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Review Article

Intelligent Methods Used for Obtaining Weather Derivatives: A Review

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Abstract: Weather is the condition of the atmosphere and forecasting is predicting the condition of the atmosphere in near future. Weather forecasting is a formidable challenge as weather is a multi- dimensional, continuous and chaotic process. The distinct nature of the model forecasting in all situations accurately is challenging. Presently weather conditions are being obtained from satellites, Doppler radar, radio sounds, observations from aircraft and ground. Collected data is subjected to various statistical and machine learning techniques. These techniques can incorporate relatively simple observation of the sky to highly complex computerized mathematical models. Weather forecasting still remains a challenging issue, due to unpredictable and chaotic nature of weather. Even with present methods the weather forecasting system may still fail to predict weather attribute, therefore there is still scope left to improve these systems. The objective of carrying out the survey is to look forward on how machine learning can help us to improve weather parameter estimation. In this paper we report the different methods carried out by leading researchers, formidable challenges and present our views on development of efficient weather forecasting system. Also, we propose a method which makes use image processing and neural networks to achieve the weather parameter estimation.

Keywords: Weather, Weather Forecasting, Weather Forecasting Systems, Artificial Intelligence, Machine Learning, Image Processing

1. Introduction

Weather forecasting has been one amongst the foremost technologically and scientifically difficult issues round the world [1]. Due to advent of technology obtaining forecasts using complex mathematical models has been facilitated. Better results have been obtained with the advent of machine learning based learning models such as genetic algorithms, neural networks and neuro-fuzzy logic [2]. The nature of modern weather forecasting is not only highly complex but also highly quantitative. The various methods used in forecasting the weather are as follows: Synoptic weather forecasting, Numerical methods and Statistical methods [3].

Weather forecasting is vital in arranging and sorting out our day by day programs. Prediction of weather makes our decision fine for a particular day. Weather forecasting can have impact on our daily activities. A good forecasting model can be helpful in reducing the damages and losses through timely and accurate weather forecasting [2]. Weather attribute estimation or prediction plays a vital role in majority of applications such as agriculture, military, aviation, etc. There is a need for a system which improves the forecasting results which can be applied in weather alerts and advisories, predicting the behavior of clouds for air transport, agricultural development, military applications, etc. Weather attribute forecasting techniques include observing the sky, using Radar, use of ground based images and/or satellite images and machine learning techniques [4-7], etc. Statistical models make use of methods such as Multiple Regressions and Exponential Smoothing, while machine learning models make use of Genetic Algorithm, fuzzy inference, neural networks etc. The main difference between the two is that Statistical methods are usually associated with linear data, while machine learning methods are related with nonlinear data [2]. Research has been carried out using genetic algorithms [8] for various aspects of weather prediction [9]. The analysis done by meteorologist is not only for current weather trend but also predict the weather for the future [10]. Whole sky imagers are becoming prevalent amongst the research community for a variety of applications and domains where the resulting images are of higher resolution than what can be acquired from satellites, and the upwards pointing nature of the camera makes it simple and easy to capture the low-lying clouds. Comparing with geographical information, weather conditions continue changing even at the same place, and thus weather variations across time spans provide extravagant information and would have impact on wider fields [5]. The elements included in weather forecasts vary from season to season and from place to place, but they ideally would include sky coverage by clouds, precipitation, temperature, relative humidity, wind speed, pressure, depressions, etc., [3]. Based on time or duration of forecasting period, the weather forecasting can be divided into six categories: [3] Now-casting (NC), Very short range forecasting, Short range forecasting, Medium range forecasting, Extended range forecasting and Long range forecasting. This is given in Table 1.

Table 1. *Accuracy of weather forecasting categories.*

Sl. No.	Forecast Type	Accuracy
1	Long range weather forecasting	Very Low
2	Extended range weather forecasting	Moderate
3	Medium range weather forecasting	High
4	Short range weather forecasting	High
5	Very short range weather forecasting	Very high
6	Now-casting	Very high

Objectives of the work to be looked forward

1. The survey needs to be carried out to analyze the advantages and disadvantages of different techniques, and also to look out for any scope of improving the existing techniques to give better forecasting results.
2. Use ground based and/or satellite images for extracting the features such as cloud detection, cloud coverage estimation, classification of clouds, wind direction, wind speed, etc. These features extracted from the images can then be used for estimation of the parameters.
3. Using machine learning techniques for estimation of different parameters such as temperature, precipitation, etc.

2. Literature Survey

Wei-Ta Chu et al. [4] proposed to estimate weather temperature prediction using Convolutional Recurrent Neural Networks (CNN). Estimation of temperature was carried out using two scenarios, one using a single outdoor image and the other using image sequence. Estimation of temperature is carried out using only image data. CNN is used when single image is used for the temperature estimation and RNN (Recurrent Neural Network) is used to estimate the temperature of the last scene from a sequence of images. SkyFinder dataset [24] and Glasner dataset [25] were used for training and testing the NN (Neural Networks). Better performance was obtained when training data was available. However, the proposed method did not incorporate humidity and wind speed to estimate the temperature. This investigation was carried out in the region which provided more clues for temperature estimation.

