UniSIM

Final Report
Image Quality Measurement

Name: Lum Tuck Sang
Student Number: T6120632
Project Supervisor : Dr Cai Zhi Qiang

Statement of Assistance

I would like to thank the following people and institutions for their support towards the completion of this project:

1) Project supervisor, Dr Cai Zhi Qiang, who had been monitoring my progress throughout the project period. He had been setting up regular meeting sessions and provided precious advice, recommendation of reference books and methodologies required for this project.

2) UniSIM and the staff for providing the supportive material, information and relevant course notes.

3) Singapore Polytechnic for providing the computer facilities, which include MATLAB® application software, which had played an important role in the implementation of fast digital image analyzing tools.

4) My employer, Rohde & Schwarz, for granting me off days to attend the tutorial sessions with the project supervisor.

Abstract

This report covers the studies and understandings of human perception of quantifying and qualifying general digital images; the criteria used in assessing the quality of images which includes objective and subjective measurement; using of existing standard quality measurement to test different types of test images and make comparisons; and finally implement an objective image quality measurement function which can correlate to the subjective quality measurement method closely. The main content of the report is basically contained in 3 chapters.

Chapter 1 provides an introduction of the whole project which includes the objectives to be achieved – i.e. to propose and implement a new objective image quality measurement criterion that is reliable and accurate. It also wrote about some literatures related to image processing, the challenges, strengths and weaknesses and scope of works as the project progresses.

Chapter 2 contains the technical report which includes a critical analysis and explanation of the project, the method adopted for the implementing the cost function, the digital image testing process, the procedure of testing the image, collection of data and the analysis of the test results obtained. An investigation was done on the reliability of results too. In this chapter, the suggested methods for implementing the objective quality measurement was mainly made reference from the books, Digital Image Processing 2nd edition & Digital Image Processing using MATLAB®, both by Rafael C. Gonzalez / Richard E. Woods. There are several techniques and examples provided by this book, which were very useful in programming the software to run the testing. The software tool use for design & analysis is MATLAB®, with image processing toolbox, which will be illustrated too.

Chapter 3 concludes the project reporting. This chapter will include a discussion on the comparisons between the implemented cost function with standard measurement method and also provides a suggestion on the improvement to be made, i.e better consistency and repeatability.

Table of Contents

1 Introduction

1.1 Aims

To study the properties of human visual system and image quality measurement; propose a new objective image quality measurement criterion that is reliable and accurate.

The project will include:

a) Study the quality control benchmarks and assessments on image quality.
b) Evaluate the existing Image Quality measurement methods, i.e subjective and objective measurements.
c) Conduct a survey with different observers to evaluate and judge some images quality.
d) Examine, study and compare some of the objective image quality measurement algorithms available, eg. mean absolute error (MAE), mean square error (MSE), signal-to-noise ratio, or peak signal-to-noise ratio (PSNR).
e) Learn the methods of Image acquisition of image file eg. BMP, TIF & JPEG files.
f) Using MATLAB® Image Processing and Image Acquisition Toolboxes for testing and comparing different types of standard Image Quality measurement.
g) Compare and review the image quality measurement results between subjective and objective measurements.
h) Experiment with some new cost functions for objective image quality measurement.
i) Evaluate and review the different new cost functions experimented.
j) Recommend and implement a cost function that can assess image quality so that the objective measurement results correlate well with subjective measurement result.

1.2 Overall objective

The overall objective is to develop an image quality measurement cost function that can assess image quality so that the objective measurement result is similar or correlates well to the subjective measurement result.

There are two criteria used in assessing the quality of images. They are subjective criterion and objective criterion. The subjective criterion relies on human beings judgments. As its name suggests, it is inconsistence and lacks repeatability, it is also time consuming and expensive. One of the standard ways of subjective measurement is called Mean Opinion Score (MOS), it is very tedious, costly and could not be carried out in real time(1). It has five scales ranging from ‘impairment is not noticeable’ (best) to ‘impairment is extremely objectionable’ (worst). On the other hand, the objective criterion available relies on the result of computing some of the following statistical error-based methods dependent on pixels difference, eg. : overall image mean absolute error (MAE), overall image mean square error (MSE), signal-to-noise ratio, or peak signal-to-noise ratio (PSNR). The smaller the MAE (or MSE) or the larger the SNR (or PSNR) is, the higher quality the signal. Although it is fast and repeatable but they have their setbacks in terms of accuracies as compare to human perception of viewing an image and also varies with images of different tone, contrast and spatial frequencies, which means that it is not possible to have a level response of the visual quality of different images from the cost function computed. Therefore, it is important to develop a new cost function to assess image quality so that the objective measurement result is similar to the subjective measurement result.

1.3 Applications

With the increase use of digital technologies over the last decades, all multimedia were digitized; management and transportations of digital image have to be fast and efficient nowadays in various commercial and government sectors like medical, defense, aerospace, telecommunications, training institutions and so on, especially with the improvement in data compression, increase in image sizes and bandwidth. All these led to the importance of a fast and reliable way of image quality measurement which can only be achieved by automatic objective measurement which also have to fair well in the sense that it takes into account of human visual perceptions.

1.4 Proposed approach and method to be employed

1. Project planning and tracking
2. Literature review on image analysis, image distortion and artifacts, human visual system (HVS), and image quality measurement criteria
3. Study the application of MATLAB® software
4. Study and simulate image quality measurement for images with different types of distortions
5. Development and implementation of a new cost function for objective image quality measurement that takes account of HVS.
6. Experiment and evaluation
7. Report writing

1.5 Skills review

- Planning and project management skill:

  In order to meet the expectation and outcome from the project, the followings were attained: the knowledge, skills, tools and techniques to project activities. The project planning was not quite well followed, unexpectedly, due to a great amount of time spent on the learning the MATLAB® programming and statistics studies. It was learned that time discipline is very important in order for the project to progress well and be completed within the planned schedule. The following are a list of project management processes(2) that were carried out:

  - Project integration management which is to ensure the various elements of the project are properly co-ordinate. Project schedule was drawn out and tracked, it consisted of project plan, project plan execution and overall change control. Meeting with supervisor were well planned, thanks to the his constant reminding, regular visits to Singapore Polytechnic to use the MATLAB® software facilities and getting on the reference materials on time.
  - Project Scope management which included all the work required to complete the project successfully, i.e. scope planning, scope definition, scope verification and scope change control. These consisted of defining the methodologies in image measurement algorithms, testing and verifying the methods and making changes where necessary.
  - Project time management involves activity definition, sequencing, activity duration estimating, schedule development and schedule control. Large part of the time was spent on learning the MATLAB® software and writing programs, leaving a small amount of time writing the reports
  - Project cost management mainly consists of resource planning, cost estimating and cost control. This part was not critical as the project does not involve hardware.
  - Project quality management involves quality planning, quality assurance & quality control. Image test programs were tested and verified by the project supervisor to ensure that the results obtained were accurate and reliable.
  - Project communication management is the generation, collection, dissemination, storage, reporting of project information. Regular communications and emails were exchanged with the supervisor which helped very much in understanding the requirements and scopes.
  - Project risk management. Towards the end of the planned project phase did I realized the risk of not completing the project on time through the slow learning progress for MATLAB® software. Fortunately it was completed in time with much help from the supervisor and early gathering of related literatures.

- Researching skill
  - Learn the quality benchmark and assessment for image quality measure, both subjective and objective. Had studied the standard MOS subjective quality measurements method as well as understood some of the standard objective methods, mainly MSE, MAE, SNR and PSNR, these will be illustrated in the report..
  - Explore and compare the different image quality measurement cost functions. A table of comparisons for MSE, MAE, SNR and PSNR and MOS was created and presented in this report
  - Literature gathering and study some related journals and reference book from internet and libraries. Had collected and read some related journals and papers written by various academics.
  - Regular consultation from project tutor. This was carried out on a regular basis of at least once a month.

- Knowledge application skill
  - To apply the knowledge obtain from completing the below courses in UniSIM: TZS305 Digital Communications which covers some topics on digital image processing (6).
  - C programming learned in Polytechnics which could help in MATLAB® programming.
  - Understanding basic concepts and methodologies in digital image processing through reference book: Digital Image Processing 2nd edition, by Rafael C. Gonzalez / Richard E. Woods
  - Image processing methods and programming in reference book: Digital Image Processing using MATLAB®, by Rafael C. Gonzalez / Richard E. Woods / Steven L. Eddins

- Software skill

In this project, the MATLAB® application software was proposed for analyzing digital image quality and implementing a new cost function, a great deal of time was spent in familiarizing the commands and coding for image processing. The MATLAB® consists of image processing & image acquisition toolboxes has indeed speed up the time in the work once the knowledge was acquired. The following list of topics were well understood :

- Introduction to MATLAB® - using ‘Help’ menu in the software.(3)
- Objects in MATLAB®, eg. the basic objects in MATLAB® are scalars, vectors, and matrices.
- Operations on vectors and matrices.
- Creating functions using MATLAB® m-files as functions in MATLAB® are written in m-files.
- Plotting of images and graphics.
- Conversions of and working with different image data classes

- Arithmetic, relational and logical operators and functions
- Flow control operations like *if, for and while* loops.

- Testing, measurement and data analysis skill
  - Different types of test images were tested and experimented with the alogorithms written in m-files and using the MATLAB® command window. Data was collected and analyze either using MATLAB® or worksheet.
  - Analysis and some critical comparisons were made on the results collected.

- Communication & presentation skill
  - Had taken reference with some good report formats available on the internet as well as followinging the guide line in the UniSIM project handbook ().
  - All drafting and ideas of implementing the algorithms were logged down in an an engineering work book.

1.6 Strength and weakness

- As the project is expected to involve a lot of experiments with different categories and classification of images as well as different algorithms, thus discipline on following the project schedule is important. This part of the project was delayed compared to the planned schedule due to the late implementation of algorithms for image analysis.

- Much knowledge was obtained from journals and papers gathered form the internet and also knowledge gained from reading the reference book, Digital Image Processing. Surprisingly, the principles and theories were quite easily grasped due to the well structured written and reference materials.

- A great deal of time will be spent on study reference books and journals to have a more in-depth knowledge of the subject.

- This project had shown that my weakest area is in software programming. A lot of time was spent on learning, written, debugging and correcting the m-files implemented Assistance were needed and obtained from the supervisor as well as a few of my colleagues in the software application department.

- Communication & presentation skill will be my strong area as my existing job requires me to conduct training and presentation to customers. This part will be applicable during the project presentation to be held in mid May 2008.

1.7 Priorities for improving my skills

- To acquire skim reading skills due to the large amount of information to be studied. Had read through most of the reference materials.

- To collect all relevant information within a short period. All reference materials were collected and purchased on schedule.

- To adjust the project schedules accordingly to meet the deadline for project submission. The time schedules adjusted was just in time for me to complete writing the project report.

2 Investigation of project background

2.1 Image quality

An essential determinant of the value of surrogate digital images is their quality. Image quality measurement has become crucial for most image processing applications. Traditionally, image quality research focuses on the subjective prediction, measurement or improvement of image quality; there are many aspects and parameters in determining the quality of an image, eg. image clearness, sharpness, colour errors, blur, noise, etc. In the past years, many efforts and attempts have been made to develop models or metrics for image quality that include elements of human visual sensitivity. However, there is no current standard and objective definition of image quality.

2.2 Subjective measurements (3)

For many years, ITU-RBT.500 has provided standards for subjective picture quality measurement. Over the last few years, this has been extended to deal with the changing measurement requirements for compressed systems. Several measurement techniques are described within this standard, two of which are described below in greater detail. The first, referred to as “The double-stimulus impairment scale method (the EBU method)” provides a measurement that can be represented within a five-grade impairment scale.

