A Novel Approach for Thunderstorm and Lightning Detection System

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Abstract: ***Thunderstorm and lightning is a sudden electrical expulsion manifested by a blaze of lightening with a muffled sound. It is one of the most spectacular mesoscale weather phenomena in the atmosphere which occurs seasonally. Every thunderstorm produce lightening, this kills more people every year than tornadoes, and prediction of thunderstorms is said to be the most complicated task in weather forecasting, due to its limited spatial and temporal extension either dynamically or physically. Various researches are been carried on for forecasting of this severe to reduce damage. Many of the researchers proposed various methodologies like STP model, MOM model, CG model, LM model, QKP model, DBD model and so on for the detection, but neither of them could provide an accurate prediction .The proposed system is to gather the satellite images obtained from dataset in order to predict whether the cloud images produces thunderstorms or not . The proposed system adopted clustering and wavelet transform techniques for thunderstorms and lightning detection using image processing and data mining. The proposed system improves the prediction rate to a greater extent, on the basis of some statistical analysis.***

Keywords: K-medoid Clustering, Wavelet Transform, ANN

1. Introduction

Computers are widely utilized in today's weather forecasting as a powerful tool to leverage an enormous amount of data. Yet, despite the availability of such data, current techniques often fall short of producing reliable detailed storm forecasts. Each year severe thunderstorms cause significant damage and loss of life, some of which could be avoided if better forecasts were available.

Thunderstorm

Thunderstorm is a vicious, climatic disturbance that is associated with heavy rains, lightening, thunders, thick clouds and gusty surface winds. Thunderstorms take place when a layer of warm and moist air rises to a larger extent, and updrafts to the cooler regions of the atmosphere. The updraft that contains moisture condenses in order to form massive cumulonimbus clouds and eventually leads to the development of precipitation. Columns of frozen air then sink earthward, striking the ground with strong downdrafts and horizontal winds. Meanwhile, electrical charges mount upon cloud particles and causes lightning. This further heats the air in a violent manner by which shock waves are produced, resulting in thunder .Usually, thunderstorms have the spatial area for a few with a life span less than an hour. However, multi-cell thunderstorms have a life span of several hours and may travel over a few hundreds of kilometers. Throughout the world it is estimated that 16 million thunderstorms occur each year, and at any given moment, there are roughly 2,000 thunderstorms in progress. There are about 100,000 thunderstorms each year in the U.S. alone. About 10% of these reach severe levels. Under the right conditions, rainfall from thunderstorms causes flash flooding, killing more people each year than hurricanes, tornadoes or lightning Cloud to ground lightning frequently occurs as part of the thunderstorm phenomena, which on severity becomes hazardous to the property, wildlife and population across the globe to a major extent. One of the most significant lightning hazards is to the wildfires, as they can even ignite the ground surfaces. Wildfires can devastate vegetation and the biodiversity of an ecosystem. Cloud to ground lightning frequently occurs as part of the thunderstorm phenomena, which on severity becomes hazardous to the property, wildlife and population across the globe to a major extent. Following figure shows how thunderstorm developed under three stages i.e, Life cycle of thunderstorm.

