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### Weather Classification using Fusion Of Deep Convolutional Neural Networks and Traditional Classification Methods

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**Abstract:** The weather phenomenon is very important in routine lives. The weather prediction, road electronic monitoring, traffic communication, capping inversion (CAP), afforestation, and the adjustment of the environmental issues are important factors to many decisions. Weather images classification may help in decision support systems. There are traditional and intelligent ways that can sufficiently achieve weather image classification. Traditional methods enhance the classification accuracy and the usability of weather phenomena. Researchers approve that machine learning has achieved better accuracies based on deep learning neural networks. This paper compares three different intelligent models by using a weather image dataset. The first model uses a convolution neural network (CNN) to classify five categories of weather images. The second model uses a fusion of convolution neural network and Decision Tree (DT). The third one uses a fusion of CNN and Support Vector Machine (SVM). The three models are applied to the collected dataset from Github and Kaggle. The study has achieved 92%, 93%, and 94% for CNN, CNN+DT, and CNN+SVM respectively. The Proposed methods have achieved high recognition accuracies for weather forecasting.

**Keywords:** Deep Learning, Convolution neural network, Support Vector Machine, Decision Tree, Weather forecasting

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## 1 Introduction

Weather forecasting is important to determine future climate expectations. Weather forecasting depends on using the new tools that are presented by technology to predict the atmospheric conditions for a certain area or a certain time. People have purposed to predict the weather since many years ago. People have tried to forecast the weather by hand and have used various machines and techniques like now casting, barometer, measuring temperature, measuring wind, and looking at sky or cloud cover. Currently, this is done by using a supercomputer to calculate the forecasting by using some measurements. Weather forecasting is made by collecting accurate data about weather conditions for settled locations then using meteorology to forecast the weather status in the future. Very big safety and security problems depend on difficult weather across the world. Cars, ships, planes, and trains accidents are the headline in the daily timeline news. Weather forecasting may solve some of these problems or at least increase the security in transportation. Human feedback is very important to determine the best forecast model for a certain area or time period.

Researchers have used traditional models for weather image classification that rely on color, texture, and edges features extractions. Previously, driving speeds were controlled by weather [1]. Modern systems gamble on a set of high costly sensors or human service to determine the weather state [2], [3], [4]. Lately, researchers try to find different economical solutions for weather forecasting. Traditional ways for weather classifications have relied on algorithms that extract color and texture features. Some traditional ways have applied edged detection algorithms. Researchers have investigated the weather predictions by depending on a single image [5-8]. There are three main steps for single image weather classification [6-8]. The initial step is to excerpt the Regions of Interest (ROIs) from the given image such as; mountains, roads, sea, and sky extraction. Using various histogram descriptors to show the different ROIs is the second step. Finally, make a classification for the images by using different classifiers such as; Support Vector Machine (SVM), or Decision Tree (DT). These approaches are good for images taken depending on some constrained regions but may fail for wild images, for example, classify images that do not contain any mountain or sea using approaches depending on sea features.

In order to enhance the weather forecasting results, machine learning [10-12] has used artificial intelligence that clones human intelligence in machines. Machine learning has taken decisions depending on the available data by using algorithms. Deep learning [13, 14] is part of machine learning. Using deep learning techniques for image processing makes development easier, faster, and more accurate. However, it is still challenging to achieve high performance in image classification, target detection, and recognition. Merging image processing with AI gives self-training models that can select the image features and classify the right category for each image with the least classification errors.

Convolution neural networks (CNN) are a class of machine learning that has used deep feature extraction and classification to give better results. Recent studies have approved that CNN works effectively on feature extraction and classification phases. CNN has many layers with different filter sizes that extract the different image features and classify each image into the correct category [15, 16]. Many CNN Models have been built and trained on more than a million images like AlexNet [17], ResNet [18], and VGGNet [19]. CNN is used in many branches like computer vision, speech recognition, and Biomedical [9]

This paper aims to find a suitable self-deep learning model for better weather images classification. This study has proposed three different weather classification models. The first one has used CNN to create the feature vector (FV) and to classify the objects into categories.

