

PREDICTION OF RAINFALL USING IMAGE PROCESSING

K.Kaviarasu¹, P.Sujith² and Mr. G. Ayaappan³

¹Kavikrish1990@gmail.com, ²palanisamy.suji@yahoo.com, ³ayappan01@gmail.com,

¹UG Scholar, Department of ECE, Sri Ramakrishna Institute of Technology, Coimbatore, ²UG Scholar, Department of ECE, Sri Ramakrishna Institute of Technology, Coimbatore. ³Lecturer, Department of ECE, Sri Ramakrishna Institute of Technology Coimbatore

Abstract—Water is elixir of life. So rainfall becomes the inevitable part of every nation which decides the prosperity and economic scenario of a country. In this fast moving world, estimation of rainfall has become a necessity especially when the global heat levels are soaring. The proposed approach here is to use the digital cloud images to predict rainfall. Considering the cost factors and security issues, it is better to predict rainfall from digital cloud images rather than satellite images. The status of sky is found using wavelet. The status of cloud is found using the Cloud Mask Algorithm. The type of cloud can be evolved using the K-Means Clustering technique. As per previous research works done by the researchers, it is stated the Nimbostratus and Cumulonimbus are the rainfall clouds and other clouds like cumulus will produce rain at some rare chances. The type of rainfall cloud is predicted by analyzing the color and density of the cloud images. The cloud images are stored as JPEG file in the file system. Analysis was done over several images. The result predicts the type of cloud with its information like classification, appearance and altitude and will provide the status of the rainfall. The proposed approach can be utilized by common people to just take the photograph of cloud and can come to conclusion about the status of rainfall and to get the desired detail.

Index Terms—Rainfall, Cloud Mask Algorithm, K-Means Clustering, Cloud Images.

I. INTRODUCTION

IN this fast moving Digital Universe, the digital images play a major role in many applications. Our application here is the digital cloud images. One of the most interesting features of Earth, as seen from ground, is the ever-changing distribution of clouds. They are as natural as anything we encounter in our daily lives. As they float above us, we hardly give their presence a second thought. And yet, clouds have an enormous influence on Earth's energy balance, climate, and weather. Our work is to recognize the type of cloud and to estimate rainfall. Rainfall plays an important role in the water cycle by providing water to the surface of the Earth. Rain sustains agriculture and provides water to streams, which is important for aquatic life and navigation. Excess rainfall, however, can be quite hazardous by causing flooding, which is a significant threat to both life and property. Because of the important role of rainfall in many aspects of life, it is not only worthwhile to observe where rainfall has occurred and how much has fallen but also to forecast rainfall.

Even small changes in the abundance or location of clouds could change the climate more than the anticipated changes caused by greenhouse gases, human-produced aerosols, or other factors associated with global change. In

order for scientists to create increasingly realistic computer simulations of Earth's current and future climate, they'll have to include more accurate representations of the behavior of clouds. The digital cloud images are collected and stored in file system. The sky status is found first and then the cloud status is found. With the cloud status we recognize the cloud type. The information about the type of cloud is given and the rainfall is estimated from the types and the color. The performance is calculated with various techniques.

Depending on their characteristics and height in the atmosphere, clouds can influence the energy balance in different ways. Clouds can block a significant portion of the Sun's incoming radiation from reaching the Earth's surface, as anyone who has had a day at the beach interrupted by heavy clouds can tell you. Due to the shadowing effect of clouds, the Earth's surface tends to be cooler than it would otherwise be. The cloud's height in the atmosphere influences how effective it is at trapping outgoing heat. A cloud that is higher in the atmosphere will emit less heat to space than an identical cloud at a lower altitude. In a global sense, the net effect of clouds depends on how much of the Earth's surface they cover, their thickness and altitude, the size of the condensed particles, and the amount of water and ice they contain. Research on clouds and the climate indicates that overall, clouds' cooling effects are more powerful than their warming effects. But how the balance between clouds' cooling and warming influences might change in the future is still very uncertain.