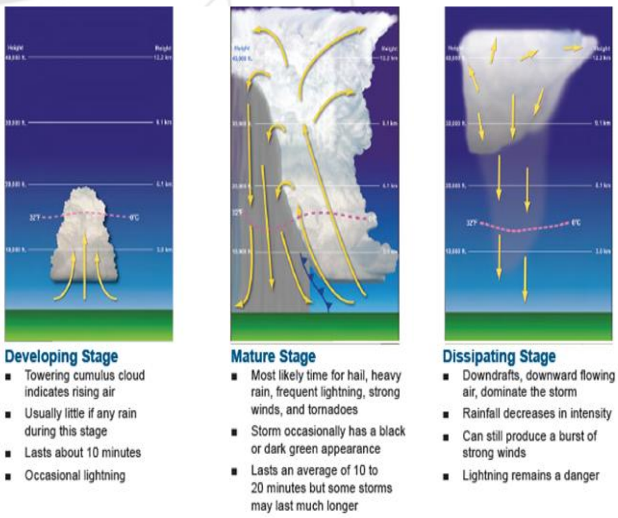

Figure 1: Thunderstorm Life Cycle

Lightning

The rising air in a thunderstorm cloud causes various types of frozen precipitation to form within the cloud. Included in these precipitation types are very small ice crystals and much larger pellets of snow and ice. The smaller ice crystals are carried upward toward the top of the clouds by the rising air while the heavier and denser pellets are either suspended by the rising air or start falling toward the ground. Collisions occur between the ice crystals and the pellets, and these collisions serve as the charging mechanism of the thunderstorm. The small ice crystals become positively charged while the pellets become negatively charged. As a result, the top of the cloud becomes positively charged and the middle to lower part of the storm becomes negatively charged. At the same time, the ground underneath the cloud becomes charged oppositely of the charges directly overhead .When the charge difference between the ground and the cloud becomes too large, a conductive channel of air develops between the cloud and the ground, and a small amount of charge (step leader) starts moving toward the ground. When it nears the ground and upward leader of opposite charge connects with the step leader. At the instant this connection is made, a powerful discharge occurs between the cloud and the ground. We see this discharge as a bright visible flash of lightning. Following figure shows lightning image.

Figure 2: Lightning Image

2. Proposed Work

The goal of this research is to scrutinize the satellite images obtained from Indian Meteorological Department, in order to predict whether the cloud images produces thunderstorms or not and find out whether lightning touches to the ground or not.

Initially, the original satellite image of clouds is taken as the input image for the experimentation. As the input image is a satellite image, it may restrain with different type of noises such as striping noise, speckle noise, blurs and so on which are ought to be removed. It may also contains various textures such as water bodies, forests, grass, asphalt, barren lands, concrete, clouds and so on. These textures are to be estranged to acquire the image of interest so that the other texture does not have an effect on the precise forecasting of thunderstorms. If the satellite image containing such types of noises and textures are analyzed, the result obtained may deviate from original value. So, the input image must be segmented. Clustering is an efficient technique to segment the input image into several clusters based on similarity measure, here Euclidean distance is used as one of the similarity metric. In the present research, k-medoids clustering is adopted for segmenting the image. Here, Segmentation is performed to image by based on various color factors because colors possess wavelength values. The image containing relatively similar wavelength values are grouped into different clusters. Here, the Haar wavelet transform is adopted for the further analysis

As satellite image is an RGB image, Haar wavelet transform automatically converts RGB image into gray scale image and further de noise the image and present it in one dimension.

Detection of Thunderstorm

Following figure shows how to find out thunderstorm result by using two algorithm i.e K-mediods and harr wavelet transform. Where K-medoids is used for clustering purpose and harr wavelet is use to generate wavelet image as well as it is use to find out the wavelength range.

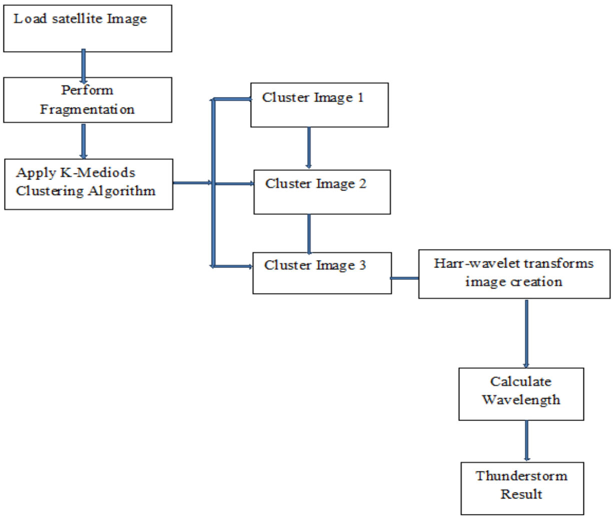

Figure 3: Flow Chart of Thunderstorm Detection

Steps for Detection of thunderstorm

Steps 1 - Gather the satellite images from Indian metrological department and load a image in order to predict whether the cloud images produce Thunderstorm or not.