The second model has used CNN in feature extraction and DT in classification. The third one has used CNN in feature extraction and SVM in classification. The rest of the research is constructed like this. The related works are presented in section 2. Section 3 explains the proposed model. Section 4 shows the given datasets. Section 5 illustrates the results. Section 6 contributes to the conclusion of the study.

## **2 Related work**

In present-days, many different forecasting models have been made as extensive research to find the highest accurate solution for the weather prediction problem. Various and many types of research target the traffic problem from the point of view of the weather classification like rain [20- 23] and fog [24- 26]. Most of the datasets are used in the weather classification models are real images captured by the camera for natural scenes like a seen for road or highway. This denotes that they contribute with a set of features that are limited to the driving assistance purpose on-road and share different backgrounds for weather classification images.

Using machine learning to extract the important features from the images is the main factor in increasing the classification accuracy. Ghaleb et al. [29] made a combined model of Self-organized feature map (SOFM) and Multilayer perceptron (MLP). The study has extracted the feature vector using SOFM. MLP is used to classify the feature map to improve the accuracy with good time in contrast to using SOFM only. The paper has reached 99% classification accuracy. Huang et al. [30] proposed a model for texture and color features to improve the image retrieval performance. They extract the colors and texture features using Gabor descriptors then normalize the features. For similarity measurement, they have used Euclidean distance. The work has proved that the proposed study gets bi-accuracy compared to others.

Deep learning techniques have achieved higher accuracies than traditional models. Feature extraction and classification phase get trained many times until the model gets learned for better image classification. Researchers have proved that Deep Learning is a very powerful technique due to its ability to handle huge amounts of data. Using hidden layers in CNN has surpassed traditional techniques, especially in objects recognition. Lu et al. [27] presented a weather classifier consisting of two classes to classify the weather images. The feature vector contains five features (Sky, Haze, Contrast, Reflection, and Shadow). The authors work collaboratively under a special framework aware of the given weather features during training and classification phases. Similarly, Zhang and Ma [28] depend on human feature description and extraction for the training cycle of their weather classifier. The study has used global and local features to analyze the images. The authors used the local features to set the characteristics of weather images, and they used the global to present the characteristics of weather images that would use with any kind of weather images. An et al. [32] presented a new weather forecasting technique using AlexNet, and ResNet. The convolutional layers of the pertained network combined with a multiclass Support Vector Machine (SVM). That study has achieved image recognition accuracy of 97 % for sunny, 100 % for cloudy, 96 % for hazy, and 95 % for the snowy category. The study research achieved high performance in the weather classification area.

According to the recent work, Xiao et al. [33] presented a novel deep convolutional neural network (CNN) named MeteCNN. The proposed model is weather phenomena classification that has been applied to the weather phenomenon database (WEAPD) that contains 6,877 images

with 11 weather phenomena. The experimental result demonstrates the superiority and effectiveness of the proposed MeteCNN model with a classification accuracy of 92% on the WEAPD testing. Another recent work from Xia et al. [34] presented a new simplified model named ResNet15 has been utilized to extract weather characteristics, and then the characteristics have extracted at the previous layer are shortcut to the next layer through four groups of residual modules. ResNet15 was used to train and test the WeatherDataset-4. WeatherDataset-4 had been collected of weather images on traffic road. The performance of the proposed ResNet15 is higher in comparison to traditional network models such as ResNet50.

### 3 Weather Classification proposed models

Deep learning is a very plenty way to exclude the vital features from the images then use the feature vector in the classification phase to achieve high classification accuracies. Deep learning techniques depend on self-learning by training the network many times until gets sure that the model gets learned. The learning phase is the main phase in deep and machine learning. The evaluation of the model is measured by calculating the classification accuracy for unseen images in the test phase. The test phase is very important to get sure that the model gets learns. This study has built three proposed methods for weather image classification. The weather recognition model has used deep learning has two phases train and test. The training phase has mainly two steps; feature extraction and classification. The test phase is very important to evaluate the model using unseen images. Figure 1 shows a block diagram for weather forecasting using the CNN model.