The purpose of this project is twofold: to recognize the type of clouds with certain methods and to estimate rainfall from certain observations. Observing rainfall is useful for evaluating moisture available for agriculture and determining how much will run off the surface into streams and rivers. For example, in moderate amounts, rainfall is necessary to grow crops, fill reservoirs, and maintain flow in rivers for navigation and shipping. However, in excess, rainfall runs off the surface in large amounts and can cause streams and rivers to overflow their banks and flood. Additionally, runoff can cause transport and loss of sediment and chemicals. Observations of rainfall are a necessary input in monitoring and forecasting soil moisture, drought, and river stages, as well as monitoring and modeling water quality. Forecasting rainfall is yet another step removed from observing soil moisture, drought, and flow in rivers and streams and provides an opportunity to produce forecasts with longer lead time. Accurately forecasting heavy rainfall can allow for warning of floods before rainfall occurs instead of

monitoring rainfall and warning based on observations. Additionally, such information is useful in agriculture to improve irrigation practices and the effectiveness of applying fertilizer, pesticides, and herbicides to crops.

Effective forecasting of rainfall is very useful in agriculture and preparedness for flooding. One purpose of this project is to evaluate a method to improve observations of rainfall. Traditionally, rainfall has been observed using only rain gages at the surface. Gages provide ground truth data, albeit with several known sources of error. Rain gages are also limited because they are observations at a single point and are often spaced sparsely and report data at infrequent intervals. Weather radars measure reflectivity, which can be related to rainfall rate. Rainfall vary greatly in space and time, and using a single conversion from reflectivity to rain rate over an entire radar scanning area for a whole event may not produce reasonable estimates of rainfall. The goal of this work was to develop two seemingly unrelated projects that could be related through future work. The steps used in this process are Data collection, Sky Status, Cloud Status, Cloud Type, Cloud Information, Rainfall Status and Performance measures.

The main objective of the thesis is to recognize the type of cloud and estimate rainfall using certain features from the digital cloud images. Use of wavelet to separate the points needed for the cluster and using k-means clustering to combine those points will provide a better performance than previous techniques used. The Scope of the work is predicting rainfall using the digital images rather than using the satellite images. The Satellite images costs lot so everyone can't get them easily. When some new techniques are used we could get more accurate prediction. The report is organized as follows. Chapter 1 explains the Overview of the Project, description and objectives. Chapter 2 briefly describes the related previous techniques. Chapter 3 contains the basic concepts. Chapter 4 explains the methodologies used in detail. Chapter 5 explains the Design and Implementation Chapter 6 shows the results and also the analysis is provided. Chapter 7 discusses conclusions and future work.

II. LITERATURE SURVEY

1) *Survey on Clouds*

D.K. Richards and G.D. Sullivan [1] describes the methods for using color and texture to discriminate cloud and sky in images captured using a ground based color camera. Neither method alone has proved sufficient to distinguish between different types of cloud, and between cloud and sky in general. Classification can be improved by combining the features using a Bayesian scheme. Malay K. Kundu and Priyank Bagrecha[2] proposed the feature Extraction algorithm is a very important component of any retrieval scheme. The M-band Wavelet Transform based feature extraction algorithm is explained in this paper. Kuo-Lin Hsu, X. Gao, and Soroosh Sorooshian[3] proposed some experiments. It shows that cold-topped cloud pixels with the same values of infrared brightness temperature may belong to different cloud type, thereby, indicating different rain rates at the underlying

