Image Compression Using Gabor Filter

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Abstract: The data is the basic component of information. This data is available in various formats that are in textual, graphical. An image is a type of graphical data. Various Programs using complex graphics are showing up in area of computing applications such as games, education, desktop publishing, graphical design and many more. Very high compression ratio severely affects the quality of the image. This paper tries to improve the compression ratio with minimizing the degradation in quality of JPEG images due to compression. Here the compression is based on filtering concept in which, Gabor filter removes the redundant information from an image. This filter tries to maintain the image quality with the reduction in storage requirements. Here the Gabor filter is implemented in MATLAB and applied to images of various resolutions, sizes and types such as space images and satellite images. The image which is filtered by this Gabor filter occupies less storage space and has better quality. The resultant image has increased compression ratio than that of the original image. Hence this indicates that the image compression is achieved in proper way.

Keywords: Image compression, Gabor filter, JPEG compression.

I. INTRODUCTION

In computer science and information theory, data compression, source coding or bit-rate reduction involves encoding information using fewer bits than the original representation. Compression can be either is lossy or lossless. Lossless compression reduces bits by identifying and eliminating statistical redundancy. No information is lost in lossless compression. Lossy compression reduces bits by identifying marginally important information and removing it. The process of reducing the size of a data file is popularly referred to as data compression; although its formal name is source coding (coding done at the source of the data, before it is stored or transmitted). Compression is useful because it helps reduce resources usage, such as data storage space or transmission capacity. The compressed data must be decompressed to be used; this extra processing imposes computational or other costs through decompression. Lossless compression is preferred for archival purposes and often for medical imaging, technical drawings, clip art, or comics. This is because lossy compression methods, especially when used at low bit rates, introduce compression artifacts. Lossy methods are especially suitable for natural images such as photographs in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in bit rate. The lossy compression that produces imperceptible differences may be called visually lossless.

1.1 Role of Filters:

In general the word “Filtering” indicates removing unwanted things from given quantity. For example the water filter removes the bacteria from the water to give pure water & air filter filters the dust particles from air to give pure air. The same concept is applied in Digital Image Processing field to remove the unwanted data.

In image enhancement filter plays a major role. It creates a new pixel with co-ordinates equal to co-ordinates of center of the neighborhood, and whose value is the result of filtering operation. A filtered image is generated as the center of the filter visits each pixel in the input image. The filtered pixel value typically is assigned to a corresponding location in a new image created to hold the results of filtering. It is seldom the case that filtered pixel replace the values of the corresponding location in original image, as which would change the content of image while filtering still is being performed.

By using the concept of convolution or correlation it is apply the filter mask to the image. Hence the new image has filtered matrix coefficients.

1.1.1 Image Smoothing:

Smoothing filters are used for blurring and for noise reduction. Blurring is used in preprocessing steps, such as removal of small details from an image prior to (large) object extraction, and bridging of small gaps in lines or curves. Noise Reduction can be accomplished by blurring with a linear filter and also by non- nonlinear filtering.

These filters can be used for image smoothing. In this the information in image edges is lost. The edges represent the High Frequency contents but this filter tries to remove those High Frequency contents. Hence sometimes this filter is called as Low pass filters. Figure 2.1 shows the results of application of smoothing filters on an image consisting of characters. The characters & lines have completely lost their edges.

1.1.2 Sharpening Filters:

The principal objective of sharpening is to highlight fine detail in an image or to enhance detail that has been blurred, either in error or as a natural effect of a particular method of image acquisition.
Uses of image sharpening vary and include applications ranging from electronic printing and medical imaging to industrial inspection and autonomous guidance in military systems.

Figure 1.2 shows the application of the image sharpening. The moon image is better viewed in last image which is sharpened. Due to edge representation which see the details of the moon surface. In this way it enhances the image by applying filters.

II. IMAGE COMPRESSION USING GABOR FILTER

Input Image (JPEG Image):
The input image is a JPEG format image. Because it is easily available from sources like Internet, Cameras & other image acquisition equipment. This is a compressed image format which is formed by Transformations & arithmetic coding algorithms as mentioned above.

Filter (Gabor Filter):

Here the Gabor filter is used for the Image Compression. As shown in figure 2.1 the JPEG format image is the input image for this filter. The Gabor filter tries to increase the compression level of the given JPEG image.

Its impulse response is defined by a harmonic function multiplied by a Gaussian function. Because of the multiplication-convolution property (Convolution theorem), the Fourier transform of a Gabor filter’s impulse response is the convolution of the Fourier transform of the harmonic function and the Fourier transform of the Gaussian function. The filter has a real and an imaginary component representing orthogonal directions. The two components may be formed into a complex number or used individually.

\[
\begin{align*}
\text{Complex} & \quad g(x, y; \lambda, \theta, \psi, \sigma, \gamma) = \exp \left( -\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2} \right) \exp \left( i \left( \frac{2\pi x'}{\lambda} + \psi \right) \right) \\
\text{Real} & \quad g(x, y; \lambda, \theta, \psi, \sigma, \gamma) = \exp \left( -\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2} \right) \cos \left( \frac{2\pi x'}{\lambda} + \psi \right) \\
\text{Imaginary} & \quad g(x, y; \lambda, \theta, \psi, \sigma, \gamma) = \exp \left( -\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2} \right) \sin \left( \frac{2\pi x'}{\lambda} + \psi \right)
\end{align*}
\]

where
\[
x' = x \cos \theta + y \sin \theta
\]
and
\[
y' = -x \sin \theta + y \cos \theta
\]
In this equation, $\lambda$ represents the wavelength of the sinusoidal factor, $\theta$ represents the orientation of the normal to the parallel stripes of a Gabor function, $\psi$ is the phase offset, $\sigma$ is the sigma of the Gaussian envelope and $\gamma$ is the spatial aspect ratio, and specifies the ellipticity of the support of the Gabor function.

