The Summary of Deep Learning in the Field of Weather Forecast Research

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Abstract. This article investigates application of deep learning in the field of meteorology at home and abroad. Summarized of deep learning and several deep learning network models widely used in meteorological field, It focuses on research and summary application of deep learning in Meteorological Department of China, and also summarized the future development trend of deep learning in weather forecast application.

1. Foreword
The rapid development of Internet and Electronic Science and technology. Continuous development of information storage and sensor detection equipment technology and meteorological equipment have become increasingly rich and Colorful, meteorological department can obtain high spatial and temporal resolution meteorological data with modern observation equipment. In the background of big data era, the weather forecast based on numerical model shows a huge development prospect, and data mining and deep learning technology are also quietly emerging in the weather forecast.

In 1956, at the seminar held by Dartmouth College, the subject of artificial intelligence was formally put forward. Up to now, artificial intelligence has experienced three technological waves: symbolism, machine proof, logic language, expert system and machine learning. At the end of the 20th century, the second technological wave, artificial intelligence has been applied in the field of meteorology. Such as weather forecast expert system, intelligent weather information collection system.

Compared with the research abroad the domestic lags behind, enters the 1990s, relevant experts of the domestic meteorological department focused on the theoretical research and exploration of artificial intelligence in the application of weather forecasting. With the rise of data mining, machine learning, and deep learning algorithms and development, artificial intelligence is widely used in all walks of life. The artificial intelligence in the field of meteorology has also developed from the initial theoretical research to practical applications. Since 2015, cnki.net has collected a large number of deep learning based on the recognition of ground area snow, satellite cloud maps, radar maps etc. Visibility, fog, precipitation and other meteorological elements or the results of numerical prediction models in the revised article.

2. Application Status of Deep Learning in Weather Forecast at Home and Abroad

2.1. Application of Deep Learning in Foreign Meteorological Forecast
From the late 1980s to the early 1990s, artificial intelligence attracted everyone's attention in the weather forecast of the United States, Canada, Britain, France and other countries.

In 1986, Rumelhart et al. [1] proposed an artificial neural network back propagation algorithm (BP), and Hinton [2] proposed a multi-hidden layer neural network (MNN) based on perceptron. With the
proposal and improvement of BP algorithm and MNN, developed countries gradually began to study and practice the application of artificial intelligence in various fields. Based on statistics and climatology, Bartok J et al. [3] used data mining technology (DMM) to study the detection methods of heavy fog and low cloud cover. Facing huge data processing, they could not achieve good results. Kwong, K et al. [4, 5] used artificial neural networks to predict wind. In terms of temperature prediction, Chen, S. et al. [6, 7] used time series models for temperature prediction. Singh S, Bambini P et al. [8] used the temperature attribute of meteorological elements and their dependence on specific data series to propose a comprehensive back propagation temperature prediction model based on time series based genetic algorithm (GA) and neural network. S Singh and J Gill [9] introduced multiple meteorological elements to study the influence of temperature prediction, such as rainfall, relative temperature, wind direction and wind speed, etc. and proposed a method based on Genetic Algorithm (Genetic Algorithm) plus BP neural network Real-time temperature prediction model. Aznarte J.L and Siebert N [10] used generalized linear models, multivariate adaptive regression splines, random forests and quantile random forests. Four machine learning algorithms are combined with numerical weather prediction for modeling and prediction, and a dynamic linear evaluation experimental method is proposed, which has a good reference for temperature prediction. Foreign research on the application of artificial intelligence in weather forecasting started early, and theory and practice are closely integrated.

2.1.1. Based on historical meteorological data, independent forecast of each meteorological element

Fang Ying et al. [11] used the three sets of data of temperature, relative humidity and wind speed at 824 meteorological stations in 2015 to construct GAM and residual self-coding of generalized additive models of temperature, relative humidity and wind speed Neural network (referred to as residual network) model, the test results show that compared with GAM, the prediction accuracy of the residual network model is significantly improved.

Zhang Yuanting et al. [12] used the daily data of the national stations in the two time periods of December 2017-February 2018 and December 2007-February 2008, and used deep learning methods to train on the two time periods. All predictions are cases with snow, and a regression model to predict the depth of snow is established. The error obtained by training this model is small, but the shortcoming is that the error in predicting extreme snowfall is greater than that of ordinary snowfall.

Yang Han [13] of Harbin Industrial University, used ARIMA model, deep feed-forward neural network model, and representative RNN-LSTM model in recurrent neural network to test the single-station temperature element in sequence, and experimented with the three models. The monitoring analysis was carried out. The experiment shows that, first, compared with the traditional ARIMA model, the deep learning model can show good prediction performance, but because the experimental data is only a single station, the dimension of the attribute is not high, the model has Regional characteristics.

Bai Yujie [14] proposed a rainfall prediction model based on ARIMA model combined with wavelet transform to improve the prediction accuracy of rainfall. After that, Bai Zhiwei et al. [15] of Yunnan Institute of Water Resources and Hydropower Research established the SPEI sequence autoregressive moving average model for predicting drought conditions in Yunnan Province. Chen Cheng [16] of South China University of Science and Engineering based on the VGG Net proposed by the Visual Geometry Group (Oxford University) and Google DeepMind, improved the convolution layer and applied the model to short-term weather forecast.

