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SCHOOL OF TECHNOLOGY MANAGEMENT & ENGINEERING, NAVI MUMBAI

CASE STUDY REPORT

TOPIC: Weather Forecasting using Deep Learning (ANN, RNN, LSTM, CNN)

SUBJECT: ARTIFICIAL INTELLIGENCE

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Abstract

The aim of this report is to present a deep neural network architecture and use it in time series weather prediction. Artificial intelligence through deep neural networks is now widely used in a variety of applications that have profoundly altered human livelihoods in a variety of ways. People's daily lives have become much more convenient. Image recognition, smart recommendations, self-driving vehicles, voice translation, and a slew of other neural network innovations have had a lot of success in their respective fields. The authors present the ANN applied in weather forecasting. The prediction technique relies solely upon learning previous input values from intervals in order to forecast future values. And also, Convolutional Neural Networks (CNNs) is a form of deep learning technique that can help classify, recognize, and predict trends in climate change and environmental data. However, due to the inherent difficulties of such results, which are often independently identified, nonstationary, and unstable CNN algorithms should be built and tested with each dataset and system separately. On the other hand, it eradicates error and provides us with data that is virtually identical to the

real value we need. Artificial Neural Networks (ANN) algorithms or benefit from it. The presented. CNN model's forecasting efficiency was compared to some state-of-the-art ANN algorithms. The analysis shows that weather prediction applications become more efficient when using ANN algorithms because it is really easy to put into practice. For this work, various weather parameters were collected from the national climate data center than with the help of the Long-short term memory(LSTM) technique and RNN technique, the neural network is trained for various combinations.

Introduction

Deep learning allows computational models to learn by gathering knowledge from experience. Complex concepts can be learned by the deep learning approach due to its hierarchical conceptualization. Deep learning has significantly benefitted the state-of-the-art in many recurring domains in the modern world. Deep Learning has an immense influence on fields such as computer vision, object detection, object recognition, and speech recognition.

Deep learning is one of the best-fitted methods of implementing face recognition systems. There are various architectures used in the face recognition domain. In this report, a detailed description and introduction to the concept of deep learning are provided. Also, a summary of three different deep learning methods used in the weather forecasting domain is evaluated. The report also consists of a detailed analysis of reputed research papers done in the same field.

Introduction to the concept of deep learning

Deep Learning has become the principal driver of numerous new applications and it's an ideal opportunity to truly take a gander at why this is the situation. With such huge numbers of different choices, we've been utilizing this for such a long time. In artificial intelligence neural system, the deep learning concept considers as a subset, calculations enlivened by the personal cerebrum, gaining a lot of data. Likewise, how individuals gain as an element of fact, deep

learning estimation would work out an undertaking more than once, every time adjusting it a bit to increase the more possible result.

We allude to deep learning in the fact that neural networks have various tiers that entitle learning. If any issue that expects "thought" to make sense of is a problem deep learning can determine out how to illuminate.

In spite of the fact that deep learning was created as a methodology of AI, the spotlight has moved for the most part on profound learning nowadays and for reasons. Customary AI alludes to the procedure of extraction of information from an enormous dataset stacked into the machine. Experts figure out the guidelines and correct blunders made by the machine. This methodology expels the negative overtraining sway which shows up much of the time in deep learning. In customary AI, a machine is given preparing information and guides to assist it with settling on the right choices. As such, in a customary AI approach, a machine can unravel a noteworthy number of undertakings, however, it can't perform them without human control. How about we examine the contrasts between conventional AI and deep learning.

Weather forecasting

Whether determining is the use of science and modernization to understand the status of the air for a given range of space and time period. Climate estimates are produced by collecting significant and measurable data about the current circumstances of the environment at an estimated spot and handling climate forecasts to expand how air will transform. Climate information for learning shared portrayals utilizing verifiable information and anticipating climate components for various client characterized climate stations at the same time in a start to finish style. The inserted highlight learning part of the models just as coupling the educated highlights of various info layers have appeared to significantly affect the forecast errand.