5 = Imperceptible
4 = Perceptible
3 = Slightly annoying
2 = Annoying
1 = Very annoying

An alternative measurement referred to as “The doublestimulus continuous qualityscale method” (DSCQS), replaces the five-grade scale above with voting on the quality of both the reference image sequence and the test image sequence. The difference between the two represents the impairment. Typically, the two images are displayed in turn, but the viewer is not told which the reference is. The form used for voting contains five adjectives relating to the absolute picture quality: excellent, good, fair, poor, and bad. However voting scores are not restricted to these five adjectives and are instead given values on a continuous scale with values between 0 and 100, where 0 and 100 represent, respectively, bad and excellent picture quality. The resulting difference values will also generally lie within the range of 0 to 100 where 0 and 100 represent respectively low and high levels of impairments. (Negative values can exist when voters consider the picture quality of the test image to be better than that of the reference image.) Picture quality measurements obtained from subjective tests are subject to variations caused by many factors.

Subjective testing methods are complex and time consuming and are only applicable for development purposes. They do not lend themselves to operational monitoring, production line testing or trouble shooting.

2.3 Objective measurement (4)

Objective measurements are performed with the aid of instrumentation, manually with humans reading a calibrated scale, which is time consuming or automatically using a mathematical algorithm.

As an example, signal-to-noise ratio is not a reliable measure of picture quality. Is not a constant for a given system and thus can give completely misleading results. Therefore image quality measurements require a direct method, using natural scenes, or an equivalent thereof, which are much more complex than traditional test signals. These complex scenes stress the capabilities of the encoder resulting in non-linear distortions that are a function of the image content.

Use of digital compression has expanded the types of distortions that can occur in the modern image being processed. Due to this increased complexity and the desire to optimize program distribution both technically and economically, the field of subjective measurement has expanded. Since signal quality measurements will not do the job, objective picture quality measurements are needed. The new objective measurement methods must also have strong correlation with subjective measurements and cover a broad range of applications. They will be able to detect much of the degradation due to the compression process. They should also be able to detect most of the picture defects now measured with signal quality methods albeit with less ease of measurement or resolving power. It is expected that picture quality distortions too small for the human to see will be measured and provide an indication of the performance of concatenated systems.

There are already several types of objective image quality measurements proposed by various researchers:

- a low complexity image quality assessment method based on frequency domain transforms. This scheme is easy to implement and reliably estimates image quality across various distortions types including images compressed using frequency domain transforms (JPEG and JPEG2000).

- proposal base on satisfying of two requirements: usefulness (that is, discriminability of image content) and naturalness (identifiability of image content).It is the degree to which an image satisfies the usefulness and naturalness requirements determines the quality of this image.

- A quality index using a Moran I statistics. The Moran statistic that measures the sharpness from a local area is a good index of quality as most image processing techniques alter the smoothness of the image.

- the square root integral (SQRI) model has been adapted to describe the effect of picture size as well as resolution on subjective image quality.

- Base on a new philosophy in designing image quality metrics: the main function of the human eyes is to extract structural information from the viewing field, and the human visual system is highly adapted for this purpose. Therefore, a measurement of structural distortion should be a good approximation of perceived image distortion.

- a method of graphical and scalar image quality measurement utilizing wavelet analysis throughout the spatial frequency range. This is done by a detailed analysis of an image for a wide range of spatial frequency content, using a combination of modulation transfer function (MTF), brightness, contrast, saturation, sharpness and noise, as a more revealing metric for quality evaluation.

2.4 The cost functions MSE, MAE, SNR & PSNR (4)

Letting the desired image be $I(h,k)$ and the result of processing be the image $I'(h, k)$, it is possible to employ simple *error* based schemes as an alternative to subjective evaluation. Thus defining an *error* as $e(h,k) = I(h, k) - I'(h,k)$ allows the derivation of some simple measures for how close the processed image is to some 'ideal' $I(h, k)$.

In a compression example for instance, $I'(h, k)$ would be the image resulting after the original $I(h, k)$ is compressed and then decoded. Lossless compression would imply that $e(h,k)$ is 0 everywhere in the image, and lossy compression would imply that $e(h,k)$ was non-zero.

In image restoration, we do not know $I(h,k)$ and the idea is to process some observed image to yield $I'(h,k)$. The question then is "How good is the restoration really?" Of course we do not have $I(h,k)$ in the first place, but that discussion is left for another time.

A number of simple measures can be generated to measure the 'observed error' as follows. The *Mean Squared Error* (MSE) is

$$\text{MSE} = \frac{1}{NM}\sum_{\vec{x}} e(\vec{x})^2$$

where the image size is *N* rows by *M* columns, the sum is over all the sites in the image, and $e(x) = e([h, k])$. Thus the MSE is the mean of the squared error values across the entire image. In some cases, the Mean Absolute Error is used as follows.

$$\text{MAE} = \frac{1}{NM}\sum_{\vec{x}} |e(\vec{x})|$$

The Signal to Noise ratio is another popular objective measure and it has units of Decibels (dB).

$$\text{SNR} = 10\log 10\frac{\frac{1}{NM}\sum_{\vec{x}} I(\vec{x})^2}{\text{MSE}}$$

This is a ratio between the signal power, measured as the sum squared intensities in the original image *I*, and the 'noise' power measured as the MSE of the error, *e*.

A more popular version of the SNR used widely in image compression is the Peak SNR this is the log of the ratio between the peak signal (image) power and the noise power. It is also measured in dB.

$$\text{PSNR} = 10\log 10\frac{255^2}{\text{MSE}}$$

where it is assumed that the image is stored as 8 bit pixels in which case the peak value at a pixel site is 255.

Unfortunately, these error measures do not align well with the Human perception of images. It is a good rule of thumb however that in comparing images using these measures, large differences in objective measurements do tend to imply similar differences in human perception of the images. However when the differences between the same objective measure on several images are small then it is no longer the case that the differences would imply similar perceptual evaluations.

2.5 Testing of image base on objective measurement(5)

The proposed method of comparing a new cost function with MSE, MAE, SNR and PSNR is to generate a comparison table with various types of distortions such as mean shift, contrast stretching, salt-pepper noise, speckle noise, Gaussian noise, blurring & JPEG compression. The subjective test scores of test images were taken and log into the table too. The subjective scores are expressed in terms of the mean subjective rank (MSR), which is the average of visual quality differences between the original and the processed images, rated by a group of subjects. A low value of subjective rank indicates higher visual quality, and lower visual quality is represented by higher value of the subjective rank. The data in the table will be presented in descending order of the images' MSR; that is, from good quality image to the worst quality image.

.

2.6 Testing images

The test images use for image analysis are listed in appendix 2. The original reference images Baboon, Bird, Boat and Lena could not be source from the internet, fortunately the project supervisor provided all of the them.

2.7 Difficulties and challenges

Some of the difficulties and challenges foreseeable in this project are:

- selection of the types of image to be measured so that it can represent a wide range of different images.
- to find out and understand the various mathematical algorithms use in image quality measurement
- there must be a large number of data samples of subjective measurements to ensure accuracy or good comparison of the cost function being proposed or implemented.
- to find out the various sources of determinant that affect the image quality which will help in working out on a more appropriate cost function.

3 Project plan

3.1 Tasks list

S/No.	Tasks	Days	Start Date	End Date
1	**PROJECT START**	**30**	**Mon 9/3/07**	**Fri 10/12/07**
1.1	Project synopsis and application	20	Mon 9/3/07	Fri 9/28/07
1.2	Project approval	15	Mon 9/24/07	Fri 10/12/07
2	**INITIAL REPORT**	**35**	**Mon 10/15/07**	**Fri 11/30/07**
2.1	Gathering of study materials and attending Workshops	25	Mon 10/15/07	Fri 11/16/07
2.2	Start Writing Initial Report	24	Mon 10/29/07	Thu 11/29/07
2.3	Completion and submission of Initial Report (TMA01)	1	Fri 11/30/07	Fri 11/30/07
3	**STUDY, EXPERIMENT & DATA COLLECTION**	**40**	**Mon 12/3/07**	**Fri 1/25/08**
3.1	Study relevant literature & subjects	12	Mon 12/3/07	Tue 12/18/07
3.2	Familarise with MATLAB® programming	7	Wed 12/19/07	Thu 12/27/07 (actual: Mar08)
3.3	Experimenting different cost function	7	Fri 12/28/07	Mon 1/7/08 (actual: Mar08)
3.4	Designing cost function	7	Tue 1/8/08	Wed 1/16/08 (actual: Mar08)
3.5	Survey on subjective image quality measurement	5	Thu 1/17/08	Wed 1/23/08 (actual: Feb08)
3.6	Data collection	20	Mon 12/31/07	Fri 1/25/08 (actual: Feb08)
4	**IMPLEMENTATION OF COST FUNCTION**	**33**	**Mon 1/28/08**	**Wed 3/12/08** (Apr 08)
4.1	Evaluation of cost function	8	Mon 1/28/08	Wed 2/6/08
4.2	Testing of proposed cost function	8	Thu 2/7/08	Mon 2/18/08
4.3	Improvement on proposed cost function (If any)	5	Tue 2/19/08	Mon 2/25/08
4.4	Redesign & Testing (If any)	12	Tue 2/26/08	Wed 3/12/08
5	**FINAL REPORT**	**28**	**Thu 3/13/08**	**Mon 4/21/08**
5.1	Start Writing Final Report	28	Thu 3/13/08	Mon 4/18/08
5.2	Completion and submission of Final Report (Final)	1	Fri 4/18/08	Fri 4/18/08
6	**PRESENTATION**	**20**	**Tue 4/22/08**	**Sat 5/17/08**
6.1	Prepare Powerpoint Presentation	20	Tue 4/22/08	Sat 5/17/08
6.2	Conduct Oral Presentation	1	Sat 5/17/08	Sat 5/17/08
6.3	**PROJECT COMPLETION**	**1**	**Sat 5/17/08**	**Sat 5/17/08**

3.2 Project Scheduling (Gantt chart)

A gantt chart generated by Microsoft Project is shown in appendix 1. The chart did help me in monitoring and controlling the progress of the project as well as for time management. As highlighted in red in the tasks list schedule in the previous page, those are the tasks that were delayed due to the more time spent on learning the MATLAB tools. Some of the software part and further evaluations were not able to complete in time, eg. creating a graphic user interface for the evaluation program. This outstanding task shall be planned until the oral presentation for better visual and ease of explanation.

3.3 Facilities / resources / planning

The following facilities/resources were used :

- Computer and Mathlab software which will be accessible at UniSIM and Centre for Signal Processing (CSP), Singapore Polytechnic.
- In office, where I can also access the computer's Mathlab.
- My home, where I spent most of the time in writing reports and analyzing the data collected using Excel sheet.
- Library, internet and IEEE database access from UniSIM were where the relevant Journals and Conference materials came from.
- Had purchased 2 reference book for more in depth studies and understanding - , "Digital image processing" and "Digital image processing using MATLAB®", both by Gonzalez.

The project schedule was planned in such a way that the first phase consists of gathering and evaluating surveys and experimenting results, in the second phase, focus on proposing the required algorithm for objective image quality measurement was carried out.

Much time was spend on finding the best algorithm and best objective measurement cost function. Unexpectedly, a lot of time was spend on learning to use the MATLAB tools for image analysis and processing.

4 Describing the PPA process

- The first meeting was held with my tutor, Dr Cai in Sep 07, to discuss on the proposed project – Image Quality Measurement. Dr Cai gave a detailed explanation on the project scope which include:

1) Digital image processing and acquisition.
2) Subjective and objective means of image quality evaluation.
3) Present object image quality measurement using MAE, MSE, SNR (or PSNR).
4) Defining the quality indices MAE, MSE, SNR and PSNR.
5) The "accurateness" of image quality measurement using the above indices as compare to subjective measurement.
6) This project is to investigate the "accurateness" of the various quality indices on different test images, and to propose and implement one that reflects better result.
7) Propose to use MATLAB® software as it is fast and efficient in image processing.

- Upon evaluating and receiving the information on the project, I found that the following would help me a great deal in completing the project:

1) The course that I took previously in UniSIM: TZS305 Digital Communication and Object oriented programming.
2) The C programming course that I learnt in Polytechnics.
3) In workplace, I had ever worked with a system call DVB quality test system, which deals with digital video quality check.
4) There is no risk foreseen, as this project would only involve a PC with MATLAB® installed and a lot of graphical and text data to be collected for reporting.