ground surfaces. It is suggested that the relationship between the satellite cloud-top brightness temperature and surface rainfall rate are non-unique for most pixel-based rainfall estimation algorithms. A scheme is developed, which first classifying cloud types based on the texture features of regional cloud images, then regressing the relationships of cloud brightness temperature and surface rain rate respective to different cloud types using the radar rainfall data. With the separation of cloud-texture types, estimated rainfall rates can be improved. A cloud-texture classification approach is introduced to process cloud images and estimates the surface rain rate underlying a cloud pixel referencing the cloud-texture type of the pixel. Instead of determining the surface rain rate based on cloud brightness temperature at a local pixel, as many rainfall estimation algorithms do (see Hsu et al., 1997; Bellerby et al., 2000), this approach extracts the features of cloud texture in a $4^\circ \times 4^\circ$ window to classify the cloud imagery into a number of cloud (texture) groups. The relationship between rainfall rate and cloud pixel brightness temperatures at each assigned cloud-texture group is identified separately using ground-based radar rainfall data. Liu Jian and Xu Jianmin[4] describes an updated operational cloud detection method of FY-2C. Compared with FY2B three channels, FY2C adds one shortwave infrared channel and split infrared channel. Research results testified that shortwave infrared and split infrared channels can be help to detect low cloud and cirrus cloud, especially at night. Anuj Srivastava and Ian H. Jermyn[5], describes the problem of identifying shape classes in point clouds. These clouds contain sampled contours and are corrupted by clutter and observation noise. Taking an analysis-by-synthesis approach, we simulate high-probability configurations of sampled contours using models learnt from the training data to evaluate the given test data. Yanling Hao, Wei ShangGuan, Yi Zhu, and YanHong Tang[6] describes that cloud image is a kind of useful image which includes abundant information, for acquired this information, the image processing and character extraction method adapt to cloud image has to be used. Content- based cloud image processing and information retrieval (CBIPIR) is a very important problem in image processing and analysis field. The basic character, like color, texture, edge and shape was extracted from the cloud image, and then the cloud image database was provided to store the basic character information. Since traditional image retrieval method has some limitation, for realized image retrieval accurately and quickly, the CBIR method is adaptive. Aleksey Golovinskiy, Vladimir G. Kim and Thomas Funkhouser[7] states that the design of a system for recognizing objects in 3D point clouds of urban environments. The system is decomposed into four steps: locating, segmenting, characterizing, and classifying clusters of 3D points. Specifically, we first cluster nearby points to form a set of potential object locations (with hierarchical clustering). Then, we segment points near those locations into foreground and background sets (with a graph-cut algorithm). Next, we build a feature vector for each point cluster (based on both its shape and its context). Finally, we label the feature vectors using a classifier trained on a set of manually labeled

objects.

Peter S. Masika [8] states that this study attempts to utilize available MSG data for developing simple cloud mask and height algorithms and thereafter compare and determine the relationship between cloud height and observed rainfall on a ground station. A multispectral threshold technique has been used: the test sequence depends on solar illumination conditions and geographical location whereas most thresholds used here were empirically determined and applied to each individual pixel to determine whether that pixel is cloud-free or cloud-contaminated. The study starts from the premise of an acceptable trade-off between calculation speed and accuracy in the output data. Wei Shangguan; Yanling Hao; Zhizhong Lu; Peng Wu[10] states that the recent development of cloud image processing technology has become very quick; the research aspects concentrate on judge the cloud type and classify the cloud mainly. These image processing methods relate to the subject category like image processing and pattern recognition etc; it has become one of the fields of most quickly development in the research of image processing technology. In cloud image, texture is an very important feature, since cloud image has clear texture structure, the computer texture analysis provide perfect future for study and analyze all kinds of cloud image. Variation method is a new image segmentation method development in recent years, which is adapt to modeling and extract deformable contour of random shape. In cloud image, recognize the target object has great application meaning.

2) Final Submission

Ville Haulamati et al. in [12] poses problem related to time series data clustering in Euclidean space using Random Swap (RS) and Agglomerative Hierarchical clustering followed by k-mean fine-tuning algorithm to compute locally optimal prototype. It provides best clustering accuracy. And also provide more improvement to k-medoids. The drawback of this algorithm is, it outperforms the quality. Beringer et al. in [15] put forth a clustering algorithm for parallel data streams. In modern years, the management and processing of so-called data streams has become a subject of dynamic research in numerous fields of computer science such as, e.g., distributed systems, database systems, and data mining. In order to maintain an up-to-date clustering structure, it is indispensable to investigate the incoming data in an online manner, tolerating not more than a constant time delay. For this purpose, they developed a resourceful online version of the classical K-means clustering algorithm. David M. Mount et al[19] states that in k-means clustering, we are given a set of n data points in d -dimensional space R^d and an integer k and the problem is to determine a set of k points in R^d , called centers, so as to minimize the mean squared distance from each data point to its nearest center. A popular heuristic for k-means clustering is Lloyd's algorithm. In this paper, a simple and efficient implementation of Lloyd's k-means clustering algorithm, which we call the filtering algorithm. This algorithm is easy to implement, requiring a kd-tree as the only major data structure. The practical efficiency of the filtering

algorithm is in two ways. First, a data-sensitive analysis of the algorithm's running time, which shows that the algorithm runs faster as the separation between clusters increases. Second, a number of empirical studies both on synthetically generated data and on real data sets from applications in color quantization, data compression, and image segmentation.

