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Image Based Automated Weather Analysis Using Deep Learning for Decision Support to Remote Farmers

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Abstract*:* In farming, weather forecasting refers to the prediction of an area's atmospheric state at a specific moment to determine whether it is suitable or unsuitable for agricultural activities. Knowledge about the current weather feed good decision for farmers in crop cultivation. The numerous daily decisions can be better prepared based on weather analysis. These choices include when to fertilize, when to irrigate crops, and when to do fieldwork in the farm. Farmers' choices will determine whether or not their crop is lucrative. A farmer must be mindful of the present climate condition in order to grow a successful crop. In recent years, estimating climate has gained significant research attention. Despite the abundance of data available for weather forecasting, the majority of them require the use of a nonlinear model before forecasting. Due to the advancement in image processing, climate detection from atmosphere images provides much information for identifying weather condition and it helps the farmers choose the appropriate time to operate effectively on a daily basis. This article examines the applicability of the combined convolutional neural network (CNN) and bidirectional gated recurrent unit (Bi-GRU) approach by developing a robust and climate estimation model from real time images acquired from farm atmosphere. The proposed work offers a method for precisely and accurately detecting actual meteorological conditions using computer vision.

Keywords: *Weather Analysis, Convolutional neural network, Bi-directional gated recurrent unit, Precision farming.*

1. Introduction

Image-based climate detection can indeed be a valuable tool to support farmers in making informed decisions regarding their agricultural practices [1]. By analysing real time images and other remote sensing data, farmers can gain insights into various weather parameters that affect crop growth and yield [2, 3].

Here are a few ways image-based weather forecasting can aid farmers in decision-making:

1.1. Precipitation Monitoring: Real time acquired images can help farmers track rainfall patterns and estimate precipitation levels in their region. This information is crucial for determining irrigation needs and scheduling planting or harvesting operations.

1.2. Temperature Monitoring: Monitoring temperature variations using images allows farmers to assess the suitability of different crops for specific growing seasons [4]. They can make informed decisions about planting times, selecting heat-tolerant varieties, and implementing frost protection measures.

1.3. Crop Health Assessment: Weather forecasting from images can provide valuable insights into crop health conditions [5]. By analysing vegetation indices such as the Normalized Difference Vegetation Index (NDVI), farmers can identify areas of stress or potential disease outbreaks.

1.4. Pest and Disease Monitoring: Image-based weather forecasting can help farmers monitor the spread of pests and diseases in their fields. By analysing images and integrating it with other data sources, such as pest migration models and disease risk maps, farmers can implement timely pest control measures and reduce crop losses.

1.5. Yield Estimation: By combining historical weather data with current image-based analysis, farmers can develop predictive models to estimate crop yields [6]. This information can assist in making marketing decisions, negotiating contracts, and planning for storage and transportation requirements.

1.6. Water Management: Acquired real time images can provide insights regarding rain level and atmosphere condition [7, 8]. Farmers can use this information to optimize irrigation practices, conserve water resources, and prevent over or under watering.

To effectively utilize image-based weather forecasting, farmers may need access to relevant data, such as satellite imagery, weather databases, and analytical tools.

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Additionally, partnerships with agricultural experts, meteorological agencies, and technology providers can further enhance the accuracy and applicability of image-based weather forecasting systems [9]. It's worth noting that image-based weather forecasting should be complemented by other information sources, such as local weather forecasts and on-the-ground observations, to ensure comprehensive decision-making.

The application of scientific methods to forecast a location's weather is known as weather forecasting. Weather forecasting involves gathering a lot of data about the atmosphere's current condition and utilising an understanding of its workings to forecast how the weather will change [10]. The confused nature of the atmosphere, the enormous amount of computational power required to solve the equations describing the atmosphere, the errors associated with the initial measurements, and the incomplete understanding of the atmospheric description process indicated that the forecast was inaccurate based on the present and forecast period. is to increase. Air has many uses. Weather alerts are important for forecasting as they are used to protect life and property. Forecasts based on atmospheric effects are important for agriculture and therefore for traders in the market.

The plant uses temperature to forecast demand for the next few days. In everyday life, people use weather to decide what to wear on a particular day. With heavy rain, snow and cold winds limiting outdoor activities, forecasting can be used to plan activities around these conditions and plan ahead and survive [11]. We present a weather forecasting model that uses neural networks to effectively predict the weather and help overcome all these problems. The advantage of neural network equipment over other weather forecasting methods is that neural network equipment uses various algorithms to reduce errors, giving us predictions that are almost equal to the true value [12]. Such networks are simulated on new data to predict future climate change.

