Detailed survey of Weather Prediction using Machine Learning Algorithms

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ABSTRACT

Perfect weather predictions are needed for a plethora of activities and it was one of the main challenging problems the entire world faced because of its multiple dimensions and non-linear trends. Weather depends on multiple climatic conditions like temperature, air pressure, humidity, wind flow speed and direction, cloud height and density, and rainfall. The most common phrases/keywords in weather prediction related articles were 'wind', 'precipitation', 'climate change', 'wind forecasting' and 'ensemble prediction’. The most common countries in which surveys were done are China, USA, Australia, India and Germany. Extreme meteorological events are often related to the occurrence of weather fronts.

Keywords—Weather, machine learning, prediction

# INTRODUCTION

Weather forecasting is the application of scientific techniques and technology to predict the conditions of the atmosphere at a certain location and time. For a long time, the researcher had attempted to establish a linear relationship between the input weather data attributes and the corresponding target attribute. But the discovery of nonlinearity within different attributes of weather data, the focus has shifted towards the nonlinear prediction of the weather. Weather forecasts are made by collecting quantitative data about the current state and previous trend of the atmosphere and using scientific understanding of atmospheric processes to predict how the atmosphere will evolve. The weather warning is important for the protection of life and property. Weather prediction has seen a variety of approaches in recent years based on Genetic Algorithms and Neural networks but these fail to capture the complex relationships between various factors which affect weather.

Machine Learning is a part of Artificial Intelligence with the help of any system can learn and improve from existing real datasets to generate an accurate output. The main techniques that are used for weather prediction is unsupervised learning, supervised learning, Support Vector Machine, FP Growth Algorithm and Decision Tree Classification. Machine learning in weather forecasting is a recent trend in the literature. There are several works which discuss this topic. Holmstrom et al. proposed a technique to forecast the maximum and minimum temperature of the next seven days, given the data of past two days. They utilized a linear regression model, as well as a variation of a functional linear regression model. They showed that both the models were outperformed by professional weather forecasting services for the prediction of up to seven days. However, their model performs better in forecasting later days or longer time scales. A hybrid model that used neural networks to model the physics behind weather forecasting was proposed. Support vector machines was also utilized for weather prediction as a classification problem.

There are three important aspects to be taken into account when planning work using machine learning methods in Numerical Weather Prediction (NWP) models. The first is to speed up computations of very computationally expensive parts of the model, the second is to improve the performance of current algorithms, and the third is to emulate the existing code with machine learning models in order to easily allow a model to run on a computer cluster with GPU accelerators. Currently used databases are usually available with very coarse resolution and consist of numerous errors. Convolutional Neural Networks (CNN) can be used to improve them with the use of Sentinel-2 satellite data, the CORINE land-cover, and the BigEarthNet database.

The transfer functions normally used in multilayer neural network are tansig, logsig. And purelin. Tansig is a neural transfer function used to calculate a layer's output from its net input. It is used because meteorological observed data is nonlinear in nature, from which it is difficult to generate the frequent patterns of similar type of data related to one of the output classes. This activation function gives output from -1 to +1. Purelin is a Neural Transfer Function used in fitting problems. This activation function is used in the middle layer between two hidden layers.

There are two types of Neural Networks: Static and dynamic. Multilayer Perceptron (MLP) and Radial Basis Function (RBF) are types of Static Neural Networks while Time Delay Neural Networks (TDNN), concentration-in-time neural networks are dynamic neural networks. All these models do a good job in identifying the seasonal variations but fail in trend and random variations. A variety of Time Series Models have also been developed like Auto regression, Autoregressive Moving Average (ARMA), Autoregressive Integrated Moving Average (ARIMA) etc. but combining time series with the neural network is mostly unexplored. A data mining based predictive model to identify the fluctuating patterns of weather conditions was also proposed. The patterns from historical data is used to approximate the upcoming weather conditions. The proposed data model uses Hidden Markov Model for prediction and k-means clustering for extracting weather condition observations. Weather prediction was studied via a hybrid approach, which combines discriminatively trained predictive models with Deep Neural Networks that models the joint statistics of a set of weather-related variables. Monitory et al. used the concept of crowd sensing, where participating users share their smart phone data to environmental phenomenon. They introduced an architecture named Sen Square, which handles data from IoT sources and crowd sensing platforms, and display the data unified to subscribers. This data is used in smart city environment monitoring.

