Nair, Navya Jain, Sayali R. Kulkarni, Hariprasad Kodamana, Viju O. John, K. S. S. Sai Srujan, Kshitij and S. Sandeep contributed to the "A Deep Learning Framework for the Detection of Tropical Cyclones From Satellite Images. The images used for testing show a precision of 97.10%. The approach proposed for the model shows specificity of 97.59%. The result of the accuracy achieved is 86.55%.

[7].Z. Guan, Chuhan Lu, Y. Kong contributed to the "A mask R-CNN model for reidentifying extratropical cyclones based on quasi-supervised thought" presented in Scientific Reports 2020[7]. In this paper, the Masked R-CNN model helped to increase the accuracy by 8.29 in predicting the cyclone. In determining the horizontal structures of the cyclones, it performed well.

8.Asif Raza,Zeng Li , Jian Liu , Xi Chen , Jingdong Liu, Hong Huo, Tao Fang and Yifan Liu contributed to "IR-MSDNet: Infrared and Visible Image Fusion Based on Infrared Features and Multiscale Dense Network". The paper describes to create the final image IR features and decoded multiscale features are used.IR-MSD Net approach has helped in enhancing the specifications of the fused images.

[9].G.Terrén-Serrang, M. Martínez-Ramón contributed to "Comparative Analysis of Methods for Cloud Segmentation in Infrared Images" [9]. In this paper the model takes relatively less computing time with high performance. In both supervised as well as unsupervised models, it has helped to achieve the best performance.

[10].Sahbi Boubaker, Adel Mellit i, Lioua Kolsi Ayoub Lefza, Mohamed Benghanem and Omar Kahoul contributed to "Deep Neural Networks for Predicting Solar Radiation at Hail Region, Saudi Arabia". In this paper, to implement half hour GHI forecasting, the combination of LSTM and CNN algorithms was done. On comparing various algorithms and in different research papers that, the deep learning algorithms like CNN, LSTM, Cov-CNN and GRU performance is best as compared with other algorithms like SVM, FFNN and RNN.

11.Junjun Hu, Jinkai Tan, Sheng Chen, Qiqiao Huang, Qidong Yang, contribute to "Tropical Cyclone Intensity Estimation Using Himawari-8 Satellite Cloud Products and Deep Learning in year 2022. The cloud parameters are considered here like its top height, optical thickness, effective radius, top temperature, cloud types and geostationary satellite for level-2 products for Himawari-8 data, which are used to train model. Also, for achieving superiority, the final model is compared through using other types of residual learning and the architecture based on CBAM.

TABLE I. EXISTING MACHINE LEARNING METHOD COMPARISON TABLE

Sr no	Authors	Year	Machine Learning algorithm	Remarks	Conclusion
1	Kumar Ashirvad, Kar Chinmoy, Banerjee Sreeparna	2019	MLP multilayer perceptron [1]	Accuracy of MLP is approximately 84%	In this paper the Multilayer perceptron (MLP) algorithm is used. By using this algorithm, authors predicted the intensity of cyclones. Image based geometric properties of Tropical Cyclone (TC) are the key factors for the approach given in this paper. TC intensity is estimated based on the images obtained from satellites using Dvorak technique. Properties or feature values of cyclone images are trained and tested by the model proposed in this paper through a multilayer perceptron.
2.	Russell L.Elsberry, Boyo Chen, Buo-Fu Chen, Hsuan-Tien Lin,	2019	Convolutional Neural Networks[2]	CNN-TC performed better than the ADT and AMSU.	The CNN-TC is able to determine the intensity by making changes to the CNN. Ability to design different models of CNN for prediction of the formation of tropical cyclones on the basis of different factors and images from satellites.

