Evaluation of weather forecast with DL

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***Abstract*—Weather forecasts plays a very important role in today's world in almost of sectors of world economy. The accuracy of making decisions related to weather evaluation using deep learning is extremely important to ensure smooth functioning of society. Earlier it used to be just numerical evaluation but recent developments in deep learning technologies has ensure that the new technologies can be effectively used for weather evaluation.In this paper, we will explore weather evaluation using deep learning techniques as well as the implementation comparing different techniques such as ANN and CNN.**

***Index Terms*—weather evaluation, Deep learning , ANN, CNN**

I. Introduction

The weather in this world constantly keeps on changing. And this affects all the human beings on earth. change in weather is constant and has severe effect on this planet. The effects of weather change are drastic sometimes which can lead to devastation of agriculture thus directly affecting humans. It can also lead to end of civilizations. Sometimes even a small change in weather can affect how we eat and what we eat as well as how we live. For example, reliable weather forecasts allow us to provide early warning of natural disasters like cyclones, tsunamis, cloud bursts, etc. that can seriously inflict damage to both lives and property [1]. To avoid all of these, there was this necessity of developing a technique that we can use and avoid the destruction. we as humans had started predicting weather or evaluating weather. Since earlier times, we were using statistics or mathematics to evaluate weather. Although this was nowhere near perfect, we still were using it. Weather being very unpredictable, Building statistical or mathematical models for evaluating weather where only few factors can be considered for evaluating weather, it was really difficult to predict the upcoming weather and also time consuming. This made a gap in the research of weather evaluation. There was always this need of another way of building models for weather evaluation. The prediction application in science and technology that makes use of the atmospheric conditions at a specific place and time is called weather forecasting [2].

With recent developments in the field of Machine learning and deep learning, the research began to fulfill the need of weather evaluation using this. It was later on found that machine learning techniques and deep learning algorithms can be implemented to evaluate or predict weather in real time and less time and also more accurate.Many researchers have been inspired to investigate hidden hierarchical patterns in the vast amount of weather datasets for weather forecasting by the emergence of deep learning techniques in the last ten years, the widespread availability of massive weather observation data, and the development of information and computer technology [3]. Also the algorithms can be trained to learn weather patterns and improved its accuracy in its prediction.All this can be done using computational power of sophisticated cyber systems. ALso, more layers or more factors can be added or trained to predict more accurate weather and learn weather patterns. The use of deep learning in weather modeling and representation has been spurred by the numerous researchers who have documented the technology's successful applications in a variety of fields [4].

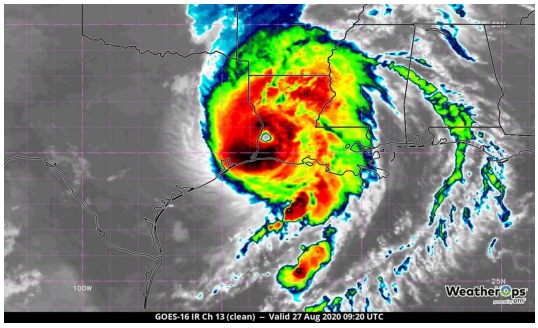

Fig. 1. Image of Stormy weather [9]

In this paper, we are going to see the weather evaluation using a deep learning technique called Convolutional neural network (CNN) which is a network architecture of deep learning. Deep learning structures algorithms in layers to create a "artificial neural network" that can learn and make intelligent decisions on its own. This is how deep learning is used in this experiment to make intelligent decisions [5]. It learns the weather patterns and trains itself on the available weather data to predict close to accurate weather predictions. Also, in this paper, we will be using a weather dataset to analyse, learn from weather data and predict weather using a deep learning technique.

II. WEATHER EVALUATION

One aspect of weather prediction remains incredibly challenging. precipitation, rain, snow, hail, sleet, is perhaps the most challenging part of the weather to predict. weather is predicted using different states and we refer to the state of several variables in the air around us, temperature, pressure, humidity, wind speed. These variables are all connected by lots of equations. Some of them describe how these variables are related to one another at a given location like how air, pressure, temperature, and density are all related to the ideal gas equation. While others describe how changes in these variables over an area are related to other variables.

