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Weather Forecasting: Era of Artificial Intelligence

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Abstract - *Weather forecasting is emerging out as the most important field of research due to the unpredictable variations in the climatic and atmospheric conditions. Since, last few decades the researchers are advancing new techniques for training the models to achieve accuracy over the nonlinear statistical datasets to prevent future destructions and global issues. Agriculture being the power and foundation of the Indian economy, the favourable climatic conditions for the crops to be grown is a key to higher yields. The concepts of artificial intelligence and machine learning have given the new dimension into the field of weather forecasting with minimal mind-blogging mathematical equations and statistical calculations. This paper reviews on the various traditional techniques from traditional weather forecasting techniques to modern methodologies involving the data mining and artificial intelligence. This paper also illustrates a proposed model that achieves high accuracy and is also useful in other areas of time series forecasting.*

Keywords **- Weather forecasting, artificial intelligence, neural network, weather elements, accuracy.**

1. Introduction

Weather forecasting is one of the major applications of science and technology, which involves projection of atmospheric condition using the collection of quantitative data that defines the numerous factors responsible for abrupt shifts in the weather over a small duration of time pertaining to a specific location. The unpredictability of the weather forecasts has aroused due to increase in the difference in current and the forecasting time, complex mathematical and statistical computations that requires high computational competency, inaccuracy in recording of the measurements and lack of knowledge in meteorology. Weather forecasting has various applications such as weather warnings (for protection of life and property), temperature and precipitation forecasts (useful for farmers and traders worldwide), predictions of the seasons (for clothing and extra-curricular activities). The paper is structured in 8 sections that gives the review on the traditional techniques and modern techniques used for weather predictions and proposed a new methodology based upon the above study.

2. TRADITIONAL FORECASTING METHODOLOGIES

Since 1861, the researchers have made a large number of attempts to achieve accuracy in weather predictions by devising various new concepts and methodologies. Owing to the nonlinearity of the environment, the precision achieved by such strategies is still below the acceptance level. Following is the short description of the common approaches utilized in weather forecasting.

2.1 Synoptic Weather Forecasting *[8]*

In this conventional approach to weather forecasting, the meteorologist designs the synoptic charts on a regular basis by monitoring and gathering data on various weather elements from multiple weather stations of the appropriate location and precise period. These synoptic maps, shape the foundation of the weather forecasts and were not in practice until late 1950s. Over several years, the analysis of synoptic charts has resulted in the creation of numerous methodological rules that helps to estimate the intensity and directions of weather systems.

2.2 Numerical Weather Predictions (NWP)

The numerical weather prediction methodology uses the power of supercomputers to compute complex scientific and mathematical equations that models atmospheric conditions to forecasts weather. The NWP method is a flaw, since the initial state is not well defined, the computer's estimation of how the initial state will evolve is not predictable.

2.3 Statistical Methods [8]

The limitations of the NWP models is overcome by the statistical methods which is focused on the premise that future will be the continuation of the past, and thus includes the weather forecasting based on historical weather records. The objective is to recognize good indicators of the future events and establish relationships among parameters in order to predict future weather. In

specific, it is used to forecast just one element of the weather at a time.

3. BACKGROUND STUDY OF WEATHER [6]

The day-to-day conditions of the atmosphere at a specific region over a particular time period with respect to quantifiable elements such as humidity, temperature, wind speed, rainfall, etc. is referred to as the weather of that place. It is a part of the natural phenomenon which maintains the equilibrium in the atmosphere and can be cloudy, rainy or sunny. The atmospheric conditions can be extreme or intense enough to cause property loss or life loss at sometimes, such weather is termed as severe weather. According to the variations in the altitudes, latitudes, region and pressure it can be categorized as tornadoes, cyclones, heavy rainfall, fog and winter storms which can be disastrous and hazardous. These conditions can be handled with the proper disaster management and prior knowledge wherein the weather forecasting comes into existence. Following is the brief description of some of the weather elements significant for the predictions of the severe weather conditions.

3.1. Temperature

It is a most important intensive property and a meteorological parameter that quantifies the measure of hotness or coldness in a given location at the particular instant of time (or can be taken as an average of the values recorded till that time) which is expressed in terms of any arbitrary scales (^oC or F^o). The temperature is measured with the help of the various devices such as thermometer, Stevenson screen and thermo-hygrograph.