- In order to complete and achieve the objective of the project successfully, I have noted the following important points:

1) Much have to be learnt on digital image processing & acquisition and related topics/journals that can be obtained from the libraries or internets. Dr Cai has recommended 2 books, "Digital image processing" and "Digital image processing using MATLAB®", both by Gonzalez, as good reference guides.
2) Will have to spend much time on the console, to learn as well as to apply the MATLAB® software (available in CSP, Singapore Polytechnics) to investigate the quality measurement algorithms. Need to track the time spent and project schedule carefully in order to complete the project on time.

- I have understood the project scope and requirement of this project after the first 2 meetings with Dr Cai. I had also attended the MATLAB® workshop conducted by Dr Lim Boon Lum. I would expect to come across some difficulties during the development of the project. The following are some of the arrangement discussed with my tutor:

1) To have regular meeting with tutor, at least once a month to report on the progress as well as discuss on any problem encountered.
2) Other communication links through emails and phone calls.
3) Upon completing the initial report, to further discuss with tutor on the strategy in working on the project efficiently.

5 Technical Reporting

5.1 Critical analysis and explanation of the project

In this project, the test images used for experimenting are natural sceneries, human beings and animals which are commonly seen in our daily lives. We did not take into accounts those static images like medical x-rays pictures and scientific pictures with obvious contrast transitions, thus the new cost function for analyzing image quality **may not** be applicable to this group of images, other methods may be further studied and proposed which is not in this project scope.

Furthermore, the new cost function implemented is purely derived from some of the statistic difference matrices like MSE, MAE, SNR or PSNR only. More accurate derivations can also include other factors like biological vision characteristics base on the density and sensitivity of cone receptors and ganglion cells (10), which play important roles in determining the ability of our eyes to resolve what we see; and also the complexity to fully understand what the present psychophysical(11) means.

The evaluation carried out in this project mainly used gray image or intensity type JPEG compressed images for comparison; a few of other distortion through mean shift, contrast stretching, salt-pepper noise, speckle noise, Gaussian noise, blurring and colour images can be tested with the new cost functions for further improvements and investigations.

This project shall serve as a further step in improving the existing quality matrices like SNR and PSNR. It also provides the fundamental skill and knowledge for further research in image assessment.

5.2 Method of design

The steps in developing the method of design are listed below; this was discussed during the initial meeting with the project supervisor (fig 1):

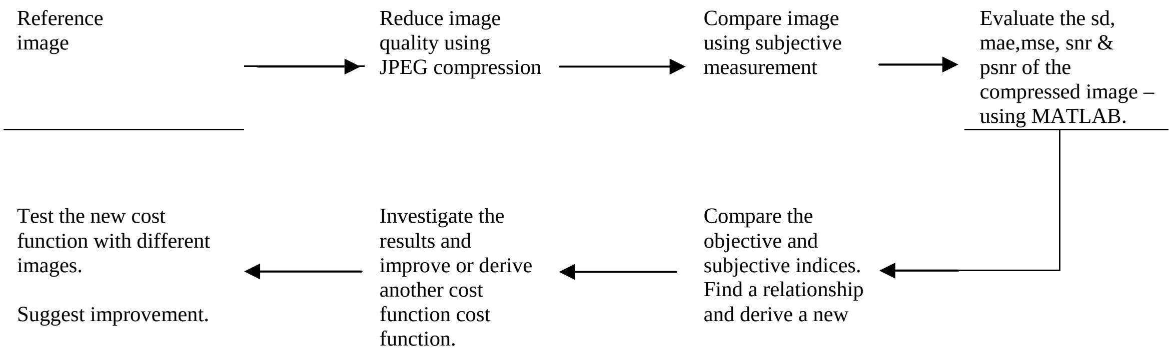


Figure 1 – block diagram shows the proposed methodology of deriving a new cost function

<u>Proposed methodology of deriving a new cost function:</u>

1. Selection of original reference test images which provides a good representation and comparison of the images that we will see in our daily lives. Four reference images were used: Baboon, Bird, Boat & Lena images.

2. Generation and arrange in order of the image distortions using JPEG compression methods of different weightings, scales of 5 to 95 in steps of 10 were used.

3. To carry out survey with a group of 10 observers on the compressed image and classified these images in order of clarity and acceptability. This is term subject quality image measurement. Special instructions were given to the observers on the method of classifications.

4. To create algorithms using MATLAB software to generate the objective matrices: standard deviation (sd), MSE, MAE, SNR & PSNR for all the compressed images reference to each of the original image.

5. With the data collected, comparisons will be made between the subjective and objective quantities obtained earlier, only the SD, SNR and PSNR were chosen in deriving. Then find a relation in the terms that we could use to generate a new cost function that can correlate better with subjective measurements.

6. With the new cost function implemented above, we will test it with various test images and compare the results with SNR or PSNR to check if it is better.

7. A further investigation and derivation will be carried out if the new cost function does not fare well.

8. Suggest improvement where necessary.

5.3 Selection of test images

The original reference images selected are shown in the four figures (fig 2.1 to 2.4)

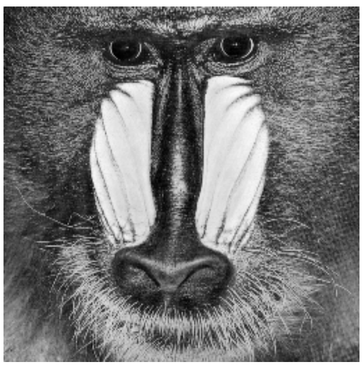


fig. 2.1 baboon.bmp

fig. 2.2 bird.tif

fig. 2.3 boat.tif

fig. 2.4 lena.tif

These 4 images were chosen as they represent images of various smoothness, coarseness and regularity. For example, the baboon and boat images show images with most area consisting of high details and frequency, i.e there are great changes in variation of intensity between neigbouring pixels. On the other hand, the bird and lena images exhibit low to medium details and most regions in these images contain small or little changes in variation of intensity between neigbouring pixels.

These images have sizes of 256x256 or 512x512 pixels, the equal in number of rows and columns and length of 2^n , eg. $256=2^8$ allows easy data manipulations using MATHLAB tools.

5.4 Reduction of image quality using JPEG compression

JPEG compression is most frequently used in image transformation and compression using discrete cosine transformation (DCT). Below block diagram illustrated the process using DCT (fig 3):

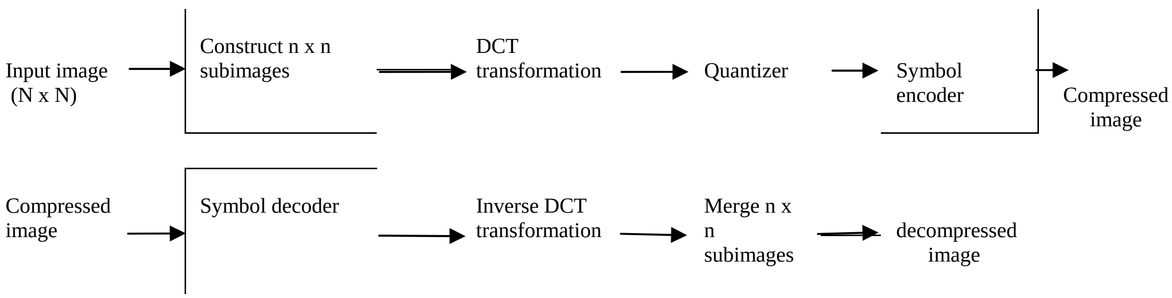


Fig 3 a typical DCT transform coding use in JPEG compression

The JPEG compression will increase distortions after recovering the original image though DCT transformer, eg. blockiness and blurring, depending on the scale of compression.

In this step of the project, the four different images listed in figures 1.1 to 1.4 will be subjected to JPEG compression using MATLAB application. This can be achieved using a simple command stated below:

```
>>imwrite(f, 'baboon5.jpg', 'quality', 5);
```

where f is the original image, here we chose *baboon.bmp*; *baboon5.jpg* is the new compressed image created from the original image with a compressed quality of index 5. Figure 4.1 and 4.2 shows the original and compressed images respectively:

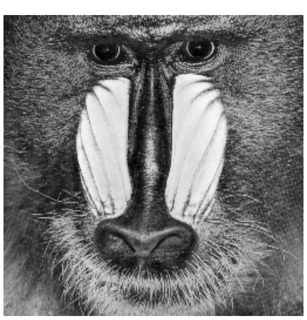


fig. 4.1 baboon.bmp fig. 4.2 baboon5.jpg

An m-file, named *CompareQuality.m* (Appendix 3) was written to speed up the process of generating the compressed image, of quality index 5-95 in steps of 10, for the four different reference images.

Below shows some figures (fig 5.1 to 5.4) obtained from JPEG compressing the *lena.tif* image with different scale levels.


fig 5.1 original image


fig 5.1 compressed scale 95


fig 5.1 compressed scale 55


fig 5.1 compressed scale 5

The calculated objective indices are listed in table 1.1 to 1.4 for the four reference images that follows:

JPEG scale	5	15	25	35	45	55	65	75	85	95
variance	3796	3796	3796	3796	3796	3796	3796	3796	3796	3796
std deviatn	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61
mae	20.53	16.39	14.34	12.66	11.32	10.13	8.64	6.72	4.31	1.50
mse	752.3	493.2	379.1	290.5	228.6	179.6	128.0	75.70	30.44	3.78
snr	13.36	15.19	16.33	17.49	18.53	19.58	21.05	23.33	27.29	36.34
psnr	19.37	21.20	22.34	23.50	24.54	25.59	27.06	29.34	33.30	42.35

Table 1.1 shows the variance, standard deviation of the original *baboon.bmp* image, and objective quality measurement indices mae, mse, snr & psnr of JPEG compression scale 0 to 95.

JPEG scale	5	15	25	35	45	55	65	75	85	95
variance	2117	2117	2117	2117	2117	2117	2117	2117	2117	2117
std deviatn	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01
mae	6.74	3.52	2.79	2.45	2.24	2.08	1.91	1.71	1.44	0.93
mse	86.14	26.47	16.68	12.69	10.51	8.90	7.35	5.72	3.87	1.60
snr	23.16	28.29	30.29	31.48	32.30	33.02	33.85	34.94	36.64	40.48
psnr	28.78	33.90	35.91	37.10	37.91	38.64	39.47	40.55	42.26	46.10

Table 1.2 shows the variance, standard deviation of the original *bird.tif* image, and objective quality measurement indices mae, mse, snr & psnr of JPEG compression scale 0 to 95.

JPEG scale	5	15	25	35	45	55	65	75	85	95
variance	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738
std deviatn	52.32	52.32	52.32	52.32	52.32	52.32	52.32	52.32	52.32	52.32
mae	9.34	5.35	4.31	3.78	3.43	3.16	2.86	2.52	2.05	1.20
mse	162.1	59.91	39.15	29.62	24.06	20.10	16.20	12.19	7.68	2.51
snr	21.18	25.50	27.35	28.56	29.46	30.25	31.18	32.42	34.42	39.27
psnr	32.07	36.39	38.24	39.45	40.36	41.14	42.07	43.31	45.31	50.16

Table 1.3 shows the variance, standard deviation of the original *boat.tif* image, and objective quality measurement indices mae, mse, snr & psnr of JPEG compression scale 0 to 95.

JPEG scale	5	15	25	35	45	55	65	75	85	95
variance	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290
std deviatn	47.85	47.85	47.85	47.85	47.85	47.85	47.85	47.85	47.85	47.85
mae	8.10	4.57	3.74	3.33	3.08	2.89	2.67	2.41	2.04	1.25
mse	120.4	41.69	27.79	21.81	18.43	16.00	13.48	10.78	7.45	2.72
snr	21.67	26.27	28.03	29.09	29.82	30.43	31.18	32.15	33.75	38.12
psnr	33.36	37.97	39.73	40.78	41.51	42.13	42.87	43.84	45.44	49.82

Table 1.4 shows the variance, standard deviation of the original *lena.tif* image, and objective quality measurement indices mae, mse, snr & psnr of JPEG compression scale 0 to 95.