The deep learning techniques and methods used in the weather forecast

1. ARTIFICIAL NEURAL NETWORK FOR WEATHER FORECASTING (ANN)

In Forecasting, it is intuitive that accuracy is very important. The input parameters for a weather forecasting model are different. Different types of data need different types of methods; and need to be handled accordingly. Statistical methods are usually associated with linear data whereas Artificial Intelligence methods are associated with nonlinear data. Different learning models based on Artificial Intelligence are genetic algorithms, neuro-fuzzy logic, and neural networks. Among these neural networks are preferred for time series forecasting for applications such as "stock index forecasting" in financial markets or "fault detection" in machine maintenance. Weather forecasting can be done more accurately using ANN. Because daily weather data has multiple parameters representing temperature, humidity, rainfall amount, cloud distance and size, wind speed and direction, etc. All these parameters are not linear, but they need to be processed together to determine temperature, rainfall, humidity, or weather status for the next day. Such types of applications need models which are complex in nature and can produce the required result by generating the patterns on their own by performing self-learning using the training data given to the model. To develop an ANN model for weather forecasting, the selection of regions for input data and parameters is necessary. The input data is to be taken from a specific area on which the model is trained and tested so that the model is able to generate accurate results. The number of input data given to the model also helps to improve the accuracy of the model by giving the results with a high degree of similarity between predicted and actual output data. The available data may be noisy thus, data should be cleaned. Similarly, it has to be normalized because all the parameters are of different units and normalization will help the input and output parameters to correlate with each other. The data should be divided into training and testing samples in proper proportion so that the results can be predicted, tested and validated properly. The structure of the NN model also has a great impact on the generation of accurate results. The multilayer ANN helps in predicting nonlinear data more efficiently. The activation function will be different for different layers of NN as per need.

One type of network that sees the node as an 'artificial neuron' is called an artificial neural network. An artificial neural network is a software implementation that resembles the

biological term central nervous system that is the human brain. Natural neurons receive signals through synapses located on the dendrites or membrane of the neuron. When the signals received are strong enough (surpass a certain threshold), the neuron is activated and emits a signal through the axon. This signal might be sent to another synapse and might activate other neurons.. The complexity of real neurons is highly abstracted when modeling artificial neurons. These basically consist of inputs (like synapses), which are multiplied by weights (strength of the respective signals), and then computed by a mathematical function that determines the activation of the neuron.

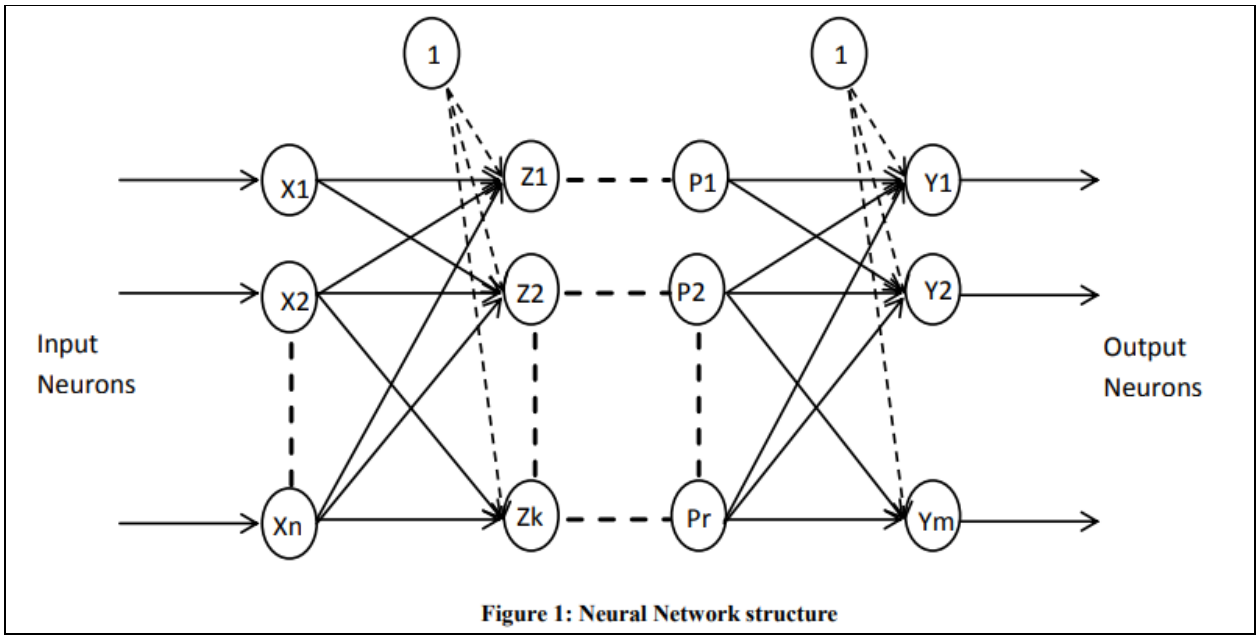

Figure 1: Neural Network structure

Another function computes the output of the artificial neuron (sometimes independence of a certain threshold). This network is of a very complex type because it contains multiple neurons associated with each other in a well-formed structure to produce complex output with minimal error. This network is mostly used to make predictions by training the model using past datasets and experience. Above Figure 1 shows an ANN structure where multiple input parameters are used as input neurons, which are then multiplied by weights and forwarded to a hidden layer where activation function is applied and then forwarded to output layer with another activation function where it finally computes the output of the artificial neuron.