3.2. Pressure

It can be defined as the force per unit area exerted by the weight of the air on a surface. It can be measured in millibars (mb) with the help of devices such as aneroid barometer, digital barometer and barograph.

3.3. Humidity

Humidity is referenced as the amount of water vapor present in the air. The higher the humidity, the wetter it feels outside as the air is clogged with water vapor that there isn't room for other particles. It is usually expressed in percentage.

3.4. Wind Speed & Wind Direction

Wind speed is expressed as the fundamental atmospheric rate at which the air moves in the atmosphere. It is measured with the help of some of the devices such as Anemometer, Wind vane and Wind sock and is expressed in kilometer per hour (kmph) or miles per hour (mph).

3.5. Cloudcover

The cloud cover is the fraction of the sky covered by clouds when observed from a particular location. Okta is the usual unit of measurement of the cloud cover which is measured with the help of the device known as ceilometers.

3.6. Precipitation

This can be defined as the amount of water that falls from the clouds towards the ground in the form of rain or snow. It is measured in millimeters with the help of the device known as rain gauge.

4. LITERATURE REVIEW

The term artificial intelligence which was coined back in 1955 has become the technological sensation in today's era. It refers to the simulation of human intelligence in machines that are programmed to think like humans that can mimic their actions. The ideal characteristic of artificial intelligence is its ability to rationalize and take actions that have the best chance of achieving a specific goal. AI is continuously evolving to benefit many different industries. Machines are wired using a cross-disciplinary approach based in mathematics, computer science, linguistics, psychology, and more.

Artificial Intelligence consists of machine learning, deep learning, neural networks as a part of it. Machine Learning can be defined as a subset of AI. Deep Learning is a subset of machine learning which has networks capable of doing supervised learning, unsupervised learning over a structured or unstructured data. Neural network is an essential part of the AI, replicated from the human brain.

4.1. *Artificial Neural Network [1]*

Artificial Neural Network is either a software or a hardware system inspired from the human biological neuron. The biological neuron is the building block of the human brain which works as accepting stimuli through dendrites, passing the signals to the brain cells along the neurons which then stimulates the specific behavior and give the output. The working of the neural network is analogues to the working of the neuron as ANN consists of several nodes that acts as neurons, it takes the data as the

input and passes it to the hidden layers (linked neurons) present in the neural network to train the inputs and gives the resultant output as input to another hidden layer to improvise further.

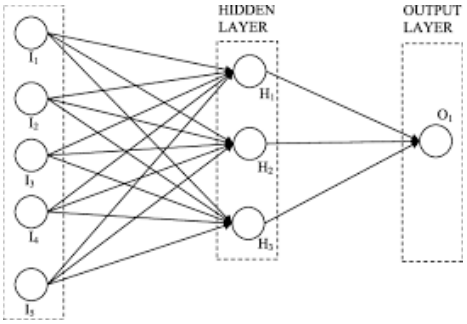

Figure 4.1 Structure of Artificial Neural Network [1]

4.2. Recurrent Neural Network [1]

Recurrent Neural Network learns from the previous data by memorizing the previous input to produce the new output. RNNs improvise by producing only one input vector and one yield vector which is varied by adjusting the bias weights by minimizing the errors in the predicted and input values between the hidden layers.

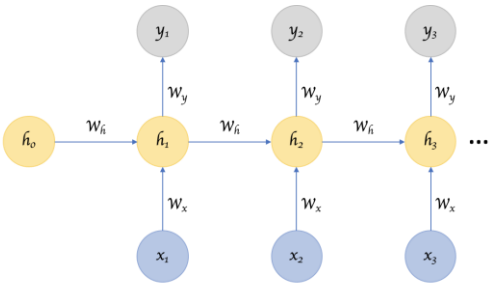

Figure 4.2 Structure of Recurrent Neural Network [ref 1]

4.3. Long Short-Term Memory Unit (LSTM) [4]

LSTM is a significant algorithm for the time series forecasting problems and natural language processing designed by Hochreiter & Schmidhuber in the year 1997. The network is improved on addition of additional layers of sigmoid and tanh activation functions which is referenced as cell state of the LSTM network. Due to the several tanh functions that maps the values between -1 to 1 this network is beneficial for the long-term dependencies.