Companies use temperature and precipitation forecasts to estimate their needs for the next few days. These forecasts are essential to agriculture [6]. For example, wind speed is related to the gradient in pressure in the surrounding area and takes the current state of the atmosphere, the values of pressure and temperature, and so on. We represent those equations describing the atmosphere in a way that a computer can understand and do for us that means instead of describing the atmosphere, we measure the value of atmospheric variables on this grid and then apply the equations only at locations on this grid. we can then iterate into the future, the more locations you do this for the higher your resolution, the more accurate your approximation of the real atmosphere becomes. In essence, a model is an approach that produces an objective value based on the unique attributes and weights assigned to each training variable [7].

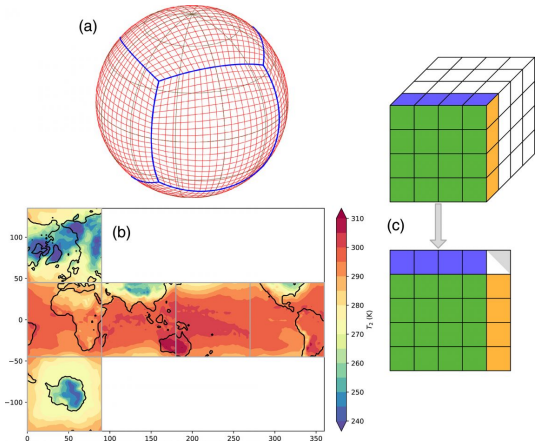

Fig. 2. First the authors divide the planet's surface into a grid with a six-sided cube (top left) and then flatten out the six sides into a 2-D shape, like in a paper model (bottom left). This new technique let the authors use standard machine learning techniques, developed for 2-D images, for weather forecasting [11]. [10]

In practical terms, you add as many points as your computer can tolerate. Our model takes into account that the weather forecast can be wrong so we have taken a single weather forecast we trained it against. If the model has taken the cloud to slightly wrong place then even without all the position, the parameters, the model wont be accurate. Any uncertainty in how you initialize a forecast such as not being exactly sure what the temperatures are or wrong locations, inaccuracy is inevitable and the error in the feed will grow exponentially. One way to tackle this is to use stochastic models where you have a slight amount of noise added to the input. sort of just random noise and you can see how much an effect that has on the output. so if we're slightly wrong about the initial conditions, we diverge away that much that the stochastic model tries to give a probabilistic representation of the set of possible outputs. Given a slight uncertainty around the initial conditions and this is how weather forecasting is done.Forecasts can be made for a specific location based on the quantitative data gathered about the current state of the atmosphere at that time and place. Using certain meteorology projects, one can also learn how the weather changes [8]. Different outcomes are generated given slightly different inputs which can show the most likely forecast but also tell you how certain you can be about that forecast. The rate of progress is just so vast that It wouldn't be surprising anymore that in a few years from now the machine learning models outperform the existing models by far post-processing using machine learning techniques such as deep neural network. Weather prediction and going forward may provide a crucial tool in predicting extreme rainfall events and thus disaster relief as well.

III. DEEP LEARNING

Deep learning is a subset of machine learning which on the other is a subset of artificial intelligence. Artificial intelligence is a general term that refers to techniques that enable computers to mimic human behavior whereas machine learning represents a set of algorithms trained on data that make all of this possible and return an output based on series of inputs. Deep learning is just a type of machine learning inspired by the structure of the human brain that is the algorithms. Deep learning attempt to draw similar conclusions as a human could by constantly analyzing data with a given logical structure. To achieve this, deep learning uses multilayered structure of algorithms called neural networks. Neural networks just as our brain similar to as we use our brain to identify patterns and classify different types of information. Neural networks can be taught to perform the same task on data they never received. With new information the brain tries to compare it with the known objects. Suppose we want to build a machine that differentiates between a cat and a dog. If you do it by machine learning, we then need to tell the machine just based on which the two can be differentiated, these features can be the sound they make or the type of claws they have. But instead with deep learning these features are picked out by neural network without human intervention.