2. Materials and Methods

The dataset used for the proposed work is Multi-class Weather Dataset for Image Classification which is composed of 1,123 images having four distinct categories. The categories are cloudy (300 images), rainy (235 images), sunshine (215 images) and sunrise (357 images). In addition to this, more images are collected from internet and a dataset is formed with an increased total image count of 1,300 images with cloudy (350 images), rainy (300 images), sunshine (250 images) and sunrise (400 images). The number of images for different categories are given in figure 1.

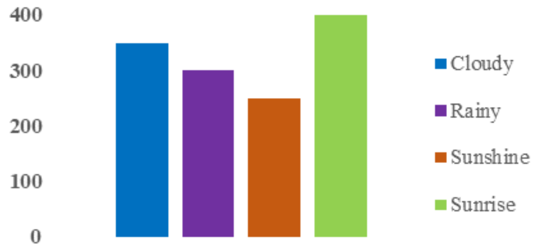

Fig. 1. Number of Images in each category

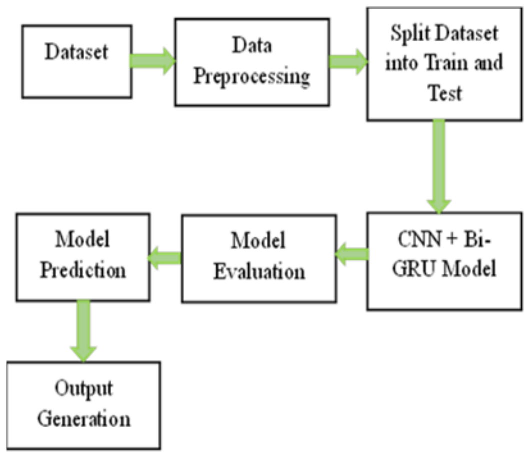

Fig. 2. Block Diagram of the proposed deep learning model

The entire architecture for the proposed work is given in figure 2. The first stage is the preprocessing stage in which the unbalanced images in the dataset with different size are resized to a fixed size. The next step is to split the images in the dataset into 80:20 ratio for training and testing purpose. Data augmentation was done to the training set images to increase the performance of the model. By generating artificial images that are typical of the current domain, data augmentation helps to address the issues caused by the dataset's small size.

Weather forecasting is a complex task that involves analyzing various atmospheric and environmental variables to predict the weather in a particular location. One method for weather forecasting uses convolutional neural network (CNN), a widely used deep learning algorithm for image recognition. Convolutional neural network (CNN) is a widely used deep learning algorithm. Powerful algorithms known as CNNs are capable of discovering patterns in huge, complex datasets. CNNs can be trained to identify trends in weather and environmental data, including temperature, humidity, wind speed, and pressure. Future climate can be predicted using this model. The bidirectional gated recurrent unit Bi-GRU is combined with CNN to obtain optimal accuracy in the proposed model. The fundamental principle of GRU is to selectively update the network's hidden state at each time step via gating techniques. Information flow into and out of the network is managed by the gating mechanisms. The reset gate and the update gate are two of the GRU's two gating systems. The update gate decides how much of the new input should be used to update the hidden state, while the reset gate defines how much of the prior hidden state should be erased. The updated hidden state is used to calculate the GRU's output.

The CNN + Bi-GRU model used in the proposed model is shown in figure 3. The model consists of an input layer, four convolutional layers, bidirectional GRU layer, four fully connected layer, a pooling layer and a softmax layer. The first convolution layer has 64 filters with a kernel size of 3x3 and the stride of convolutional kernel is 1. A ReLU activation layer is followed by the three convolutional layer to introduce non-linearity to the proposed model. The higher-level features are extracted for classification by the help of additional convolutional layers with a kernel size of 3x3 and filter size of 128, 512 and 1024 respectively.

