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

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Abstract
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) are 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, non-stationary, and unstable CNN algorithms should be built and tested with each dataset and system separately. On the other hand, to eradicate 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.

Keywords: Weather forecasting, Artificial Neural Network, Convolutional Neural Network

1. Introduction

Predicting future actions is a critical problem throughout the sciences and engineering, and it is needed in all aspects of life. All countries depend on their strategies and development projects on the principles and modern research techniques to develop a more successful plan, including the prediction of price, temperature, and weather [1] [2]. Weather prediction is the scientific knowledge used to forecast the state of the atmosphere in a given area. Weather predictions are based on the qualitative information on the current condition of the climate is being collected and also the application of scientific knowledge processes in the atmosphere to predict why the environment would change in the future [3] [4]. It must be intelligent in particular for them to quickly read statistical data in order to produce patterns and rules to research and forecast the future based on historical data [5] [6] [7]. People need weather reports to decide what to wear on a specific day on a regular basis. Since wet weather, snow, and freezing rain greatly limit outdoor activities, predictions can be used to schedule actions around these occurrences, as well as to plan accordingly and withstand them [8] [9]. Because of its effect on public social life, forecasting has drawn the attention of several researchers from various fields

[9]. Any procedure can be predicted using Neural Networks (NN) if enough data is created to precisely plan the model. They can construct designs and identify functionality that is too complex to be observed through various procedures, thereby taking into account the solid markers of new intrigue situations [10] [11]. Various papers and researches proposed weather forecasting models to use an ANN and CNN in order to accurately predict the weather and help solve all of the problems. Since forecast data is nonlinear which follows certain irregular patterns and trends, many conventional techniques can be used to improve model productivity and achieve predictions that are better than the previous forecasts [12] [13]. However, ANN has proven to be a more effective method of increasing reliability and accuracy. It is a fast-growing machine learning technique that uses non-linear statistical models for classifying data and weather forecasting [14] [15] [16]. The advantage of ANN over other weather prediction methods is that it employs various algorithms to reduce error and provides us with data that is really similar to the real meaning. Utilizing newer data, a network was created to predict the weather trend in the future [17] [18]. Weather forecasting is real-time forecasting in which the model's performance is needed for regular weather forecasts, daily or weekly climate plans, and so on. As a consequence, the reliability of the data is a critical factor in this prediction [19] a number of problems are covered that should be considered in order to achieve dependable outcomes in Section two. The remainder of this paper is laid out as follows: The first section contains an introduction that explains the importance of forecasting weather in general. The second section literature review which describes the various situations in which CNN or ANN for predicting the weather can be used in practice. Then, the methodology is identified in section three. In section four, we discuss the results. Finally, section five brings the paper to a conclusion.

2. Literature review

NN has a great role and positive impact in the case of prediction weather. In [20] they explained the quantifiable rainfall forecasting is extremely difficult due to variations of rainfall over time and space. Air temp, wind direction, and pressure all have an effect on rainfall depth. Along with the complexities of the atmospheric reasons that occur rain, as well as a scarcity of data at the necessary spatial and temporal scale. In general, using just a physically-based system model to predict rainfall is not feasible. Significant advances in artificial intelligence, especially pattern recognition techniques, allow for a more careful approach to the Tar creation of rainfall prediction models. ANN is a type of technique that employs a mapping function of variables. They proposed using ANN apps to forecast the spatial distribution of water inside a catchment area.

Multilayer Feedforward NNs (MLFN), partial RNNs (Elman), and Time-Delay NNs (TDNN) were classified and presented as three different types of ANN. The information specifications as well as the reliability that these 3 types of ANNs will achieve to provide sufficient rain range forecasts one period ahead of advance.

In [21] they described how an ANN utilizing past lightning with meteorological data, it is possible to forecast the frequency of lightning strikes. Because of its ability to recognize patterns, ANN is used. Which are applied through studying patterns and associations in data. Lightning can be predicted at least four hours in advance using a 2-layer Back-Propagation NN. Several network architectures, activation functions, and training algorithms were robustly evaluated in addition to identifying the most suitable network with great performance also quality ability. As shown by the regression coefficients affinity of cohesion, post-processing is used to strengthen the existing network. The computation burden in this study was overcome by adding a predictor element to the innovative parts of the research and training patterns in order to achieve an approximate solution.