3.	Virendra Singh, J. N. Tripathi, Anil Kumar Singh, Amit Kumar and M. Sateesh	2021	Dvorak technique on the basis of infrared band[4]	Good Accuracy compared to other algorithms	In this paper, analytical and rating of skill study is performed each over a thirty-minute scale with admiration to different degrees of cyclone characteristics like intensity.
4.	Iksha Gurung, Rahul Ramachandran, Manil Maskey, Aaron Kaulfus, Ramasubramanian, Muthukumaran , Brian Freitag, Drew Bollinger	2019	Dvorak technique[3]	RMSE was 13.62 kts	In this study, the authors provide models that are substantially evaluated and systematically transferred to manufacturing via comparing CAM-recognized functions to Dvorak T-wide variety pics. The version is trained using neighbourhood servers to avoid the excessive fee of necessities for the duration of training. After the training of the model, it's uploaded to the system of production. The website advanced the usage of React and Redux technology for the view and state management framework.
5.	Xiaoling Zhang ,Hao Su, Min Yan, Shunjun Wei, Chen Wang, Jun Shi	2021	Mask R-CNN with PrROI pooling[5]	Segmentation of AP of 64, AP50 of 93 and AP 75 of 73 on Resnet 101	In this paper, for VHR remote sensing images, it helped in increasing accuracy of detection of object and instance segmentation. To directly enhance the precision, it may compute the two-order integral using the properties of a continuous map.
6.	Aravind Nair, Navya Jain, Sayali R. Kulkarni, Hariprasad Kodamana, Viju O. John, K. S. S. Sai Srujan, Kshitij, S. Sandeep.	2021	CNN+LSTM [6]	86.55 percent (training set)	The images used for testing show a precision of 97.10%. The approach proposed for the model shows specificity of 97.59%. The result of the accuracy achieved is 86.55%.
7	Chuhan Lu, Y. Kong, Z. Guan	2020	SPPNet and RoIAlign[7]	90.87 percent(training set)	The Masked R-CNN model helped to increase the accuracy by 8.29 in predicting the cyclone. In determining the horizontal structures of the cyclones, it performed well.
8.	Xi Chen, Asif Raza , Jian Liu , Jingdong Liu, Hong Huo , Zeng Li , Tao Fang, and Yifan Liu.	2021	IR-MSDNet[8]	Log average Miss Rate(MR) of 27.45per (longest among other models)	In this paper, to create the final image IR features and decoded multiscale features are used to design the final images. IR-MSD Net approach has helped in enhancing the specifications of the fused images.
9.	G.Terrén-Serrang, M. Martínez-Ramón	2020	Markov Random Field[9]	Statistic of 94.68 in testing images	The model takes relatively less computing time with high performance. In both supervised as well as unsupervised models, it has helped to achieve the best performance.
10.	Lioua Kolsi., Mohamed Benghanem, Ayoub Lefza, Omar Kahouli, Adel Mellit, and Sahbi Boubaker,	2021	CNN and LSTM algorithm[10]	Accuracy is of 96%	The forecasting of GHI is done for half an hour for the hybrid model using the LSTM and CNN algorithms. After the research, the paper shows that the CNN, LSTM, Cov-CNN, and GRU algorithms achieve the accuracy better than using various machine learning models like RNN, FFNN, conventional SVM, and stochastic approaches.
11.	Junjun Hu,Jinkai Tan ,Sheng Chen,Qiqiao Huang ,Qidong Yang	2022	Convolutional Neural Network[11]	The mean absolute error is 3.23 and the root mean square error is 4.06.	The cloud parameters are considered here like its top height,optical thickness, effective radius, top temperature, cloud types and geostationary satellite for level-2 products for Himawari-8 data, which are used to train models. Also, for achieving superiority, the final model is compared through using other types of residual learning and the architecture based on CBAM.

III. Recent Technologies Used

A. Dvorak technique

This is popularly known as a cloud pattern recognition method which depends on the model of cyclone decay as well as cyclone development. With the help of the Dvorak technique, the pattern recognition from the structure of the storm and the intensity of storm from the images that are obtained from the satellite. Scientist can calculate convective cloud pattern of tropical cyclone with the help of this It is the Dvorak technique that provides the best estimates of cyclone intensity - a vital component in issuing weather warnings.