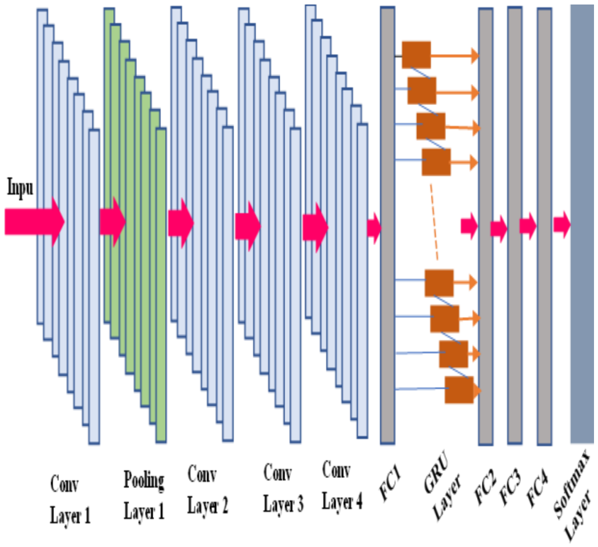

Fig. 3. Proposed CNN+Bi-GRU Model

After the convolutional layers, 1024 feature maps obtained are fed to a fully connected layer with 256 neurons. The output of fully connected layer is subjected to bi-directional GRU layer which is a sort of bidirectional recurrent neural network that just has input and forget gates. It enables predictions about the current state to be made using data from both earlier time steps and subsequent time steps. Subsequently, the output from Bi-GRU is passed through three fully connected layer (FC2, FC3 & FC4) with 256, 128 and 64 neurons respectively. The fully connected layers are finally connected to a softmax output layer for final climate detection.

3. Results and Discussion

For the evaluation of the proposed method, experiments are conducted in windows 10, i5 processor, speed 2.5ghz, 4GB RAM, in python environment using pycharm. The images are initially preprocessed by resizing the images to a fixed size of 224x224 resolution. The images are mapped to their respective classes by creating a .csv file and label the images with appropriate classes. An example of .csv file is shown below in Table 1. Sample images representing various categories from dataset is given in figure 4.

Table. 1 Dataset Label

image_path	target
Cloud/cloud_2.jpg	0
Rainy/rainy_113.jpg	1
Sunshine/sunshine_98.jpg	2
Sunrise/sunrise_228.jpg	3

Fig. 4. Sample Images from dataset a) Images from Multi-class Weather Dataset b) Images added from internet

The model is trained with 15 epochs in batches of 30 with a learning rate of 0.001 using ADAM optimizer. The loss function considered is the cross-entropy loss function. With a training time of around four minutes, we were able to achieve a training accuracy of 95.9% and a validation accuracy of 93.4%. During training, CNN learns patterns in the input data and maps them to the corresponding results, in this case the weather. The accuracy and loss in every epoch are shown in figure 5 and figure 6. It is clearly evident from the figure that, the accuracy value attains maximum between epoch 8 and 12. Correspondingly, the loss value is also very low between epoch 8 and 12. The performance metrics for the experiments conducted is summarized in Table 2. From the table it is evident that, the proposed method achieves an accuracy of 95.25% with a precision of 93%, a recall of 92% and F1 score of 93%.