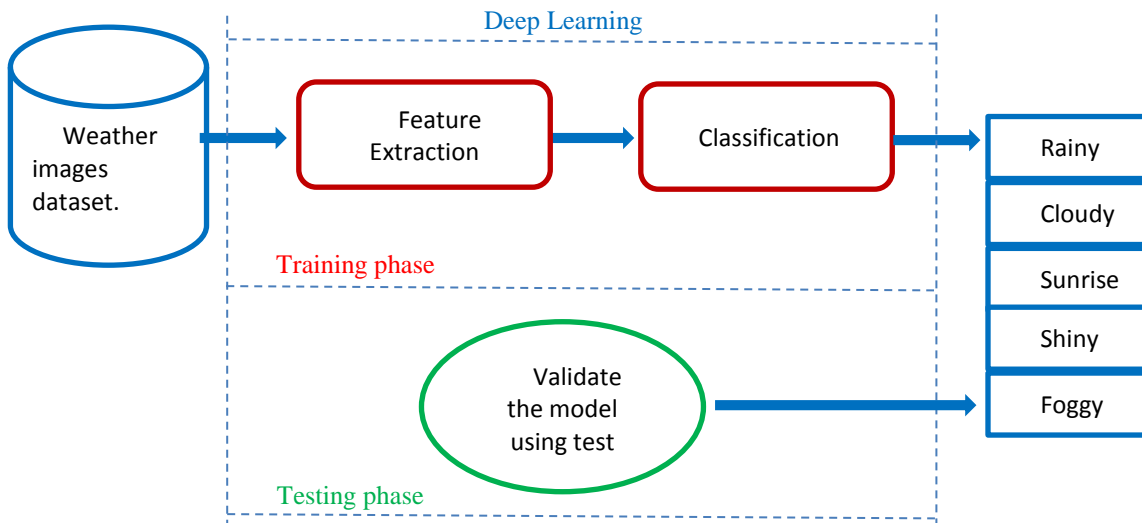


Figure. 1: Block diagram of the deep learning architecture.

### **3.1 Feature extraction**

The feature extraction phase presents new features that are a linear combination of the important existing features of the image. The new feature vector consists of different values in contrast to the original image features value. The main aim is to minimize the features that required catching the same information. The efficiency of the feature extraction techniques depends on how much the new reduced feature values can summarize most of the information contained in the original image (input image).

The three proposed models used CNN network for the feature extraction. CNN is a neural network that trains and classifies images into categories depending on their features. The input is an image and the feature vector has been computed by using a mask that applies to that image. The output is a feature vector. CNN uses many convolution layers, different filter sizes, max-pooling layers, normalization layers, fully connected layers, drop layers, and activation functions. The convolutional layer contains a group of digital filters that make the convolution procedure on the input image. The convolutional layers have a filter with variant size and pooling layers to perform feature extraction. If we have an input image for object recognition, the convolution layers detect features such as two eyes, mouth, and short or long ears, four or two legs, a short tail, and so on.

The most important parameters are the number and the size of the kernels. Max-pooling is the pooling layer that is used as a dimensionality reduction of the data. CNN used nonlinear activation functions such as Relu and softmax. The last layer of CNN is the fully connected layer (FC). FC layers can learn effectively non-linear combinations of input features. The high-level features in the data are represented as the output of the convolutional layers. FC layers are very important because they are the connection between the flattened layers of the last CL and the output layer. FC applies activation function and is used in both phases; feature extraction and classification. The proposed CNN model consists of three CL followed by Relu activation function, max-pooling layers, and three FC layers.

### **3.2 Classification**

The function of predefining the image and what its capturing is called image classification. An image classification model is an applied deep learning model that is trained many times until get learned to achieve the classification phase and recognize the images into various classes. For example, you may train a model to recognize photos captured from real life that contain three different types of animals: birds, lions, and crocodiles. So, the model will train many times until get learned then start to classify the input images into three categories. This study represents three different classification technologies to recognize weather photos that may help in weather forecasting. FC, SVM, and DT are the three classification algorithms applied in this study.