The standard deviation sigma of the Gaussian factor determines the (linear) size of the receptive field. Its ellipticity and herewith the ellipticity of the receptive field ellipse is determined by the parameter gamma, called the spatial aspect ratio. It has been found to vary in a limited range of $0.23 < \gamma < 0.92$. Sigma cannot be controlled directly in the applet. Its value is determined by the choice of the parameters lambda and b.

The parameter lambda is the wavelength and $1 / \lambda$ the spatial frequency of the cosine factor in the Gabor function. The ratio sigma / lambda determines the spatial frequency bandwidth of simple cells and thus the number of parallel excitatory and inhibitory stripe zones which can be observed in their receptive fields. The half-response spatial frequency bandwidth $b$ (in octaves) and the ratio sigma / lambda are related as follows:

$$b = \log_2 \frac{\sigma}{\lambda} = \frac{\ln 2}{\lambda} \cdot \sqrt{\frac{n^2}{\sigma} + \frac{n^2}{\sigma}}, \quad \sigma = \frac{1}{\lambda} \sqrt{\frac{\ln 2}{2}} \cdot 2^{\frac{b^2}{2} + 1}$$

Neurophysiological research has shown that the half-response spatial-frequency bandwidths of simple cells vary in the range of 0.5 to 2.5 octaves in the cat (weighted mean 1.32 octaves) and 0.4 to 2.6 octaves in the macaque monkey (median 1.4 octaves). While there is a considerable spread, the bulk of cells have bandwidths in the range 1.0-1.8 octaves. Some researchers propose that this spread is due to the gradual sharpening of the orientation and spatial frequency bandwidth at consecutive stages of the visual system and that the input to higher processing stages is provided by the more narrowly tuned simple cells with half-response spatial frequency bandwidth of approximately one octave. Since lambda and sigma are not independent when the bandwidth is fixed, only one of them, lambda, is considered as a free parameter which is used in the applet.

The angle parameter theta specifies the orientation of the normal to the parallel excitatory and inhibitory stripe zones - this normal is the axis $x'$ - which can be observed in the receptive fields of simple cells.

Finally, the parameter phi, which is a phase offset in the argument of the cosine factor, determines the symmetry of the concerned Gabor function: for phi=0 degrees and phi=180 degrees the function is symmetric, or even; for phi=90 degrees and phi=90 degrees, the function is antisymmetric, or odd, and all other cases are asymmetric mixtures of these two.

Fig: 2.2: Demonstration of a Gabor filter

Demonstration of a Gabor filter applied to Chinese OCR. Four orientations are shown on the right $0^\circ$, $45^\circ$, $90^\circ$ and $135^\circ$. The original character picture and the superposition of all four orientations are shown on the left.

Gabor filters are directly related to Gabor wavelets, since they can be designed for a number of dilations and rotations. However, in general, expansion is not applied for Gabor wavelets, since this requires computation of bi-orthogonal wavelets, which may be very time-consuming. Therefore, usually, a filter bank consisting of Gabor filters with various scales and rotations is created. The filters are convolved with the signal, resulting in a so-called Gabor space. This process is closely related to processes in the primary visual cortex. The real part of the complex Gabor function is a good fit to the receptive field weight functions found in simple cells in a cat's striate cortex.

The Gabor space is very useful in image processing applications such as optical character recognition, iris recognition and fingerprint recognition. Relations between activations for a specific spatial location are very distinctive between objects in an image. Furthermore, important activations can be extracted from the Gabor space in order to create a sparse object representation.

III. RESULTS

After performing Gabor Filtering on several JPEG images types such as Satellite Images, Aerial Images, Space Images and Object Close up images, the compression ratio of these kinds of images has increased.

Below’s figures is the image database showing original JPEG image compression ratio its size on memory and filtered image compression ratio its size on memory:
Table 1. Filter Performance

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Default</th>
<th>Analysis</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wavelength ((\lambda))</td>
<td>2</td>
<td>Increases (&gt;2)</td>
<td>Pixel Intensity Decreases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decreases (&lt;2)</td>
<td>Pixel Intensity Increases</td>
</tr>
<tr>
<td>2. Bandwidth ((B))</td>
<td>1</td>
<td>Increases (&gt;1)</td>
<td>Sharpness Increases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decreases (&lt;1)</td>
<td>Sharpness Decreases</td>
</tr>
<tr>
<td>3. Aspect Ratio ((\gamma))</td>
<td>0.5</td>
<td>Increases (&gt;0.5)</td>
<td>Image Darkens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decreases (&lt;0.5)</td>
<td>Image Brightens</td>
</tr>
<tr>
<td>4. Phase Offset ((\psi))</td>
<td>0</td>
<td>Increases (&gt;0)</td>
<td>Dark Image</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decreases (&lt;0)</td>
<td>Dark Image</td>
</tr>
<tr>
<td>5. Orientations ((\theta))</td>
<td>0 to 360</td>
<td>Number of (\theta) Increases</td>
<td>Image Quality Preserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of (\theta) Decreases</td>
<td>Image Quality Degraded</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

From the results it is conclude that the Gabor Filter is used as JPEG Image Compression tool. The filter input parameters decide the filter performance and this performance are directly related to image compression ratio and resultant filtered image quality.

V. REFERENCES

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