5.5 Compare images using subjective quality measurement

For simplicity, I had devised a criterion of quantifying the quality listed below, adapted from Mean Opinion Score (MOS) base on human visual system:

1. Viewing distance 0.5m, to look out for amount of blockiness and distortions when checking the quality.
2. Observers will asked to view the original image for 3 sec each time before they viewed another compressed image.
3. Observers will select the best quality image from the list of compressed images and give a rating of 1.
4. The worst image will next be identified with a rating of 10.
5. After that, observers will list the rest of the images in order of quality rating from 2 to 8.

6. Finally the observers were asked to identify 3 levels of acceptability of all the images:
   - Very acceptable (high quality): A
   - Just acceptable (considerable quality): B
   - Not acceeptable (obvious distortion): F

   The alphabet grading, A,B & F were then recorded besides each of the corresponding rating number obtained in steps 4 & 5.
7. The overall data were recorded, based on majority common opinion for analysis (see results in table 2). Other results of less popular opinion were discarded.

JPEG scale	5	15	25	35	45	55	65	75	85	95
Baboon	10-F	9-F	8-F	7-F	6-F	5-B	4-B	3-B	2-A	1-A
Bird	10-F	9-F	8-F	7-F	6-F	5-F	4-F	3-F	2-B	1-A
Boat	10-F	9-F	8-F	7-F	6-F	5-B	4-B	3-A	2-A	1-A
Lena	10-F	9-F	8-F	7-F	6-F	5-F	4-B	3-B	2-A	1-A

Table 2 – rating of image quality through subjective measurement collected from 10 observers.

5.6 Generation of MSE, MAE, SNR and PSNR for the compressed images

The standard statistical objective quality are show below:

$$\text{MSE} = \frac{1}{NM}\sum_{\vec{x}} e(\vec{x})^2$$

$$\text{MAE} = \frac{1}{NM}\sum_{\vec{x}} |e(\vec{x})|$$

$$\text{SNR} = 10\log 10\frac{\frac{1}{NM}\sum_{\vec{x}} I(\vec{x})^2}{\text{MSE}}$$

$$\text{PSNR} = 10\log 10\frac{255^2}{\text{MSE}}$$

where $e(\vec{x})$ is the error matrix between pixels of original and distorted images, image size is *N* rows by *M* columns, and MSE is the mean square error.

The objective measurement results were already generated in paragraph 5.4 using the m-file *CompareQuality.m* , here we demonstrate how they were evaluated using the command window in MATLAB.

The commands used in MATLAB to generate the indices are quite straight forward:
Example:

```
>> I= imread( 'lena.tif' ) ;                 % store reference image data in I (512x512 image)
>> I1=imread( 'lena50.jpg' ) ;               % store compressed image data in I1
>> I2 =abs( double(I)-double( I1) ) ;        % calculate the error matrix
>> var= var( I( :),1) ;                      % calculate the variance
>>sd=std(  I ( :),1) ;                       % calculate the std variation
>>mse=1/(512^2)*sum( I2(:).^2) ;             % calculate the mse
>>snr=10*log10( sum( I (:).^2) / (512^2)/mse) ;  % calculate the snr
>>psnr=10*log10( 511^2/mse) ;                % calculate the psnr
```

The results evaluated here and the subjective results are combined in table 3.1 to table 3.4 for analysis in the next step.

5.7 Comparison & analysis of data collected

Tables3.1 to 3.4 listed all the measure results obtained four the reference images, baboon, bird, boat & lena. The data had been grouped under *'just failed'* , *'just best'* , and all the data under 'acceptable' subjective measurements(red , green and blue circles) for easy manipulations and analysis. That means the number of quality levels had been reduced to three.

From the results we can observe a few relationships:

1. The SNR and PSNR indices were represented by smaller value and reasonable dynamic range, and they exhibits linear function; while the MAE and MSE have non linear characteristics, high dynamic range as well as consisting of large numbers.

2. As the standard deviation of each reference image increases, the acceptance subjective measurement data tends to be lower too. For example, the baboon image with standard deviation of 61.61 is acceptable by observers with SNR: 21.05 and PSNR: 27.06 (see table 3.1) while the bird image with standard deviation of 46.01 has values of SNR: 36.64 and PSNR: 42.26 as acceptable.

3. The dynamic range of SNR and PNSR between the 'just failed' and 'just best' is higher as standard deviation increases, as observed for baboon: 5.8dB for standard deviation of 61.61 and boat/lena have dynamic range of about 3dB with standard deviation of 52.3 and 47.9 respectively. For the bird image, it could exhibits the same characteristics if we take more measurement between JPEG compression scale between 85 and 95.

4. The ‘acceptable’ level for baboon image has values of only about 27dB PSNR and 21dB SNR, while the rest have values of about 40dB and 30dB respectively for PSNR and SNR respectively. The baboon image also has relatively high standard deviation as compared to other images.

‘just failed’ ‘acceptable’ ‘just best’

JPEG scale	5	15	25	35	45	55	65	75	85	95
Subject. results	10-F	9-F	8-F	7-F	6-F	5-B	4-B	3-B	2-A	1-A
Ref std dev	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61	61.61
mae	20.53	16.39	14.34	12.66	11.32	10.13	8.64	6.72	4.31	1.50
mse	752.3	493.2	379.1	290.5	228.6	179.6	128.0	75.70	30.44	3.78
snr	13.36	15.19	16.33	17.49	18.53	19.58	21.05	23.33	27.29	36.34
psnr	19.37	21.20	22.34	23.50	24.54	25.59	27.06	29.34	33.30	42.35

Table 3.1 - shows the subjective and objective quality measurement results for **baboon** image of different compression scale.

JPEG scale	5	15	25	35	45	55	65	75	85	95
Subject. results	10-F	9-F	8-F	7-F	6-F	5-F	4-F	3-F	2-B	1-A
Ref std dev	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01	46.01
mae	6.74	3.52	2.79	2.45	2.24	2.08	1.91	1.71	1.44	0.93
mse	86.14	26.47	16.68	12.69	10.51	8.90	7.35	5.72	3.87	1.60
snr	23.16	28.29	30.29	31.48	32.30	33.02	33.85	34.94	36.64	40.48
psnr	28.78	33.90	35.91	37.10	37.91	38.64	39.47	40.55	42.26	46.10

Table 3.2 - shows the subjective and objective quality measurement results for **bird** image of different compression scale.

JPEG scale	5	15	25	35	45	55	65	75	85	95
Subject. results	10-F	9-F	8-F	7-F	6-F	5-B	4-B	3-A	2-A	1-A
Ref std dev	52.32	52.32	52.32	52.32	52.32	52.32	52.32	52.32	52.32	52.32
mae	9.34	5.35	4.31	3.78	3.43	3.16	2.86	2.52	2.05	1.20
mse	162.1	59.91	39.15	29.62	24.06	20.10	16.20	12.19	7.68	2.51
snr	21.18	25.50	27.35	28.56	29.46	30.25	31.18	32.42	34.42	39.27
psnr	32.07	36.39	38.24	39.45	40.36	41.14	42.07	43.31	45.31	50.16

Table 3.3 - shows the subjective and objective quality measurement results for **boat** image of different compression scale.

JPEG scale	5	15	25	35	45	55	65	75	85	95
Subject. results	10-F	9-F	8-F	7-F	6-F	5-F	4-B	3-B	2-A	1-A
Ref std dev	47.85	47.85	47.85	47.85	47.85	47.85	47.85	47.85	47.85	47.85
mae	8.10	4.57	3.74	3.33	3.08	2.89	2.67	2.41	2.04	1.25
mse	120.4	41.69	27.79	21.81	18.43	16.00	13.48	10.78	7.45	2.72
snr	21.67	26.27	28.03	29.09	29.82	30.43	31.18	32.15	33.75	38.12
psnr	33.36	37.97	39.73	40.78	41.51	42.13	42.87	43.84	45.44	49.82

Table 3.4 - shows the subjective and objective quality measurement results for **lena** image of different compression scale.

From the observations, we could reduce the data further and build a correlation table shows in tables 4.1 and 4.2. Only the standard deviations, PSNR and SNR indices were used for further analysis. The values for 'just failed' and 'just best' were directly taken from table 3.1 to 3.4; as for the 'acceptable' group which consists of more than one PSNR and SNR values for some images, they were replaced by their mean values.

Subjective level	PSNR			
Image:	baboon	boat	lena	bird
Std deviation	**61.61**	**52.32**	**47.85**	46.01
'just failed'	18.53	29.46	30.43	34.94
'acceptable'	21.32	30.715	31.665	36.64
'just best'	27.29	32.42	33.75	40.48

Table 4.1 – SNR values compare with subjective measurement

Subjective level	PSNR				
Image:	baboon	boat	lena	bird	**Proposed index**
Std deviation	**61.61**	**52.32**	**47.85**	**46.01**	
'just failed'	24.54	40.36	42.13	40.55	**40**
'acceptable'	27.33	41.605	43.355	42.26	**42**
'just best'	33.3	43.31	45.44	46.1	**44**

Table 4.2 - PSNR values compare with subjective measurement

According to the results in tables 4.1 and 4.2, the SNR and PSNR show similarities in terms of dynamic range and linearity, thus we will only deal with PSNR to obtain a relationship function. As the PSNR for baboon deviates quite far from other images, we could devise a linear function of standard deviation against PSNR values. By applying this function on the PSNR, we could obtain a more consistent value across all natural images. A new index 40, 42 & 44, were proposed base on the new function to exhibit relationship with subjective indices 'just failed', 'acceptable' and 'just best'. This new indices were chosen as they represents most pictures taken in real life.

With the new proposed index we tabulate a table for the difference between PSNR and the new proposed index as shown in table 4.3.

Subjective level	PSNR - Proposed index			
Image:	baboon	boat	lena	bird
Std deviation	61.61	52.32	47.85	46.01
'just failed'	-15.46	0.36	2.13	0.55
'acceptable'	-14.67	-0.395	1.355	0.26
'just best'	-10.7	-0.69	1.44	2.1

Table 4.3 – Difference values between PSNR and proposed index

A graph was plotted as shown in fig 6, for values of PSNR against standard deviation for the three subjective levels to find a relationship.

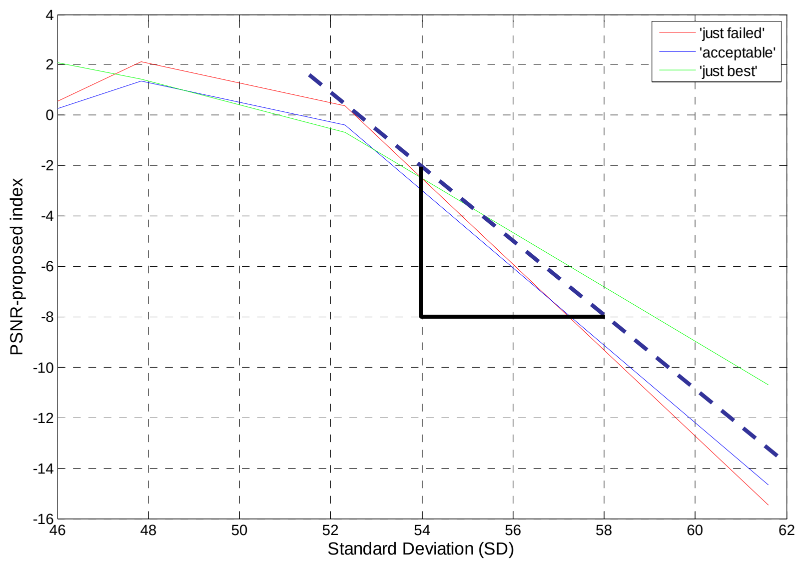


fig 6 – graph plotted for delta PSNR against Standard deviation for the three subjective levels .

The delta PSNR values are quite constant above standard deviation of 52. For SD values from 52 to 62, we could devise a linear equation, so as to bring these values closer to those above SD of 52. The gradient of the lines from SD of 52 to 62 is calculated as follows:
Using the dotted line as estimation, gradient m=(-2-(-8))/(54-58)= **-1.5**
The interception, c, can be found by c=delta PSNR-1.5*SD=-2-(-1.5*54)=**79**
Thus a new cost function (PSNR*) was derived base on the following equation, where we change PSNR values falling above 52dB accordingly :

SD < 62 PSNR* = PSNR +1.5*(SD) - 79
SD ≥ 62 PSNR* = PSNR+0 (no change in its value)

With the equation above we could be able to produce consistent readings across all types of images by determining its SD.

