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FORECASTING OF WEATHER CONDITION USING DEEP LEARNING ALGORITHMS

Dr. Smita Agrawal[1], Srijan[2], Siddarth Jain[3]

[1]*Professor, Department of Information Technology, JECRC College*
[2]*B.Tech Student, Department of Information Technology, JECRC College*
[3]*B.Tech Student, Department of Information Technology, JECRC College*

ABSTRACT

To predict weather conditions accurately and timely was the big challenge for the meteorological scientists using conventional theory-driven numerical weather prediction methods in the past century. But now days with the successful application of data-driven deep learning methods, it has been proven that deep learning methods can effectively mine the temporal and spatial features from the spatial-temporal data. Meteorological data is a typical big geospatial data. Weather prediction using Deep learning methods is expected to be a strong supplement to the conventional method. Many researchers have tried to introduce data-driven deep learning to forecast the weather conditions, and have achieved some preliminary results. This paper surveys the state-of-the-art studies to forecast weather conditions using deep learning- algorithms.

Keywords - weather, forecasting, deep learning, machinelearning

[1] INTRODUCTION

Predicting the future weather conditions based on the historical collected data is termed as Weather Prediction. Weather forecasting plays a vital role in our day to day life to make suitable and efficient decisions on many fields such as agriculture, tourism, human and animal health, business etc. Machine learning or deep learning models provide sharp accuracy on deriving features using meteorological dataset. Due to the rapid fluctuations and drastic changes in weather conditions, the process of predicting weather conditions iscomplicated and challenging. Losses can be minimized byknowing the weather conditions beforehand.

The traditional weather prediction methods which make use of satellite images and weather stations are expensive because they include expensive and highly complex methods. Weather prediction using machine learning is less expensive, less time consuming, convenient and real-time and accurate in nature.

Multi Target regression (MTR) is a machine learning technique which can predict more than one variable at a time. Recurrent Neural Network (RNN) is a deep learning model which makes use of multiple hidden layers to train the model and provide accurate results.

[2] RELATED WORK

Afan Galih et al.[1] investigates deep learning techniques for weather forecasting. This study compares prediction performance of Recurrence Neural Network (RNN), Conditional Restricted Boltzmann Machine (CRBM), and Convolutional Network (CN) models. These models are tested using weather dataset provided by BMKG (Indonesian Agency for Meteorology, Climatology, and Geophysics) which are collected from a number of weather stations in Aceh area from 1973 to 2009 and El-Nino Southern Oscilation (ENSO) data set provided by International Institution such as National Weather Service Center for Environmental Prediction Climate (NOAA). Forecasting accuracy of each model is evaluated using Frobenius norm. The result of this study expected to contribute to weather forecasting for wide application domains including flight navigation to agriculture and tourism.

Nitin Singh et al.[2] develop a weather forecasting system that can be used in remote areas. The data analytics and machine learning algorithms, such as random forest classification, are used to predict weather conditions. In this paper, a low-cost and portable solution for weather prediction is devised.

A H M Jakaria et al.[3] predicted outcomes using regression technique. Authors found that Random Forest Regression (RFR) is the superior regressor, as it ensembles multiple decision trees while making decision. In addition, it has shown comparison of several other state-of-the-art ML techniques with the RFR technique. The incorporated regression techniques are Ridge Regression (Ridge), Support Vector (SVR), Multi-layer Perceptron (MLPR), and Extra- Tree Regression (ETR). Evaluation results show that these machine learning models can predict weather features accurately enough to compete with traditional models.

Siddharth Singh et al.[4] explores three machine learning models for weather prediction namely Support Vector Machine (SVM), Artificial Neural Network(ANN) and a Time Series based Recurrent Neural Network (RNN). It also discussed the steps followed to achieve results. RNN using time series along with a linear SVC and a five-layered neural network is used to predict the weather. The results of these models are analyzed and compared on the basis of Root Mean Squared Error between the predicted and actual values. For weather Forecasting, this paper uses Pandas, NumPy, Keras, Git, Matplotlib, TensorFlow, Anaconda and Google Cloud Services. It is found that Time Series based RNN does the bestjob of predicting the weather.

Xinbang Zhang et al.[5] this article adopts the Automated Machine Learning (AutoML) technique and proposes a deep learning framework to model the dynamics of multi-modal meteorological data along spatial and temporal dimensions.