2.1.2. Based on image recognition and analysis, forecast short-term neighbouring weather

In the field of meteorology, artificial intelligence image recognition technology is mainly used in radar and satellite image analysis. In recent years, image recognition technology has also begun to be applied to the recognition of weather elements for automatic meteorological observation.

In order to promote the application of artificial intelligence (AI) technology in weather forecast, Shenzhen Meteorological Bureau co-organized the "Global AI Meteorological Challenge" with the theme of short-term heavy precipitation intelligent near-season prediction through cooperation with Alibaba and the Hong Kong Observatory for two consecutive years (2017-2018). The 2018 question
was increased from "face-to-point" (that is, radar echo map predicts single-point precipitation) in 2017 to "face-to-face" (that is, radar echo map was used to predict radar echo map). The data set consists of radar data maps of Guangdong and Hong Kong in the flood season before 2010-2017, adopting the international standard data format of grayscale, and constitutes the standard radar data set SRAD2018 (Standardized Radar Dataset 2018). A total of 320,000 sets of data, of which 300,000 sets are The training set, and another 10,000 sets for the preliminary and final test data sets. In the end, the CUHK (SZ) group of the Chinese University of Hong Kong won the championship. Judging from the data score of the competition, the score based on the AI method is higher than that of the optical flow method, indicating the specific potential of artificial intelligence technology in solving the problem of near-field prediction.

Li Bingjie et al. [18] selected the satellite cloud image datasets of Sunflower No. 8 and Fengyun No. 2 and used the GoogLeNet network to divide the cloud into three cloud types: cumulus, layered, and cirrus, with an accuracy of 95.67%. Cumulus, cumulonimbus, stratified cloud, cirrus cloud, and clear sky are classified into 5 categories with an accuracy of 96.8%. Although the classification accuracy is higher than that of using the support vector machine fusion Gabor transform and gray level co-occurrence matrix algorithm to achieve feature extraction, it still does not meet the requirements, and there is a serious over-fitting phenomenon. Finally, by reducing the number of inception modules, adjusting network parameters, and simplifying the number of network layers, GoogLeNet has been improved. The improved network can achieve 98% classification accuracy for the above three cloud-type images, and 5 classification accuracy can reach 98.4 %, To meet business needs, and effectively alleviate the problems of over-fitting and large consumption of computing resources in the GoogLeNet cloud classification network.

Huang Xiaoyu et al. [18] used the Nanyue Alpine Meteorological Observation Station of Hunan Province and Huaihua National Climate Reference Station from January to March 2018 to take a picture of the snow-capped weather phenomenon at two stations from January to March 2018. The pictures were modeled and trained, and tested with the test pictures of Nanyue Station and Huaihua Station. The test results show that the artificial intelligence identification model can better extract the key features of the different stages of snow accumulation, and the recognition effect is good. The conditions and the consistency before and after the judgment further eliminate the air leak judgment. The model can provide important technical support for the automatic observation of snow meteorological elements.

3. Application Research of Deep Learning in Meteorological Bureaus of Provinces in China
At present, various provinces of the China Meteorological Bureaus have made different progress in studying the application of deep learning in weather forecasting. The meteorological departments of the southern coastal provinces have begun research and application in the direction of artificial intelligence. The Guangdong Meteorological Bureau used the Ali platform to carry out short-term precipitation forecasting based on deep learning with good results. Beijing Meteorological Bureau applies machine learning method to temperature forecast. The objective correction method of precipitation factors based on machine learning in Fujian Provincial Meteorological Bureau. A radar echo extrapolation method based on depth neural network was developed by the central meteorological station and Tsinghua University, Compared with traditional methods, the accuracy of this method is improved by about 40%.

Inland provinces such as Shaanxi, Gansu, Inner Mongolia, and Shanxi Provincial Meteorological Bureau lag behind in the study of combining artificial intelligence with weather forecast services. In 2018, Li Shehong, Shaanxi Provincial Meteorological Bureau, published an article "Framework and Frontier Applications of Deep Learning Knowledge System in Meteorology" introducing the basic concepts and related exercises of data mining, machine learning and deep learning, the framework of deep learning knowledge system in meteorology, and the current The mainstream deep learning tools Caffe and TensorFlow ,only focus on basic theoretical discussions on the application of artificial intelligence in the field of meteorology, not carry out experimental tests based on data.
4. Application Trend of Deep Learning in Meteorological Forecast

With the rapid development of artificial intelligence technology, the application of artificial intelligence in weather forecast has broad prospects. Deep learning image analysis and recognition technology is widely used in the recognition of meteorological radar and satellite cloud images and later inversion prediction. It is well received and sought after by forecasters. Although the recognition of meteorological observation elements has been developed slowly, it provides meteorological automatic observation. Development ideas; based on a large amount of historical meteorological data, predicting meteorological element data, deep learning shows a good prediction effect, but good prediction effect is only applicable to stable climatic conditions, for extreme, abnormal, sudden and severe weather Process, deep learning cannot accurately predict in advance; the weather and climate system is a dissipate, high-order nonlinear system with multiple sources of instability, and its complex internal interactions and random changes lead to the variability and complexity of the weather and climate. Therefore, it is difficult for deep learning technology to replace classic numerical prediction methods for a long time in the future. The future development trend is to complement the advantages of deep learning and numerical forecasting, and to use deep learning, image recognition and other technologies to display their advantages in short-term forecasting and extended-period forecasting, and become a powerful supplement to numerical forecasting.

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