2. CONVOLUTIONAL NEURAL NETWORK (CNN)

The convolutional neural system is the principal deep neural systems model that has been effectively prepared in the field of PC vision and has accomplished extensive application accomplishments. The convolutional neural systems layer is as yet a vital piece of the deep neural system and broadly applied in the characterization and acknowledgment of the designs and video handling. All the more explicitly, a look into Convolutional Neural Systems (CNN) has demonstrated to be viable in tackling picture grouping and division issues.CNNs empower examination and extraction of the spatial data in pictures, working from fine-grained subtleties into more significant level structures. The transient measurement can be added to these systems by adding a third hub to the convolutional bits. This work shows how CNNs can be used to decipher the yield of Numerical Weather Prediction (NWP) consequently creating neighborhood conjectures. CNN's can give a model to decipher numerical climate model fields legitimately and to create nearby climate conjectures.

CNN is a form of NN that is primarily used for data processing in a grid topology. CNN's have been successfully used in the literature for image recognition and other computer vision tasks. In at least one of the network's layers, CNNs employ a specific linear operation known as convolution. Photos, for example, can be represented as 2D grids, whereas time series data, like energy consumption data, can be represented as 1D grids. As a function extractor, CNN has been used. The extracted features will be fed into a regular classification algorithm. A CNN deep learning framework consists of a series of cascading layers that perform basic functions including convolution and sub-sampling, leading to a series of fully connected layers that work similarly to a conventional ANN. CNNs have essentially become a de-facto standard method for solving a wide range of problems throughout the computer vision Field, Pattern Classification, and Image Recognition. Learning a CNN network from scratch, on the other side, necessitates a huge dataset, which is a time-consuming process in most real-world applications. To solve the weather classification problem, they use CNNs. There are many explanations for their decision to use this method: CNN is a type of NN that catches nonlinear

mapping between various areas, such as feature space & label space. In a variety of image description and classification techniques, Deep CNN has shown its strong discriminating ability. CNNs are edge convolutional architectures that are simple and clear, allowing weather classification to be simplified without the use of engineered features. The majority of CNN research is focused on object detection and recognition. Forecast identification, on the other hand, is not related to these concerns. It will be more sensitive to variables like lighting and the state of the environment and sunlight than to object-related details like color and size. Figure 2 . CNN's fundamental framework.

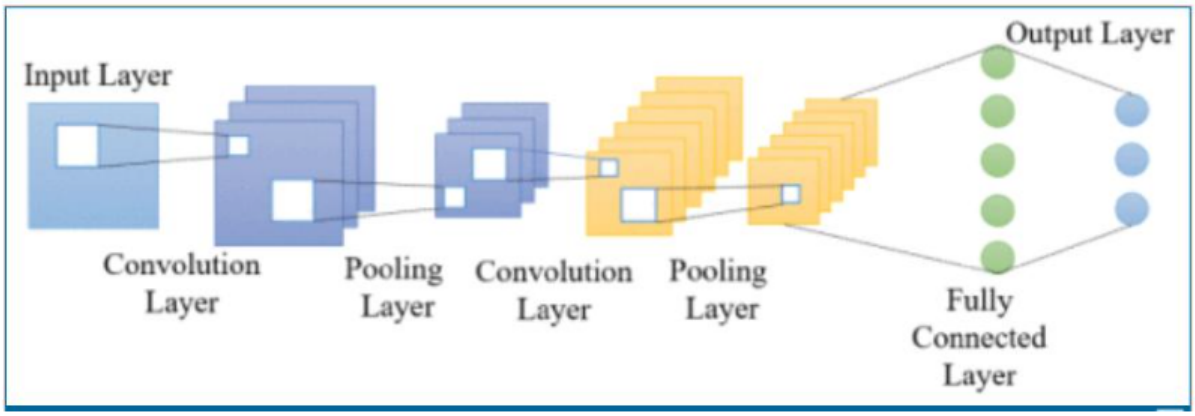

Figure 2. CNN's fundamental framework [37]

3. LSTM and RECURRENT NEURAL NETWORK (RNN)

A repetitive neural framework (RNN) is a sub of ANN where associations between units structure a planned diagram with an arrangement. This empowers to present dynamic fleeting behavior for a period game plan. This is far-fetched with a feed-forward method system, intermittent neural system can utilize its mind from inside stockpiling to proceeding grouping of information sources. Climate estimating model utilized the intermittent neural system with LSTM calculation basically expects to assemble information that is climate parameters, similar to temperature, mugginess, force, dew point, wind pace, drizzle, and permeability. Those are taken as neurons of contribution to the repetitive neural system. Climate determining is finished

by gathering data related to present-day climate with respect to the past and the current state of the climate and also using these data to prepare the LSTM model.