**II. LITERATURE SURVEY**

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| **Title** | **Authors** | **Methodology used** | **Remarks** |
| Weather Forecasting Using ANN with Error Backpropagation Algorithm | Meera Narvekar, PriyancaFargose and Debajyoti Mukhopadhyay | ANN with error back propagation | Used a dataset of over 7 years.Scope of model was limited to Mumbai.  Tansig, logsig and pureline activation functions were used.  There were 28 input neurons, 10 in hidden layer 1 and 10 in hidden layer 2 and 5 output neurons.  Error rate= 0.0773 and accuracy = 90% |
| Machine Learning in Weather Prediction and Climate Analyses—Applications and Perspectives | Bogdan Bochenek and Zbigniew Ustrnul | ‘tidytext’ R package for text mining | Text mining and analysis of 500 most relevant articles since 2018 were done.  Most common methods in NWP articles were DL, RF, ANN, SVM and XGB.  ML is efficient in predicting weather. |
| intelligent weather forecast | LL. LAI, H. BRAUN, Q.P. ZHANG, Q. WU, Y.N. MA, W.C. SUN, L.YANG | Dynamic weighted time delay neural networks | Done for short-term temperature and rainfall forecasting over East coast of China.  Applied on 8 different weather forecasting stations.  Data was read as an ASCII file. Preprocessing included accounting for missing data, reducing chaotic behaviours, low pass filter and normalization.  Error rate for 2 stations =0.7092; 4 stations = 0.7485; 8 stations = 0.8223 |
| A novel weather prediction model using a hybrid mechanism based on MLP and VAE with fire‑fly optimization algorithm | Veera Ankalu Vuyyuru, G. Appa Rao, Y. V. Srinivasa Murthy | A novel weather prediction model using a hybrid mechanism based on MLP and VAE with fire‑fly optimization algorithm | Data was collected from Delhi.  VAE was used to process global features and its output was given as input to MLP where local or internal features were extracted.  Fire-fly optimization was used for VAE-MLFNN and MLP.  Goal was to minimize RMSE.  Accuracy for different criteria such as temperature, snow, humidity, pressure, wind speed and visibility varied from 80-95% |
| Daily Weather Forecasting using Artificial Neural Network | Meera Narvekar, PriyancaFargose | Artificial Neural Networks | Preprocessing algorithms employed were cleaning, normalizing and splitting into train data and test data.  Instances considered were intensity of rainfall and sky conditions.  Weight and bias were initialized randomly and adjusted with MSE. Learning rate parameter and sigmoid activation function was used.  ANN with back propagation was concluded to be most appropriate for weather predictions. |
| Disease Manifestation Prediction from weather Data Using Extreme Learning Machine | B.K.Singh, R.P.Singh, TejasveeBisen, Shweta Kharayat IEEE publisher 2018. | Proposed ELM (Extreme learning machine) algorithm | Predicting when a disease will increase to a threshold that causes significant economic loss is important to prevent. Experiments were conducted for different activation functions and it could give satisfactory accuracy of 91.5% for radial basis function |
| Survey on weather Forecasting Using Data Mining. | Christy Kunjumon, SreelakshmiS.Nair,Deepa Ranjan S, Padma Suresh, S.L Preetha IEEE publisher(phase 7) 2019 | Support Vector Machine(SVM) algorithm. | This complete paper narrates different data mining techniques and methodology for weather prediction. Based on result, it can be concluded that the support vector machine algorithm can gives better weather prediction with higher accuracy and provides better result. |
| Real Time Weather Prediction System Using IOT and Machine Learning | Gaurav Verma, Pranjul Mittal, ShaistaFarheen | K-nearest neighbour | The temperature, light and humidity are the three important parameters that are monitored and uploaded on thingspeak cloud.  A Logistic regression model has been used in Jupyter notebook environment that is trained with prerecorded values of parameters and used to predict the weather parameters in real time environment. The result of the model is also compared with the other works available in literature and the proposed system is slightly better in terms of accuracy. Further, the system can be modified to be used at commercial level and have many applications in smart homes, buildings, sports |
| Weather Forecasting Using Machine Learning Techniques | Siddharth Singh , Mayank Kaushik, Ambuj Gupta, Anil Kumar Malviya | Support Vector Machine(SVM), Artificial Neural Network(ANN),Time Series Recurrent Neural Network (RNN) | The paper compares the three methods using the parameter root mean square error between actual value and predicted value. The software used is pandas , NumPy, Keras , Git ,Matplotlib, TensorFlow, Anaconda and google cloud services. Data is collected from different airport weather stations of India. Various attributes like atmospheric pressure, relative humidity, dew point etc are used. It is concluded that RNN gives the least root square error |
| Smart Weather Forecasting Using Machine Learning: A Case Study in Tennessee. | A H M Jakaria, Md Mosharaf Hossain, and Mohammad Ashiqur Rahman | Random Forest Regression (RFR),Ridge Regression (Ridge), Support Vector (SVR), Multi-layer Perceptron (MLPR), and Extra-Tree Regression (ETR) | Real weather data is collected from 10 cities. Root mean square error is measured to evaluate the models. The target variable for this record is assigned as the temperature at the same timestamp of the next day. They compare root mean square error for one city case and ten city case using different regression models. They come to the conclusion that RFR is more accurate in finding the weather as it shows a low RMSE close to 3.0 for ten city case and a high value for one city case. |