Wei-Ta Chu et al. [5] claimed to "estimate weather information from single images by constructing computational models using random forest classifiers. The principle focus was to build a large scale image collection associated with different weather properties, image metadata and elevation obtained from multiple platforms, and then obtaining the statistics to show the relationships between photo taking behaviours and weather properties, lastly build a weather type classifier based on the random forest approach based on visual features and photo taken time". To push this research field forward authors express need for specially designed features, or comments and tags to images to be considered to design more elegant computational models.

Cewu Lu et al. [6] proposed collaborative learning approach for two class weather classification (sunny and cloudy) using data driven CNN feature with weather-specific feature. Datasets used were Sun Dataset [26], Labelme Dataset [27] and Flickr. Further advancements can be achieved by using larger datasets which can be incorporated to label more weather conditions.

Christodoulos I. Christodoulou et al. [7] stated to have "developed a system based on multi-feature texture analysis and modular neural networks that will facilitate the automated interpretation of satellite cloud images for classification of cloud types (altocumulus – altostratus, cumulonimbus, cirrus – cirrostratus, cumulus – stratocumulus, stratus, and clear conditions) which can be later used for weather analysis. The statistical K-nearest Neighbour (KNN) classifier and the neural network Self Organizing Feature Map (SOFM) classifier were used for classification of the cloud images". The developed system was able to accurately classify cloud images with a success rate of 61% using SOFM classifier and 64% using KNN classifier for the six classes.

Anna Volokitin et al. [11] proposed a method for "temperature prediction using CNN with VGG–16 architecture. Temperature predictions using the pooling layers make better features than the commonly employed fully connected layers. Majority of the temperature prediction was carried out. It is suggested by the author that the accuracy of the prediction is poor at day level as the time of the year is not directly predicted by the temperature but is the result of multiple interactions between the scene objects, sunlight, and the temperature".

Jiwan Lee et al. [12] proposed clustering learning based weather estimation model to help prevent road hazards due to different weather conditions. This method can be applied to any environment where several CCTVs are installed and images can be gathered and stored in real time. It is mentioned that selecting multiple ROI (Region of Interest) helps detect minute changes in the weather.

Shuang Liu et al. [13] proposed a method for automatic cloud detection using superpixel segmentation (SPS) method. To carry out the experiment Kiel dataset [URL] and IapCAS [URL] datasets were used. Compared to fixed threshold, global threshold, and local threshold interpolation, this algorithm gives a better performance of cloud detection.

Christophe Papiner et al. [14] proposed “a method to discriminate low clouds from the ground during night from a single METOSTAT image using Contextual Spatio – Temporal labelling approach. In this work they exploited the local motion based measurements; thermal parameters estimated over blocks and intensity images, along with local contextual information. The proposed method produces segmentation maps displaying temporal coherency along the image sequence. The formulation of the cloud classification problem leads to the minimization of the global energy function due to which an original minimization scheme was developed based on the ICM (Iterated Conditional Mode) deterministic iterative relaxation algorithm embedded in a spatially “progressive” scheme. The main focus is to propagate information from reliable points toward areas presenting uncertain motion-based measurements”.

Majid Mahrooghy et al. [15] proposed a method to improve the cloud classification and precipitation estimation using Link-based Cluster Ensemble (LCE). Satellite Precipitation Estimation (SPE) which makes use of Precipitation Estimation from Remotely Sensed Imagery using an Artificial Neural Network Cloud Classification (PERSIANN-CCS) algorithm is modified by incorporation of LCE which involves segmentation of infrared cloud images into patches; cloud patch feature extraction; clustering cloud patches using LCE; and dynamic application of brightness temperature (Tb) and rain-rate relationships, derived using the images from GOES – 12 satellite.

Soumyabrata Dev and Stefan Winkler [16] mentions “a supervised segmentation framework for ground-based sky/cloud images based on systematic analysis of different colour spaces and components using partial least-squares regression (PLS). A probabilistic approach using PLS based regression for the segmentation of ground based sky/cloud images was proposed. Hybrid Thresholding Algorithm (HYTA) Database and Singapore Whole Sky Imaging Segmentation (SWIMSEG) database [28] are used to achieve the experimental results. Authors recommend this method for high-dynamic-range images; and also look forward for classifying clouds into different types or estimate cloud altitude and movement”.

3. Proposed Methodology

The primary intention of this review is to design and develop a technique for weather attribute forecasting using ground based image datasets and/or satellite images, atmospheric pressure, wind direction and speed information, etc. The block diagram of the proposed method is given in Figure 1.