III. WAVELET AND CLUSTERING

A. Data Flow

The input image is digital cloud. When the input is given to the system, we apply wavelet in order to split the status of sky from the input image. In previous papers law's texture description was taken into account to differentiate between the sky and cloud. Now we evolve with the feature extracted image to represent the status of sky. After that the feature extracted images of sky status is processed with cloud mask algorithm and we evolve with the feature extracted image to represent the status of cloud. Now k-means clustering is applied to the image to find the type of cloud from its shape and density. After finding the cloud type the Information about cloud and the status of rain can be found. Now the data flow diagram to explain the process is shown as follows:

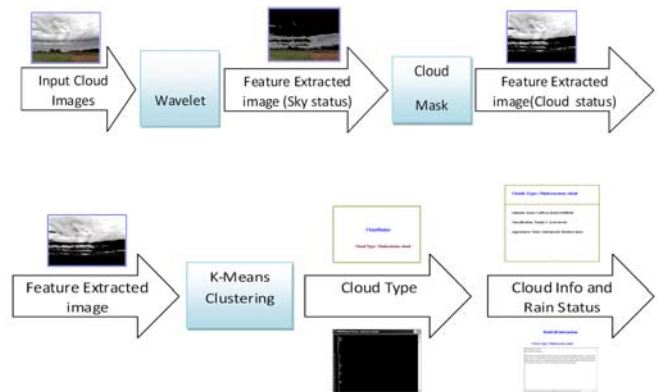


Figure 3.1 Data flow Diagram

B. Data Collection

Here in the data collection phase we use the simple digital cloud images. We store the image in the file system. The dimension chosen for the images is 400x300. The images were taken from internet and also with 10 megapixel camera. With the digital camera the clouds above Tirunelveli area and Nagercoil area were taken and they are added in the file system in order to find the type. Some images were taken during the rain so as to identify the rain clouds.

C. Sky Status

The second step is sky status. In the previous year's some of the papers stated that the sky cover is found out using the laws texture description. But we use wavelet for finding the sky status. It separates the point needed for the cluster. In wavelet separation points are used in the identification of the clouds or

sky. For eg: brain tumour, blood cells detection, molecule identification and bone crack detection, if wavelet is used it produces a better result. Our application is cloud so the cloud is the separation point. The wavelet threshold for the clouds is > 50 and < 200 . The formula to find the sky status is

$$\text{Seg}(n) = \text{Segment}(\text{image}[I,j])$$

$$\text{Sky Status} = \Sigma \text{ Highest Segmentation Value} + \text{Smallest Segmentation Value}$$

D. Cloud Status

The third step we use is the cloud status. The cloud varies according to the thickness. So the high density is detected. The middle level density will be considered as the sky. In mild time or moody time sky is considered as cloud. To find the mask the histogram equalization is used the value with the highest weight will be considered as sky and the others will be considered as cloud. Also the cloud mask algorithm is used here. The formula to find the cloud status is given as follows.

$$\text{Cloud Status} = \text{Total No. of Segment} - \text{Sky Status}$$

The cloud mask algorithm consists of certain tests. Single pixel threshold tests are used first. Dynamic histogram analysis is used to get threshold. Thick High Clouds (Group 1): Thick high clouds are detected with threshold tests that rely on brightness temperature in infrared and water vapor bands. Thin Clouds (Group 2): Thin clouds tests rely on brightness temperature difference tests. Low Clouds (Group 3): Low clouds are best detected using solar reflectance test and brightness temperature difference. Spatial uniformity test is also used over land surface. High Thin Clouds (Group 4): This test is similar to Group1, but it are spectrally turned to detect the presence of thin cirrus. Brightness temperature difference test and spatial uniformity test are applied. Temporal uniformity test is also used.

