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Research Article

Predicting Weather Forecast Uncertainty With Machine Learning

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Abstract:
Weather forecasts are inherently uncertain. Therefore, for many applications forecasts are only considered valuable if an uncertainty estimate can be assigned to them. Currently, the best method to provide a confidence estimate for individual forecasts is to produce an ensemble of numerical weather simulations, which is computationally very expensive. Here, we assess whether machine learning techniques can provide an alternative approach to predict the uncertainty of a weather forecast given the large-scale atmospheric state at initialisation. We propose a method based on deep learning with artificial convolutional neural networks that is trained on past weather forecasts. Given a new weather situation, it assigns a scalar value of confidence to medium range forecasts initialised from said atmospheric state, indicating whether the predictability is higher or lower than usual for the time of the year. While our method has a lower skill than ensemble weather forecast models in predicting forecast uncertainty, it is computationally very efficient and outperforms a range of alternative methods that do not involve performing numerical forecasts. This shows that it is possible to use machine learning in order to estimate future forecast uncertainty from past forecasts. The main constraint in the performance of our method seems to be the number of past forecasts available for training the machine learning algorithm.

K E Y W O R D S: Machine Learning, Statistical Methods, Weather Forecast, And Ensembles

INTRODUCTION:

Modern society's ever-increasing demand for more accurate weather forecasts is evident to most people. The spectrum of needs for weather predictions ranges from the general public's desire to know if for instance, the weekend will permit an outing at the beach, or an organization's rally, or an outdoor wedding reception. Such diverse industries as airlines and fruit growers depend heavily on accurate weather forecasts to have an idea of what their next schedule of flight would appear to be or if the weather will be suitable for harvesting. In addition, in developed countries, the designs of buildings, and many industrial facilities rely heavily on a sound knowledge of the atmosphere. Weather forecasting can be defined as the act of predicting future weather conditions or an attempt to indicate the weather conditions which are likely to occur. Weather forecasting is the application of Science and Technology to predict the state of the atmosphere for a future time and a given location. Human beings have attempted to predict the weather informally for millennia, and formally since at least the nineteenth century. Weather forecasts are made by collecting qualitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve within the next few hours. Once, an all-human endeavour based mainly upon changes in barometric pressure, current weather conditions and sky conditions, forecast models are now used to determine future conditions. A model, in this context, is a computer program that produces meteorological information for future times at given positions and altitudes. The horizontal domain of a model is either global, covering the entire earth, or regional, covering only part of the earth. Regional models also are known as limited area models. Human input is still required to pick the best possible forecast model to base the forecast upon, which involves pattern recognition skills, knowledge of model performance and knowledge of model biases. The chaotic nature of the atmosphere, error involved in measuring the initial conditions, an incomplete understanding of atmospheric processes mean that forecast become less accurate as the difference in current time and the time for which the forecast is being made increases. There are a variety of end users to weather forecasts. Weather warnings are important forecasts because they are used to protect life and property. Forecasts based on temperature and precipitation are important to agriculture, and therefore to commodity traders within stock markets. Temperature forecasts are also used by utility companies to estimate demand over coming days. On an everyday basis people use weather forecasts to determine what to wear on a given day. Since in recent time in Uyo – Nigeria for example, outdoor activities are severely curtailed by heavy rains, forecasts can be used to plan activities around these events, and to plan ahead and survive them.

LITERATURE SURVEY

In the paper presented by A H M Jakaria et.al [1], a study was made by collecting the weather data of Nashville in Tennessee and data of surrounding cities. The training data set consisted of two months worth of weather data of July and August 2018. Many machine learning models were implemented such as Extra Tree Regression, Random Forest Regression, Support Vector Regression and Ridge Regression. They have found Random Forest Regressor to be a better regressor as it ensembles multiple decision trees while making decision. Their evaluation results have shown that machine learning models can give accurate results comparable to the traditional model

In a study conducted by Man Galih Salman et al [2], a comparison was made among different deep learning models such as Convolutional Networks, Conditional Restricted Boltzmann Machine, Recurrent Neural Network. The dataset for training and testing the models have been collected from the indonesian Meteorological department. Rainfall is the feature being predicted while keeping the other variables independent. RNN method was found to give adequate accuracy when compared to the other models.

