ABSTRACT

Digital Image Analysis and Pattern Recognition is one of the promising areas of research in remote sensing and automated weather forecast and assessment. Manual screening and prediction of weather situations is time consuming and a qualitative process. Computer aided analysis and quantitative predictions will assist in the existing qualitative methods. The aim of this work is to give a quantitative feature description of Doppler Weather Radar (DWR) images for classification of different weather conditions using spatial domain local region based texture analysis. MATLAB® R2012a version Image Processing Toolbox is utilised in this analysis. DWR is widely used in operational weather forecasting from which a pictorial depiction of the weather around the station is available in the form of an image at every 5-10 minutes interval. These images aid real time monitoring of meso and synoptic scale weather systems. Hence they are used by weather forecasters in nowcasting of severe weather producing thunderstorms right from genesis to dissipation. Frequency Domain Analysis of such DWR images is useful in extracting vital information about textural features. Image texture parameters usually reflect coarseness, smoothness, contrast, and randomness of pixel distribution. Statistical measurements such as higher order moments and correlation represent similarity of pixels. Statistical features of localized spatial regions give interesting data to quantify the region numerically.

The onset of precipitation region in the images was localized based on colour features. Spatial domain and frequency domain analysis were performed in the localized region. Textural feature calculations including first and second order moments, smoothness, skewness (third order moments), entropy, contrast measure, correlation, energy and homogeneity calculations were done. Frequency domain analysis such as Fourier Transform gives meaningful information on low-frequency and high-frequency pixel interactions in the form of DC and AC coefficients. Also Gabor filters with different preferred orientations and spatial frequencies are used to calculate Gabor energy quantity. Translation invariant features such as complex moments of local power spectrum gives meaningful representation of texture. The extracted features were considered as feature space derived from two measurement space such as spatial and frequency domains. Finally the classification task can be performed using supervised mode of Artificial Neural Networks (ANN).

METHODS

• Spatial granularity and repetitiveness are two main characteristic aspects of texture.
• Spatial Domain Texture Features are derived from statistical parameters of first or second order.
• Texture measures derived by the gray level co-occurrence matrix method are based on 2nd order statistics.
• Many Mathematical Transforms such as Fourier, DCT, Gabor, Wavelets, etc., give frequency distribution of pixels and offer very good energy compaction for various analyses.
• One of the unique properties of Gabor filters is their ability to discriminate textural features in a way similar to that of human vision.
• Gabor Transform is a special case of Short Term Fourier Transform.
• A 2-D Gabor filter is an oriented sinusoidal grating modulated by a 2-D Gaussian function, with a modulating frequency ‘W’, given by
  \[ G(x,y) = \hat{g}(x,y) \exp (2\pi jW(x \cos \theta + y \sin \theta)) \]

  where \( \hat{g}(x,y) = \frac{1}{\sqrt{2\pi \sigma_m^2}} \exp \left( \frac{-(x^2 + y^2)}{2\sigma_m^2} \right) \)

The filter results of a symmetric and an asymmetric filter can be combined in a single quantity which is called Gabor - energy. This is defined as

\[ E_m(x,y) = \frac{1}{N^2} \sum_{i,j} [G_{x,i,m}(x,y) + G_{y,i,m}(x,y)] \]

where \( r_{x,m}^2 \) and \( r_{y,m}^2 \) are the responses of the linear symmetric and asymmetric Gabor filters respectively.

Complex Moment Feature:
• The real and imaginary parts of the complex moments of the local power spectrum are proposed as features.
• These features are translation invariant inside homogenous texture regions and give information about the presence or absence of dominant orientations in the texture.

RESULTS

<table>
<thead>
<tr>
<th>Features</th>
<th>Blue Region with Clear Sky</th>
<th>Yellow Region with Moderate Rainfall</th>
<th>Red Region with Heavy Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoothness</td>
<td>0.0008</td>
<td>0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>Entropy</td>
<td>2.926</td>
<td>4.335</td>
<td>4.985</td>
</tr>
<tr>
<td>Contrast</td>
<td>0.666</td>
<td>2.056</td>
<td>2.879</td>
</tr>
<tr>
<td>Homogeneity</td>
<td>0.741</td>
<td>0.573</td>
<td>0.476</td>
</tr>
<tr>
<td>Gabor-energy feature</td>
<td>224.835</td>
<td>93.159</td>
<td>152.080</td>
</tr>
<tr>
<td>Complex Moments (order-2)</td>
<td>145.181</td>
<td>24.577</td>
<td>47.862</td>
</tr>
<tr>
<td>Complex Moments (order-3)</td>
<td>77.902</td>
<td>13.187</td>
<td>25.682</td>
</tr>
<tr>
<td>Complex Moments (order-4)</td>
<td>143.648</td>
<td>24.317</td>
<td>47.356</td>
</tr>
<tr>
<td>Normalized Mean Energy</td>
<td>0.222</td>
<td>0.038</td>
<td>0.109</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The pilot study shows promising results in quantitative validation of severe weather predictions with ground truth values. Preliminary results of the entropy analysis indicate the extent of instability in the atmosphere (blue region / clear sky) over the neighborhood of a thunderstorm cell. Highest instability in the core region of the heavy rainfall activity indicating intense downdrafts and increased pressure of wind flow from the thundercloud is brought out in synergy with the thermodynamic process in a thundercloud. In the moderate rainfall case, a comparatively higher instability than the clear sky areas where lower entropy and hence a stable environment is evident.

The higher moments in clear sky condition indicate prevailing turbulent activity favoring formation of thunderstorms. In moderate rainfall condition the updrafts and downdrafts in a convective cloud are minimum indicated by lower values of moments compared to heavy rainfall activity when the moment values are higher. Similarly higher contrast and lesser homogeneity values indicate heavier rainfall activity. The Gabor-energy feature indicates the extent of spatial distribution of rainfall like highly localized, heavy rainfall (up to 2-3 km) and spatially widespread (up to 5 km) moderate rainfall activity.

- This analysis is an attempt to quantify the texture of DWR images based on spatial and frequency domain features.
- Pilot study results were cross-validated with actual realised rainfall event.
- This analysis if done and thresholds are derived for each type of weather occurrence, would be an added interpretation technique for radar meteorologists in addition to those already in vogue.

REFERENCES


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