Tropical Cyclone Intensity Detection Using CNN

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Project Guide:

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1.Abstract

Development of a deep Convolutional Neural Network (CNN) for Tropical Cyclone intensity estimation using half-hourly INSAT-3D IR Images and development of a web application for visualization of the imagery. INSAT3D/3DR observations are available at every 15-minute interval and these observations are very useful in understanding the instantaneous structural changes during evolution, intensification, and landfall of Tropical Cyclones.

Keywords: -Tropical cyclone · Cyclone eye · Prediction models · CNN· AlexNet CNN

2.Introduction

Datasets of Cyclones captured by INSAT-3D over the Indian Oceans are available since 2012. These datasets can be used for training and testing of the Model. Traditional methods for Intensity estimation require accurate centre determination for intensity estimation. Development of CNN based model for intensity estimation will be very useful during the initial stage of cyclone formation when determination of accurate centre becomes difficult.

A TC is said to be a high-speed rotating storm, characterized by a low-pressure centre with a closed low-level atmospheric movement of winds which produces heavy rain.

According to researchers about 90% of the damage is due to flood by sea water formed by high intensity winds.

There are many techniques proposed by researchers towards intensity detection apart from Dvorak and modified Dvorak techniques. Feature-based techniques are mostly focused on the geometric features of the TC images. Machine learning algorithms were introduced to solve many problems like image classification.

Earlier MLP algorithm used in order to predict the TC intensity, but the approach proposed here depends on image based geometric features of TC. Intensity prediction using sea surface temperature is a popular method and many research works have been done in this area. A recent research attempt based on sea surface temperature is given in.

The TC eye detection is an important phase towards TC intensity detection. TC eye is considered to be a unique area and is characterized by the cloud-free zone and is surrounded by thick cloud and weak wind. Eye generally forms at the centre of Central Dense Over- cast (CDO) region of storm and in most cases diameter of the Eye of a storm is about 10–50 km. In the Dvorak technique, the presence of eye in satellite images are used for approximation of TC intensity.

The proposed model here is used to train and test the feature values of TC images through multilayer perceptron (MLP). MLP is considered to be a supervised learning technique. MLP is a class of feed forward artificial neural network and it consists of input layer, output layer and at least one hidden layer. In MLP each node treated as a neuron which follows a non-linear activation function except for input nodes. It uses a supervised learning procedure called backpropagation algorithm and used for training and testing of the model.

In this paper Sect. 2 describes the dataset. Section 3 describes the methods and implementation details of the proposed algorithm. Section 4 is devoted to results and discussion and Sect. 5 concludes the proposed work.

3.Literature Survey

Applications of satellite remote sensing from geostationary (GEO) and low earth orbital (LEO) platforms, especially from passive microwave (PMW) sensors, are focused on TC detection, structure, and intensity analysis as well as precipitation patterns. The impacts of satellite remote sensing on TC forecasts are discussed with respect to helping reduce the TC's track and intensity forecast errors. Finally, the multi-satellite-sensor data fusion technique is explained as the best way to automatically monitor and track the global TC's position, structure, and intensity.

Limitations:

Limitations in satellite IR/VIS observations at early stages of storm development when its centre is not obvious or overcast.

Advantage:

The advantages of geostationary satellites (GEO) are frequent observations over a large domain.

4. Research Methodology

There following steps are taken for model formulation and implementation:

1. Image recognition process
2. Pre-processing of TC images
3. Feature extraction from TC images

Training and testing through MLP

1. Collection of TC images: - TC images are collected from the dataset.
2. Pre-processing of TC images: - In the pre-processing step, images are cropped based on ROI. Here images of D, CS and ESCS are passes through Gaussian blur or Gaussian smoothing to remove the noise
3. Features extraction from TC images: - Mean (M), variance (V), density (D), decentricity (DC), area of cyclone (AC) and area of eye (AE) are extracted from a TC image.

Multilayer perceptron for training and testing: - MLP is an artificial neural network which is used to train and test the proposed model. MLP is a feedforward network with one or more hidden layers [5]. It uses backpropagation algorithm for finding the gradient.

AlexNet CNN

AlexNet was the first convolutional network which used GPU to boost performance.

1. AlexNet architecture consists of 5 convolutional layers, 3 max-pooling layers, 2 normalization layers, 2 fully connected layers, and 1 softmax layer.

2. Each convolutional layer consists of convolutional filters and a nonlinear activation function ReLU.

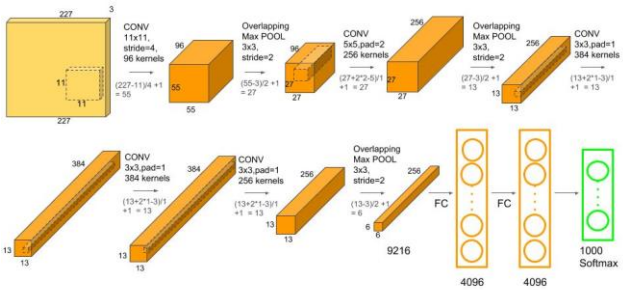
3. The pooling layers are used to perform max pooling.

4. Input size is fixed due to the presence of fully connected layers.

5. The input size is mentioned at most of the places as 224x224x3 but due to some padding which happens it works out to be 227x227x3
6. AlexNet overall has 60 million parameters.