In [22] presented a comparative study of artificial neural network algorithms for predicting short-term regular-stream flows. Conjugate Gradient (ANN-CG), Backpropagation (ANN-BP), Levenberg–Marquardt (ANN-LM), and Cascade Correlation (ANN-CC) are four separate ANN algorithms that are implemented to continuously streamflow data of the United States in the North Platte River. Untrained data is used to validate the models. The outcomes of the various algorithms are compared to one another. The correlation analysis has been used in the analysis and was shown to be efficient in evaluating sufficient input vectors of ANNs. The results showed that the Levenberg–Marquardt (LM) algorithm requires a similar period it takes to train the network compared to the other three algorithms. The back-propagation algorithm has an exceptionally high iteration and practice time. In brief regular streamflow prediction, the LM generated the best flow predictions when compared to any of the other models. The CG and CC models also provide more accurate streamflow predictions than the BP model. The correlation analysis was also used to evaluate the correct input vector for the ANN, according to the report.

In [23] addressed the use of ANNs, to predict dew point temperature 1 to 12 hours in advance utilizing prior weather information as inputs. The study looks at developing general models of dew point temperature prediction everywhere in Georgia utilizing three-layer backpropagation ANNs and temperature data collected over 3 years across 20 stores from Georgia. The collection of important climate inputs, the establishment of ANN criteria, and the collection of the length of previous input data were all specific goals. In comparison to dew point temperature, significant climate ANN inputs contained humidity level, solar radiation, wind speed, air pressure, and surface tension, according to an iterative search. Since dew point temperature, together with air temp, influences the strength of freezing and warmer temperatures, which can harm crops, machinery, and buildings, as well as cause loss of life to humans and animals, these forecasts are helpful for agricultural decisions.

In [24] they studied how CNN could classify weather from images and evaluated the recognition output of the layers of both the ImageNet-CNN and the Weather trained CNN. In the role of weather classification, the method outperforms the latest technology by a large margin. They also looked at how all of the layers of CNNs behaved, and some interesting results were discovered.

In [25] presented that deep learning can be used to identify extreme weather patterns through climate data. Deep CNN architecture was created to identify tropical cyclones, weather fronts, and atmospheric rivers. It's the first time deep CNN has been used to solve problems with climate pattern recognition. This promising application could pave the way for tackling a wide range of pattern detection issues for climate science. The DNN develops high-level models directly from data, theoretically avoiding the use of conventional subjective thresholding criteria for detecting events based on climate variables. The findings of this study will be used to measure the current and future trends in climate extreme weather events, and also investigate changes in thermodynamics and dynamics of extreme events in the face of global warming.

In [26] presented Short-Term Wind Speed Forecasting by utilizing ANN algorithms such as Bayesian Regularization, Scaled Conjugate Gradient algorithms, and Levenberg-Marquardt backpropagation of Lelystad Wind Farm. Predicting wind speed is important to wind energy because it has a significant impact on large-scale implementation. The key problem is that daily wind speed curves are extremely unpredictable. Even in cases of high volatility, the simulation results made accurate predictions. The ANN model was developed to estimate wind speed for each day of 2014, and the findings demonstrate that it performed effectively often in the presence of unpredictable weather changes.in[19] explained that on the basis of regular weather classification, by using an aerosol index for input data, a smart system based on ANN is developed to forecast solar radiation. To predict the next day's 3-hour solar radiation outcomes, an ANN by using Non - linear Auto-Regressive of (NARX) method is used. In order to obtain a precise forecast for PV power generation three hours ahead of time, Air temperature, altitude, wind direction, and prevailing winds data were used to create earlier models. The PV System forecasting model's expected results are assessed using statistical metrics such as Mean Square Error (MSE).

In [27] the NN approach was successfully implemented to the complicated precipitation now casting issue, especially with CNNs. They consider radar echo extrapolation to be a problem of spatial-temporal sequence forecasting and have suggested a new CNN model, RDCNN, to solve it. RDCNN combines RDSN and PPL to create a cyclic structure through hidden layers, and convolution layers enable RDCNN to handle moment captured images more efficiently. Experimentation proved RDCNN's efficacy for radar echo extrapolation, particularly in the border case.

In [28] developed ANN model to predict wind speed 10, 20, 30 minutes, and 1 hour in advance. It is depicted in India's mountainous area. The data series shown is WS data that has been averaged over 10 minutes. The ANN models were evaluated at 10, 20, 30 minutes, and 1-hour early estimation. Mean absolute error (MAE), mean error (ME), mean square error (MSE), and root mean square error (RMSE) were among the calculation error samples performed. This experiment can be used to monitor wind power online.

In [29] proposed a novel acoustic rain gauge that is built on CNN. At various rainfall rates, an investigation of the numerical or perceptual properties of rain-generated acoustics is presented. The device is particularly straightforward, relying on a plastic shaker, a microphone, and a limited signal processing system. In terms of accuracy and the ability to react to rapid changes throughout precipitation intensity, the output is excellent. It's important to remember that the temporal resolution of the maximum rain predictor that is used to label a database is low, particularly in low rainfall areas. Taking into consideration the normal micro-variances of annual rainfall, an accuracy rate of 93 percent can be considered, given that system's overall output does not degrade. Include erroneous classifications between classes. The latest acoustic rainfall data defies expectations. Traditional ones that have no mechanical parts so don't need to be maintained. Generally, a preferred method is sufficient for a rainfall rate management system, with the primary advantage of becoming a fully automated instrument that can be quickly integrated into existing networks and platforms.