5.8 Testing of of new cost function with the reference images

The new cost function derived in section 5.7 was implemented with MATLAB as shown below:

```
>>I1=double('lena.tif');                % store reference image data in I (512x512 image)
>>I2=double('lena50.jpg'));             %store compressed image data in I1 matrix
>> D=abs(I1-I2);                        % calculate the error
>> stddev_I=std(I1(:),1);               % calculate the std variation
>> mse=1/(512^2)*sum(D(:).^2);          % calculate the mse
>> psnr=10*log10((511)^2/mse);          % calculate the psnr
>> if stddev_I>=62                      % if std deviation > or = 62
   y=psnr;                              % psnr no change
else                                    % if std deviation < 62
   y=psnr+1.5*(stddev_I)-79;            % psnr* = psnr +1.5*(SD) - 79
end
```

An m-file, named NewQualityFunction.m (Appendix 4) was written to speed up the process of generating the compressed image, of quality index 5-95 in steps of 5, for the four different reference images as well as their new PSNR index (PSNR*) using the new cost function. The results were extracted and shown in table 5. They are highlighted so as to relate to subjective measurement.

Red : unacceptable
Blue: acceptable
Green: best quality

JPEG scale	5	15	25	35	45	55	65	75	85	95
Baboon	32.78	34.62	35.76	36.91	37.96	39.00	40.47	42.76	46.71	55.77
Bird	18.79	23.91	25.92	27.11	27.92	28.65	29.48	30.56	32.27	36.11
Boat	31.56	35.88	37.72	38.94	39.84	40.62	41.56	42.79	44.80	49.65
Lena	33.36	37.97	39.73	40.80	41.51	42.13	42.87	43.8	45.45	49.82

Table 5 – new PSNR (PSNR*) values obtained and highlighted to show its subjective index.

By rearranging table 5 by their subjective, we could obtain a clearer comparison as shown in table 6.

JPEG scale	unacceptable					acceptable			best quality	
Baboon	19.37	21.20	22.34	23.50	24.54	25.59	27.06	29.34	33.30	42.35
Bird	37.10	37.91	38.64	39.47	40.55		42.26		46.10	
Boat	32.07	36.39	38.24	39.45	40.36	41.14	42.07		43.31	45.31
Lena	30.75	32.51	33.56	34.29	34.90		35.65	36.62	38.22	42.60

Table 6 – rearrangement of PSNR* values against subjective index.

From table 6, we notice that the new PSNR (PSNR*) under acceptable rating for baboon image were adjusted to a reasonable values that is comparable to other test images. We could tell that any values of PSNR* will produce a good image quality. However there are still some deficiencies using this new cost function:
1. The PSNR* were quite low for bird image, at PSNR* of 36.11 it should be of best quality.
2. On the other end, the lena compressed images should be considered bad although the PSNR* shows values of 40.78, 41.51 and 42.13.

Other than these, the new cost function proved to be useful for measuring baboon and boat images.

5.9 Improvement - Propose another new cost function

After generating the new cost function, a discussion on the method and results obtained was carried out with the project tutor. He suggested that other methods of comparison can also be used beside standard deviations, eg. comparisons of image using histogram and image frequencies. It was also advised that by breaking the full image into small subimages could improve the accuracies of calculations as well as reducing any sudden change in contrast.

I had chosen the comparisons of HVS with image frequencies. A more detail study on HVS and image frequencies related material was to be done.

5.10 The Discrete Cosine Transform (DCT) (9)

The discrete cosine transform (DCT) is actually a simplified and efficient method used in JPEG image compression, it is adapted from discrete fourier transform (DFT), it breaks down an image into smaller parts and arranging them in differing importance (base on frequency bands), which is proportionate to human visual quality. That is, it transform image from the spatial domain to the frequency domain, see fig 7.

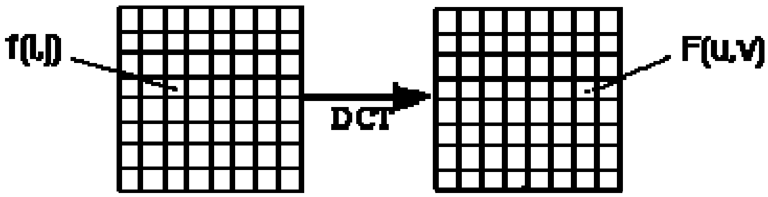


Fig 7 - DCT Encoding

The general equation for a 2D (*N* by *M* image) DCT is defined by the following equation:

$$F(u,v) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \left(\frac{2}{M}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \Lambda(i).\Lambda(j).cos\left[\frac{\pi.u}{2.N}(2i+1)\right] cos\left[\frac{\pi.v}{2.M}(2j+1)\right].f(i,j)$$

and the *inverse* 2D DCT transform is $F^{-1}(u,v)$, i.e.:
where

$$\Lambda(\xi) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for} \xi = 0 \\ 1 & \text{otherwise} \end{cases}$$

The basic algorithm of the DCT is as follows:

1. The input image is N rows by M column.

2. f(i,j) is the intensity of the pixel in row i and column j.

3. F(u,v) is the DCT coefficient in row k1 and column k2 of the DCT matrix.

4. For most images, much of the signal energy lies at low frequencies; these appear in the upper left corner of the DCT.

5. Compression is achieved since the lower right values represent higher frequencies, and are often small - small enough to be neglected with little visible distortion.

6. The DCT input is an 8 by 8 array of integers. This array contains each pixel's gray scale level.

7. 8 bit pixels have levels from 0 to 255

8. Therefore an 8 point DCT would be:
where

$$\Lambda(\xi) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for} \xi = 0 \\ 1 & \text{otherwise} \end{cases}$$

9. F[0,0] is define as DC and AC components.

10. The output array of DCT coefficients contains integers; these can range from -1024 to 1023.

In computation, it is more efficient and simpler to implement and to regard the DCT as a set of **basis functions** which given a known input array size (8 x 8) can be pre-computed and stored. This involves simply computing values for a convolution mask (8 x8 window) that get applied (summ values x pixelthe window overlap with image apply window accros all rows/columns of image). The values as simply calculated from the DCT formula. The 64 (8 x 8) DCT basis functions are illustrated in Fig 8. DCT is similar to the Fast Fourier Transform (FFT), but can approximate lines well with fewer coefficients

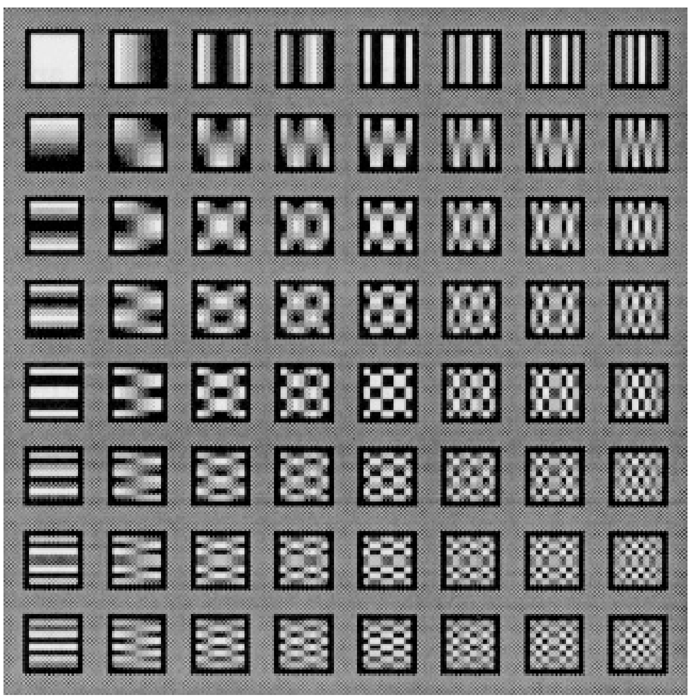


Fig 8 DCT basis functions

5.11 Human visual system (HVS)

There are many HVS characteristics that may influence the human visual perception on image quality. Although HVS is too complex to fully understand with present psychophysical means, the incorporation of even a simplified model into objective measures reportedly leads to a better correlation with the response of the human observers. Many algorithms have successfully employed HVS models (14).

Human often perceive increase in contrast as improved in quality in an image. (DIP Pg 61, 62) Several different spectral densities may be perceived by us as identical. When the colors created by these spectral densities are placed side by side, we find it impossible to distinguish between them. (pg 901) The human eye can resolve details as small as 1 minute of arc under normal light conditions. This is called the visual acuity. If we view a very small area from a normal viewing distance, our eyes cannot see the details in the area and end up integrating them, such that we only see an average intensity coming from the area (13).

5.12 Implementation of another cost fuction

Base on the further literature studies in DCT and HVS, a method of generating a new or may be better image quality measurement cost function could be realized by taking into accounts the following related variables:

1. *PSNR from subjective measurement*.
In this process, due to the time constraint to complete it in time and gathering observers, I had done the measurements base on my personal opinion with advice from the project supervisor. Only the PSNRs for acceptable, meaning "just good", quality image were collected. As most images consist of both high, medium and low frequencies, this time round only selective regional images were taken from some reference image according to their frequencies.

2. *Frequencies of image to be measured*.
These values were collected through evaluation using DCT function on subimages.

3. *Size of image to be measured*.
It was suggested that smaller subimages broke down from the full image will reduce error and produce more accurate results; and the row by column size has to be $2^{\wedge n}$, for simplifying DCT process, preferably 8x8 or 16x16. (12)

Algorithm for implementing another new cost function:

1. PSNR readings were taken down for some test images taken from regions of baboon and lena images which were deemed acceptable. The regional image taken consisted of low, high and medium frequencies. Figures 9.1 & 9.2 show the regions taken.

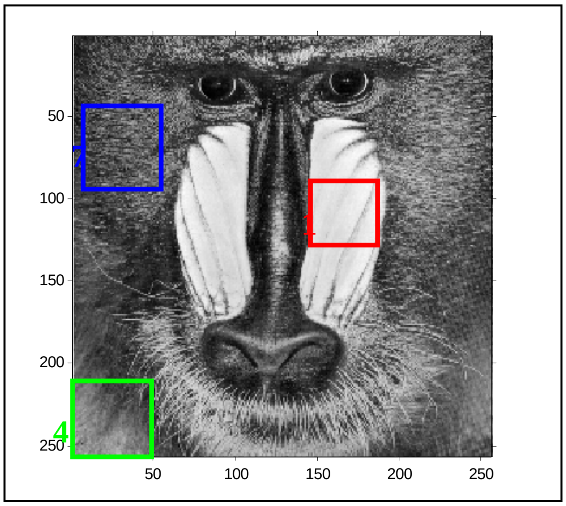


Fig 9.1 - baboon's regions taken for subjective measurement

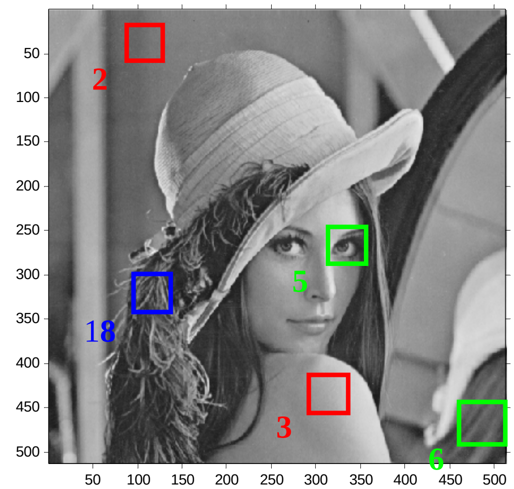


Fig 9.2 - lena's regions taken for subjective measurement

2. Reference image was broken down into small blocks of subimage of 8x8 pixels using MATLAB.

3. Each block was in turn transformed by DCT. A simple program using MATLAB is written for this process :

4. The DCT transformed subimage was arranged in regions of low frequencies(LF), medium frequencies(MF) and high frequencies (HF) as in fig 10 below, pixel 1 contains the DC component:

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64
65	66	67	68	69	70	71	72

Fig 10 - DCT transformed subimage – red: LF, green: MF and blue: HF

5. By setting a suitable threshold, 8 was selected here, 1s and 0s were produced to show the characteristic of the subimage in term of frequencies, this is carried out using MATLAB program. See results from figures 11.1 to 11.24. The circles in the figures mean visible quality error

eg.