The Recurrent Neural Network Architecture is a natural generalization of feedforward neural networks to sequences, RNNs are networks with loops in them, which results in information persistence. The RNN can map sequences to sequences whenever the alignment between the inputs and the outputs is known ahead of time. LSTMs are a type of Recurrent Neural Network capable of learning long-term dependencies. They were introduced by Hochreiter and Schmidhuber. LSTMs remember information for long periods of time thanks to their inner cells which can carry information unchanged at will. The network has complete control over the cell state, it can add, edit or remove information in the cell using special structures called gates.

The summary of selected research papers

1. *Sequence to sequence weather forecasting with long short-term memory recurrent neural networks. International Journal of Computer Applications, 143(11), 7-11.*

The results of this paper show that a deep LSTM network can forecast general weather variables with good accuracy. The success of the model suggests that it could be used on other weather-related problems, and while Theano provides an excellent environment to compile and train models, it also gives the ability to carry any model into a production server and integrate them in pre-existing applications (as an example, one could perform real-time predictions on the top of an existing web application). Our vision is for this model to represent the cornerstone of an Artificial intelligence-based system that can replace humans and traditional methods in weather forecasting in the future. combining numerical models and image recognition ones (in satellite images for example) might form the basis of a new weather forecasting system that can outperform and overcome the traditional expensive ones and become the new standard in wealth.

2. *Narvekar, M., & Fargose, P. (2015). Daily weather forecasting using artificial neural network.*

In this paper, different methods for weather forecasting are reviewed. ANN with

backpropagation is recommended for weather forecasting. ANN with backpropagation uses an iterative process of training where it repeatedly compares the observed output with targeted output and calculates the error. This error is used to readjust the values of weights and bias to get an even better output. Hence this method tries to minimize the error. Thus, an Artificial Neural network with a Backpropagation algorithm seems to be the most appropriate method for forecasting weather accurately. Weather Forecasting has a big challenge of predicting the accurate results which are used in many real time systems like electricity departments, airports, tourism centers, etc. The difficulty of this forecasting is the complex nature of parameters. Each parameter has a different set of ranges of values. This issue is addressed by ANN. It accepts all complex parameters as input and generates the intelligent patterns while training and it uses the same patterns to generate the forecasts. The Artificial Neural Network model proposed in this paper indicates all the parameters for input and output, training and testing data set, the number of hidden layers and neurons in each hidden layer, weight, bias, learning rate and activation function. The Mean Squared Error between the predicted output and the actual output is used to check accuracy.

3. *A. Subashini, S. D., 2019. Advanced Weather Forecasting Prediction, Karaikudi: International Journal for Research in Applied Science & Engineering Technology (IJRASET).*

Both machine learning algorithms using weather data lead realistic perfection were outflanked by proficient climate or weather determining directions or forecasting, demonstrating that over longer timeframes, our models may beat proficient ones. In this research work, a proposed tool for forecasting weather system is implemented using recurrent neural network with LSTM technique. In this model the data is trained using LSTM method. From experimental result, it is observed that LSTM neural network gives a substantial results with high accuracy among the other weather forecasting techniques. Future work might explore ways to extend the proposed here to allow weather stations to be added or removed over time. Another possible research direction is to explore ways of leveraging datasets where different values have different predictor variables.

4. *Deterministic weather forecasting models based on intelligent predictors: A survey*

With the advancement of Big Data technologies and deep learning techniques, weather forecasting and climate prediction can be done effectively and accurately. The proposed survey discusses the recent research works related to weather forecasting, along with a detailed analysis of the results. The classification of weather fore-casting models are done mainly based on methodology employed and weather parameter to be predicted. The main limitation identified in the evaluation of the existing systems is the lack of stability assessment of the weather forecasting models. All the existing models only evaluate the prediction accuracy. The results claimed by the authors are analyzed for assessing the performance of different techniques. ANN and SVM are established to be more reliable machine learning techniques for weather forecasting, and recently, neural networks with deep architectures and hybrid models offer promising results in the field of weather prediction. The survey provides the state of the art models for weather forecasting, its challenges, available open datasets, and future research directions. This detailed literature review will help researchers who intend to explore the field of weather forecasting as a reference guide.