In [30] they using wind-related dependent variable' characteristics, a hybrid method for wind power capacity besides electricity generation at coastal sites was proposed. Wind speed predictions will increase wind energy performance by enhancing performance and increasing the financial potential of such a variable renewable energy source. The proposed method is validated using data from three Kuwaiti coastal locations. The hybrid model, which combines ANN with Particle Swarm Optimization (PSO), for the calculation for wind speed, predicted wind direction one month in advance. The NN begins by evaluating its output with a variable neuron in the hidden layer before determining the best ANN topology. The hybrid ANN-PSO framework surpasses ANN-based marginal systems with low root-mean-square-error values and means square-error values, according to statistical indices compared to both predicted and observed findings.

In [31] presented a dramatically improved data-driven international weather prediction system that uses a deep CNN to predict a global grid of many simple atmospheric variables. An off-line density projection to a cubed-sphere system, enhancements to a CNN model, and the reduction of the error function across several steps in a forecast series are all new features in this framework. At timeframes of many weeks and longer, the enhanced model provides weather predictions that are permanently reliable and generate accurate weather patterns. The model outperforms durability, atmospheric chemistry, as well as a coarse-resolution stochastic Numerical Weather Prediction (NWP) model of short-term to moderate forecasting. From some few input atmospheric random variables, the information model will learn to predict complicated surface temperature trends. The model generates a practical seasonal pattern on yearly time scales, guided solely by the specified variance of top-of-atmosphere solar pushing. The data-driven CNN outperforms practical weather prediction systems by a factor of ten, meaning that machine learning could be an efficient way of large-ensemble predictions.

In [32] presented a new model of wind speed prediction problems based on CNNs. They demonstrate that the suggested model is the most effective at describing the spatiotemporal progression of wind direction than conventional CNN-based systems because different aspects of input data are used to know the underlying dynamic feedback interactions. The suggested framework learns new concepts for wind forecasting by using spatiotemporal multivariate multifaceted historical weather info. They put their theories to the test using 2 actual weather tables. The suggested framework learns new concepts of wind prediction by using Spatio-temporal multivariate multilayered past weather information. They test their theories on 2 real-world weather datasets. Observations through Denmark's cities as well as the Netherlands are included in the datasets. CNN models in two and three dimensions, as well as a two-dimensional framework via the attention layer, and a two-dimensional system with upscaling with distance-wise separable convolutions are all compared to the developed framework.

In [33] showed that environmental conditions including minimum temperature, rainfall rate, air pressure, highest temperature, strain, and others play a significant role in agriculture. Getting accurate weather prediction technology in a country such as India will enable farmers to increase crop productivity. Weather knowledge can have a direct or indirect effect on the manufacturing sector, not just farmers. The use of ANN, a computational intelligence technique, is a positive step toward developing an intuitive framework capable of processing nonlinear weather patterns and making forecasts. The proposed work focuses on designing a user-friendly framework that can predict the weather with the lowest possible error rate and a more appropriate design. The ANN design, dataset choice, input explanatory variable, and appropriate training set all should be sufficient and real for the best prediction results.

3. Methodology

In this review paper, two NN system designs have been selected to be utilized as weather prediction models for vitality utilization. Each system model has its advantages and expenses. The first one is ANN, which is used several algorithms such Long Short-Term Memory (LSTM) which is part of Recurrent Neural Network (RNN) or enhanced from it. LSTM networks are suitable for a variety of processing, classifying, and making forecasts according to time-series information. It was used to forecast wind speed for every day and showed that it worked well even in the face of unexpected weather changes. At the same time by using NARX that is another algorithm from ANN, in order to obtain a precise forecast for three hours ahead of time, humidity, temperature, and wind speed, we did not get a convincing outcome. And secondly, we have chosen CNN from different applications in the weather prediction area. If implemented in wind speed prediction problems, we show that is able to classify the spatiotemporal evolution of wind speed data through learning the underlying dynamic input-output interactions from different dimensions of the data input. On the other side if apply CNN to predict a global grid of many simple atmospheric variables necessitates a huge dataset, which is a time-consuming process in most real-world applications.