In a study conducted by Dires Negash Fente et al. [3], the LSTM algorithm has been used. Different combinations of weather parameters such as pressure temperature, dewpoints wind speed, precipitation and many other weather parameters were used to train the neural network model. The data required for training the model has been obtained from National Climate Data Center from the year 2007 to 2017. After using the data to train the model using LSTM algorithm, it was found that LSTM algorithm gave substantial results accuracy wise, among other weather prediction techniques.

In the paper presented by E B Abhrahamsen et al. [4] , two different neural network models were studied. One is an Artificial Neural Network and the other is an Artificial Neural Network with Exogenous input. Four different models were built each with a prediction period of 1, 3,6 and 12 hours. All the ANN models use the ReLu as the activation function in the hidden layer and a linear activation function in the output layer. IN the ANN models only temperature was used as the input to the network. Where as in ARX models another feature, precipitation was introduced as another input and improved the prediction accuracy. So they have concluded that with the introduction of more inputs accuracy of these models can be improved.

EXISTING METHOD:-

developments in neural networks, especially deep neural networks, have had great impacts in the fields including computer vision, natural language processing, and speech recognition . Instead of sticking with fixed shallow structures of neural networks with hand-designed features as inputs, researchers are now able to integrate their understandings of different tasks into the network structures. Different building blocks including convolutional neural networks (CNN) , and long short-term memory (LSTM) have allowed deep neural networks to be highly flexible and effective. Various techniques have also been proposed so that neural networks with many layers can be trained effectively without the vanishing of gradients or severe overfitting. Applying deep neural networks to short-term load forecasting is a relatively new topic. Researchers have been using restricted Boltzmann machines (RBM) and feed-forward neural networks with multiple layers in forecasting of demand side loads and natural gas loads

ALGORITHM:

The deep hybrid model consist of two components, 2D CNN layers to capture the spatial information and GRU model to capture the temporal information representation learning for long term dependencies. Finally the hybrid model predicts the traffic flow for short term. The traffic flow dataset is trained with CNN and GRU model extracts deep features, the residual learning improves the accuracy by summing up the density from CNN with GRU. The hyper parameters of CNN network layer is given as the dense layer is set to 256, with filter 64 with convolution layer and the max pooling layer is set to 2,kernel size is set to 1 and finally activation function of all CNN layer is given as ReLU. The hyper parameter of GRU is given as the number of cell is set to 64 and the dense layer in the GRU is set to 8 and finally GRU. The overall CNN hyper parameter of batch size 128 and the epoch (no of iteration) 10, testing and validation dataset is given as 0.7 and 0.3, the Adam optimizer with drop rate is 0.2 is used to train the neural network. The network weight is updated during the training using Adam optimization algorithm. To stop the overfitting in neural network dropout rate is set by 0.2, which drops the percentage of nodes at each iterations during the training.

MODULES:

Data collection since invention of the first weather instruments in the seventeenth century weather observation has undergone considerable refinement. Denser monitoring networks, more sophisticated instruments and communication systems, and better-trained weather observers, have produced an increasingly detailed, reliable and representative record of weather and climate. In weather forecasting, data collection.

Data assimilation and analysis In order to do their work, most numerical models look at the atmosphere as a series of boxes. In the middle of each box is a point for which the model actually calculates weather variables and makes forecasts. The result of this three dimensional boxing up of the atmosphere is known as the grid; the point in the middle is the grid point, and the distance between one point and another is called the grid spacing (Ackerman and Knox, 2003). Grid point models of the atmosphere can get fussy when the data in the initial conditions is not obtained at exactly the location of the grid point. Also, the process of creating an evenly spaced data set from irregularly spaced observations is called interpolation. Ackerman and Knox (2003) then say that, the multiple jobs of interpolating and smoothing the data for use in numerical models are collectively called data assimilation. During the data assimilation process, information gained from the observations is used in conjunction with a numerical model's most recent forecast for the time that observations were made, since this contains information from previous observations. This is used to produce a three-dimensional representation of the temperature, moisture and wind called a meteorological analysis. This is the models estimate of the current state of the atmosphere. Data assimilation proceeds by analysis cycles. In each analysis cycle, observations of the current (and possibly, past) state of a system are combined with the result from and mathematical model (the forecast) to produce an analysis, which is considered as "the best" estimate of the current state of the system. This is called the analysis step. Essentially, the analysis step tries to balance the uncertainty in the data and in the forecast. The model is then advanced in time and its result becomes the forecast in the next analysis cycle.