E. Cloud Type

The major task here is to find the type of cloud as per the cloud status each and every cloud will be having its own shape and density and the values are matched accordingly. The type of cloud is identified by using clustering. We use K-means clustering to combine the pixels in order to differentiate the clouds. The thickness of the clouds will be in the base part. The color, Shape and Texture are the concepts used in order to find the type of cloud. The formula to find the cloud type is shown as follows:

$$H(n) = \sum_{n=0}^{255} C[i, j]$$

$$\text{Cloud id} = \text{Highest Density of Cloud Status}$$

K-Means algorithm is an unsupervised clustering algorithm that classifies the input data points into multiple classes based

on their inherent distance from each other. The algorithm assumes that the data features form a vector space and tries to find natural clustering in them. The points are clustered around centroids $\mu_i, \forall i=1 \dots k$ which are obtained by minimizing the objective

$$V = \sum_{i=1}^k \sum_{x_j \in S_i} (x_j - \mu_i)^2$$

where there are k clusters $S_i, i = 1, 2, \dots, k$ and μ_i is the centroid or mean point of all the points $x_j \in S_i$. As a part of this project, an iterative version of the algorithm was implemented. The algorithm takes a 2 dimensional image as input. Various steps in the algorithm are as follows:

- Compute the intensity distribution (also called the histogram) of the intensities.
- Initialize the centroids with k random intensities.
- Repeat the following steps until the cluster a label of the image does not change anymore.
- Cluster the points based on distance of their intensities from the centroid intensities.
- Compute the

$$C^{(i)} := \arg \min_j \|x^{(i)} - \mu_j\|^2$$

new centroid for each of the clusters.

$$\mu_i = \frac{\sum_{i=1}^m 1\{c_{(i)} = j\} x^{(i)}}{\sum_{i=1}^m 1\{c_{(i)} = j\}}$$

where k is a parameter of the algorithm (the number of clusters to be found), i iterates over the all the intensities, j iterates over all the centroids and μ_i are the centroid intensities.

F. Cloud Information

The fifth step is cloud information where the theoretical proof of the clouds that is the height, Altitude, Classification and appearance are given.

G. Rainfall Estimation

The major step is the estimation of rainfall here the rainfall is estimated as per the type we recognize. Cumulonimbus and nimbostratus are the rainfall clouds. So we take the color and shape and also the width and find the rainfall status the temperature is also taken into account. The analysis part consists of Sky Status, Cloud Status, Sky Density and Cloud Density. The cloud density and sky density is calculated using the formula

$$\text{CloudDensity} = \sum_i^n \sum_j^m C[i, j]$$

$$SkyDensity = \sum_i^n \sum_j^m S[i, j]$$

The formula to find the sky status is shown as follows;

$$SS[n] = \sum_{n=0}^{255} S[i, j]$$

The formula to find the cloud status is shown as follows

$$TS[n] = \sum_{n=0}^{255} T[i, j]$$

The formula for wavelet, K-Means clustering and the performance measure are shown as follows:

$$Wavelet = 1 - \frac{WaveletFeature}{TotalNo.ofPixels}$$

$$Clustering = 1 - (Kmeans Cluster Value)$$

$$Performance = \frac{TotalNo.ofCloudvalues}{TotalNo.ofpixels} \times 100$$

$$PSNR = 10 \log_{10} \left\{ 255^2 \left(\frac{1}{UV} \times \sum_{i=0}^U \sum_{j=0}^V \|I(i, j) - O(i, j)\|^2 \right)^{-1} \right\}$$

Here, PSNR is the Peak Signal Noise Ratio, $I(i, j)$ is the input and $O(i, j)$ is the output. U, V represents the rows and columns respectively. In the measurement part we compare the two parts. The performance with Laws and wavelet and next is with using k means clustering and without using k means clustering.

IV. DESIGN AND IMPLEMENTATION

A. Implementation Methods

The implementation method consists of six phases. In the first phase data is collected. In the second phase the status of sky is found. In the third phase the status of cloud is found. In the fourth phase the type of cloud is evolved. In the fifth phase the information about the cloud and the status of rain are displayed. In the sixth phase the analysis and measurement takes place.