Ashesh Chattopadhyay et al.[6] introduce a data-driven framework that is based on analog forecasting (prediction using past similar patterns) and employs a novel deep learning pattern-recognition technique (capsule neural networks, CapsNets) and an impact-based autolabeling strategy. Using data from a large-ensemble fully coupled Earth system model,CapsNets are trained on midtropospheric large-scale circulation patterns (Z500) labeled 0–4 depending on the existence and geographical region of surface temperature extremes over North America several days ahead. The trained networks predict the occurrence/region of cold or heat waves, only using Z500, with accuracies (recalls) of 69–45% (77– 48%) or 62–41% (73–47%) 1–5 days ahead.

Bogdan Bochenek et al.[7] performed an analysis of the 500 most relevant scientific articles published since 2018,concerning machine learning methods in the field of climate and numerical weather prediction using the Google Scholar search engine. With the created database, it was also possible to extract the most commonly examined meteorological fields (wind, precipitation, temperature, pressure, and radiation), methods (Deep Learning, Random Forest, Artificial Neural Networks, Support Vector Machine, and XGBoost), and countries (China, USA, Australia, India, and Germany) in these topics. Authors concluded that machine learning methods will be a key feature in future weather forecasting.

Roberta Duarte et al.[8] investigate the use of a deep learning (DL) model to temporally evolve the dynamics of gas accreting on to a black hole in the form of a radioactively inefficient accretion flow (RIAF). This study trained a convolutional neural network (CNN) on a data set that consists of numerical solutions of the hydrodynamical equations for a range of initial conditions. It found that deep neural networks trained on one simulation seem to learn reasonably well the spatiotemporal distribution of densities and mass continuity of a black hole accretion flow over a duration of $8 \times 10^4 GM/c^3$, comparable to the viscous time- scale at $r = 400GM/c^2$; after that duration, the model drifts from the ground truth suffering from excessive artificial mass injection. Models trained on simulations with different initial conditions show some promise of generalizing to configurations not present in the training set, but also suffer from mass continuity issues.

Dongha Shin et al. [9] predict these parameters considering various input/output (I/O) variables and learning algorithms applied to weather forecasts on hourly weather data. Finally, it predict photovoltaic power generation based on the best sunshine and solar radiation prediction results. The data structure underlying all predictions relies on four models applied to fundamental weather factors on sunshine and solar radiation data two hours ago. Then, the photovoltaic power generation prediction is implemented using four models depending on whether to add the predicted sunshine and solar radiation data obtained at the previous step. The prediction algorithm relies on an adaptive neuro-fuzzy inference system and artificial neural network (ANN) techniques, including dynamic neural network (DNN), recurrent neural network (RNN), and long short-term memory (LSTM). The results of the conducted experiment indicate that ANN perform better than the neuro-fuzzy approach. Moreover, it demonstrate that RNN and LSTM are more suitable for the time series data structures compared with DNN.

Sagar Garg, et al. [10] test three different probabilistic machine learning methods -- Monte Carlo dropout, parametric prediction and categorical prediction, in which the probability distribution is discretized. Authors found that plain Monte Carlo dropout severely underestimates uncertainty. The parametric and categorical models both produce fairly reliable forecasts of similar quality. The parametric models have fewer degrees of freedom while the categorical model is more flexible when it comes to predicting non-Gaussian distributions.

Jonathan A. Weyn et al [11] present an ensemble prediction system using a Deep Learning Weather Prediction (DLWP) model that recursively predicts six key atmospheric variables with six-hour time resolution. This computationally efficient model uses convolutional neural networks (CNNs) on a cubed sphere grid to produce global forecasts. The trained model requires just three minutes on a single GPU to produce a 320- member set of six-week forecasts at 1.4° resolution. Ensemble spread is primarily produced by randomizing the CNN training process to create a set of 32 DLWP models with slightly different learned weights. Although DLWP model does not forecast precipitation, it does forecast total column water vapor and gives a reasonable 4.5-day deterministic forecast of Hurricane Irma. In addition to simulating mid-latitude weather systems, it spontaneously generates tropical cyclones in a one-year free-running simulation. Averaged globally and over a two-year test set, the ensemble mean RMSE retains skill relative to climatology beyond two-weeks, with anomaly correlation coefficients remaining above 0.6 through six days. Primary application of this study is to subseasonal-to-seasonal (S2S) forecasting at lead times from two to six weeks. Current forecast systems have low skill in predicting one- or 2-week-average weather patterns at S2S time scales. The continuous ranked probability score (CRPS) and the ranked probability skill score (RPSS) show that the DLWP ensemble is only modestly inferior in performance to the European Center for Medium Range Weather Forecasts (ECMWF) S2S ensemble over land at lead times of 4 and 5–6 weeks. At shorter lead times, the ECMWF ensemble performs better than DLWP.