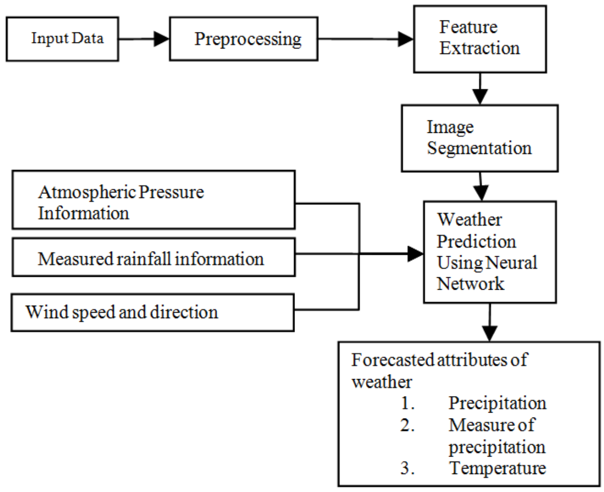

Figure 1. *Block diagram of weather attribute prediction approach using proposed method.*

3.1. Input Data

Here the data considered will be the ground based image datasets and/or satellite images. The ground based image datasets such as SkyFinder dataset [24], Archieve of Many Outdoor Scenes (AMOS) dataset [29], Glasner dataset [25], etc., may be utilized for training and testing purposes.

3.2. Preprocessing

Pre-processing is a generally refers for operations with images at the lowest level of abstraction. For pre-processing both input and output are intensity images. These iconic images are of similar kind as the original info captured by the image sensor, with an intensity image generally represented by a matrix of image function values (brightness). Pre-processing aims to improve the image data by suppressing unwilling distortions or enhancing some image features.

From the input data obtained there may be introduction of noise in the images. Denoising of these images becomes a critical task before extraction of any features is done.

3.3. Feature Extraction and Image Segmentation

Once the input data (images) are passed through pre-processing stage, next we look to identify/extract few important features of the weather from the images available. In image segmentation we use the features extracted to segment the relevant data.

Nowadays sky/cloud images captured by ground based cameras are extensively used as they find their applications in numerous fields, including satellite communications, weather prediction, climate modelling, and renewable energy generation. Sky/cloud imaging can be achieved in different ways. T. Shiraishi et al., and Lee and M. T. Mahmood specify that suggest “Satellite imagery” [17-18] and Q. Zhang and C. Xiao specify “aerial photographs” [19] are popular, in particular, for large-scale surveys; airborne light detection and ranging (LiDAR) data are extensively used for aerial surveys

[20]". The images obtained from the devices provide high-resolution data about local cloud formation, movement, and other atmospheric phenomena [16].

The analysis of clouds and their features is important for a wide variety of applications. It has been used for now casting to deliver accurate weather forecasts [14], rainfall, and satellite precipitation estimates [15], in the study of contrails [21], and various other day-to-day meteorological applications [7, 16]. For cloud cover estimation, cloud detection plays a vital role, which classifies each pixel of all-sky images into clear sky element or cloud. Currently, most of the cloud detection algorithms consider color as the primary characteristic for differentiating cloud from clear sky. This is because of the scattering difference between cloud particles and air molecules. Cloud detection is actually treated as an application of image segmentation, and therefore, applying image segmentation techniques for cloud detection is a natural consideration [8]. Estimating image properties from visual content is a fundamental step of various computer vision studies [5, 30-32].

The satellite images may be useful source for extracting information related to wind direction and speed. This in turn may be used to estimate the cloud behavior by correlating the ground based images.

3.4. Weather Prediction Using Neural Network

In this stage we make use of the results obtained from previous stages and try to forecast few weather attributes. In order for this stage to work we look for machine learning techniques. Under machine learning techniques specifically we can go for Neural Networks. When we speak of neural networks we check for two aspects – learning and testing phases. In learning phase we use part of the available ground based image dataset and/or satellite images for training the neural network. Once the neural network is trained we look out for whether the system provides accurate enough results by using the remainder of the ground based image dataset and/or satellite images as testing images. When we are performing this operation we may also look for optimizing the information available at this stage. We can check for different optimization algorithms such as Jaya Optimization Algorithm (JOA) [22], Rider Optimization Algorithm (ROA) [23], etc.

The atmospheric pressure, wind speed and wind direction which affect the precipitation can be stored for images which will be used for training the neural network. This information along with relevant images (ground based images or satellite images) will be fed to the weather prediction unit for training purpose. Once the neural network gets trained then the remainder of the images can be used for testing the system developed.

4. Conclusion

It has been observed from the study that because of the distinct nature of the model forecasting in all situations accurately is challenging. Almost all statistical form leads to adaptation towards linear models, and machine learning techniques fit under nonlinear models. When a problem contains real world data it becomes challenging to determine the nonlinearity or linearity of the time series data under consideration. In forecasting models, processing time may not be a major concern but accuracy is a major challenge. Therefore large numbers of complex models have been developed to achieve better accuracy. Papers were surveyed to highlight the diversity of forecasting techniques /methods and the time scales of forecasting methods. Also we conclude that in most of the cases, statistical form leads to adaptation towards linear models, and machine learning techniques fit under nonlinear models.

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