Objective Methods for Measuring QoE

How well does PSNR correlate with MOS?

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# Correlation of the PNSR with the MOS

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Your main task is to find out what is the correlation between the Peak Signal-to-Noise Ratio (PSNR) indicator and Mean Opinion Score (MOS). Those should be calculated using the subjective data generated during the “Subjective Methods of Measuring QoE” classes. The goal is to assess how well an objective measure (PSNR) can predict a subjective quantity (MOS). One of many ways to verify potential prediction capabilities is to calculate the Pearson correlation coefficient.

In order to find the correlation, you first need two data vectors - PSNR values and MOS values for each PVS (Processed Video Sequence; in this case PVS stands for the image tested). To calculate the PSNR both original (i.e. Source Reference Circuit, SRC) and distorted (i.e. PVS) images are needed. You can find those in the Images tested folder. SRCs reside in the SRCs subfolder and PVSs in the PVSs subfolder. The latter one is additionally divided into two subfolders (Gaussian Blur and JPEG-2000) to indicate a type of distortion used. In each of those there is the info.txt file specifying a mapping between the SRCs and PVSs. For details on how to calculate the PSNR in Matlab please refer to the [PSNR sub-section](#_jz8kmqkk23vn).

Having the PSNR for each PVS you need to compare those with MOS values. MOS values can be calculated using CSV files provided (RESULTS.csv, USER.csv and TESTS\_FILE.csv). Each CSV file represents a table of values extracted from the SQL database used during the subjective experiment. Here is a short description of each table:

* RESULTS.csv - each row represents a score given by a single tester (identified by ID\_USER) to a single image (identified by ID\_FILE). Scores are placed in the MOS column[[1]](#footnote-1).
* TESTS\_FILE.csv - each row represents a single image. The ID column here corresponds to the ID\_FILE column in the RESULTS.csv file. The FILE\_PATH column specifies the location of each image. Note that this path is not in line with ours Google Drive. “jp2k” folder corresponds there to ours Images tested/JPEG-2000, “gblur” to Images tested/Gaussian Blur and “refimgs” to Images tested/SRCs.
* USER.csv - each row represents a single tester. The ID column here corresponds to the ID\_USER column in the RESULTS.csv file.

The MOS for each image can be calculated by averaging all scores given to an image with a given ID\_FILE.

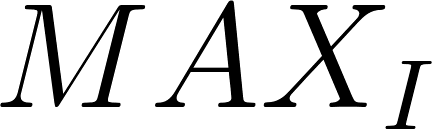
Using the vectors with PSNR values and MOS values you can calculate the correlation between the two. This result (being in the range [-1, 1]) says whether there is any linear correlation between the PNSR and the MOS. For details on how to calculate the Pearson correlation in Matlab please refer to the [Pearson Correlation Coefficient sub-section](#_c65qbyy3fzw2).

# Theoretical Fundamentals

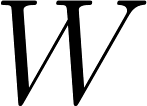
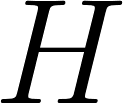
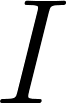
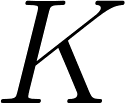
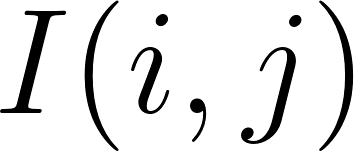
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This section explains two concepts crucial to deal with the objective of this laboratory. The first of them is Peak Signal-to-Noise Ratio (PSNR) and the second one is Pearson Correlation Coefficient. Both of them are described in the two following subsections.

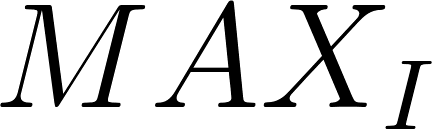
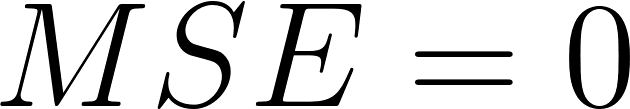
## PSNR

PSNR stands for Peak Signal-to-Noise Ratio. In the context of digital image processing it is a measure of difference between two images. It is based on pixel-by-pixel analysis of image content. To be more precise, it uses mean squared error (MSE) measure and maximum possible pixel value ([](https://www.codecogs.com/eqnedit.php?latex=MAX_I%250)). [Equation 1](#3a1wibqfs9yw) gives a formal definition of MSE and [Equation 2](#hhfcflmwqyvm) uses it to define the PSNR.

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| **Equation 1.** Mean squared error between two images I and K |

[](https://www.codecogs.com/eqnedit.php?latex=W%250) and [](https://www.codecogs.com/eqnedit.php?latex=H%250) stand for width and height of images, respectively. [](https://www.codecogs.com/eqnedit.php?latex=I%250) and [](https://www.codecogs.com/eqnedit.php?latex=K%250) are the two images being compared. [](https://www.codecogs.com/eqnedit.php?latex=I(i%2Cj)%250) stands for value of the pixel being in the i-th row and j-th column.

|  |
| --- |
|  |
| **Equation 2.** Peak Signal-to-Noise Ratio (PSNR) between two images I and K |

Importantly, [](https://www.codecogs.com/eqnedit.php?latex=MAX_I%250) has the value of 255 for an 8-bits deep image (i.e. pixels’ values expressed as 8-bits numbers). Also notice that PSNR takes the value of infinity if there is no difference between the two images (i.e. when [](https://www.codecogs.com/eqnedit.php?latex=MSE%20%3D%200%250)).

