IMAGE QUALITY ASSESSMENT

EE 5359 Multimedia project
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Universality in the title

The measurement of Image Quality (Q) does not depend:

- On the images being tested.
- On Viewing conditions or the individual observers.

Mathematical model.
Applied to various image processing applications.
Attempt to measure the quality of the image.
MSE

- MSE (Mean Square Error) is a signal fidelity measure where the goal is to compare two signals by providing a quantitative score that describes the degree of similarity/fidelity or, conversely, the level of error/distortion between them. Let \( x = \{ x_i \mid i = 1, 2, \cdots, N \} \) and \( y = \{ y_i \mid i = 1, 2, \cdots, N \} \) are two finite-length, discrete signals and \( N \) is the number of pixels. Then MSE is given by

\[
MSE(x, y) = \frac{1}{N} \sum_{i=1}^{N} (x_i - y_i)^2
\]
PSNR

- Peak Signal to Noise Ratio (PSNR) is the ratio between the maximum possible power of the signal and the power of the corrupting noise that affects the fidelity of its representation.
- It is widely used as a measure of quality of reconstruction of lossy compression codes.

\[ PSNR = 10 \log_{10} \frac{L^2}{MSE} \]

where \( L \) is the dynamic range of allowable image pixel intensities and MSE is the mean square error. For an 8 bit-PCM, \( L \) is 255.
Advantages of Mathematical model

- Easy to calculate.
- Low computational complexity.
- Independent of viewing conditions and individual observers.
- HVS has no clear advantage over the basic mathematical models[1].
DEFINITION

\[ x \rightarrow \text{Original Image}, \quad y \rightarrow \text{Test Image.} \]

\[ Q = \frac{4\sigma_{xy} \bar{x} \bar{y}}{\left(\sigma_x^2 + \sigma_y^2\right)[(\bar{x})^2 + (\bar{y})^2]} ; \quad Q-\text{Quality Index.} \]

\[ \bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i ; \quad \bar{y} = \frac{1}{N} \sum_{i=1}^{N} y_i ; \quad \bar{x}, \bar{y} \rightarrow \text{Mean of original Image } x \text{ and Test Image } y. \]

\[ \sigma_x^2 = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2 ; \quad \sigma_x^2 = \text{Variance of original Image } x. \]

\[ \sigma_y^2 = \frac{1}{N-1} \sum_{i=1}^{N} (y_i - \bar{y})^2 ; \quad \sigma_y^2 = \text{Variance of Test Image } y. \]

\[ \sigma_{xy} = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y}) ; \quad \text{Cross Variance between } x \text{ and } y. \]
MODELLING OF Q

\[
Q = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \cdot \frac{2\bar{x}\bar{y}}{(\bar{x})^2 + (\bar{y})^2} \cdot \frac{2\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2}
\]

- Loss of Correlation
- Luminance distortion
- Contrast distortion
Description

- The dynamic range of Q is [-1,1]. The value of 1 is achieved when the original image and test image are equal and the worst value when the test image is twice the mean of original image subtracted by the original image.
- Universal image quality is a full reference (FR) method of image fidelity as it considers the error (difference) between a distorted image and a reference image and attempts to quantify an error incorporating a variety of known properties of human visual system.
Q models any distortion as a combination of below three different factors:

- The first component is the correlation coefficient between x and y, which measures the degree of linear correlation between the two images. Its dynamic range extends between $[1, -1]$. Although the images are linearly related, there might be some relative distortions which are evaluated in the second and third components.

- The second component with dynamic range $[0, 1]$ measures the closeness of mean luminance between x and y. The maximum value of 1 is achieved when the means of the original and test images are same.
Description

• The third component measures how similar contrasts of the image are. The dynamic range is between \([0,1]\) and the best value of 1 is achieved when the standard deviations of the original image and the test image are the same.
• This method is very simple to calculate as it is a mathematical model.
APPLICATION

- Measure statistical features locally and combine.
- Sliding window of selected size moves one pixel at a time first horizontally and then vertically covering all the pixels in the image.

\[ Q = \frac{1}{M} \sum_{j=1}^{M} Q_j. \]

\[ M = \text{number of steps}. \]
SLIDING WINDOW

The number of steps 'M' is calculated from the code. Image size is (L*L).
Movement of sliding window
VERTICAL MOVEMENT OF SLIDING WINDOW
CORRUPTIONS IN IMAGES

- Impulsive salt and pepper noise.
- Additive Gaussian noise.
- Multiplicative speckle noise.
- Mean shift.
- Contrast stretching.
- Blurring.
- JPEG compression[11],[12].
SSIM