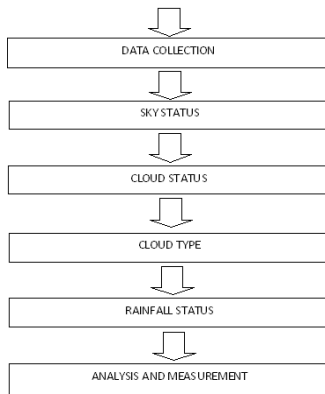


Figure 4.1 Implementation Methods

B. Implementation Environment

All the methods and algorithms described in this thesis were implemented using JAVA on windows XP operating system. The digital cloud images used in the experiments were obtained from internet and 10 Mega Pixel Digital Camera. The images are stored in the File System. The file format used to store the images is *.jpeg. Each image in the file system is of size 400 x 250 pixels.

C. Data Collection

The data collected is the digital cloud images. We store the image in the file system. The dimension chosen for the images is 400 x 250. The images were taken from internet and also with 10 megapixel camera. The format used is *.jpeg. With the digital camera the clouds above Tirunelveli area and Nagercoil area were taken and they are added in the file system in order to find the type and predict rainfall. Some images were taken during the rainy so as to identify the rain clouds. Now we have included twelve images for the initial purpose. Any number of images can be added in the file system. Some sample data can be shown as follows.



Figure 4.2 a) Sample Input 1 b) Sample Input 2

D. Sky Status

On considering the sky status, In the previous year's some of the papers stated that the sky cover is found out using the laws texture description. But we use wavelet for finding the sky status. It separates the point needed for the cluster. In wavelet separation points are used in the identification of the clouds or sky.



Figure 4.3 a) Sky status of Input 1 b) Sky status of Input 2

Our application is cloud so the cloud is the separation point. The wavelet threshold for the clouds is > 50 and < 200 . Here the sky is separated from the given input image. The sample output evolved for cloud status is shown as such:

E. Cloud Status

On considering the cloud status, the cloud varies according to the thickness. So the high density is detected. The middle level density will be considered as the sky. In

mild time or moody time sky is considered as cloud. To find the mask the histogram equalization is used the value with the highest weight will be considered as sky and the others will be considered as cloud. The cloud mask algorithm is used here in order to separate the cloud. Here the Cloud is separated from the given input input image. The sample output evolved for cloud status is shown as such:



Figure 4.4 a) Cloud status of Input 1 b) Cloud status of Input 2

F. Cloud Type

The Cloud type is found by using clustering concept. Especially K-Means clustering is used to find the type of cloud. The sample output evolved for cloud status is shown as such:



Figure 4.5 a) Cloud Type of Input 1 b) Cloud Type of Input 2

G. Cloud Information

The information about cloud consists of Altitude, Classification and Appearance.

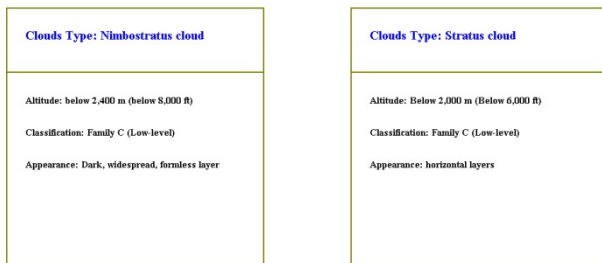


Figure 4.6 a) Cloud Info of Input 1 b) Cloud Info of Input 2

H. Rainfall Status

The rainfall information is given according to the type of cloud and their precipitation. Each and every type of cloud is not a rainfall cloud. Among the type of clouds Nimbostratus and Cumulonimbus clouds are rainfall clouds and some other clouds like Cumulus produce rain at some rare cases.