### 3.3 Proposed models

This study proposed three different models:

#### a. CNN Model

This model has used CNN for feature extraction and classification. The front convolutional layers are responsible for the feature extraction phase and the last layers (fully connected layer) in CNN model are responsible for the classification phase. The softmax function is an activation function that is applied by the last layer of FC. The last FC layer is the output layer of the CNN model. Table 1 displays the setup for CNN proposed models. Figure 2 shows a full architecture of the CNN model based on weather dataset classification. The figure illustrates the three convolution layers followed by max-pooling and the fully connected layers.

**Table1** Setup of CNN's Model

Layer	Filter size	No. of Kernel	No. of Nodes	Size of Stride	Activation Function
CL1	3x3	32	*	2x2	Relu
Max pooling	2x2	*	*	*	*
CL2	3x3	64	*	1x1	Relu
Max pooling	2x2	*	*	*	*
CL3	3x3	128	*	1x1	Relu
Max pooling	2x2	*	*	*	*
FC1	*	*	512	*	Relu
FC2	*	*	125	*	Relu
FC3 (output)	*	*	5	*	softmax

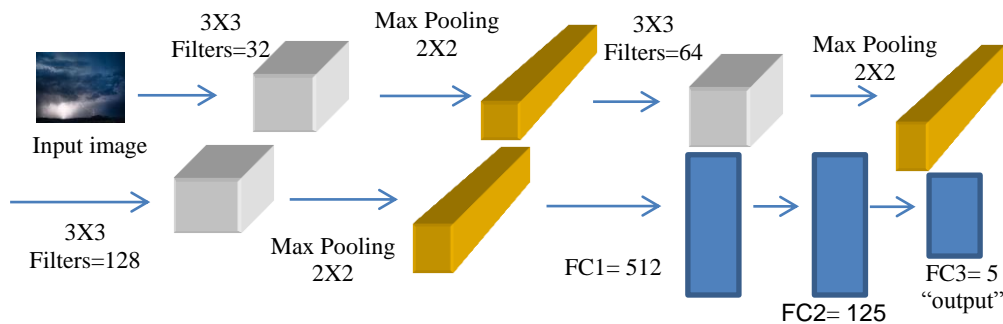


Figure. 2: CNN Model Architecture for weather database.

### **b. CNN +DT Model**

Decision The Decision Tree (DT) algorithm is one of the supervised learning algorithms. It is different from the other supervised learning algorithms; it can be used for clarifying regression and recognition problems too. The aim of using a Decision Tree is to make a training model that can use to know the category of the input image by learning smooth decision rules.

The second proposed model is a combination of CNN and DT. We have used the front convolutional layers that are responsible for the feature extraction phase and applying them to the DT algorithm for the classification phase. The model has applied CNN as shown in table 1 then combined the result with DT classifier to improve the classification accuracy.

### **c. CNN+SVM Model**

One of the supervised machine learning algorithms is SVM which is efficient in performing object detection, regression, and classification. It can clarify the linear and non-linear problems and achieve good results for many problems. SVM is created to separates the data into classes. SVM has achieved many amazing results before [32].

This model is the third proposed model that has made a combination of CNN and SVM. The convolutional layers are responsible for the feature extraction phase and applying the SVM algorithm for the classification phase. The model has applied CNN as shown in table 1 then combined the result with the SVM classifier to increase the classification accuracy.

## **4 Datasets Collections**

This study has used the weather dataset from Kaggle [31] that consists of five different categories of weather images. The data has been collected from the internet throw Kaggle and Github. The used images contain licenses found from Unsplash, Pexels, and Flickr. Not all the images take the same license. Kaggle dataset has about 1500 known images with the validation images. Images don't have fixed dimensions, and they are different sizes. Certainly, each image belongs to one class. Each category is saved in a different separate labeled folder. Each image has been rated for the weather condition on five categories Cloudy, foggy, rainy, Shine, and Sunrise. The dataset splits into 80% for training and 20% for the testing phase. Figure 3 shows sample images for the five classes of weather datasets.