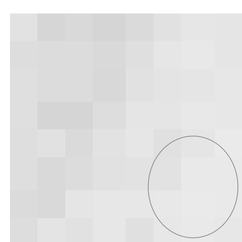
```
I=imread('baboon.bmp');        % read reference image
I2=I(101:108,161:168);         % 8x8 region selected
QUALITYmeas1(I2,100);          % measure PSNR with compression 100
A=freq_level(I2);              % measure the LF, MF and HF component
```

Where QUALITYmeas1, freq_level are .m functions written. (appendix 5)

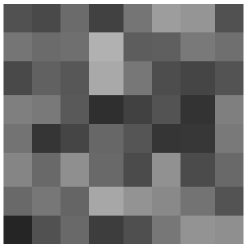
6. The ones (‘1’) that were grouped under the 3 regions were summed up for each region.

Reference image(region 1)
LF, MF, HF: 5,1,0
Fig 11.1

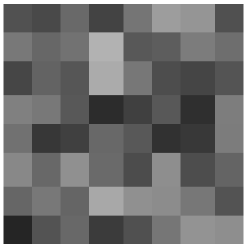
JPEG compression 100
(PSNR: 29.07, acceptable)
Fig 11.2



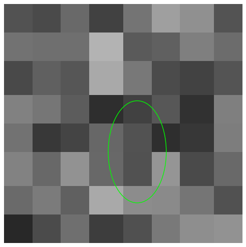
JPEG compression 98(failed)
Fig 11.3



Reference image(region7)
LF, MF, HF: 13,30,11
Fig 11.4



JPEG compression 94
(PSNR: 10.78, acceptable)
Fig 11.5

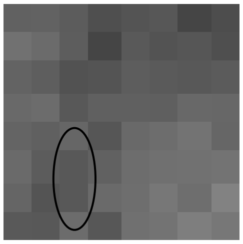


JPEG compression 92(failed)

Fig 11.6

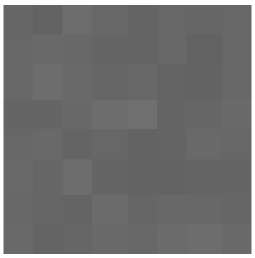
Reference image(region4)
LF, MF, HF: 7,9,1
Fig 11.7

JPEG compression 98
(PSNR: 19.62, acceptable)
Fig 118

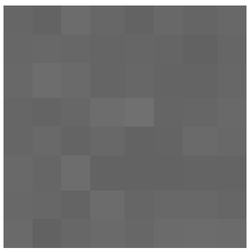


JPEG compression 96(failed)

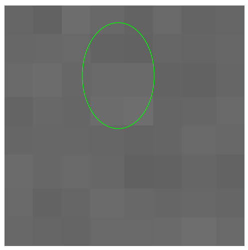
Fig 11.9



Reference image(region2)
LF, MF, HF: 0,1,0
Fig 11.10

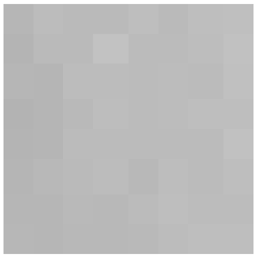


JPEG compression 98
(PSNR: 24.59, acceptable)
Fig 11.11

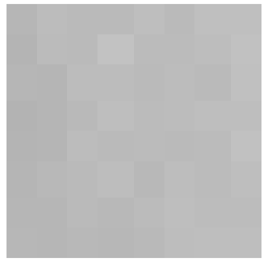


JPEG compression 96(failed)

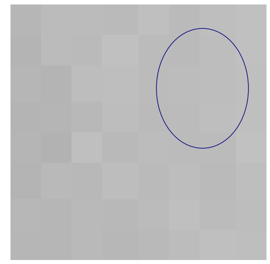
Fig 11.12



Reference image(region3)
LF, MF, HF: 2,0,0
Fig 11.13

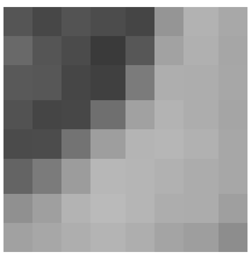


JPEG compression 99
(PSNR: 25.26, acceptable)
Fig 11.14



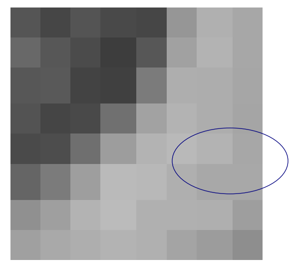
JPEG compression 97(failed)

Fig 11.15



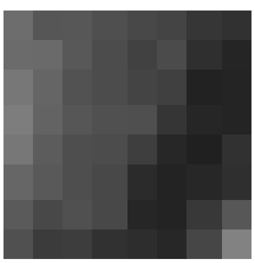
Reference image(region5)
LF, MF, HF: 14,14,0
Fig 11.16

JPEG compression 98
(PSNR: 19.72, acceptable)
Fig 11.17

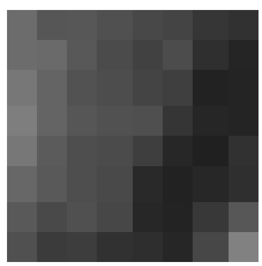


JPEG compression 96(failed)

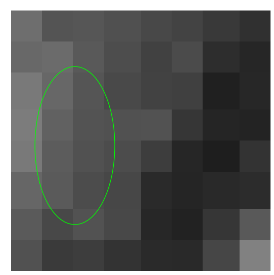
Fig 11.18



Reference image(region8)
LF, MF, HF: 12,11,3
Fig 11.19

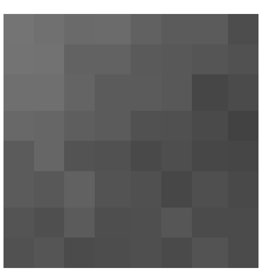


JPEG compression 98
(PSNR: 21.58, acceptable)
Fig 11.20

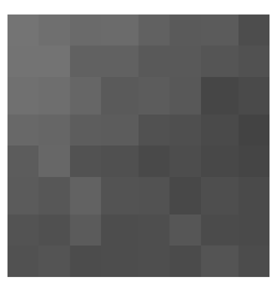


JPEG compression 96(failed)

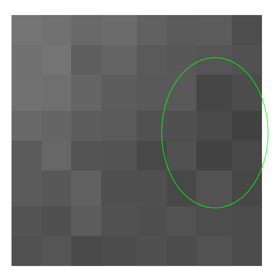
Fig 11.21



Reference image(region6)
LF, MF, HF: 6,2,3
Fig 11.22



JPEG compression 98
(PSNR: 19.33, acceptable)
Fig 11.23



JPEG compression 96(failed)

Fig 11.24

7.1 A table was generated to consolidate all the data listed in table 7.

Region	LF	MF	HF	PSNR
3	2	0	0	25.26
2	0	1	0	24.59
1	5	1	0	29.07
5	14	14	0	19.72
4	7	9	1	19.62
6	6	2	3	19.33
8	12	11	3	21.58
7	13	30	11	10.78

Table 7 - Frequencies components for each regional image

7.2 The proportionate ratio were evaluated in table 8, arrange in oreder of decreasing PSNR.

	LF	MF	HF	PSNR
Freq components	1	0	5	25.26
ratio	0.17	0.00	0.83	
Freq components	0	0	2	24.59
ratio	0.00	0.00	1.00	
Freq components	1	0	0	29.07
ratio	1.00	0.00	0.00	
Freq components	11	3	12	19.72
ratio	0.42	0.12	0.46	
Freq components	14	0	14	19.62
ratio	0.50	0.00	0.50	
Freq components	9	1	7	19.33
ratio	0.53	0.06	0.41	
Freq components	2	3	6	21.58
ratio	0.18	0.27	0.55	
Freq components	30	11	13	10.78
ratio	0.56	0.20	0.24	

Table 8 - Frequencies components for each regional image

From the results in table 8, we generated a relationship based on the following equation:

PSNR* = (ratio_LF*a + ratio_MF*b + ratio_HF*c) * PSNR,

Where a, b & c are constant to be found by trial and error.

It was found that when a=0.62, b=0.86 & c=2.2, which were found out through a systematic ways to get a smallest deviation of PSNR** of the 8 regional images. Athough the smallest deviation evaluated is still quite big, 9.57dB, we will still try it out to check if it could work well to obtain a better objective measurement index.

Thus, this new equation was used for the next final step of image measurement processing:

PSNR** = (ratio_LF*0.62 + ratio_MF*0.86 + ratio_HF*2.2)* PSNR

8. Both the reference and compressed images were broken down into non-overlapping blocks of 8 by 8 pixels and compared, PSNR was evaluated for each individual block or subimage, the 3 frequency components of LF,MF & HF for each block were evaluated from the reference subimage. The equation :

PSNR** = (ratio_LF*0.62 + ratio_MF*0.86 + ratio_HF*2.2)* PSNR ,

was applied to each individual block, and the mean of sum of PSNR** values for all blocks in the whole image will be the new PSNR base on this cost function. Below table shows the result gathered and a comparison can be made with the subjective measurement data collected in section 5.7.

9. An m-file, named NewQualityFunction1.m (Appendix 6) was written to speed up the process of generating the compressed image, of quality index 5-95 in steps of 5, for the four different reference images as well as their new PSNR index (PSNR*) using this new cost function base on image frequencies. The results were extracted and shown in table 9. They are highlighted so as to relate to subjective measurement.
Red : unacceptable
Blue: acceptable
Green: best quality

JPEG scale	5	15	25	35	45	55	65	75	85	95
Baboon	8.63	10.78	11.96	13.03	13.97	14.93	16.30	18.51	22.51	32.04
Bird	16.32	20.08	21.47	22.18	22.68	23.10	23.57	24.18	25.19	27.63
Boat	13.05	16.76	18.17	18.92	19.47	19.93	20.48	21.20	22.37	25.54
Lena	12.77	16.12	17.30	17.95	18.41	18.77	19.22	19.79	20.74	23.60

Table 9 – new PSNR (PSNR**) values obtained and highlighted to show its subjective index.

By rearranging table 9 by their subjective, we could obtain a clearer comparison as shown in table 10.

JPEG scale	unacceptable					acceptable			best quality	
Baboon	8.63	10.78	11.96	13.03	13.97	14.93	16.30	18.51	22.51	32.04
Bird	22.18	22.68	23.10	23.57	24.18		25.19		27.63	
Boat	13.05	16.76	18.17	18.92	19.47	19.93	20.48		21.20	22.37
Lena	16.12	17.30	17.95	18.41	18.77		19.22	19.79	20.74	23.60

Table 10 – rearrangement of PSNR** values against subjective index.

From table 10, we notice that the new PSNR (PSNR**) under acceptable rating for baboon image were adjusted to a reasonable values that is comparable to other test images (if we take the value 18.5dB). We could tell that any values of PSNR** will produce a good image quality. As compared to the PSNR* derived by SD, this new function seems to produce a better correlation to subjective measurement. Note under the best quality subjective index, the PSNR** values were quite consistant in the range of 20 to 27dB. However there are still some deficiencies using this new cost function:

1. The PSNR** values were still quite low at the unacceptable and acceptable index for baboon image.

2. The PSNR* was for the bird image was higher than the other images by about 6dB. Although still better than the previously derived PSNR*, which is about 10dB.

6 Critical Review and Reflections

Below is the consolidated results (table 11) using image quality measure index PSNR and the 2 new cost fuctions PSNR* and PSNR**. Base on observations, the PSNR rating is quite consistent for Bird, Boat & Lena images for the 3 classes of acceptabilty, but the the Baboon index is quite far out by more than 10dB for all acceptability levels. For PSNR* index using SD as comparison, although the maximum & minimum deviations are not higher than 10dB, but the results of Baboon/Boat and Bird/Lena were out by about 8dB. As for the PSNR** index, using image frequencies as to obtain a relationship, the results deviation are much lesser than the former two, except for the baboon image which deviates more at the unacceptable level.