This means that a deep learning algorithm in computer vision will first build representations based on its own low level representations, which it will learn from a raw image and It will then repeat the process for higher levels [13]. In an artificial neural network signals travel between nodes

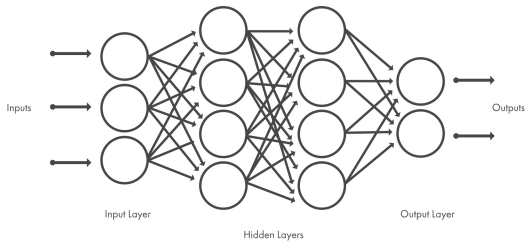

Fig. 3. Deep Learning Network [12]

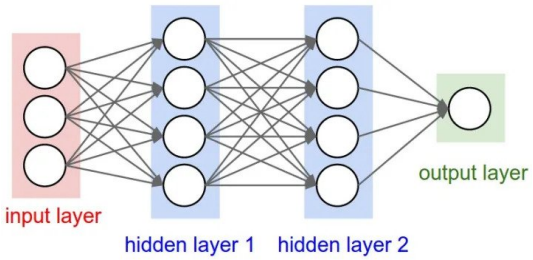

Fig. 4. Artificial Neural Network [14]

and assigns corresponding weights to the next one. A heavier weighted node will exert more effect on the next layer of the nodes. In the end, the final layer compiles the weighted inputs to produce an output. Deep learning carries some limitations. Training a deep learning model requires huge chunks of data set to make it decently accurate. computational power, training a deep learning system requires a high amount of computation. That's why we generally employ using graphical processing unit which have more cores than CPU and also carries a higher cost. Training time, training and average, learning system takes weeks or even months to process and make it perfect. Training time is usually dependent on the amount of data and the number of players in the hidden network.

A. Artificial Neural Network (ANN)

Imagine a neural network is a kind of black box which takes one or multiple inputs like the sensors of a self-driving car, processing them into one or multiple outputs like the controls for that car. The neural network itself consists of many smaller units called neurons. These neurons are grouped into several layers. Neurons of one layer are connected to the neurons of the next layer through weighted connections which really are just connections. Connections is a real valued number attached to them and neuron takes the value they're connected to and multiplies the patients weight some before connecting the so-called activation function which simply mathematically transforms the value. But finally can be passed on to the next layer. This way the inputs are propagated through the whole network. The difficult part is to find the right weights in order to get the right results. This can be done through a wide range of techniques such as machine learning. The aim of using neural networks to simulate the human brain is to create machine learning models that can perform tasks that are difficult for computers to perform using traditional methods [15].

In other way, we can also explain Artificial Neural Network. Artificial Neural network is an information processing model similar to the human brain. The way the human race brain processes information similarly the artificial neural network processes the information but the artificial neural network cannot do the functionalities of brain because the brain is a very complex nervous system. It does a lot of computation and those computations cannot be replicated in an artificial neural network but still we can do most of the functions what brain does in artificial neural network. An artificial neural network is composed of a large number of highly interconnected processing units. Those processing units are called as neurons. These neurons are connected so that we can solve a particular problem. For example, the human being learn a particular concept or anything by experience. Initially with some examples he may learn or he may get some knowledge but as in when he has been shown with a more number of examples the human being will learn or get more knowledge. Similar to that one, when you go on giving more and more number of example to artificial neural network it will get on getting more and more knowledge. It will learn more and more and artificial neural network is configured for a specific application or to solve a particular problem. That is to solve a spam classification face recognition pattern recognition or similar to such kind of any application. You cannot solve all the problems using one artificial network. A particular artificial neural network can solve one problem at a time and this is the one very important part to remember. Each neuron is connected with other neurons with a connection link in artificial neural network. Each computation unit is called as a neuron and the network contain multiple number of neurons. Regarding inputs, neurons can be divided into two categories: single input neurons and multiple input neurons [16]. They are connected with one another such that connection is done with a link and that each and every link is associated with a particular weight. Whenever we given a signal to that particular neuron then that input signal and the weight will be transferred to the next neuron with the help of this particular link. The artificial neural network is characterized by their ability to learn, recall and generalize the training patterns or the data. Similar to the human being the way human brain works with the same note the artificial neural network works. Like they will learn then they recall and generalize the training pattern. They have the capability to model the networks of original neurons as found in the brain and that's the reason these artificial neural networks are called as the processing units of artificial neural networks. There will be multiple number of neurons in each of them and have their own internal state. That internal state is called as the activation level. Then that activation level is transmitted to other neurons with the help of other link.