To calculate the PSNR in Matlab issue the psnr(A, ref) command. For its description please refer to the [“A List of Useful Matlab Functions and Their Descriptions” section](#_qggsqqzg9zug) and Matlab’s documentation.

## Pearson Correlation Coefficient

The Pearson correlation coefficient describes an extent of the linear correlation between two variables. It takes values from the range [-1, 1], where 1 means total positive linear correlation (when one is growing, the other is growing as well), 0 means no linear correlation and -1 means total negative linear correlation (when one is growing, the other is decreasing). [Equation 3](#bxoss68fskuq) shows a formula for the Pearson correlation coefficient for two random variables A and B. Importantly, both those random variables are assumed to have [](https://www.codecogs.com/eqnedit.php?latex=N%250) scalar observations.

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|  |
| **Equation 3.** The Pearson correlation coefficient for two random variables A and B, each having  scalar observations |

[](https://www.codecogs.com/eqnedit.php?latex=a_i%250) is the i-th observation of random variable (r.v.) A, [](https://www.codecogs.com/eqnedit.php?latex=%5Cbar%7Ba%7D%250) is the sample mean of r.v. A and [](https://www.codecogs.com/eqnedit.php?latex=s_a%250) is the sample standard deviation of r.v. A. The same goes for r.v. B.

To find the Pearson correlation coefficient in Matlab use the corrcoef(A,B) command. For its description please refer to the [“A List of Useful Matlab Functions and Their Descriptions” section](#_qggsqqzg9zug) and Matlab’s documentation.

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# A List of Useful Matlab Functions and Their Descriptions

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| --- | --- |
| A = imread(filename) | Loads an image to the A array. |
| imshow (A) | Displays an image from the A array. |
| imshow(A, 'initialmagnification','fit') | Displays an image from the A array in a bigger size (if the image is small). |
| [nc nl] = size(M) | Shows the size of the image M (nc - number of columns, nl - numbers of lines). |
| A1 = double (A) | Changes the type of a numerical array to double (needed for some operations). |
| A = uint8 (A1) | Changes the type of a numerical array to uint8 (8-bit unsigned integer). |
| A1 = im2double(A) | Converts the A image to the double type. If the input image is of the uint8 type (pixel values in a discrete range [0, 255]), the output image will contain pixel values in a continuous range [0, 1]. |
| subplot(m,n,p) | Divides the current figure into an m-by-n grid and creates an axes for a subplot in the position specified by p. Matlab numbers its subplots by row, such that the first subplot is the first column of the first row, the second subplot is the second column of the first row, and so on. |
| title(‘your title’) | Adds the ‘your title’ title to the plot. |
| P = psnr(A, REF) | Calculates the peak signal-to-noise ratio for the image in array A, with the image in array REF as the reference. |
| R = corrcoef(A,B) | Returns the matrix of correlation coefficients between two random variables A and B. A and B should be column vectors. |

# Additional Exercise

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You are encouraged to write your own Video Quality Indicator (VQI). In particular, we would like you to write an indicator correlated with exposure time (also called shutter speed). To make things easier we are providing you with an algorithm. Let us also assume that we are working with images and not videos (in practice, most of the algorithms operate frame-by-frame). Your task is to transform the algorithm into a code. Here is the algorithm:

1. Convert the input image into grayscale representation with 8-bits deep pixels.
2. Divide the image into 8x8 pixels blocks[[2]](#footnote-2).
3. Find a sum of pixels in each block.
4. Find four (4) largest and four (4) smallest sums.
5. Calculate average luminance using those 4 largest and 4 smallest sums.
   1. Please keep in mind that we are talking about a pixel-wise average. Thus, when using 8 blocks, each 8x8 pixels large, the total sum has to be divided by 512 (because 8 blocks \* (8 pixels \* 8 pixels) = 512 pixels).
6. The average luminance approximates exposure time.
   1. We can say that this average luminance is correlated with exposure time, but defining a precise relationship is much more demanding.

The task is worth **11** points and a deadline is the end of the semester. We expect a source code, which we could test with our image samples. We prefer Python 3, but accept a language of your choice if Python is not your thing.

# Copyright Notice

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This laboratory exercise utilises [LIVE Image Quality Assessment Database](http://live.ece.utexas.edu/research/Quality/subjective.htm). Please see the text below for its copyright notice.

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The database is to be cited in the bibliography as:

H. R. Sheikh, Z. Wang, L. Cormack and A. C. Bovik, "LIVE Image Quality Assessment Database Release 2", <http://live.ece.utexas.edu/research/quality>.

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The rest of the images were public domain Kodak PhotoCD images obtained from the Internet.

1. MOS is not the most fortunate name for this column. You are right to assume that it should be called “SCORE”. [↑](#footnote-ref-1)
2. Many legacy compression algorithms compress video frames in such 8x8 pixels blocks. [↑](#footnote-ref-2)