	Intensity	Category
0	48	Tropical Storm
1	31	Tropical Depression
2	28	Tropical Depression
3	47	Tropical Storm
4	52	Tropical Storm
...	...	...
408	35	Tropical Storm
409	31	Tropical Depression
410	26	Tropical Depression
411	29	Tropical Depression
412	86	Typhoon

413 rows × 2 columns



Deep CNN

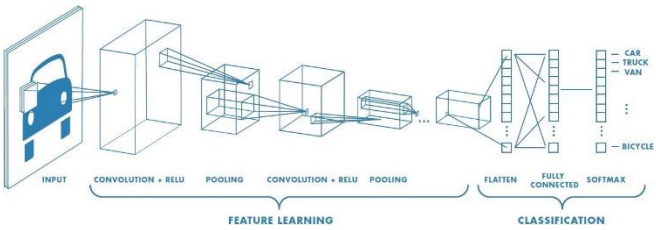
The strength of DCNNs is in their layering. A DCNN uses a three-dimensional neural network to process the red, green, and blue elements of the image at the same time. This considerably reduces the number of artificial neurons required to process an image, compared to traditional feed forward neural networks.

Deep convolutional neural networks receive images as an input and use them to train a classifier. The network employs a special mathematical operation called a "convolution" instead of matrix multiplication.

The architecture of a convolutional network typically consists of four types of layers: convolution, pooling, activation, and fully connected.

	Intensity	Category
0	54	Tropical Storm
1	26	Tropical Depression
2	24	Tropical Depression
3	62	Tropical Storm
4	33	Tropical Depression
...	...	...
408	40	Tropical Storm
409	34	Tropical Storm
410	33	Tropical Depression
411	31	Tropical Depression
412	91	Typhoon

413 rows × 2 columns



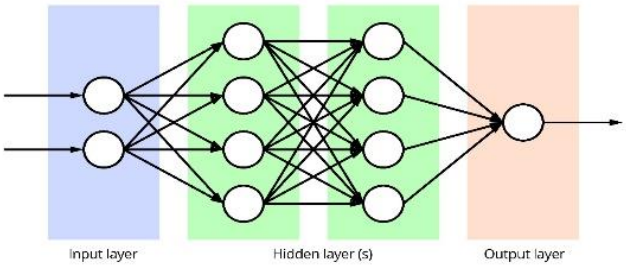
Neural networks

A neural network is a series of algorithms that endeavours to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, either organic or artificial in nature.

Neural networks can adapt to changing input; so, the network generates the best possible result without needing to redesign the output criteria. The concept of neural networks, which has its roots in artificial intelligence, is swiftly gaining popularity in the development of trading systems.

- Neural networks are a series of algorithms that mimic the operations of an animal brain to recognize relationships between vast amounts of data.
- As such, they tend to resemble the connections of neurons and synapses found in the brain.

- They are used in a variety of applications in financial services, from forecasting and marketing research to fraud detection and risk assessment.
- Neural networks with several process layers are known as "deep" networks and are used for deep learning algorithms
- The success of neural networks for stock market price prediction varies.



5.Data Sets

TC images are collected from Institute of Meteorological Satellite Studies and IMD. The images were taken from satellite known as INSAT 3D, Kalpana1 and Meteosat-7. The complete dataset is divided into the three categories based on the intensity.

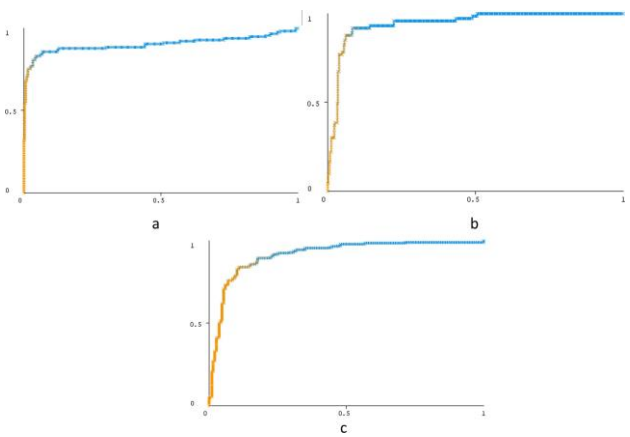
5. Conclusion

In this study we propose a DL-based model for TC intensity estimation using the H-8 L2 cloud

products CLOT, CLTT, CLTH, CLER, and CLTY. The model uses VGG as the basic architecture and integrates "attention mechanism" and "residual learning" to reduce the number of parameters as well as to improve the estimation precision. The model was trained and optimized under six-fold cross-validation data and was further evaluated using independent test data. The following useful conclusions can be drawn:

(a) For cross-validation, the model behaves differently for different TC intensity intervals. Generally, underestimation is seen in strong TCs, and overestimation is observed in weak TCs. Over specific regions, biases in estimated intensities for landfall TCs have smaller fluctuations than those for nautical TCs due to the imbalance in the recorded TC samples, which may affect the model's training and feature representation. For the independent test, our model produced a relatively low RMSE of 4.06 m/s and an MAE of 3.23 m/s, which are comparable to those determined from existing studies using Dvorak-based techniques and various other CNN-based DL techniques.

(b) By visualizing the outputs from one of the convolutional layers, we were able to clearly identify various cloud organization patterns, storm whirling patterns, and TC structures, which helped the model represent the complex changes in the TC intensity and produce reliable estimations. Moreover, the initial cloud products were able to reflect some of the factors associated with TC intensity, such as warm moist air, convergence, divergence, and convective activity. Furthermore, by examining the initial cloud products under different intensity levels, we were able to determine that our model has a tendency to overestimate (underestimate) weak (strong) TCs. Finally, the superiority of the model designed in this paper is demonstrated through a comparison with other residual learning and CBAM-based architectures.



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