Step 2 - Perform fragmentation in order to detect objects or divide the image into regions which can be considered homogeneous according to a given criterion, such as color, motion, texture.

Step 3 - Apply k-mediod algorithm, and create three clusters i.e. cluster image1 cluster image2, cluster image3.

Step 4 – Using cluster image 3, apply harr-wavelet algorithm, which convert RGB image into gray scale image and de noise the image and present it in one dimension.

Step 5 – Calculate wavelength, Based on wavelength value, it determine whether input image having thunderstorm or not. As wavelength range is between 250-350 nm. Then result is thunderstorm.

3. Detection of Lightning Position from Ground

Following figure shows flow chart of detection of lightning position from ground by scanning input image pixel by pixel depending on pixel result get known.

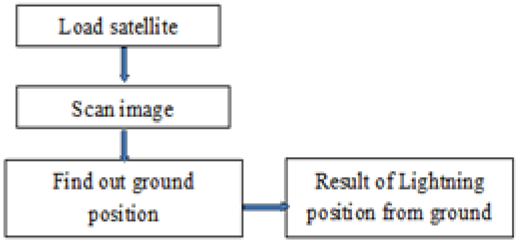

Figure 4: Flow Chart of Detection of Lightning Position from Ground

Steps for Detection of Lightning Position from Ground

Step 1 - Gather the satellite images from Indian metrological department and load a image in order to find out lightning position from ground.

Step 2 - Remove background of lightning images so that lightning part is clear visualized.

Step 3 - Scan image pixel by pixel tin order to find out ground position, and if pixel value is greater than 85nm then result should be "lightning touches to the ground" otherwise "lightning not touches to the ground".

4. Result Analysis

In proposed system, the satellite images obtained from Indian Meteorological Department is analyzed to identify the presence of thunderstorms within the clouds. On analysis of these satellite images a square root balance sparsity norm threshold value is computed and is established to be in between an optimal range of 9 - 11.As satellite image is a visible spectrum, its wavelength value always lies in the range of 350 nm-450 nm. Based on this criterion, the wavelength range for the feature extracted images is tested and on observation of these results, a range of 350nm-450nm is established for the clouds containing thunderstorms. The main goal of the present research is to detect the thunderstorms as accurate as possible. In order to compute accuracy for the present research TP, TN, FP, FN values are to be computed. The true positive (TP) specifies the positive tuples that were correctly labeled. The true negative (TN) specifies the negative tuples that were correctly labeled. The false positive (FP) specifies the negative tuples that are incorrectly labeled. The false negative (FN) specifies the positive tuples that are incorrectly labeled. The four basic performance measures i.e. sensitivity, specificity, accuracy and precision are computed for the present research in order to test how well the proposed system is working and the computations are done by using following equations .

$$\text{Sensitivity} = TP/(TP+FN) \quad (1)$$

$$\text{Specificity} = TN/(FP+TN) \quad (2)$$

$$\text{Accuracy} = (TP+TN)/(TP+FP+FN+TN) \quad (3)$$

$$\text{Precision} = TP/(TP+FP) \quad (4)$$

Table 1: Performance Measure Factors

Performance measure	Percentage (%)
Sensitivity	92.10
Specificity	85.18
Accuracy	89.23
Precision	89.74