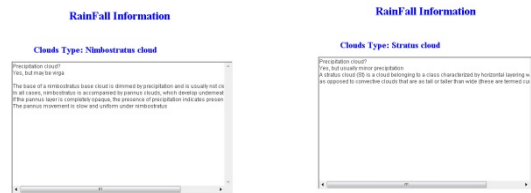


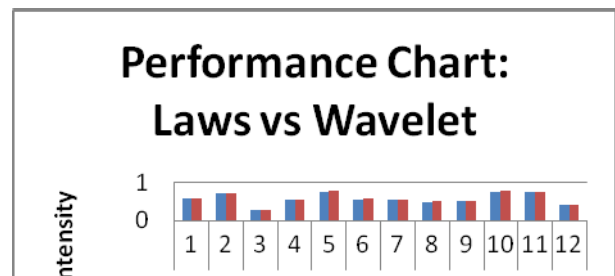
Figure 4.7 a) Rainstatus of Input 1 b) Rainstatus Info of Input 2

V. ANALYSIS

A. Comparing Performance with Wavelet and Laws Textures

TABLE 1 PERFORMANCE MEASURE OF LAWS AND WAVELET

S. No	Name of Image	Performance Measure	
		Laws	Wavelet
1	Img1	0.575	0.579
2	Img2	0.697	0.703
3	Img3	0.252	0.253
4	Img4	0.533	0.541
5	Img5	0.748	0.753
6	Img6	0.549	0.554
7	Img7	0.533	0.541
8	Img8	0.479	0.485
9	Img9	0.495	0.5
10	Img10	0.747	0.752
11	Img11	0.725	0.748
12	Img12	0.409	0.412



B. Comparing Performance with K Means and without K Means

TABLE 2
PERFORMANCE MEASURE WITH K MENAS AND WITHOUT K MEANS

S. No	Name of Image	Performance Measure	
		Without K-means	With K-means
1	Img1	1.963	2.463
2	Img2	2.758	3.295
3	Img3	1.115	1.115
4	Img4	1.786	1.86
5	Img5	3.316	3.317
6	Img6	1.849	1.849
7	Img7	1.786	1.86
8	Img8	1.6	2.161
9	Img9	1.653	1.698
10	Img10	3.294	3.446
11	Img11	3.038	3.764
12	Img12	1.412	1.718

TABLE 3
OVERALL PERFORMANCE MEASURE

S. No	Name of Image	Performance Measure	
		Existing	Proposed
1	Img1	40.88%	42.18%
2	Img2	30.21%	53.12%
3	Img3	8.60%	72.59%
4	Img4	36.68%	45.46%
5	Img5	25.12%	58.20%
6	Img6	38.26%	45.06
7	Img7	36.68%	45.46
8	Img8	31.26%	51.96%
9	Img9	32.92%	48.83%
10	Img10	24.37%	58.03%
11	Img11	27.31%	55.91%
12	Img12	40.88%	42.18%

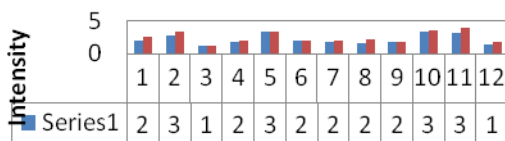
VI. CONCLUSION

The type of cloud is recognized and the rainfall is estimated by using the novel methods like Wavelet and K-means Clustering. The performance is better compared to the previous techniques like Laws and other clustering techniques. Considering the cost factors and security issues, the digital cloud images were used to predict rainfall rather than satellite images. The status of sky is found using wavelet. The status of cloud is found using the Cloud Mask Algorithm and histogram equalization. The type of cloud can be evolved using the K-Means Clustering technique. The type of rainfall cloud is predicted by analyzing the color and density of the cloud images. The cloud images are stored as JPEG file in the file system. Analysis was done over several images. The result predicts the type of cloud with its information like classification, appearance and altitude and will provide the status of the rainfall. In future the accuracy can be increased by using other transforms like curvelet, contourlet etc. The parameters like dew point, temperature, wind direction, humidity and precipitation can be included to increase the performance. Certain specific rainfall estimation algorithms can be used for getting the result in a dynamic way.

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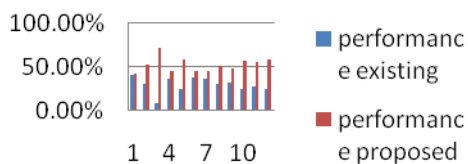
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Performance Chart: Clustering without...



C. Comparing Overall Performance

Performance Chart



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