- Structural similarity index (SSIM) represents perceptual image quality based on the structural information.
- SSIM is an objective image quality metric and is superior to traditional quantitative measures such as MSE and PSNR.
- The structural similarity (SSIM) index is a method for measuring the similarity between two images.
- The SSIM index can be viewed as a quality measure of one of the images being compared, provided the other image is regarded as of perfect quality.
MODELLING OF SSIM

\[ SSIM(x, y) = [l(x, y)]^\alpha [c(x, y)]^\beta [s(x, y)]^\gamma \]

\( \alpha > 0, \beta > 0 \) and \( \gamma > 0 \) are parameters used to prioritize the components.

Where,

\[ l(x, y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1} \]

\[ c(x, y) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x^2 + \sigma_y^2 + C_2} \]

\[ s(x, y) = \frac{\sigma_{xy} + C_3}{\sigma_x\sigma_y + C_3} \]
Parameters of SSIM

\[
\mu_x = \sum_{i=1}^{N} w_i x_i
\]
Mean of original image

\[
\sigma_x = \left( \sum_{i=1}^{N} w_i (x_i - \mu_x)^2 \right)^{\frac{1}{2}}
\]
Standard deviation of original image

\[
\sigma_{xy} = \sum_{i=1}^{N} w_i (x_i - \mu_x)(y_i - \mu_y)
\]
Cross standard deviation between original image and test image.

Similarly the values of the test image are calculated.

\[w=\text{Circular-symmetric Gaussian weighting function}\]
\[C1, C2, C3 \text{ are three constants to prevent instability}\]
Block diagram of SSIM
Lena image with distortions

Original image, MSE = \(0\), Q = \(1\), PSNR = inf dB

Mean shift, MSE = 224.9933, Q = 0.9894, PSNR = 24.6090 dB

Contrast stretching, MSE = 225.0932, Q = 0.9372, PSNR = 24.6072 dB

Impulsive salt and pepper noise, MSE = 225.0932, Q = 0.6494, PSNR = 24.6019 dB

Multiplicative speckle noise, MSE = 224.7482, Q = 0.448, PSNR = 24.61 dB

Additive Gaussian, MSE = 225.1804, Q = 0.3891, PSNR = 24.6055 dB
Lena image with distortions

Blurring, MSE=224.1397, Q=0.3461, PSNR=24.6256 dB

JPEG compression, MSE=215.1139, Q=0.2876, PSNR=24.8041 dB
Gold hill image with distortions

ORIGINAL IMAGE, MSE=0, PSNR=INF, Q=1, SSIM=1, MSSIM=1

MEAN SHIFT, MSE=121, PSNR=27.30dB, Q=0.9928, SSIM=0.9927, MSSIM=0.9929

CONTRAST STRECHING, MSE=120.9002, PSNR=27.3065, Q=0.9498, SSIM=0.9698, MSSIM=0.9672

IMPULSIVE SALT-PEPPER NOISE, MSE=120.2122, PSNR=27.3313dB, Q=0.8290, SSIM=0.8643, MSSIM=0.8402

MULTIPLICATIVE SPECKLE NOISE, MSE=121.4297, PSNR=27.2876dB, Q=0.6758, SSIM=0.7032, MSSIM=0.7067

ADDITIVE GAUSSIAN NOISE, MSE=121.1260, PSNR=27.2984dB, Q=0.6151, SSIM=0.6556, MSSIM=0.6553

BLURRING, MSE=121.9371, PSNR=27.2694dB, Q=0.5080, SSIM=0.6671, MSSIM=0.6372

JPEG COMPRESSION, MSE=117.4739, PSNR=27.4314dB, Q=0.4963, SSIM=0.6824, MSSIM=0.6385
Couple image with distortions