B. Convolutional Neural Network (CNN)

A convolutional neural network is a type of neural network that is most often applied to image processing problems. It's probably seen in action anywhere computer is identifying objects in an image. Convolutional neural networks can also be used in natural language processing. The fact that they are useful for these fast growing areas is one of the main reasons they're so important in deep learning and artificial intelligence. A regular neural network has an input layer, hidden layers and an output layer. The input layer accepts inputs in different forms while the hidden layers perform calculations on these inputs and the output layer then delivers the outcome of the calculation and extractions. Each of these layers contain neurons that are connected to neurons in the previous layer and each neuron has its own weight. Convolutional neural networks work differently as they treat data as spatial instead of neurons being connected to every neuron. In the previous layer, they are connected to neurons close to it. Convolutional neural networks are a potent deep learning algorithm that can process millions of parameters while reducing processing costs. They work by taking an input (2D image), convolving it using filters or a kernel, and then producing output volumes [17].

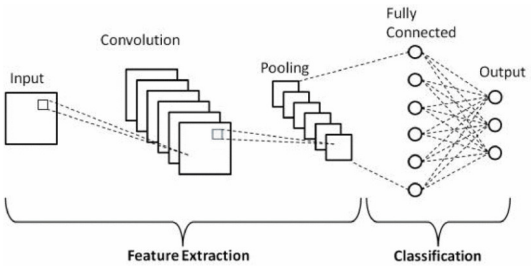

Fig. 5. Convolutional Neural Network [19]

Like a normal neural network a convolutional neural network is made-up of multiple layers. There are a couple of layers that make it unique like the convolutional layer and the pooling layer. However like other neural networks it will also have a relu or rectified linear unit layer and a fully connected layer. The relu layer acts as an activation function ensuring non linearity as the data moves through each layer in the network. Without it the data being fed into each layer would lose the dimensionality that we want to maintain. The fully connected layer meanwhile allows you to perform classification on your data set. The convolutional layer is the most important. We have the pooling layer, this down samples or reduces the sample size of a particular feature map. This also makes processing much faster as it reduces the number of parameters the network needs to process. The output of this is a pooled feature map. There are two ways of doing this, Max pooling which takes the maximum input of a particular convolved feature or average pooling which simply takes the average. These steps amount to feature extraction whereby the network builds up a picture of the image data according to its own mathematical rules. Certain convolutional neural networks use more complex convolution techniques, like tiled convolution, deconvolution, and dilated convolution, which are based on linear convolution [18]. There are a number of ways you can train a convolutional neural network. If you're working with unlabeled data, you can use unsupervised learning methods. One of the best popular ways of doing this is using auto encoders this allows you to squeeze data in a space with low dimensions. Another option is to use generative adversarial networks. With this again you train two networks the first gives you artificial data samples that should resemble data in the training set and the second is a discriminative network it should distinguish between the artificial and the true model. A convolutional neural network is a feed forward network that filters spatial data while a recurrent neural network as the name implies feeds data back into itself. Recurrent neural networks are better suited to sequential data.

IV. USE CASE

In this section, We are using deep learning for weather evaluation. For the same, we will be using Artificial neural network(ANN) and Convolutional Neural Network (CNN) as architectures for evaluating. This dataset [20] consists of different weather metrics for 18 different cities across Europe. This dataset showcases data from the period 2000 to 2010. The task is to evaluate weather conditions to Barbeque in the open. And the data is classified into two, true and false. For this, we will consider weather data for Dresden city and try to figure out favourable conditions to do barbeque outside in the open in Dresden. This dataset can be found on Kaggle by the name "Weather Prediction". For this, we will compare ANN and CNN and also figure out its accuracy in its prediction and decide which algorithm performs better with respect to this example. Here are some of the snippets of the python code [21] used for performing Deep Learning techniques.

```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
.
.
.
.
df = pd.read_csv(r"dataset.csv")
df_bbq = pd.read_csv(r"dataset-bbq.csv")
```

With data pre processing, we first imported the all the required libraries like numpy, pandas, seaborn and matplotlib. After this, we imported both the datasets, weather and barbeque using pandas. Since, It contains 18 cities of the europe, we decided to focus on Dresden. For this, we tailored the dataset to data of Dresden by trimming all the unnecessary

columns. Similarly, we can tailor another dataset for Dresden city which has only true or false classification.

After this, Using matplotlib and seaborn, we prepared plots for different weather parameters like wind gust, wind speed, cloud cover, humidity, pressure, global radiation, precipitation, sunshine, minimum temperature, maximum temperature. This leads us further to creation of models for Artificial Neural Network(ANN) and Convolutional Neural Network (CNN).