B. MLP multilayer perceptron

An artificial neural network is made up of thick, completely linked layers that can change any input dimension to the desired dimension. It is called a multi-layer perception because of its many layers. To develop the neural network, several neurons are connected so that some of their outputs are also their inputs. Extraction of the feature value and properties of the cyclone from the images is taken for multilayer perceptron.[1]

C. Convolutional Neural Networks

The advantage of CNN is that it uses machine learning for the identification of the key elements without the intervention of humans. It is frequently used for classifying and recognising images and objects. The primary activity in this layer is convolution, and during each network iteration, the network learns the weights of the convolution filters. By employing CNN as applied in past papers, there is no longer a requirement to use conventional techniques to accurately determine the centre of a cyclone and estimate its strength using satellite images.[12]

D. Support Vector Machine and Multiple Logistic Regression

For classification, a support vector machine is employed. as well as for regression problems but is used mainly for classification purposes. The algorithm creates a division that divides the data into classes. It uses a trick to find the best row separator. It is a clear and more accurate way to learn functions that are complex and nonlinear.[13]

IV. Graph Comparison Between Different Algorithms

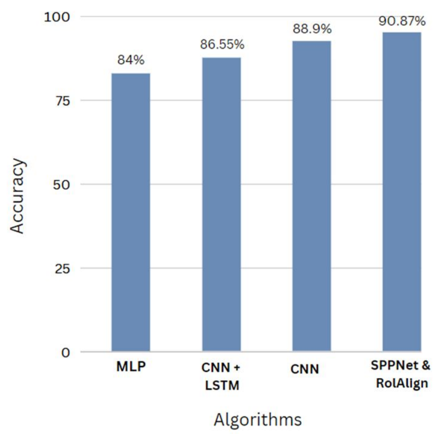

Fig 3: Graph Comparison Between Different Algorithms

V. Scope Of Implementation

The DL-based approach for TC intensity estimate is promising, but further research is desperately needed to advance the approach. Additional factors including sea level pressure, surface temperature, steering flow, water vapor, vertical wind shear, etc. should be taken into account in future studies. Future research on many topics, such as the estimation of wind speed for tropical cyclones with lesser intensities using passive microwave data, might be taken into consideration. In the future, it might be necessary to investigate the model performance during rapid intensification of a specific storm in order to comprehend how the model changes with changes in the storm structure.

VI. Conclusion

We illustrated the learning and overall performance of different kinds of models using various algorithms. Using basic tools and simplified techniques the strategy is far beneficial for detection of the cyclone intensity and its centre. In this review paper, we introduced an overall description and different approaches for intensity estimation of tropical cyclones using various deep learning algorithms. With use of these algorithms, it is possible to quickly and with little human effort to determine the strength category of a cyclone sample. Various accuracies are being discussed in comparison with different deep learning Techniques.

ACKNOWLEDGMENT

It would be our utmost pleasure to express our sincere thanks to our guide Prof. Kuldeep Vayadande who gave us the opportunity to do more research on the topic "Cyclone Intensity Estimation On INSAT 3D IR Imagery Using Deep Learning Algorithms", which also helped us in doing a plenty of ideas and that we came to understand about such a lot of new things.

REFERENCES

[1] Chinmoy Kar, Ashirvad Kumar, Sreeparna Banerjee contributed to "Tropical cyclone intensity detection by geometric features of cyclone images and multilayer perceptron" presented in Springer Nature Switzerland AG in 2019.

[2] Buo-Fu Chen, Boyo Chen, Hsuan-Tien Lin, Russell L.Elsberry contributed to "Estimating Tropical Cyclone Intensity by Satellite Imagery Utilizing Convolutional Neural Networks" published on 1 April 2019 in AMS journal.