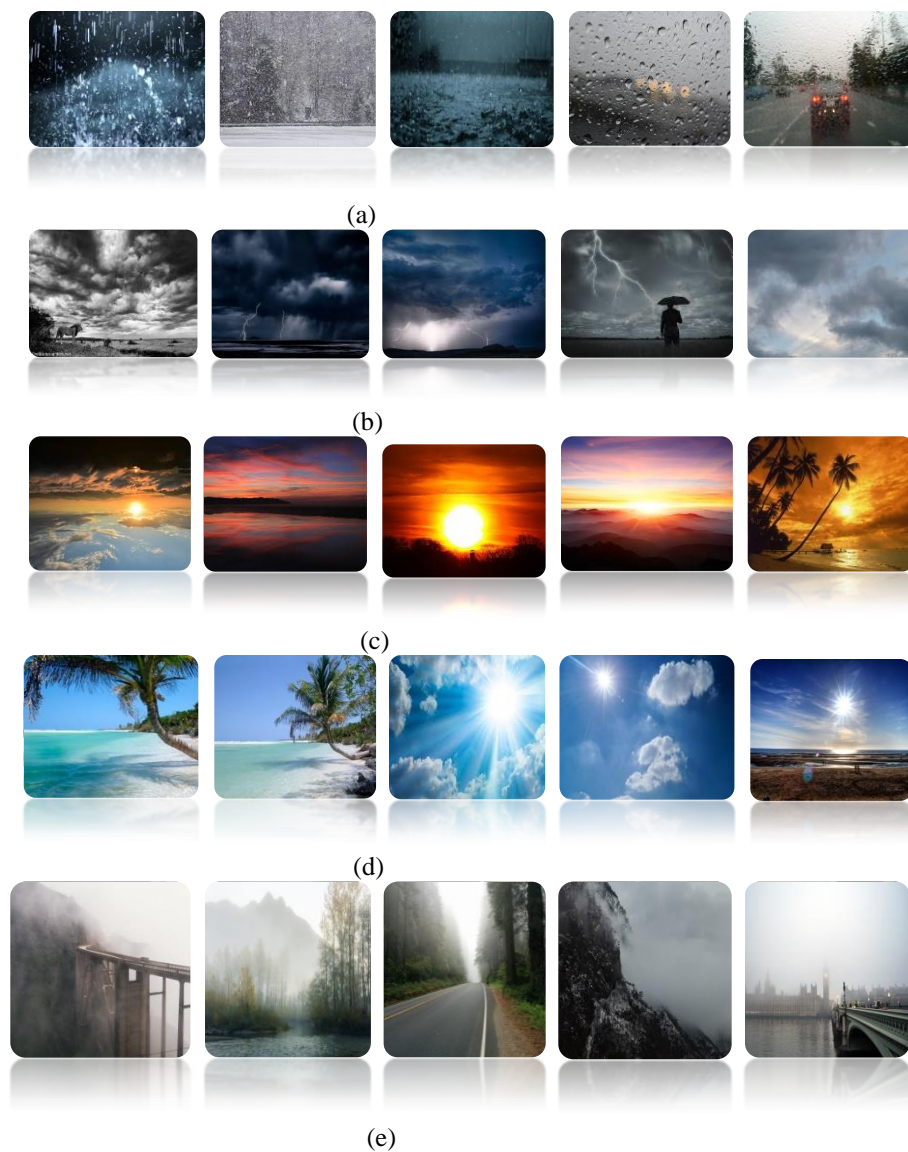


Figure. 3: Sample images of weather dataset; (a) Rainy, (b) Cloudy, (c) Sunrise, (d) Shiny , and (e) Foggy weather images samples.

## 5 Experimental Results

This study applies three experiments on the weather dataset to classify the images into five categories.