Sudhan Murugan Bhagavathi et al.[12] proposed a weather forecasting model based on machine learning for improving the accuracy and efficiency of forecasting. This research is proposed a weather prediction model for short-range prediction based on numerical data. Daily weather prediction includes the work of thousands of worldwide meteorologists and observers. Modernized computers make predictions more precise than ever, and earth-orbiting weather satellites capture pictures of clouds from space. However, in many cases, the forecast under many conditions is not accurate. Numericalweather prediction (NWP) is one of the popular methods for forecasting weather conditions. NWP is a major weather modeling tool for meteorologists which contributes to more accurate accuracy. In this research, the weather forecasting model uses the C5.0 algorithm with *K*-means clustering. The C5.0 is one of the better decision tree classifiers, and the decision tree is a great alternative for forecasting and prediction. The algorithm for clustering the *K*-means is used to combine identical data together. For this process, the clustering of *K*-means is initially applied to divide the dataset into the closest cluster of *K*. For training and testing, the meteorological data collection obtained from the database Modern-Era Historical Analysis for Research and Applications (MERRA) is used. The model's performance is assessed through MAE mean absolute error (MAE) and root mean square error (RMSE). And the proposed model is assessed with accuracy, sensitivity, and specificity for validation. The results obtained are compared with other current machine learning approaches, and the proposed model achieved predictive accuracy of 90.18%

[3] Comparative Analysis

This study compares the performance of deep learning algorithms to predict weather conditions, as shown in Table I

Table I: Comparative Analysis

Reference	Machine Learning /Deep Learning Algorithms	Results
1	Recurrence Neural Network (RNN), Conditional Restricted Boltzmann Machine (CRBM), and Convolutional Network (CN)models	Forecasting accuracyof each model is evaluated using Frobenius norm
2	random forestclassification,	low-cost and portable solution for weather prediction is devised.
3	Random Forest Regression (RFR), ML with the RFR technique. The incorporated regression techniquesare Ridge Regression (Ridge), Support Vector (SVR), Multi-layer Perceptron (MLPR), and Extra-Tree Regression (ETR).	machine learning models can predict weather features accurately enough tocompete with traditional models.
4	Support Vector Machine (SVM), Artificial Neural Network(ANN) and a Time Series based Recurrent Neural Network (RNN).	Time Series based RNN does the best job of predicting the weather

5	Automated Machine Learning (AutoML)and proposed deep learning framework	evaluate our model's performance on long- term weather forecasting.
6	novel deep learningpattern-recognitiontechnique (capsule neural networks, CapsNets) and an impact-based autolabeling	CapsNets accuracy increases to 80% (88%).
7	(Deep Learning, Random Forest, Artificial Neural Networks, Support Vector Machine, andXGBoost),	machine learning methods will be a key feature in future weather forecasting.
8	convolutional neuralnetwork (CNN)	data-driven machine learning approach should be verypromising
9	adaptive neuro-fuzzyinference system andartificial neural network (ANN) techniques, includingdynamic neural network (DNN), recurrent neural network (RNN), and long short-term memory (LSTM).	ANN perform better than the neuro-fuzzy approach RNN and LSTM are more suitable for the time series data structures comparedwith DNN.
10	probabilistic machinelearning methods -- Monte Carlo	plain Monte Carlodropout severely underestimates uncertainty. The parametric and categorical models both produce fairly reliable forecasts of similar quality.
11	Deep Learning Weather Prediction (DLWP)	At shorter lead times, the ECMWF ensembleperforms better than DLWP.
12	C5.0 algorithm with *K*-means clustering	proposed model achieved predictiveaccuracy of 90.18%.

[4] SUMMARY

From the results shown in Table 1, it has been observedthat different types of deep learning algorithms were used by various researchers to forecast the weather conditions at different geographical locations. Researchers have experimented with deep learning/machine learning algorithms such as Recurrence Neural Network (RNN), Conditional Restricted Boltzmann Machine (CRBM), random forest classification, Random Forest Regression (RFR), ML with the RFR technique, Ridge Regression (Ridge), Support Vector(SVR), Multi-layer Perceptron (MLPR), extra-Tree Regression (ETR), Support Vector Machine (SVM), Artificial Neural Network (ANN) , Time Series based Recurrent Neural Network (RNN), Deep Learning, Random Forest, XGBoost, convolutional neural network (CNN), adaptive neuro-fuzzyinference system techniques, including dynamic neural network (DNN), long short-term memory (LSTM), Probabilistic machine learning methods -- Monte Carlo , Deep Learning Weather Prediction (DLWP) and C5.0 algorithm with *K*-means clustering. This study concludes that C5.0 algorithm with *K*-means clustering algorithm performed best as compared to other algorithms.

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