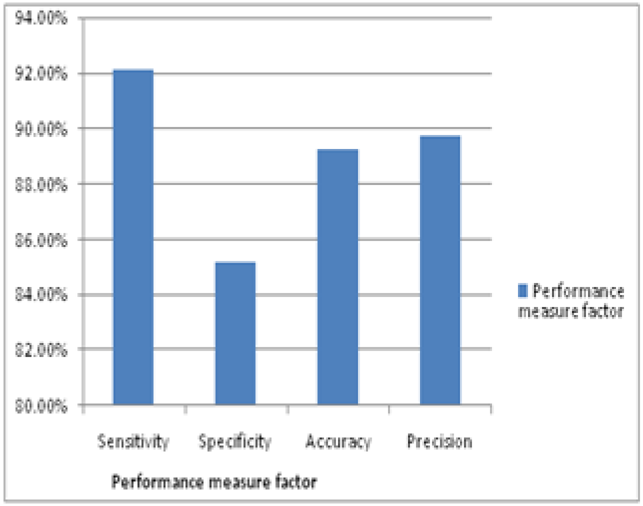

Figure 5: Graph of Performance Measure Factors

Above table performance measure factors and above figure graph of performance measure factor shows the performance of proposed system calculated in terms of parameter such as Sensitivity, Specificity, Accuracy, and Precision. There it is observed that the proposed system gives the better result for the given parameter.

Table 2: Comparison Accuracy of Proposed Model

Model	Accuracy (%)
STP model	39
MOM model	42
CG model	61
LM model	76
QKP model	38
DBD model	39
Proposed model	**89.2**

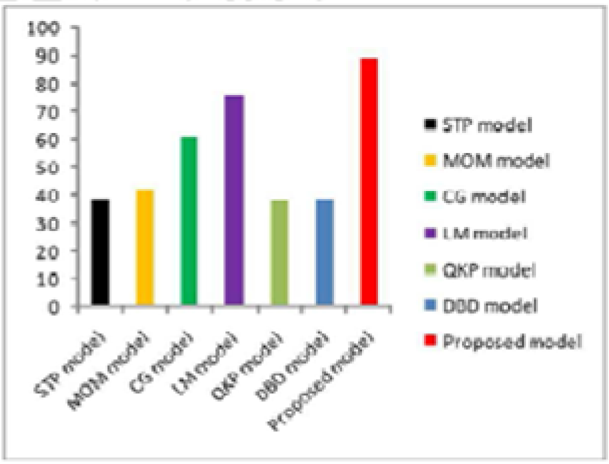

Figure 6: Comparison Graphs for Proposed Model

The proposed method is compared with previous methodologies for the prediction of thunderstorms. The comparison graph is drawn for all the algorithms and is shown in above figure. The graph clearly shows that the proposed method is outperforming when compared with the previous methodologies.