There are many factors that could have affected the outcome of the results.
1) The subjective measurement method adopted may have many uncertainties even though clear instructions had been give. Lightings, individual preference & mood are some of the factors that were difficult or impossible to control.

2) The compressed images scales interval chosen were in steps of 2 and 5 for PSNR** and PSNR* indices, these may too have affected the results due the resolution or dynamic range of values.

JPEG scale	unacceptable					acceptable			best quality		Index
Baboon	19.37	21.20	22.34	23.50	**24.54**	25.59	**27.06**	29.34	**33.30**	42.35	PSNR
Bird	37.10	37.91	38.64	39.47	**40.55**		**42.26**			46.10	
Boat	32.07	36.39	38.24	39.45	**40.36**	41.14	**42.07**		**43.31**	45.31	
Lena	37.97	39.73	40.78	41.51	**42.13**		**42.87**	43.84	**45.44**	49.82	
Baboon	32.78	34.62	35.76	36.9	**37.96**	39	**40.47**	42.8	**46.71**	55.77	PSNR*
Bird	27.11	27.92	28.65	29.5	**30.56**		**32.27**		**36.11**		
Boat	31.56	35.88	37.72	38.9	**39.84**	40.62	**41.56**		**42.79**	44.8	
Lena	30.746	32.507	33.56	34.3	**34.904**		**35.65**	36.6	**38.223**	42.597	
Baboon	8.63	10.776	11.96	13	**13.973**	14.929	**16.3**	18.5	**22.514**	32.043	PSNR**
Bird	22.18	22.679	23.1	23.6	**24.18**	25.187	**25.19**		**27.63**		
Boat	13.05	16.764	18.17	18.9	**19.468**	19.932	**20.48**		**21.197**	21.2	
Lena	17.297	17.952	18.41	18.8	**19.224**		**19.22**	19.8	**20.742**	23.599	

Table 11 – consolidated results for PSNR, PSNR* and PSNR**

3) The number of images used as reference may not be enough to represent the wide ranges of contrast, frequencies and standard deviation in real world.

The outcome may not be as perfect as planned, however much have been learnt on the method of image compression using DCT in JPEG format. The human perception of images was also studied, i.e comparison of HVS with standard objective measurement. The digital image structure was very well understood, likewise for digital image processing and analysis using MATLAB image toolboxes. A full understanding of mathematical calculation using matrix as well as statistical studies will require to fulfill this project objective.

In the course of the project, I found out that the discipline to track and follow the schedule is important to avoid any last minute work. Another important area is to identify the critical tasks that may delay or hold up other tasks. Some of the sub tasks were not be able to complete on time due to much time spent on learning programming of MATLAB, which I only realized towards the end of the project . I could have conducted more testing and evaluations to improve on the consistencies of the new cost functions implemented; graphic user interface could not be learnt in time to add into this report. However, it will be planned to be ready before the oral presentation in mid May 2008.

I also found out that regular meetings and discussions with the project tutor can speed up the learning curve then carrying out the project alone. In fact, the supervisor provided great source of help and ideas on implementing this project, otherwise I do not think the project can be completed in time.

This project experience has also gave me an insight on the systematic way of planning the work and the skill of carrying out the works systemic and the methodology in creating algorithm on paper and the realizing it.

6.1 Objectives Reviewed

Below are the objectives to be met towards the end of the project:

1) Study the quality control benchmarks and assessments on image quality.
One of the subjective benchmark used commercial is the mean opinion score or MOS, The HVS is our terminal of image processing systems, thus the most correct method of quantifying image quality is through subjective evaluation. In practice, however, subjective evaluation needs to organize the observers to mark the distorted images, this is not efficient and costly. In this project, an adaptation from the MOS was used to produce results for comparison with objective index.

2) Evaluate the existing Image Quality measurement methods, i.e subjective and objective measurements.
The project has provided a lot of opportunities for processing, evaluations and comparisons of data gathered from subjective and objective measurements.

3) Conduct a survey with different observers to evaluate and judge some images quality.
Survey was carried out with 10 observers, data were recorderd and compared with objective quality measurement results

4) Examine, study and compare some of the objective image quality measurement algorithms available, eg. mean absolute error (MAE), mean square error (MSE), signal-to-noise ratio, or peak signal-to-noise ratio (PSNR).

5) Learn the methods of Image acquisition of image file eg. BMP, TIF & JPEG files. Using MATLAB® Image Processing and Image Acquisition Toolboxes for testing and comparing different types of standard Image Quality measurement.
This objectives was well met with the many images processing carried out through the experimental stage of the project and in implementing the new cost function.

6) Compare and review the image quality measurement results between subjective and objective measurements.
Comparison and observation were made between subjective measurement and PSNR, SNR, MAE and MSE.

7) Experiment with some new cost functions for objective image quality measurement.
All the 4 standard cost functions MAE, MSE, SNR and PSNR were experimented with different types of images and subjected to various scale of compressions.

8) Evaluate and review the different new cost functions experimented.
The results recorded from experimenting with MAE, MSE, SNR and PSNR were compared and criticized.

9) Recommend and implement a cost function that can assess image quality so that the objective measurement results correlate well with subjective measurement result.
Two cost functions were implemented, one by finding the relationship with SD of an image, the other was implemented by finding the relationship with image frequencies. Some reference images were subjected to testing with these cost functions. The results were fully recorded, reviewed and compared.

The results were not as perfect as expected, however, it rather correlates better than PSNR when comparing with subjective measurement.

6.2 Further improvement

The experiments and evaluations carried out for objective image measurement in this project were focus purely on gray images, more research have to be done in realizing it on RGB images. Higher accuracy or consistency of cost function could be implemented with experiment on more types of images as well as conducting more surveys using MOS. At present, there are already many types of objective measurement designed and proposed by researchers, these suggested methods, eg. using region of interest, ROI, method that on takes into account of the image regions that are sensitive to HVS; evaluating overlapping subimages; the foveated wavelet image quality measurement(15); edge-based structural similarity for image quality assessment(16) and the list goes on. We could study and do research on these methods which could help in providing more ideas and insights to improve on the statistic error measurement.standards.

7 Appendices

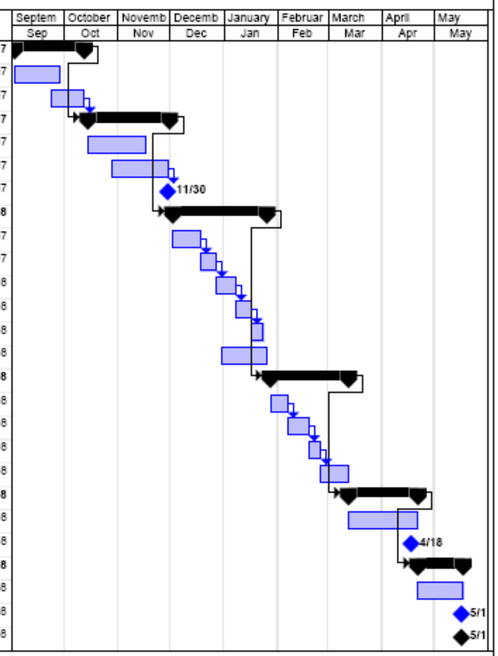
Appendix 1

Project schedule generated from Microsoft Project

UNISIM TZS402 PROJECT SCHEDULE
IMAGE QUALITY MEASUREMENT

Nov 2007

ID	Task Name	Duration	Start	Finish
1	**PROJECT START**	**30 days**	**Mon 9/3/07**	**Fri 10/12/07**
2	Project synopsis and application	20 days	Mon 9/3/07	Fri 9/28/07
3	Project approval	15 days	Mon 9/24/07	Fri 10/12/07
4	**INITIAL REPORT**	**35 days**	**Mon 10/15/07**	**Fri 11/30/07**
5	Gathering of study materials and attending Workshops	25 days	Mon 10/15/07	Fri 11/16/07
6	Start Writing Initial Report	24 days	Mon 10/29/07	Thu 11/29/07
7	Completion and submission of Initial Report (TMA01)	1 day	Fri 11/30/07	Fri 11/30/07
8	**STUDY, EXPERIMENT & DATA COLLECTION**	**40 days**	**Mon 12/3/07**	**Fri 1/25/08**
9	Study relevant literature & subjects	12 days	Mon 12/3/07	Tue 12/18/07
10	Familarise with Matlab programming	7 days	Wed 12/19/07	Thu 12/27/07
11	Experimenting different cost function	7 days	Fri 12/28/07	Mon 1/7/08
12	Designing cost function	7 days	Tue 1/8/08	Wed 1/16/08
13	Survey on subjective image quality measurement	5 days	Thu 1/17/08	Wed 1/23/08
14	Data collection	20 days	Mon 12/31/07	Fri 1/25/08
15	**IMPLEMENTATION OF COST FUNCTION**	**33 days**	**Mon 1/28/08**	**Wed 3/12/08**
16	Evaluation of cost function	8 days	Mon 1/28/08	Wed 2/6/08
17	Testing of proposed cost function	8 days	Thu 2/7/08	Mon 2/18/08
18	Improvement on proposed cost function (if any)	5 days	Tue 2/19/08	Mon 2/25/08
19	Redesign & Testing (if any)	12 days	Tue 2/26/08	Wed 3/12/08
20	**FINAL REPORT**	**28 days**	**Thu 3/13/08**	**Mon 4/21/08**
21	Start Writing Final Report	28 days	Thu 3/13/08	Mon 4/21/08
22	Completion and submission of Final Report (Final)	1 day	Fri 4/18/08	Fri 4/18/08
23	**PRESENTATION**	**20 days**	**Tue 4/22/08**	**Sat 5/17/08**
24	Prepare Powerpoint Presentation	20 days	Tue 4/22/08	Sat 5/17/08
25	Conduct Oral Presentation	1 day	Sat 5/17/08	Sat 5/17/08
26	**PROJECT COMPLETION**	1 day	Sat 5/17/08	Sat 5/17/08



Date: 18 Nov 2007
Aurthor: Lum Tuck Sang
T6120632

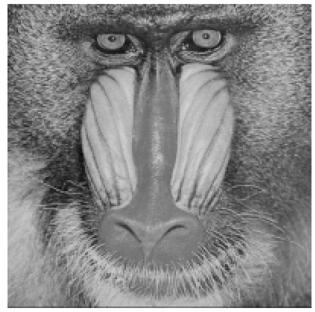
Task | Milestone | Summary

Page 1

Appendix 2

Test images

fig 1 lena.tif (512x512)



g 2 baboon.bmp(256x256)

fig 3 bird.tif(256x256)

fig 4 boat.tif(512x512)