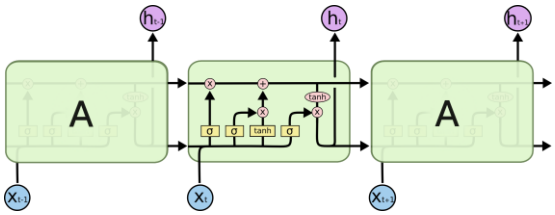

Figure 4.3 Structure of LSTM [2]

5. PROPOSED METHODOLOGY

We proposed a system that overcomes the numerous limitations encountered by the Numerical Weather Prediction Models which is used at different weather forecasting agencies till date. The proposed system requires less computational capabilities with strong qualitative and quantitative data contributing to the more reliable performance.

The following figure 5.1 illustrates the system architecture of the proposed system. Using the concept of recurrent neural network in addition to the Long Short-Term Memory Units to improvise the learning model helps in minimizing the errors in each epoch and improving the precision of the weather elements being predicted. This is achieved with the introduction of sigmoid and tanh functions in the LSTM network to map the inputs between 0 to 1 to produce optimum predictions. The input to the model is the past 14 days weather conditions of the weather elements such as temperature, pressure, humidity and cloudcover and the output is the predictions of coming 14 days for the above-mentioned weather elements.

The past weather conditions are collected with the help of the weather API used from the world weather online. As the weather predictions is the instance of time series forecasting the variable parameter used is the time and the predicted parameter is the weather elements being forecasted individually with the same approach as described above.

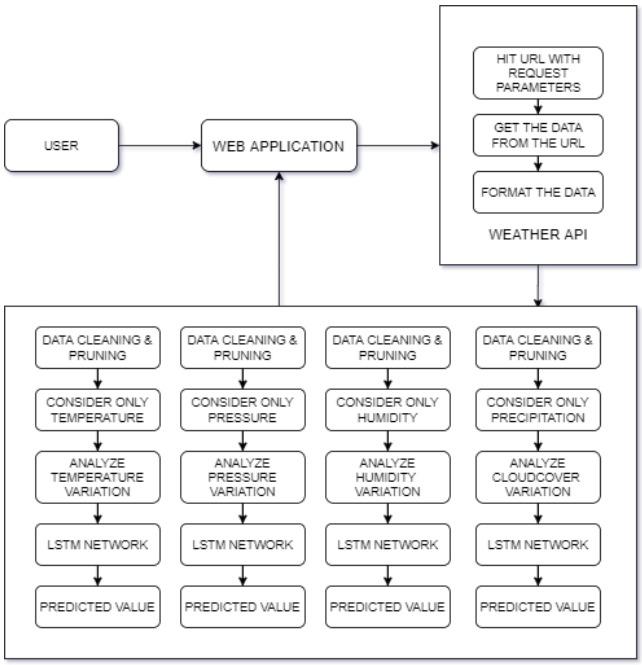

Figure 5.1 System Architecture

6. MODEL ANALYSIS & TRAINING

The significance of analysing, diagnosing, understanding and refining the neural network with the help of interactive visualization, is very important for data scientist, to improvise the accuracy of the model and design the best fit neural network design to achieve accurate precisions. Following figure shows the graphs being plotted between epochs, loss and accuracy to analyse the fitness of the model and diagnose it to improvise the model for high accuracy.

Each element has three graphs for the analysis of the fitness of the model. The model train vs validation loss graph shows the loss of the model during the training and testing of the data. If the graph is parallel to the x-axis indicates that there is no scope of improvement as the loss is constant. The graph of model train vs validation loss depicts the fitness of the model. If both the curves coincide then the model is good fit model, if the testing line is below or above the training line it signifies the overfit and the underfit model. [5]

Apart from these statistical analysis using graphs, the goodness of fit of the model was also measured by the metric mean squared error and mean absolute error. Lower the value of both these metrics, lower the loss and thus higher is the accuracy of the model. [7]

The model is also analysed by exposing it to the new datasets and is trained further to improve the training capabilities. Henceforth, the outcome of the model analysis and training of the neural networks on the tested datasets is the underfit model which can be further improved on training the model with the data of around 60-70 years (twice that of now), and higher number of epochs.