3.1. Artificial Neural Network -ANN

It is a nonlinear model that resembles a human neural network [34]. For several years, ANNs have been used to model problems in math, technology, health, finance, geology, meteorology, science, neurology, and other fields [35]. A web of linked nodes makes up an ANN. This process utilizes an input layer, hidden layers, as well as an output layer to define an object, which is told by the human mind. Each layer has many nodes, which are linked to the nodes throughout the layer pre and post with borders. Each edge has a value, which is changed during the training phase [36]. Due to the number of different nodes, it creates a model that has the ability to fit very well. The downside is that train such a model takes a lot of time [37].

To tackle the estimation of very complex structures, an ANN model weaves together mathematical learning achievement from amplified datasets (e.g. dry prediction and rainfall). There is no need to specify the underlying physical mechanism between the outputs and inputs since they are versatile and less presumption [38]. This makes the ANN ideal for weather prediction, particularly when the factors that trigger a drought are unknown. The ANN model basically learns through previous experiences with how the input is changed with time. To make future projections, it creates a practical input-output numerical technique. The required information and its subsequent output values are needed for training and testing an ANN model or forecasting a variable [39].

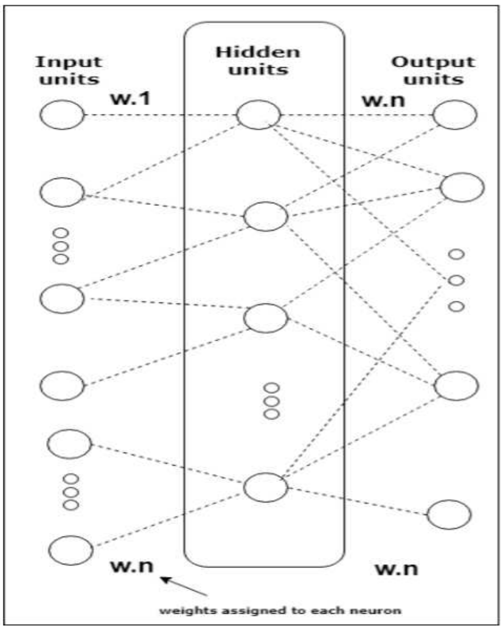

Figure 1. General architecture of ANN [8]

3.2. Convolution Neural Network-CNN

CNN is a form of NN that is primarily used for data processing in a grid topology [40]. CNNs 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 [41] [42]. 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, led 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 [43]. 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 [24].

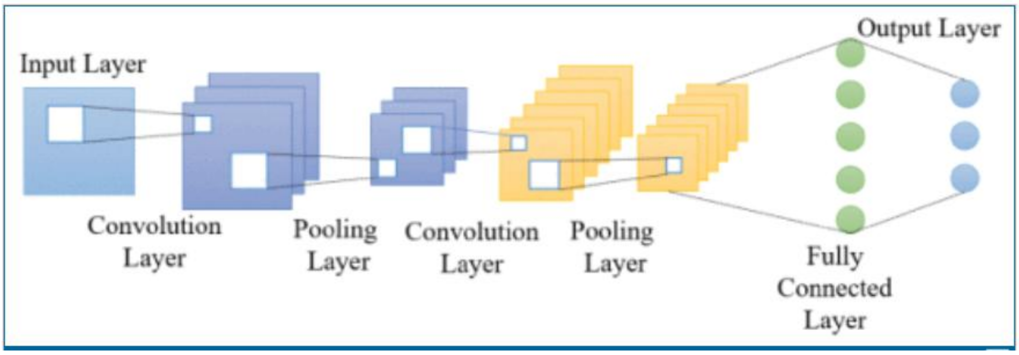

Figure 2. CNN's fundamental framework [37]

4. Results and discussion

Based on a set of previous research and studies mentioned in the literature review section and choosing samples from the results, which have been summarized in the table below to clarify and compare the models that have been chosen.

Table 1. **T**he outcomes of a number of weather forecasting applications that have implemented ANN algorithms and CNN algorithm

Method/ Model	Objective	Significant Result
CNN	classification of the weather-dependent on image recognition	By a large margin, the findings exceed the state-of-the-art (82.2 percent compared with 53.1 percent) [24]
ANN	Wind Speed Prediction for Power Generation in the Short Term	Evaluate the ANN models 10, 20, 30 minutes, and 1 hour before forecasting. The static failure of 10 minutes ahead forecasting error is considered to be the least. [28]
CNN	Estimates of rainfall levels that are correct	When it comes to being able to respond to sudden changes throughout rainfall distribution, the output is good. [29]
ANN	Wind energy potential using a hybrid model	At all sites, the findings of the forecasting model showed significantly higher accuracy in prediction. [30]
CNN	Multidimensional CNN for wind speed forecasting	The proposed model will forecast wind speeds more accurately several steps ahead of time. [32]
ANN	Artificial Neural Networks for Weather Prediction	with a much more acceptable design can predict the weather with the lowest error rate, and more accuracy. [33]

5. Conclusion

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 differences before 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.

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