The first experiment is carried out to measure the classification accuracies for the weather dataset by using the CNN model. The experiment was applied by using a weather dataset. The accuracies classification results for the rainy, cloudy, sunrise, shiny, and foggy categories were 95%, 93%, 91%, 100%, and 81% respectively. The experiment reached average accuracy for the five classes 92%.



Figure 4 shows CNN model classification accuracy results. We observe from this experiment that the CNN model has reached 100% for the shiny class. Also, the minimum value is for the foggy class with 81% classification accuracy.

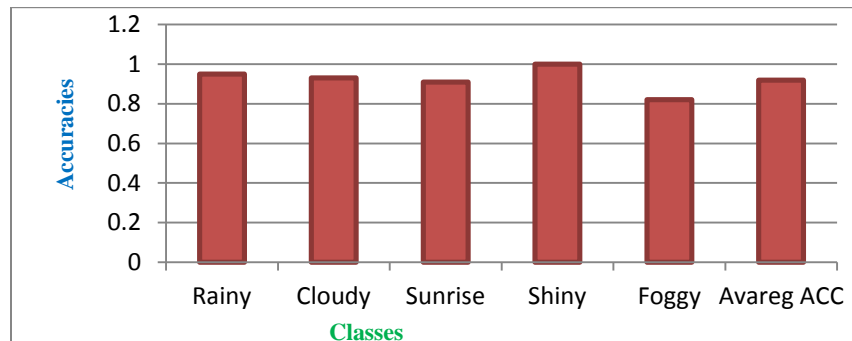


Figure. 4: CNN classification accuracy for rainy, cloudy, sunrise, shiny and foggy categories.

The second experiment was carried out to measure the classification accuracy for the weather dataset by using the CNN+DT model. The experiment was applied using the weather dataset. The accuracy classification results for the rainy, cloudy, sunrise, shiny and foggy categories were 96%, 97%, 94%, 95%, and 82% respectively. The experiment gave average accuracy for the five classes 93%. Figure 5 shows CNN+DT model classification accuracy results. We observe from this experiment that the CNN+DT model reached the highest classification accuracy for cloudy class with 97% classification. And the lowest accuracy was for the foggy class with 82% classification accuracy. Also, we observed from the previous two experiments that the CNN+DT model achieved the highest average accuracy compared with the CNN model.

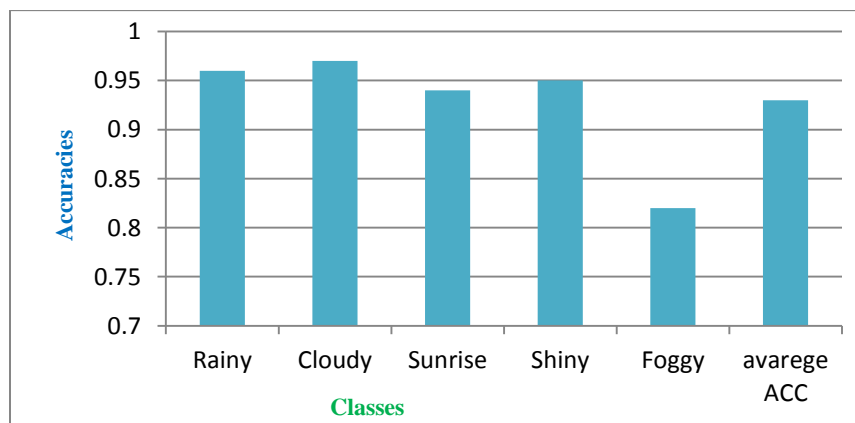


Figure. 5: CNN+DT classification accuracy for rainy, cloudy, sunrise, shiny and foggy categories.

The third experiment was carried out to measure the classification accuracy for the weather dataset by using the CNN+SVM model. The experiment was applied using a weather dataset. The accuracy classification results for the rainy, cloudy, sunrise, shiny and foggy categories are 98%, 97%, 95%, 96%, and 83% respectively. The experiment achieved average accuracy for the five classes of 94%. Figure 6 shows CNN+SVM model classification accuracy results. We observe from this experiment that the CNN+SVM model has reached the highest classification

accuracy for the rainy class with 98% classification accuracy. Also, the lowest accuracy is for the foggy class with 83% classification accuracy.