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| Machine Learning Paradigms for Speech Recognition: An Overview | Li Deng and Xiao Li, IEEE | Maximum likelihood linear regression (MLLR), Hidden Markov model (HMM), Bayesian-sensing HMM | To develop automatic systems capable of generalizing from previously observed examples, by constructing or learning functional dependencies between arbitrary input and output domains. |
| Machine Learning in Automatic Speech Recognition: A Survey | Jayashree Padmanabhan & Melvin Jose Johnson Premkumar | Gaussian mixture models, Hidden Markov models, Machine learning, Support vector machines, SVM/HMM hybrid systems, MLP/HMM systems, | Markov models used in prediction problems. determining the probability of the model in generating the sequence.  Determining the most likely state sequence that generates the outcome is decoding, using the Viterbi algorithm; updating the model parameters for maximizing the likelihood of occurrence is training, adopted by Baum-welch algorithm. |
| Applications of Support Vector Machines to Speech Recognition | Aravind Ganapathiraju, Jonathan E. Hamaker, Joseph Picone | Support vector machines(SVM), aussian mixture models (GMM), Hidden Markov models (HMM), Expectation–Maximization (EM) algorithm, Empirical risk minimization (ERM) | SVM automatically controls generalization and parameterization as part of the overall optimization process.  The Switchboard (SWB) task, which is based on two-way telephone recordings of conversational speech, is very different from the AD task in terms of acoustic confusability and classifier complexity |
| Speech Recognition for COVID-19 Keywords Using Machine Learning | Wael Ben Amara, Amani Touihri, Salma Hamza. | Artificial neural network (ANN),Support Vector Machine (SVM). | The proposed method in this research is a way to detect individuals carrying the virus based on the list of symptoms they provide, but in practice this should be done very precisely in order to avoid false outputs and especially false negatives. |
| An Evaluation on Speech Recognition Technology based on Machine Learning | Tribhuwan Kumar, Rajesh K, Kalyan Chakravarthi, Suman Rajest | Speech Recognition with RNN. | The speech signal recognition is based on a machine-learning algorithm to merge the speech features and attributes. As a result of voice as a bio-metric implication, the speech signal is converted into a significant element of speech improvement. The experimental result shows the improved proposed speech recognition algorithms accuracy with another state of the art method. |
| Machine Learning Based Speech Emotions Recognition System | Dr. Yogesh Kumar, Dr. Manish Mahajan | Support Vector Machine (SVM) classifier. Convolution Neural network (CNN) classifier. K-Nearest Neighbours (KNN). | Performance analysis based on different machine learning techniques for different languages. In the paper, the detailed review on KNN, SVM, CNN classifier for speech emotion recognition system is used. The overall aim is to work on the emotions generated by humans using the above mentioned algorithms. |
| Speech Recognition Using Machine Learning | Vineet Vashisht, Satya Prakash yadav, Aditya Kumar pandey | Speech computer or speech synthesizer, text-to-speech(TTS) system, Neural Machine Translation (NMT) | Voice detection with real-time predictive voice translation device optimization using multimodal vector sources of information and functionality was presented. The key production and commitment of this work is the manner in which external information input is used to increase the system's accuracy, thereby allowing a notable improvement, compared to the processes of nature. In addition, a new initiative has been launched from an analytical standpoint, while remaining a realistic one, and was discussed. |
| Convolutional Neural Networks for Speech Recognition | Ossama Abdel-Hamid, Abdel-rahman Mohamed, Hui Jiang, Li Deng, Gerald Penn, and Dong Yu | Hybrid ANN-HMM framework, Convolution Neural network (CNN) classifier. | This paper describes how to apply CNNs to speech recognition in a novel way, such that the CNN’s structure directly accommodates some types of speech variability. This Hybrid CNN-HMM approch delegates temporal variability to HMM, while convolving along the frequency axis creates a degree of invariance to small frequency shifts,which normally occur in actual speech signals due to speaker differences. |
| “Controlling Email System Using Audio with Speech Recognition and Text to Speech” 2021 | Harsh D Shah, Amit Sundas,  Shabnam Sharma. | A hidden Markov model (HMM) | The proposed system is intended to build a framework for control email over voice and reduce the effort of manual typing the mail along with saving time. The powerful advantage of the HMM approach combined with MFCC features is better suited to these criteria and provides strong recognition results |
| “Sign Languages to Speech Conversion Prototype using the SVM Classifier” | Malli Mahesh Chandra,RajkumarS,Lakshmi Sutha Kumar. | Support vector machines (SVMs) | In this paper the user can speak English or some Indian languages through the gestures using proposed prototype. Around 22 gestures in ASL and 11 gestures in ISL are trained and tested successfully. An accuracy of 100% is achieved for ISL database with 25% test data and 75% training data. And an accuracy of 98.91% is achieved for ASL database with 25% test data and 75% training data |