Table 3: Result Analysis of Thunderstorm Detection System

Image Number	Standard Deviation(σ)	Square Root Balance Sparsity Norms Threshold (τ)	Wavelength Factor ($d\Delta/d\lambda$)	Wavelength $(\lambda)=(\tau * d\Delta/d\lambda)$	Type of Thunderstorm	Ligtning Position
Image1.Jpg	2.95	10.96	30.89	455.29	Severe Thunderstorm	Touch to ground
Image2.Jpg	2.3	9.88	39.71	399.64	Thunderstorm	Touch to ground
Image3.Jpg	1.93	10.25	47.2	414.82	Thunderstorm	Touch to ground
Image4.Jpg	2.73	10.13	33.41	409.96	Thunderstorm	Touch to ground
Image5.Jpg	2.94	10.5	31.05	424.94	Thunderstorm	Touch to ground
Image6.Jpg	2.03	9.75	44.83	394.58	Thunderstorm	Touch to ground
Image7.Jpg	2.03	9.75	44.83	394.58	Thunderstorm	Touch to ground
Image8.Jpg	1.99	10.25	45.75	414.82	Thunderstorm	Touch to ground
Image9.Jpg	2.79	10.38	32.69	420.08	Thunderstorm	Touch to ground
Image10.Jpg	1.83	9.78	49.83	395.84	Thunderstorm	Touch to ground
Image11.Jpg	2.52	9.94	36.17	402.19	Thunderstorm	Touch to ground
Image12.Jpg	2.3	9.63	39.68	389.52	Thunderstorm	Touch to ground
Image13.Jpg	2.02	9.67	45.07	391.34	Thunderstorm	Touch to ground
Image14.Jpg	2.42	9.63	37.68	389.52	Thunderstorm	Touch to ground
Image15.Jpg	2.59	9. 81	35.26	397.13	Thunderstorm	Touch to ground
Image16.Jpg	3.76	13.13	24.25	531.37	Severe Thunderstorm	Touch to ground
Image17.Jpg	1.38	8	66.28	323.76	No Thunderstorm	Not Touch to ground
Image18.Jpg	2.59	9.5	35.24	384.47	Thunderstorm	Touch to ground
Image19.Jpg	2.65	11.12	34.38	450.03	Thunderstorm	Touch to ground
Image20.Jpg	1.94	10.37	47.08	419.67	Thunderstorm	Touch to ground
Image21.Jpg	3.98	15	22.88	607.05	Severe Thunderstorm	Touch to ground
Image22.Jpg	3.19	9.25	28.55	384.63	Thunderstorm	Touch to ground
Image23.Jpg	2.21	9.5	41.24	384.47	Thunderstorm	Touch to ground
Image24.Jpg	2.94	10.69	30.97	432.62	Severe Thunderstorm	Touch to ground
Image25.Jpg	2.34	9.13	38.93	389.45	Thunderstorm	Touch to ground
Imag 26.Jpg	3.01	10.87	30.27	439.91	Sever Thunderstorm	Touch to ground
Image27.Jpg	2.53	10.5	36.05	424.94	Thunderstorm	Touch to ground
Image28.Jpg	2.1	9.06	43.48	386.34	Thunderstorm	Touch to ground
Image29.Jpg	1.65	9.38	55.17	381.24	Thunderstorm	Not Touch to Ground
Image30.Jpg	1.86	8.94	49.05	394.71	Thunderstorm	Touch to ground
Image31.Jpg	2.39	9.63	38.18	389.52	Thunderstorm	Touch to ground
Image32.Jpg	2.5	10.31	36.43	417.25	Thunderstorm	Touch to ground
Image33.Jpg	2.68	9.75	33.98	394.58	Thunderstorm	Touch to ground
Image34.Jpg	1.94	9.63	47.05	389.52	Thunderstorm	Touch to ground
Image35.Jpg	2.3	9.13	39.68	431.65	Sever Thunderstorm	Touch to ground
Image36.Jpg	3.27	11	27.9	445.17	Sever Thunderstorm	Touch to ground
Image37.Jpg	2.19	9.13	41.71	392.43	Thunderstorm	Touch to ground
Image38.Jpg	2.12	9.6	43.01	388.63	Thunderstorm	Touch to ground
Image39.Jpg	3.36	10.88	27.12	372.92	Thunderstorm	Not Touch to ground
Image40.Jpg	2.9	15.13	31.43	543.62	Sever Thunderstorm	Touch to ground
Image41.Jpg	2.85	12.88	31.98	462.78	Sever Thunderstorm	Touch to ground
Image42.Jpg	3.2	12.25	28.48	464.23	Sever Thunderstorm	Touch to ground
Image43.Jpg	3.63	14.25	25.11	512	Sever Thunderstorm	Touch to ground
Image44.Jpg	2.12	8.75	42.99	314.39	No Thunderstorm	Not Touch to ground
Image45.Jpg	2.71	10.75	33.63	378.45	Thunderstorm	Touch to ground
Image46.Jpg	2.59	9.88	35.19	354.81	Thunderstorm	Touch to ground
Image47.Jpg	2.63	10.31	34.65	380.44	Thunderstorm	Touch to ground
Image48.Jpg	2.71	12.25	33.63	440.14	Severe Thunderstorm	Touch to ground
Image49.Jpg	2.06	13.25	44.24	486.07	Severe Thunderstorm	Touch to ground
Image50.Jpg	2.17	9.6	42	344.93	Severe Thunderstorm	Touch to ground
Image51.Jpg	3.32	13.3	27.45	485.23	Severe Thunderstorm	Touch to ground
Image52.Jpg	1.84	9.8	49.53	352.11	Thunderstorm	Touch to ground
Image53.Jpg	2.4	9.9	37.97	355.71	Thunderstorm	Touch to ground
Image54.Jpg	1.9	10.38	47.97	372.95	Thunderstorm	Touch to ground
Image55.Jpg	2.86	13.12	31.87	491.4	Severe Thunderstorm	Touch to ground
Image56.Jpg	2.32	9.06	39.28	325.53	Thunderstorm	Touch to ground
Image57.Jpg	1.94	9.25	46.98	332.35	No Thunderstorm	Not Touch to ground
Image58.Jpg	2.67	9.8	34.13	352.11	Thunderstorm	Touch to ground
Image59.Jpg	1.8	9.8	50.63	352.11	Thunderstorm	Touch to ground