NUMERICAL WEATHER PREDICTION

According to Lutgens and TarBuck (1989), the word "numerical" is misleading, for all types of weather forecasting are based on some quantitative data and therefore could fit under this heading. Numerical weather prediction is based on the fact that the gases of the atmosphere obey a number of known physical principles. Ideally, these physical laws can be used to predict the future state of the atmosphere, given the current conditions. This situation is analogues to predicting future position of the moon based on physical laws and the knowledge of its current position. Still, the large number of variables that must be included when considering the dynamic atmosphere makes this task extremely difficult. Manipulating the huge data sets and performing the complex calculations necessary to do this (weather prediction) on resolution fine enough to make the result useful requires the use of some of the most powerful supercomputers. Referring to the work of Houghton (1986), the task of writing the equations and the boundary conditions in a suitable form and then of solving them with high speed digital computers is known as numerical modeling. By comparing the behaviour of the model with that of the real atmosphere, the validity of the procedures employed by the model is tested. The most important application of numerical modeling is the development of methods sufficiently reliable and sufficiently fast to be used in routine weather forecasting

Model Output Post Processing The raw output is often modified before being presented as the forecast. This can be in the form of statistical techniques to remove known biases (a term used to describe a tendency or preference towards a particular perspective, ideology or result) in the model, or its adjustment to take into account consensus among other numerical weather forecast. MOS or Model Output Statistics is a technique used to interpret numerical model output and produce sitespecific guidance. This guidance is presented in coded numerical form, and can be obtained for nearly all National Weather Service reporting stations.

CLASSIFIER:

Although a forecast model will predict weather features evolving realistically into the distant future, the errors in a forecast will inevitably grow with time due to the chaotic nature of the atmosphere and the inexactness of the initial observations. The detail that can be given in a forecast therefore decreases with time as these errors increase. These become a point when the errors are so large that the forecast has no correlation with the actual state of the atmosphere. However, looking at a single forecast gives no indication of how likely that forecast is to be correct. Ensemble forecasting entails the production of many forecasts in order to reflect the uncertainty into the initial state of the atmosphere (due to the errors in the observations and insufficient sampling). The uncertainty in the forecast can then be assessed by the range of different forecasts produced. However, the simple logic behind ensemble forecasting is that two runs of a model are not enough to base a forecast upon. Ensemble forecasts are increasingly being used for operational weather forecasting. Ensemble forecasting requires a sophisticated understanding of the atmosphere and computer models.

PROPOSED METHOD:

AI BASED MODEL TO FORECASTING WEATHER

Model for forecasting short-term electric load based on deep residual networks. The proposed model is able to integrate domain knowledge and researchers' understanding of the task by virtue of different neural network building blocks. Specifically, a modified deep residual network is formulated to improve the forecast results. Further, a two-stage ensemble strategy is used to enhance the generalization capability of the proposed model. We also apply the proposed model to probabilistic load forecasting using Modified Monte Carlo dropout. Three public datasets are used to prove the effectiveness of the proposed model. Multiple test cases and comparison with existing models show that the proposed model is able to provide accurate load forecasting results and has high generalization capability.

We aim at extending existing structures of ANN for STLF(short term load forecasting) by adopting state-of-the-art deep neural network structures and implementation techniques. Instead of stacking multiple hidden layers between the input and the output, we learn from the residual network structure proposed in and propose a novel end-to-end neural network model capable of forecasting loads of next 24 hours. An ensemble strategy to combine multiple individual networks is also proposed. Further, we extend the model to probabilistic load forecasting by adopting Modified Monte Carlo dropout. The contributions of this work are three-folds. First, a fully end-to-end model based on deep residual networks is proposed. The proposed model does not require external feature extraction or feature selection algorithms, and only raw data of loads, temperature and information that is readily available are used as inputs. That the forecasting performance going to be greatly enhanced by improving the structure of the neural networks and adopting the ensemble strategy, and that the proposed model has good generalization capability across datasets.