Appendix 3

```
function Eval_results=CompareQuality(y)

% This function creates image of different quality of the original
% it uses 'lena.jpg', 'bird.jpg', 'boat.jpg' & 'baboon.jpg'as examples
%
% This function also evaluates variance & standard deviation of
reference image
% and the mae, mse, snr, psnr of image to be measured.
%
% For example: x=CompareQuality('lena.tif'), the variance,sd,mae, mse,
snr,
% psnr will be stores in array x(1:6).
% Used in Image Quality Measurement Project by Sunny LUM 15th Mar 2008

a=imread('lena.tif');
b=imread('baboon.bmp');
c=imread('bird.tif');
d=imread('boat.tif');

if isequal(a,imread(y))
img=imread(y);
w='lena';
    for q=95:-5:0
    filename = sprintf('%s%d%s',w,q,'.jpg');
    imwrite(img, filename, 'quality', q);
    end

elseif isequal(b,imread(y))
img=imread(y);
w='baboon';
    for q=95:-5:0
    filename = sprintf('%s%d%s',w,q,'.jpg');
    imwrite(img, filename, 'quality', q);
    end

elseif isequal(c,imread(y))
img=imread(y);
w='bird';
    for q=95:-5:0
    filename = sprintf('%s%d%s',w,q,'.jpg');
    imwrite(img, filename, 'quality', q);
    end

elseif isequal(d,imread(y))
img=imread(y);
w='boat';
    for q=95:-5:0
    filename = sprintf('%s%d%s',w,q,'.jpg');
    imwrite(img, filename, 'quality', q);
    end
```

```
else
    error('error');
end

    Eval_results=zeros(6,20);
        for p=0:5:95
            filename_1 = sprintf('%s%d%s',w,p,'.jpg');
            ref_img=double(imread(y));
            msr_img=double(imread(filename_1));
            dif_img=abs(ref_img-msr_img);

            var_refimg=var(ref_img(:),1);
            Eval_results(1,p/5+1)=var_refimg;

            stddev_refimg=std(ref_img(:),1);
            Eval_results(2,p/5+1)=stddev_refimg;

            mae_img=mean(dif_img(:));
            Eval_results(3,p/5+1)=mae_img;

            s=size(ref_img(:));
            if isequal(s(1,1),262144)
                mse_img=1/(512^2)*sum(dif_img(:).^2);
                Eval_results(4,p/5+1)=mse_img;

                snr_img=10*log10(sum(ref_img(:).^2)/(512^2)/mse_img);
                Eval_results(5,p/5+1)=snr_img;

                psnr_img=10*log10(511^2/mse_img);
                Eval_results(6,p/5+1)=psnr_img;

            elseif isequal(s(1,1),65536)
                mse_img=1/(256^2)*sum(dif_img(:).^2);
                Eval_results(4,p/5+1)=mse_img;

                snr_img=10*log10(sum(ref_img(:).^2)/(256^2)/mse_img);
                Eval_results(5,p/5+1)=snr_img;

                psnr_img=10*log10(255^2/mse_img);
                Eval_results(6,p/5+1)=psnr_img;

            else
                error('accept 256x256 & 512x512 images only');

            end
    end
```

Appendix 4

```
function y=NewQualityFunction(x,z)

% This new function evaluates the quality of image of different
standard
% deviations.
% x is the reference image & z is the image to be measured.
% The result is stored in y.
%
% Used in Image Quality Measurement Project by Sunny LUM
I=imread(x);
s=size(I(:));

I1=double(I);
I2=double(imread(z));
D=abs(I1-I2);

if  isequal(s(1,1),262144)
     m=512;

    elseif  isequal(s(1,1),65536)
        m=256;
        new_function=zeros(1,2);

    else
        error('accept 256x256 & 512x512 images only');
end

stddev_I=std(I1(:),1);
mse=1/(m^2)*sum(D(:).^2);
psnr=10*log10((m-1)^2/mse);
y(1,1)=stddev_I;

if stddev_I>=62
    y(1,2)=psnr;

else
    y(1,2)=psnr+1.5*(stddev_I)-79;

end
```

Appendix 5

```
function y=QUALITYmeas1(x,q)

% This function evaluates the Variance, SD, MAE, MSE,
% SNR & PSNR  of a compressed jpg image against
% the original image, where :
% x=reference image and q=compression quality(0...100).
% eg. QUALITYmeas1('baboon.bmp',50) .
% The compressed image is stored in filename tempXX.jpg,
% where XX is the quality number.
% Used in Image Quality Measurement Project by Sunny LUM
%
q1=q-2;
if ischar(x)
I=(imread(x));
    else
    I=x;
end

m=size(I,1);

if isequal (m,size(I,2))
filename = sprintf('%s%d%s','temp',q,'.jpg');
filename1 = sprintf('%s%d%s','tempx',q1,'.jpg');
imwrite(I, filename, 'quality', q);
imwrite(I, filename1, 'quality', q1);
I1=(imread(filename));
I2=(imread(filename1));
%imtool(I);imtool(I1);imtool(I2);
close all;
figure, imshow(I), figure, imshow(I1), figure, imshow(I2);
y=zeros(6,1);

ref_img=double(I);
msr_img=double(I1);
dif_img=abs(ref_img-msr_img);
mean_refimg=mean(ref_img(:));

var_refimg=var(ref_img(:),1);
y(1,1)=var_refimg;

stddev_refimg=std(ref_img(:),1);
y(2,1)=stddev_refimg;

mae_img=mean(dif_img(:));
y(3,1)=mae_img;

mse_img=1/(m^2)*sum(dif_img(:).^2);
y(4,1)=mse_img;

snr_img=10*log10(sum(ref_img(:).^2)/(m^2)/mse_img);
```

```
y(5,1)=snr_img;

psnr_img=10*log10((m^2-1)/mse_img);
y(6,1)=psnr_img;

    else error ('accept image of equal no. of rows & columns only')
end
```

Appendix 6

```
function u=NewQualityFunction1(y,z)

% This new function evaluates the quality of image of different
frequencies.
% y is the reference image & z is the image to be measured.
% The result is stored in u.
%
% Used in Image Quality Measurement Project by Sunny LUM
lf=[2,9,17,10,3,4,11,18,25,33,26,19,12,5];
mf=[6,13,20,27,34,41,49,42,35,28,21,14,7,8,15,22,29,36,43,50,...
    57,58,51,44,37,30,23,16,24,31,38,45,52,59];
hf=[60,53,46,39,32,40,47,54,61,62,55,48,56,63,64];

if ischar(y)
I1=(imread(y));
    else
    I1=y;
end


if ischar(z)
I2=(imread(z));
     else
    I2=z;
end

if  isequal(numel(I1),65536)
        m=1024;

    elseif isequal(numel(I1),262144)
        m=4096;

    else error('accept 256x256 & 512x512 images only');

end

w=zeros(m,3);
f=zeros(m,1);

I11=im2col(double(I1),[8 8],'distinct');
I22=im2col(double(I2),[8 8],'distinct');

for n=1:1:m

I111=reshape(I11(1:64,n),8,8);
I222=reshape(I22(1:64,n),8,8);
```

```
I1dd=abs(dct2(I111))>8;
w(n,1:3)=[sum(I1dd(lf(:))),sum(I1dd(mf(:))),sum(I1dd(hf(:)))];

d=abs(I111-I222);
mse=1/(64)*sum(d(:).^2);
psnr=10*log10((63)^2/mse);


if isequal(sum(w(n,:)),0)
    f(n,1)=psnr;
else
    f(n,1)=(w(n,1)/sum(w(n,:))*0.62...
        +w(n,2)/sum(w(n,:))*0.88...
        +w(n,3)/sum(w(n,:))*2.2)*psnr;
end

u=mean(f(:));

end
```

```
function y=QUALITYmeas1(x,q)

% This function evaluates the Variance, SD, MAE, MSE,
% SNR & PSNR  of a compressed jpg image against
% the original image, where :
% x=reference image and q=compression quality(0...100).
% eg. QUALITYmeas1('baboon.bmp',50) .
% The compressed image is stored in filename tempXX.jpg,
% where XX is the quality number.
% Used in Image Quality Measurement Project by Sunny LUM
%
q1=q-2;
if ischar(x)
I=(imread(x));
    else
    I=x;
end

m=size(I,1);

if isequal (m,size(I,2))
filename = sprintf('%s%d%s','temp',q,'.jpg');
filename1 = sprintf('%s%d%s','tempx',q1,'.jpg');
imwrite(I, filename, 'quality', q);
imwrite(I, filename1, 'quality', q1);
I1=(imread(filename));
I2=(imread(filename1));
%imtool(I);imtool(I1);imtool(I2);
close all;
figure, imshow(I), figure, imshow(I1), figure, imshow(I2);
y=zeros(6,1);

ref_img=double(I);
msr_img=double(I1);
dif_img=abs(ref_img-msr_img);
mean_refimg=mean(ref_img(:));

var_refimg=var(ref_img(:),1);
y(1,1)=var_refimg;

stddev_refimg=std(ref_img(:),1);
y(2,1)=stddev_refimg;

mae_img=mean(dif_img(:));
y(3,1)=mae_img;

mse_img=1/(m^2)*sum(dif_img(:).^2);
y(4,1)=mse_img;

snr_img=10*log10(sum(ref_img(:).^2)/(m^2)/mse_img);
```

```
y(5,1)=snr_img;

psnr_img=10*log10((m^2-1)/mse_img);
y(6,1)=psnr_img;

    else error ('accept image of equal no. of rows & columns only')
end
```

```
function y=QUALITYmeas1(x,q)

% This function evaluates the Variance, SD, MAE, MSE,
% SNR & PSNR  of a compressed jpg image against
% the original image, where :
% x=reference image and q=compression quality(0...100).
% eg. QUALITYmeas1('baboon.bmp',50) .
% The compressed image is stored in filename tempXX.jpg,
% where XX is the quality number.
% Used in Image Quality Measurement Project by Sunny LUM
%
q1=q-2;
if ischar(x)
I=(imread(x));
    else
    I=x;
end

m=size(I,1);

if isequal (m,size(I,2))
filename = sprintf('%s%d%s','temp',q,'.jpg');
filename1 = sprintf('%s%d%s','tempx',q1,'.jpg');
imwrite(I, filename, 'quality', q);
imwrite(I, filename1, 'quality', q1);
I1=(imread(filename));
I2=(imread(filename1));
%imtool(I);imtool(I1);imtool(I2);
close all;
figure, imshow(I), figure, imshow(I1), figure, imshow(I2);
y=zeros(6,1);

ref_img=double(I);
msr_img=double(I1);
dif_img=abs(ref_img-msr_img);
mean_refimg=mean(ref_img(:));

var_refimg=var(ref_img(:),1);
y(1,1)=var_refimg;

stddev_refimg=std(ref_img(:),1);
y(2,1)=stddev_refimg;

mae_img=mean(dif_img(:));
y(3,1)=mae_img;

mse_img=1/(m^2)*sum(dif_img(:).^2);
y(4,1)=mse_img;

snr_img=10*log10(sum(ref_img(:).^2)/(m^2)/mse_img);
```

```
y(5,1)=snr_img;

psnr_img=10*log10((m^2-1)/mse_img);
y(6,1)=psnr_img;

    else error ('accept image of equal no. of rows & columns only')
end
```

8 References

1) "A guide to the project management body of knowledge" 3rd edition, PMI standards Project Management Institute, Four Campus Boulevard, Newton Square, PA 19073-3299 USA, 2004.

2) Written by Lionel Durant, European Market Specialist, Video Technologies, Tektonix - "Comparing Objective and Subjective Picture Quality Measurements", Tektronix technical brief, 1998

3) Matlab® Version 7 – "Image acquisition & image processing toolbox help file", 2005

4) Dr. A. C. Kokaram, Department of Electronic and Electrical Engineering, University of Dublin Trinity College, - "Introduction to Electrical Engineering Digital Image and Video Processing", 2004

5) D.Venkata Rao, N.Sudhakar , B.Ravindra Babu, L.Pratap Reddy - " An Image Quality Assessment Technique Based on Visual Regions of Interest Weighted Structural Similarity", GVIP Journal, Volume 6, Issue 2, September, 2006

6) Unisim course material, "T305 Digital Communications, Block 3, Message Coding" Pg 39 to 46.

7) Gonzalez - "Digital image processing", 2002

8) University of Southern Ca lifornia – http://sipi.usc.edu/database/database.cgi?volume=misc

9) Dave Marshall - http://www.cs.cf.ac.uk/Dave/Multimedia/node231.html

10) Wavelet-based foveated image quality measurement for Region of interest image coding (Zhou Wang1, Alan C. Bovik1, and Ligang Lu2)

11) ISO 20462, A psychophysical image quality measurement standard Brian W. Keelana and Hitoshi Urabe).

12) Gonzalez - "Digital image processing", 2002 -Pg 478.

13) Human Visual system: http://www.ecs.csun.edu/~dsalomon/DC2advertis/AppendH.pdf - pg 906.

14) Objective Image/Video Quality Measurement -A Literature Survey Zhou Wang (pg1-2)

15) wavelet-based foveated image quality measurement for Region of interest image coding. Zhou wang, alan c. Bovik, and ligang lu.

16) Edge-based structural similarity for image quality assessment. Guan-hao chen, chun-ling yang, lai-man po, sheng-li xie.