Image60.Jpg	2.56	9.25	35.6	332.35	No Thunderstorm	Not Touch to ground
Image61.Jpg	1.81	8.75	50.35	314.39	No Thunderstorm	Not Touch to ground
Image62.Jpg	2.22	9.18	41.05	329.84	No Thunderstorm	Not Touch to ground
Image63.Jpg	2.51	9.37	36.31	336.66	No Thunderstorm	Not Touch to ground
Image64.Jpg	2.4	9.75	37.97	350.32	Thunderstorm	Not Touch to ground
Image65.Jpg	2.71	9.86	33.63	354.27	Thunderstorm	Touch to ground

In table 3, it calculate wavelength of each input image by standard formula and result of thunderstorm is depend upon range of wavelength. If wavelength lies between the range 350-450 then results is thunderstorm otherwise there is no thunderstorm. Also it finds out weather the lightning touches to the ground or not.

Table 4: Prediction of Thunderstorm

Image Number	*Experimentally Obtained Result*	*Historically Established Result*	*Prediction*
Image1.Jpg	Thunderstorm	Thunderstorm	TRUE
Image2.Jpg	Thunderstorm	Thunderstorm	TRUE
Image3.Jpg	Thunderstorm	Thunderstorm	TRUE
Image4.Jpg	Thunderstorm	Thunderstorm	TRUE
Image5.Jpg	Thunderstorm	Thunderstorm	TRUE
Image6.Jpg	Thunderstorm	Thunderstorm	TRUE
Image7.Jpg	Thunderstorm	Thunderstorm	TRUE
Image8.Jpg	Thunderstorm	Thunderstorm	TRUE
Image9.Jpg	Thunderstorm	Thunderstorm	TRUE
Image10.Jpg	Thunderstorm	No Thunderstorm	FALSE
Image11.Jpg	Thunderstorm	Thunderstorm	TRUE
Image12.Jpg	Thunderstorm	Thunderstorm	TRUE
Image13.Jpg	Thunderstorm	Thunderstorm	TRUE
Image14.Jpg	Thunderstorm	Thunderstorm	TRUE
Image15.Jpg	Thunderstorm	Thunderstorm	TRUE
Image16.Jpg	Thunderstorm	Thunderstorm	TRUE
Image17.Jpg	No Thunderstorm	No Thunderstorm	FALSE
Image18.Jpg	Thunderstorm	Thunderstorm	TRUE
Image19.Jpg	Thunderstorm	Thunderstorm	TRUE
Image20.Jpg	Thunderstorm	Thunderstorm	TRUE
Image21.Jpg	Thunderstorm	Thunderstorm	TRUE
Image22.Jpg	Thunderstorm	Thunderstorm	TRUE
Image23.Jpg	Thunderstorm	Thunderstorm	TRUE
Image24.Jpg	Thunderstorm	Thunderstorm	TRUE
Image25.Jpg	Thunderstorm	Thunderstorm	TRUE
Image 26.Jpg	Thunderstorm	Thunderstorm	TRUE
Image27.Jpg	Thunderstorm	Thunderstorm	TRUE
Image28.Jpg	Thunderstorm	Thunderstorm	TRUE
Image29.Jpg	Thunderstorm	Thunderstorm	TRUE
Image30.Jpg	Thunderstorm	Thunderstorm	TRUE
Image31.Jpg	Thunderstorm	Thunderstorm	TRUE
Image32.Jpg	Thunderstorm	Thunderstorm	TRUE
Image33.Jpg	Thunderstorm	Thunderstorm	TRUE
Image34.Jpg	Thunderstorm	Thunderstorm	TRUE
Image35.Jpg	Thunderstorm	Thunderstorm	TRUE
Image36.Jpg	Thunderstorm	Thunderstorm	TRUE
Image37.Jpg	Thunderstorm	Thunderstorm	TRUE
Image38.Jpg	Thunderstorm	Thunderstorm	TRUE
Image39.Jpg	Thunderstorm	Thunderstorm	TRUE
Image40.Jpg	Thunderstorm	Thunderstorm	TRUE