Preparation of Test Data

Taking various kinds of test data does the above testing. Preparation of test data plays a vital role in the system testing. After preparing the test data the system under study is tested using that test data. While testing the system by using test data errors are again uncovered and corrected by using above testing steps and corrections are also noted for future use.

Using Live Test Data:

Live test data are those that are actually extracted from organization files. After a system is partially constructed, programmers or analysts often ask users to key in a set of data from their normal activities. Then, the systems person uses this data as a way to partially test the system. In other instances, programmers or analysts extract a set of live data from the files and have them entered themselves.

It is difficult to obtain live data in sufficient amounts to conduct extensive testing. And, although it is realistic data that will show how the system will perform for the typical processing requirement, assuming that the live data entered are in fact typical, such data generally will not test all combinations or formats that can enter the system. This bias toward typical values then does not provide a true systems test and in fact ignores the cases most likely to cause system failure.

Using Artificial Test Data:

Artificial test data are created solely for test purposes, since they can be generated to test all combinations of formats and values. In other words, the artificial data, which can quickly be prepared by a data generating utility program in the information systems department, make possible the testing of all login and control paths through the program.

The most effective test programs use artificial test data generated by persons other than those who wrote the programs. Often, an independent team of testers formulates a testing plan, using the systems specifications.

The package "Virtual Private Network" has satisfied all the requirements specified as per software requirement specification and was accepted.

USER TRAINING

Whenever a new system is developed, user training is required to educate them about the working of the system so that it can be put to efficient use by those for whom the system has been primarily designed. For this purpose the normal working of the project was demonstrated to the prospective users. Its working is easily understandable and since the expected users are people who have good knowledge of computers, the use of this system is very easy.

MAINTAINENCE

This covers a wide range of activities including correcting code and design errors. To reduce the need for maintenance in the long run, we have more accurately defined the user's requirements during the process of system development. Depending on the requirements, this system has been developed to satisfy the needs to the largest possible extent. With development in technology, it may be possible to add many more features based on the requirements in future. The coding and designing is simple and easy to understand which will make maintenance easier.

TESTING STRATEGY :

A strategy for system testing integrates system test cases and design techniques into a well planned series of steps that results in the successful construction of software. The testing strategy must co-operate test planning, test case design, test execution, and the resultant data collection and evaluation .A strategy for software testing must accommodate low-level tests that are necessary to verify that a small source code segment has been correctly implemented as well as high level tests that validate major system functions against user requirements.

Software testing is a critical element of software quality assurance and represents the ultimate review of specification design and coding. Testing represents an interesting anomaly for the software. Thus, a series of testing are performed for the proposed system before the system is ready for user acceptance testing.

SYSTEM TESTING:

Software once validated must be combined with other system elements (e.g. Hardware, people, database). System testing verifies that all the elements are proper and that overall system function performance is achieved. It also tests to find discrepancies between the system and its original objective, current specifications and system documentation.

UNIT TESTING:

In unit testing different are modules are tested against the specifications produced during the design for the modules. Unit testing is essential for verification of the code produced during the coding phase, and hence the goals to test the internal logic of the modules. Using the detailed design description as a guide, important Conrail paths are tested to uncover errors within the boundary of the modules. This testing is carried out during the programming stage itself. In this type of testing step, each module was found to be working satisfactorily as regards to the expected output from the module.

In Due Course, latest technology advancements will be taken into consideration. As part of technical build-up many components of the networking system will be generic in nature so that future projects can either use or interact with this.The future holds a lot to offer to the development and refinement of this project.

CONCLUSIONS

With the help of more advanced techniques of machine learning, we can only try to forecast the weather conditions. But we are not sure of the results matching exactly the same as the actual values, this is because weather also depend on the increase in the number of buildings and concrete structure, changes in the vegetation, an increase in the number of vehicles and pollution level. But these factors are a machine learning problem in their own domain. Integrating all these factors would be a challenging task. Utilization of machine learning models in prediction of weather conditions in short periods of time, which can run on less resource-intensive machines.Accurate prediction of weather related information in and around the city of Bengaluru. Prediction of variables such as rainfall possibilities, temperature, humidity etc. Evaluation of the proposed techniques and comparison of several machine learning models in the prediction of future weather conditions.

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