Firstly, we will start with the creation of simple ANN model. For model building of ANN, we use a sequential model. In total, we use three layers for this model. All the three are the Dense layers. First Dense layer is using Relu as its Activation function. Second Dense layer is also using Relu as its Activation function. Third and final layer of this model is Dense layer and its activation function is sigmoid. The loss function we are using here is binary_crossentropy and the optimizer is set to adam. Verbose in this model is set to 1 and we are using 200 epochs to train the model. After training, the accuracy of the ANN model comes around at 97.94%.

```
#A very simple ANN model with 2 layers
model = Sequential([
        Dense(X_train.shape[1], activation="relu"
        Dense(X_train.shape[1]/2, activation="rel
        Dense(1, activation = 'sigmoid'),
    ])

model.compile(loss='binary_crossentropy',
optimizer='adam', metrics = ['accuracy'])

model.fit(x=X_train,
          y=y_train,
          epochs=200,
          validation_data=(X_test, y_test),
          verbose=1)
```

Similarly, we constructed CNN model. For model building of CNN, we use a sequential model. In total, we have 4 layers for this model. First layer is the reshape layer which reshapes the input. Second layer is the 1D convolutional layer, which has Relu as its activation function. Then the third layer is the Flatten layer, which flattes the output. And the fourth and the final layer is the Dense layer and it has sigmoid as its activation function. Similar to ANN model, we are using binary_crossentropy as loss function, adam as optimizer, Verbose as 1 and we are using 200 epochs to train the cnn model. After training, the accuracy of the CNN model comes around at 96.71%.

```
model_2 = Sequential(
    [Reshape((1,X_train.shape[1],1)),
     Conv1D(filters=10, kernel_size=2,
    activation='relu',
    input_shape = (1,X_train.shape[1],1)),
     Flatten(),
     Dense(1, activation = 'sigmoid')
                    ])

model_2.compile(loss='binary_crossentropy',
optimizer='adam',metrics=['accuracy'])

model_2.fit(x=X_train,
          y=y_train,
          epochs=200,
          validation_data=(X_test, y_test),
          verbose=1)
```

After comparing ANN and CNN, we can say that in this specific example, ANN is more accurate than CNN. This also establishes the fact that CNN can be more productive and effective in terms of image processing and ANN is better suited for other forms of data. Although this cannot be a general statement. Rather it is specific to this example of weather evaluation using Deep learning.

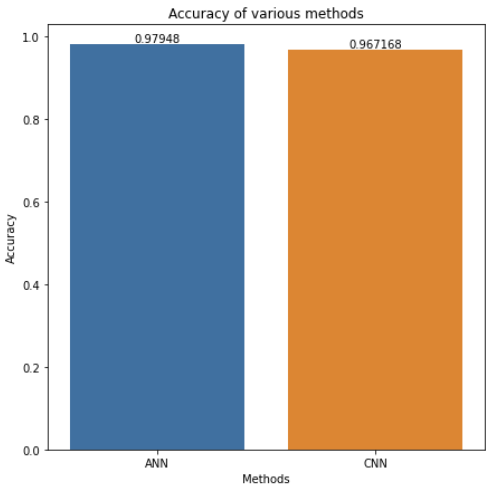

Fig. 6. Accuracy of various methods

V. CONCLUSION

In this paper, we have seen how the weather evaluation is done using Deep Learning. For this, we used two different Algorithms for predicting or evaluating weather, ANN and CNN. In the use case, we tried to figure out whether the weather is favourable to do barbeque outdoors. We used Dresden city's data for such evaluation. We compared the accuracies of these two different techniques and figure out the more accurate technique for the above use case. More and more models like this needs to be developed to improve its accuracy and predict weather more accurately. As weather impacts most of our living, we need to develop and improve the existing models as the technology advances.

VI. FUTURE WORK

From the above example, it is evident that Deep learning can be used to predict or evaluate weather. With respect to above use case, the model can be optimized further with more data points. The current model is trained a few data points compared to the scale of data used for weather evaluations in real time. This affects the accuracy and predictions as well. Therefore, more data points may solve the issue and will be comparable with real time weather evaluations. With respect to research in Deep learning domain is increasing day by day as the time and technology progresses. Newer, more complex and more accurate models for such evaluation for real time weather are being optimized.

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