**ORIGINAL IMAGE**
MSE=0, PSNR-INF dB, Q=1, SSIM=1, MSSIM=1

**MEAN SHIFT**
MSE=80.9952, PSNR=29.0462 dB, Q=0.9947, SSIM=0.9940, MSSIM=0.9947

**CONTRAST STRETCHING**
MSE=80.9063, PSNR=29.0510 dB, Q=0.9623, SSIM=0.9631, MSSIM=0.9627

**IMPULSIVE SALT-PEPPER NOISE**
MSE=80.8258, PSNR=29.0548 dB, Q=0.8836, SSIM=0.9057

**MULTIPLICATIVE SPECKLE NOISE**
MSE=81.2837, PSNR=29.0308 dB, Q=0.7152, SSIM=0.7613, MSSIM=0.7553

**ADDITIONAL GAUSSIAN NOISE**
MSE=80.6942, PSNR=29.0629 dB, Q=0.7039, SSIM=0.7511, MSSIM=0.7444

**BLURRING**
MSE=81.2747, PSNR=29.0313 dB, Q=0.7500, SSIM=0.8329, MSSIM=0.8238

**JPEG COMPRESSION**
MSE=81.9302, PSNR=28.9944 dB, Q=0.6761, SSIM=0.8015, MSSIM=0.7771
MSSIM (Mean SSIM)

- This measure is an single overall quality of the entire image. The MSSIM metric is an extension of SSIM which computes the luminance, contrast and structural components at various scales and combines them in the following equation. This metric is a right indication of an image quality as the features vary at every pixel of the image and hence the mean value is considered.

\[
\text{MSSIM}(X, Y) = \frac{1}{M} \sum_{j=1}^{M} \text{SSIM}(x_j, y_j)
\]
### RESULTS

#### TABULATED RESULTS FOR LENA IMAGE

<table>
<thead>
<tr>
<th>S.no</th>
<th>Image</th>
<th>Mean square error</th>
<th>PSNR (dB)</th>
<th>Q</th>
<th>SSIM</th>
<th>MSSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Original image</td>
<td>0</td>
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<td>1</td>
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<tr>
<td>5.</td>
<td>Multiplicative speckle Noise</td>
<td>224.7482</td>
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<td>0.4408</td>
<td>0.5009</td>
<td>0.4883</td>
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<tr>
<td>6.</td>
<td>Additive Gaussian noise</td>
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<td>7.</td>
<td>Blurring</td>
<td>224.1397</td>
<td>24.6256</td>
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<td>8.</td>
<td>JPEG Compression</td>
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<td>24.8041</td>
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## RESULTS

### TABULATED RESULTS FOR GOLDHILL IMAGE

<table>
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<tr>
<th>S.no</th>
<th>Image</th>
<th>Mean square error</th>
<th>PSNR (dB)</th>
<th>Q</th>
<th>SSIM</th>
<th>MSSIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Original image</td>
<td>0</td>
<td>Inf</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>2.</td>
<td>Mean shift</td>
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<td>27.3029</td>
<td>0.9928</td>
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<td>3.</td>
<td>Contrast streching</td>
<td>120.9002</td>
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<td>4.</td>
<td>Impulsive salt-pepper noise</td>
<td>120.2122</td>
<td>27.3313</td>
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<td>0.8402</td>
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<td>Multiplicative speckle Noise</td>
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<td>Additive Guassian noise</td>
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<tr>
<td>7.</td>
<td>Blurring</td>
<td>121.9371</td>
<td>27.2694</td>
<td>0.5080</td>
<td>0.6671</td>
<td>0.6372</td>
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<td>8.</td>
<td>JPEG Compression</td>
<td>117.4739</td>
<td>27.4314</td>
<td>0.4963</td>
<td>0.6824</td>
<td>0.6385</td>
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</tbody>
</table>
## RESULTS

### TABULATED RESULTS FOR COUPLE IMAGE

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<tr>
<th>S.no</th>
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<th>PSNR (dB)</th>
<th>Q</th>
<th>SSIM</th>
<th>MSSIM</th>
</tr>
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<td>1.</td>
<td>Original image</td>
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<td>Inf</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
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<td>2.</td>
<td>Mean shift</td>
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<td>6.</td>
<td>Additive Guassian noise</td>
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<td>0.8013</td>
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</tbody>
</table>
CONCLUSIONS

• Q which is a simple and mathematical model seems to be a better metric in image quality than compared to traditional MSE and PSNR. The success is due to the strong ability of Q to measure the structural distortion occurred during the image degradation processes when compared to MSE which is sensitive to energy of errors.

• There is no doubt that precise modeling of HVS is always better but a well defined mathematical framework of the model can ease in successful quality metric.
CONCLUSIONS..

- The SSIM index is a particular implementation of the philosophy of structural similarity from an image formation point of view. The key success of SSIM is the concept of structural information and structural distortion.

- SSIM index exhibit input-dependent behavior in measuring signal distortions. The MSSIM is a better metric than UIQI in the case of distortions like blurring and JPEG compression due to the inclusion of the constants $C_1, C_2$ in SSIM which avoid the instability. Even though the MSE of different distortions is same, SSIM and MSSIM truly represent the visual (perceptual) qualities.
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REFERENCES


THANK YOU!!!!
• QUESTIONS???