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. Following figure shows how thunderstorm developed under three stages i.e., Life cycle of thunderstorm.

![Figure 1: Thunderstorm Life Cycle](image)

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 and horizontal winds.
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.

![Lightning Image](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 produce 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 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.

![Flow Chart of Thunderstorm Detection](chart)

**Figure 3: Flow Chart of Thunderstorm Detection**

**Steps for Detection of thunderstorm**

1. Gather the satellite images from Indian meteorological department and load a image in order to predict whether the cloud images produce Thunderstorm or not.
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.
3. Apply k-mediod algorithm, and create three clusters i.e. cluster image1 cluster image2, cluster image3.
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.
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.
Steps for Detection of Lightning Position from Ground

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

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

Step 3 - Scan image pixel by pixel in order to find out ground position, and if pixel value is greater than 85 nm 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.

\[
\text{Sensitivity} = \frac{TP}{(TP+FN)} \quad (1)
\]
\[
\text{Specificity} = \frac{TN}{(FP+TN)} \quad (2)
\]
\[
\text{Accuracy} = \frac{(TP+TN)}{(TP+FP+FN+TN)} \quad (3)
\]
\[
\text{Precision} = \frac{TP}{(TP+FP)} \quad (4)
\]

Table 1: Performance Measure Factors

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

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 (%) |
|----------------|--------------|
| SLP model      | 39           |
| MOM model      | 39           |
| CG model       | 39           |
| LM model       | 39           |
| OKP model      | 38           |
| DBD model      | 39           |
| Proposed model | 89.2         |

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 | Square Root Balance Error | Spatial Norms Threshold (T) | Wavelength Factor (λ/λ0) | Wavelength (nm) | Type of Thunderstorm | Lightning Position |
|--------------|--------------------|---------------------------|-----------------------------|--------------------------|----------------|----------------------|--------------------|
| Image 1.jpg  | 2.95               | 10.66                     | 30.89                       | 452.29                   |                | Touch to ground      |                    |
| Image 2.jpg  | 2.3                | 8.88                      | 39.71                       | 399.61                   |                | Touch to ground      |                    |
| Image 3.jpg  | 2.03               | 10.52                     | 47.2                        | 418.81                   |                | Touch to ground      |                    |
| Image 4.jpg  | 2.73               | 10.13                     | 33.41                       | 499.96                   |                | Touch to ground      |                    |
| Image 5.jpg  | 2.94               | 10.5                       | 31.85                       | 454.94                   |                | Touch to ground      |                    |
| Image 6.jpg  | 2.03               | 9.75                      | 44.83                       | 384.51                   |                | Touch to ground      |                    |
| Image 7.jpg  | 2.3                | 9.75                      | 44.83                       | 394.51                   |                | Touch to ground      |                    |
| Image 8.jpg  | 1.99               | 10.25                     | 45.75                       | 414.82                   |                | Touch to ground      |                    |
| Image 9.jpg  | 2.76               | 10.38                     | 32.69                       | 410.09                   |                | Touch to ground      |                    |
| Image 10.jpg | 1.83               | 9.78                      | 49.83                       | 395.81                   |                | Touch to ground      |                    |
| Image 11.jpg | 2.52               | 9.54                      | 36.17                       | 402.13                   |                | Touch to ground      |                    |
| Image 12.jpg | 2.3                | 9.63                      | 39.68                       | 389.52                   |                | Touch to ground      |                    |
| Image 13.jpg | 2.02               | 9.67                      | 45.67                       | 391.34                   |                | Touch to ground      |                    |
| Image 14.jpg | 2.42               | 9.63                      | 37.08                       | 392.51                   |                | Touch to ground      |                    |
| Image 15.jpg | 2.59               | 9.81                      | 35.26                       | 397.11                   |                | Touch to ground      |                    |
| Image 16.jpg | 3.76               | 13.33                     | 24.25                       | 533.31                   |                | Touch to ground      |                    |
| Image 17.jpg | 1.38               | 8                          | 60.20                       | 323.74                   |                | Touch to ground      |                    |
| Image 18.jpg | 2.59               | 9.5                       | 35.24                       | 384.47                   |                | Touch to ground      |                    |
| Image 19.jpg | 2.65               | 11.32                     | 34.38                       | 450.09                   |                | Touch to ground      |                    |
| Image 20.jpg | 1.94               | 10.37                     | 47.08                       | 419.67                   |                | Touch to ground      |                    |
| Image 21.jpg | 3.98               | 10                        | 22.88                       | 407.01                   |                | Touch to ground      |                    |
| Image 22.jpg | 3.19               | 9.25                      | 28.55                       | 384.63                   |                | Touch to ground      |                    |
| Image 23.jpg | 2.21               | 9.5                       | 41.24                       | 384.47                   |                | Touch to ground      |                    |
| Image 24.jpg | 2.04               | 10.49                     | 30.97                       | 432.65                   |                | Touch to ground      |                    |
| Image 25.jpg | 2.34               | 9.13                      | 38.93                       | 389.45                   |                | Touch to ground      |                    |
| Image 26.jpg | 3.01               | 10.87                     | 30.27                       | 439.91                   |                | Touch to ground      |                    |
| Image 27.jpg | 2.53               | 10.5                       | 30.05                       | 424.94                   |                | Touch to ground      |                    |
| Image 28.jpg | 2.1                | 9.06                      | 40.48                       | 386.34                   |                | Touch to ground      |                    |
| Image 29.jpg | 1.65               | 9.30                      | 55.17                       | 381.24                   |                | Touch to ground      |                    |
| Image 30.jpg | 1.86               | 8.94                      | 40.05                       | 304.71                   |                | Touch to ground      |                    |
In Table 3, it calculates wavelength of each input image by standard formula and result of thunderstorm is dependent upon range of wavelength. If wavelength lies between the range 350-450 then result is thunderstorm otherwise there is no thunderstorm. Also, it finds out whether 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       |
| Image26.Jpg  | Thunderstorm                   | Thunderstorm                    | TRUE       |
| Image27.Jpg  | Thunderstorm                   | Thunderstorm                    | TRUE       |
| Image28.Jpg  | Thunderstorm                   | No Thunderstorm                  | FALSE      |
| 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  | Thunderstorm                   | Thunderstorm                    | TRUE       |
| 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 transform for the prediction of thunderstorms. It was demonstrated that the proposed system gives better result as compared 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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