[3] Manil Maskey, Rahul Ramachandran, Muthukumaran Ramasubramanian , Iksha Gurung, Brian Freitag, Aaron Kaulfus, Drew Bollinger, Dan Cecil, JJ Miller contributed in "Deep Learning-based Tropical Cyclone Intensity estimation system" Published in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing

[4] Amit Kumar, Anil Kumar Singh1, J. N. Tripathi, M. Sateesh and Virendra Singh contributed to "Evaluation of INSAT-3D-derived Hydro-Estimator and INSAT Multi-Spectral Rain Algorithm over Tropical Cyclones", presented in 2016 Online International Conference on Green Engineering and Technologies (IC-GET).

[5] Hao Su; Shunjun Wei; Min Yan; Chen Wang; Jun Shi; Xiaoling Zhang contributed to "Object Detection and Instance Segmentation in Remote Sensing Imagery Based on Precise Mask R-CNN". presented in 2021 published in IGARSS IEEE International Geoscience and Remote Sensing Sym-posium,

[6] Aravind Nair, K. S. S. Sai Srujan, Sayali R. Kulkarni, Kshitij ,Navya Jain, Hariprasad Kodamana, S. Sandeep and Viju O. John contributed to the "A Deep Learning Framework for the Detection of Tropical Cyclones From Satellite Images", presented in IEEE Geoscience and Remote Sensing Letters 2022.

[7] Chuhan Lu, Y. Kong, Z. Guan contributed to the "A mask R-CNN model for reidentifying extratropical cyclones based on quasi-supervised thought" presented in Scientific Reports 2020.

[8] Asif Raza , Jingdong Liu , Yifan Liu , Jian Liu , Zeng Li , Xi Chen , Hong Huo , and Tao Fang contributed to "IR-MSDNet: Infrared and Visible Image Fusion Based on Infrared Features and Multiscale Dense Network" published in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.

[9] G.Terrén-Serrang, M. Martínez-Ramón contributed to "Comparative Analysis of Methods for Cloud Segmentation in Infrared Images".

[10] Sahbi Boubaker, Mohamed Benghanem, Adel Mellit, Ayoub Lefza, Omar Kahouli, and Lioua Kolsi contributed to "Deep Neural Networks for Predicting Solar Radiation at Hail Region, Saudi Arabia" published in IEEE Access 2021.

[11] Jinkai Tan ,Qidong Yang ,Junjun Hu ,Qiqiao Huang ,Sheng Chen* Tropical Cyclone Intensity Estimation Using Himawari-8 Satellite Cloud Products and Deep Learning presented in MDPI in 2022"

[12] Chong Wang , Gang Zheng* contributed in " Tropical Cyclone Intensity Estimation from Geostationary Satellite Imagery Using Deep Convolutional Neural Networks presented in IEEE Transactions on Geoscience and Remote Sensing (Volume: 60)2021.

[13] Chen, Zhao; Yu, Xingxing; Chen, Guangchen; Zhou, Junfeng , "A Semisupervised Deep Learning Framework for Tropical Cyclone Intensity Estimation" presented in Conference: 2019 10th International Workshop on the Analysis of Multitemporal Remote Sensing Images (MultiTemp)

[14] Guangchen Chen, Zhao Chen, Feng Zhoul , Xingxing yul , He Zhang', Lingyun Zhu, "A Semisupervised Deep Learning Framework for Tropical Cyclone Intensity Estimation" presented in 2019 10th International Workshop on the Analysis of Multitemporal Remote Sensing Images (MultiTemp).

[15] A. Krizhevsky, I. Sutskever, and G. E. Hinton, contributed in "ImageNet classification with deep convolutional neural networks," in Advances in Neural Information Processing Systems.

[16] J. Yosinski, J. Clune, A. Nguyen, T. Fuchs, and H. Lipson. Contributed in "Understanding neural networks through deep visualization." In 2015.

[17] E. A. Ritchie, K. M. Wood, O. G. Rodriguez-Herrera, M. F. Pineros, and J. S. Tyo, contributed in "Satellite-derived tropical cyclone intensity in the north Pacific Ocean using the deviation-angle variance technique," in June. 2014.