**III. MACHINE LEARNING ALGORITHM DISCUSSION**

The machine learning algorithms used in weather predictions thus far are:

* Ensemble Neural Networks
* General Regression Neural Network
* Regression models
* Recurrent Neural Networks
* Multi-Layer Perceptron
* Genetic Algorithms
* Fuzzy clustering
* Artificial Neural Networks
* Back error propagation
* Support Vector Machines
* K-nearest neighbour
* Naïve Bayes Classifier
* Decision tree
* Learning vector propagation
* Deep Learning
* Random forest
* XGBoost
* Principal component analysis

**IV. APPLICATIONS**

Weather forecasting is very necessary for making strategic plans and executing daily tasks in multiple application areas like

* Airport: As Airport traffic is vastly reliant on weather conditions, weather forecasting is very necessary for efficient air traffic control.
* Agriculture (Crop growth and production): Crops grown anywhere are majorly dependent on the weather and therefore help in profitable and healthy growth.
* Electricity: Electricity is produced in various ways through natural forces such as tidal, wind and water, monitoring them closely using the weather forecast can help in efficient use of the grid.
* Water reservoir: The volume of water stored can be regulated according to the rainfall prediction.
* Tourism: People’s preference of climate is very subjective, with accurate weather forecasting they can choose the time to visit places in their desired weather.
* And daily life

Applications also include

* Climate monitoring: Climate refers to weather conditions over a large area, the average weather conditions help in monitoring the climate.
* Drought detection: Farmers can accurately determine the period over which the crops can be grown.
* Severe weather and flash flood warnings: These natural conditions can be very fatal, timely warnings can be put out to avoid catastrophes.
* River monitoring and control: Rivers can have multiple subsidiaries and canals can also be constructed, water flow can be rerouted and regulated so that floods and droughts can be avoided.
* Numerical weather prediction, model initialization and verification.

Governments and businesses are utilizing their predictions to safeguard life and property and boost operation quality and schedule various day-to-day operations for individuals.

Farms, airlines, hospitals, fire services etc. can provide an hour’s or even a day’s notice with accurate weather forecasting.

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