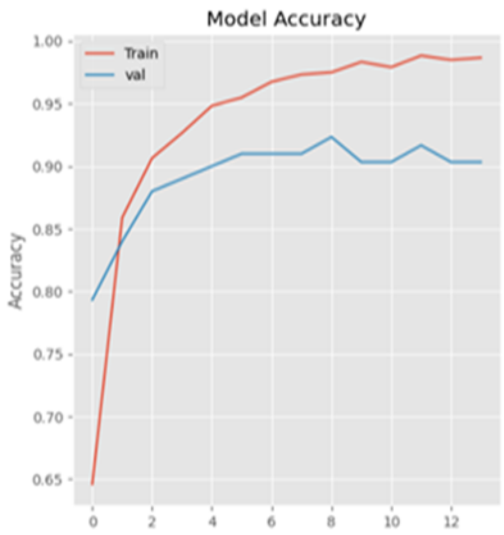

Fig. 5. Accuracy on training and validation

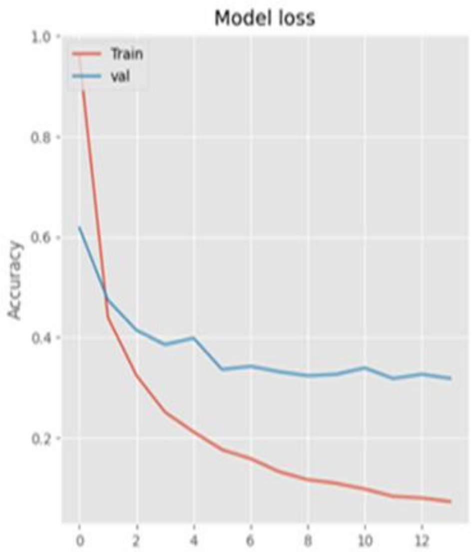

Fig. 6. Model Loss on training and validation

Table. 2 Performance Metrics

Climate Category	**Accuracy**	**Precision**	**Recall**	**F1 Score**
Cloudy	0.96	0.92	0.90	0.91
Rainy	0.95	0.90	0.90	0.93
Sunshine	0.98	0.94	0.93	0.90
Sunrise	0.93	0.96	0.96	0.97
Average	**0.95**	**0.93**	**0.92**	**0.93**

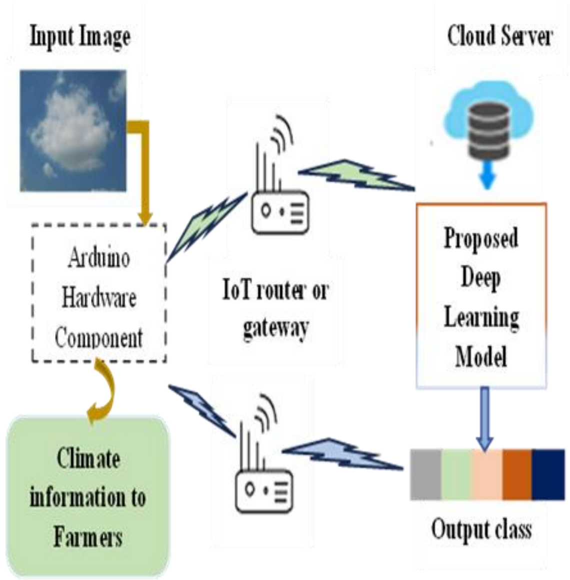

Fig. 7. Deployment of proposed model in IoT

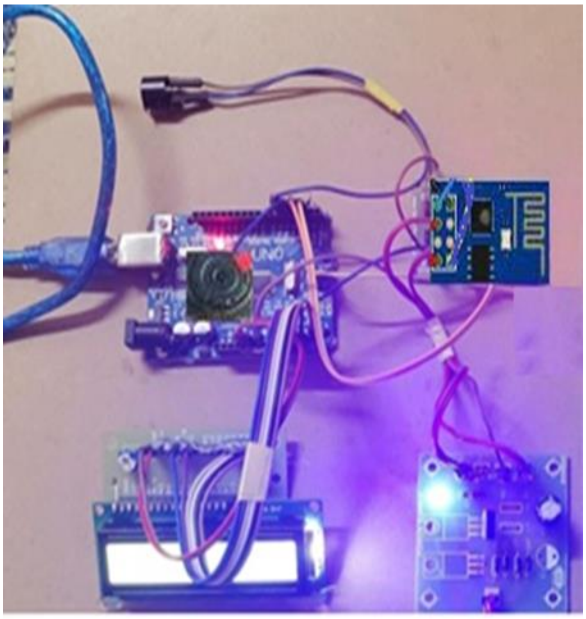

Fig. 8. Arduino Hardware Component

The schematic diagram for the deployment of the proposed climate analysis model in IoT is shown in figure 7. The input atmospheric climate image is acquired using OV7670 module connected to ATmega328P microcontroller-based Arduino UNO. The proposed output signal from hardware component is sent to the central cloud server through IoT gateway using the communication module ESP 8266. The Arduino hardware component is shown in figure 8. The trained deep learning model is deployed in the central server and the output class for the acquired input image is obtained from the trained model during the testing phase. Finally the recognized climate class is sent to the hardware component through IoT gateway using the communication module and the recognized climate information is passed to the remote users.

4. Conclusion

Image based automated weather analysis model is presented in this paper and the proposed model is well suited for the implementation in IoT environment. Analysis of weather prediction based on the global forecasting metrics sometimes find difficult to identify the current weather condition of local region. Hence a real time weather analysis is a demand for farmers for getting better understanding regarding the present weather condition. This research can be used to develop a model that generally supports the farmers by generating real time climate analysis based on the atmospheric images. The evaluation made using the conducted experiments yields a promising result in terms of accuracy.

Conflicts of interest

The authors declare no conflicts of interest.

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