Image41.Jpg	Thunderstorm	Thunderstorm	TRUE
Image42.Jpg	Thunderstorm	Thunderstorm	TRUE
Image43.Jpg	Thunderstorm	Thunderstorm	TRUE
Image44.Jpg	No Thunderstorm	No Thunderstorm	FALSE
Image45.Jpg	Thunderstorm	Thunderstorm	TRUE
Image46.Jpg	Thunderstorm	Thunderstorm	TRUE
Image47.Jpg	Thunderstorm	Thunderstorm	TRUE
Image48.Jpg	Thunderstorm	Thunderstorm	TRUE
Image49.Jpg	Thunderstorm	Thunderstorm	TRUE
Image50.Jpg	Thunderstorm	Thunderstorm	TRUE
Image51.Jpg	Thunderstorm	Thunderstorm	TRUE
Image52.Jpg	Thunderstorm	Thunderstorm	TRUE
Image53.Jpg	Thunderstorm	Thunderstorm	TRUE
Image54.Jpg	Thunderstorm	Thunderstorm	TRUE
Image55.Jpg	Thunderstorm	Thunderstorm	TRUE
Image56.Jpg	Thunderstorm	Thunderstorm	TRUE
Image57.Jpg	No Thunderstorm	No Thunderstorm	FALSE
Image58.Jpg	Thunderstorm	Thunderstorm	TRUE
Image59.Jpg	Thunderstorm	Thunderstorm	TRUE
Image60.Jpg	No Thunderstorm	No Thunderstorm	FALSE
Image61.Jpg	No Thunderstorm	No Thunderstorm	FALSE
Image62.Jpg	No Thunderstorm	No Thunderstorm	FALSE
Image63.Jpg	No Thunderstorm	No Thunderstorm	FALSE

Table 4 shows prediction of thunderstorm in which comparison of historical result and experimentally obtained result (proposed system result) and calculate prediction Prediction is calculated, if both are having thunderstorm then prediction is true if one of the result is no thunderstorm then result is false. There it is observed that the proposed method predicts the thunderstorms with an average accuracy of 89.2 % which is far better than the existing system.

5. Conclusions

In the proposed system, experiments have been conducted with k-medoids clustering technique and Haar wavelet transforms for the prediction of thunderstorms. It was demonstrated that the proposed system gives better result as compare to the previous methods such as STP model, MOM model, CG model, LM model, QKP model, DBD model in the detection of thunderstorms. In order to compute accuracy, the four basic performance measures is considered i.e. sensitivity, specificity, accuracy and precision are computed. The proposed method predicts the thunderstorms with an average accuracy of 89.2% which is far better than the existing system. In this we discussed about the prediction of thunderstorms and lightning detection system. The proposed system uses hybrid approach, this system adopted clustering and wavelet transform techniques for thunderstorms and lightning detection using image processing and detecting whether lightning produce from thunderstorm touches to the ground or not.

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