From the three experiments, the foggy class has achieved the lowest accuracy in comparison with the cloudy and shiny classes. The foggy images have the lowest colors in comparison to the other classes. Additionally, the foggy images do not focus on sun or water drops it depend on the live capturing of normal scenes like road, mountain, and sea images. We can conclude that foggy images in more complicated in classification compared to the other classes.

We observe from the three experiments that the CNN+SVM model has achieved the highest average accuracy compared with CNN and CNN+DT models. Table 2 shows a classification accuracy comparison between the three proposed models and the state-of-the-art models. Xiao et al [33] presented recent work of weather forecasting using image classification based on CNN.

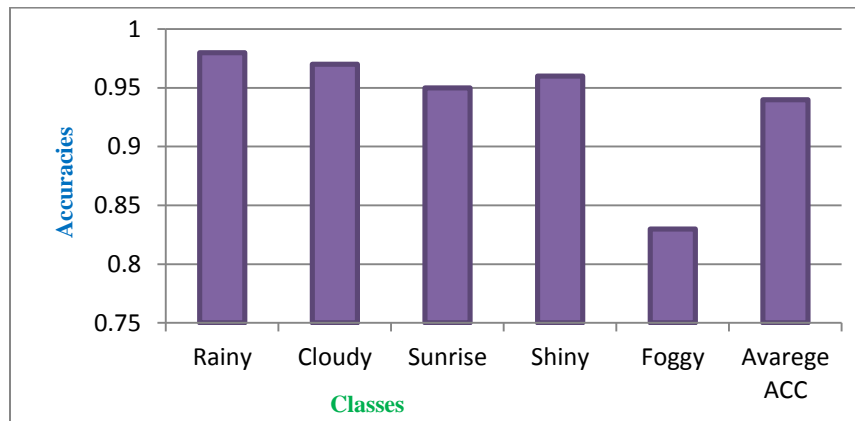


Figure. 6: CNN+SVM classification accuracy for rainy, cloudy, sunrise, shiny and foggy categories.

Table2 Classification accuracy comparison for CNN, CNN+DT and CNN+SVM proposed models.

Model	Average Accuracy
Proposed CNN	92%
Proposed CNN+DT	93%
Proposed CNN +SVM	94%
MeteCNN [33]	92%

## 6 Conclusion

Determination of weather conditions has become a more important topic because it can help in controlling many accidents which depend on whether climate. Because of the intelligence in the emergency issues, the weather conditions have become easier to detect. Advanced systems depend on sensors or robot assistance to know the weather circumstances. Researchers have put their studies in computer vision. The single images are used in computer vision techniques that classify the weather circumstances. Many studies have proved that CNN is a good model for images classification. This research has built three different models based on CNN to increase

the average weather classification accuracy. SVM and DT is a supervised network used for the classification phase.

In this study, we proposed three models and made three experiments on the weather datasets. The three proposed models are CNN, CNN+DT, and CNN+SVM. CNN models applied on weather dataset that consisted of five classes; rainy, cloudy, sunrise, shiny, and foggy.

The first experiment applied the CNN model. The experiment achieved 95%, 93%, 91%, 100%, and 81% classification accuracy for rainy, cloudy, sunrise, shiny and foggy respectively. The average accuracy for CNN model is 92%. The second experiment applied the CNN+DT model. The experiment achieved 96%, 97%, 94%, 95%, and 82% classification accuracy for rainy, cloudy, sunrise, shiny, and foggy respectively. CNN+DT model achieved 93% average accuracy. The third experiment applied the CNN+SVM model. The experiment achieved 98%, 97%, 95%, 96%, and 83% classification accuracy for rainy, cloudy, sunrise, shiny and foggy respectively. CNN+SVM model achieved 94% average accuracy. All in all, the paper presents three different intelligent models based on CNN. The study has proved that the combination between CNN and SVM achieves high classification accuracies for the weather dataset.

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