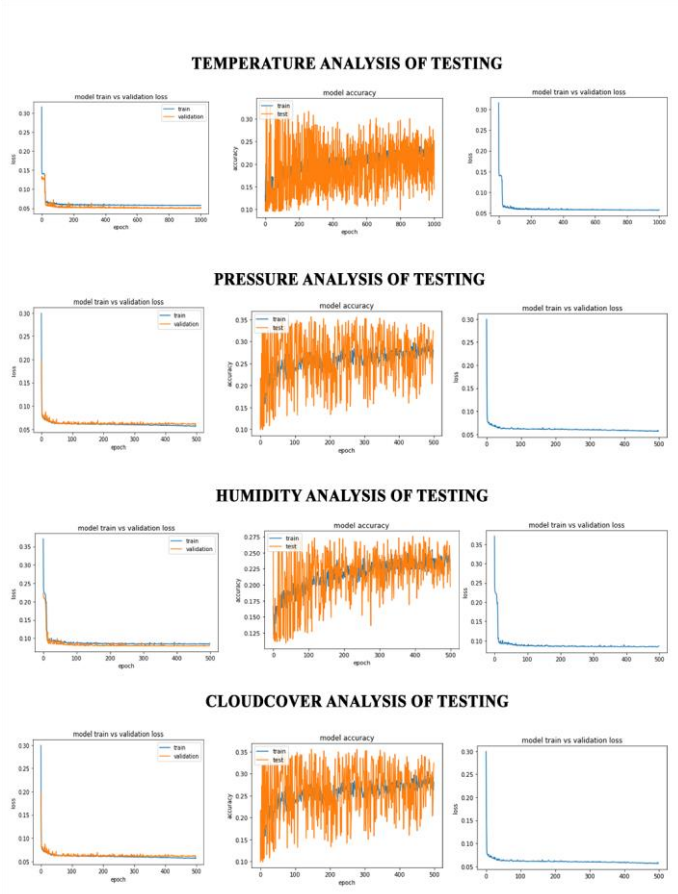

Figure 6.1 Model Analysis

7. RESULT

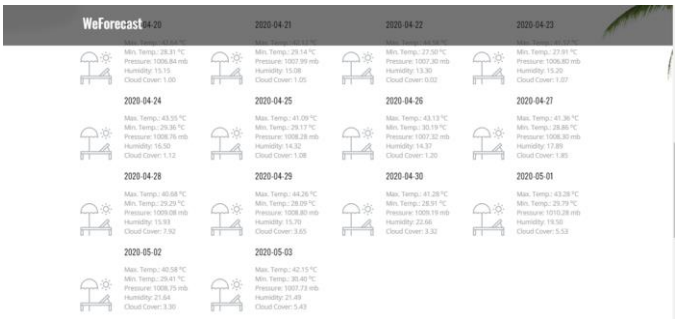

Figure 7.1 Predicted Values with GUI

The above figure shows the predicted values displayed with the help of the simple, attractive and responsive web application having all the weather elements that are being predicted as temperature, pressure, humidity and cloudcover. The accuracy achieved with this approach is 87% in addition to the predictions at 14^{th} day. During the study of the various other approaches used by the scientist for weather forecasting such as Feed Forward Network and Back Propagation network the accuracy achieved is better and can be further increased by introducing more data to the proposed system.

8. CONCLUSIONS

Weather which stands out as the most important part of our life due to its resemblance and dependability in every work and at every time its prediction has eventually resulted of significant importance. Several new methodologies have evolved with the introduction of new scientific techniques that reduces human efforts and time. Artificial intelligence which stimulates the human brain with high speed and accurate mind-blogging computations have given the new dimensions to the field of weather forecasting. Use of Recurrent neural network which learns from the past historic data in addition to the Long Short-Term Memory Unit (LSTM) algorithm has resulted in the design of a new significant proposed system that produces accurate results with high precision and remembers the computed results for a long period of time due to the sigmoid and tanh activation functions. Thus, the system proposed in this paper yields the accuracy of 86.9% with the prediction of a fortnight on the input of the previous fortnight.

The model proposed can be further improved on introducing it to the quantitative and qualitative data over 50 years and can achieve the accuracy of 96% for long period of time.

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