5. *DeepDownscale: A Deep Learning Strategy for High-Resolution Weather Forecast*

Downscaling is an important procedure for weather and climate applications in which coarse resolution forecasts are refined to meet a desired resolution. Many users rely on downscaling results to make decisions in many disciplines. A typical form of this procedure is known as dynamical downscale in which a high-resolution regional model is run with lowresolution data from another model as input. However, running regional models in the required resolution is very costly. On the other hand, much research has been done to improve resolution of images (and video) in computer science, in what is known as super-resolution. Typically, these techniques rely on the fact that much information is redundant and a highresolution image can be recovered from the low-resolution input. However, most of the literature assume a known noise/error function. Our proposed strategy is based on Deep Neural Networks. This approach has a major advantage that the super-resolution procedure is learned from data in a supervised

learning fashion. Moreover, there is no need to manually labeling the data, since one can always run the model in both resolutions to generate training examples - even though there is a computational cost associated with this procedure - but also it is possible to use observations as labels. From our experiments, we observed significant improvement of the proposed strategy compared with standard downscale procedures. Moreover, the strategy is cheap enough to run in a single GPU system, and even training can be run on that system.

6. *Larraondo, Pablo Rozas, Inaki Inza, and Jose A. Lozano. "Automating weather forecasts based on convolutional networks." Proceedings of the ICML Workshop on Deep Structured Prediction, PMLR. Vol. 70. 2017.*

This work demonstrates how CNNs can be directly applied to the output of numerical weather models by using observed data to annotate the samples. The design of the CNNs used in our experiments is very simple compared to some of the state-of-the-art architectures (Simonyan & Zisserman, 2014; Szegedy et al., 2015). Despite their simplicity, results show that convolutional layers can be used to interpret the output of weather models. The NWP parameters used in the experiments are not directly correlated to the precipitation output variable. NWPs have many other variables, such as humidity, vorticity or even total precipitation, that could be used to forecast precipitation patterns with better accuracy. The purpose of this initial experiment was to demonstrate that CNNs can learn certain configurations of the atmospheric pressure systems and associate them with precipitation events (fronts, convection, etc). Apart from weather model interpretation, these techniques open a new research pathway for the automatic generation of derived products. Some of the variables contained in NWPs are computed based on parameterisations or statistical models instead of physical equations. We think that these variables can be computed using CNN based models, potentially offering better results.

7. *An evaluation of CNN and ANN in prediction weather forecasting: A review*

Weather forecasting would be the use of technology and science to predict the weather in a specific region. That's one of the world's very complicated problems. Predicting accurate results, which can be used in several real-time applications, is a major challenge of weather

forecasting. The complexity of the parameters makes prediction difficult. Each parameter has its own set of value ranges. ANN is working on a solution to this problem. It recognizes those complex parameters for input and, while practicing, produces intelligent patterns, which it then uses to create forecasts. This review compares the accuracy of CNN and ANN on weather prediction. Each of them has unique characteristics and features that set them apart from the others. As a result, we must concentrate and comprehend their differencesbefore deciding how to process a forecast. Complex nonlinear interactions across dependent and independent variables can be detected indirectly by ANN. It will also achieve about the same level of accuracy as CNN for data classification issues. Since you'd have to supplement the data to enlarge the dataset and contend with CNN's storage and hardware dependencies, CNN is an excessive solution for a data classification issue. LSTM, MLP, and BP algorithms are used in ANN experiments. We note that ANN forms have a significantly higher performance than CNN, so we can infer that ANN is preferable

CONCLUSION

Over the years weather forecast has gained great acceptance and importance. The climate expectation area has consistently been exposed to many research and exchange matters in PC vision. With the development of deep learning strategies, climate forecast has accomplished a colossal progression. This is because of the unfathomable learning limit of deep learning techniques. As of now, climate forecast frameworks executed with deep learning techniques are utilized worldwide because of their strength and precision. In my perspective the explanation for this tremendous intrigue for climate expectation frameworks actualized with deep learning methods is non-meddling.

In our point of view utilizing deep learning procedures in the climate, expectation area has upgraded monstrous productivity and precision level while additionally making frameworks that

are hearty on the discovery of rain, storm, windy and sunny with the guide of deep learning methods the climate forecast space has arrived at its top with critical execution enhancements.

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