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Mobile CMOS Image Sensor Test System through Image Processing Technique

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ABSTRACT
These days, with the rise in technology, the image sensing used to play an important role. The image sensing capability plays an important role in the safety and security of the people. The image sensors in the automobiles have resulted in increasing the safety of the drivers and passengers of the vehicle. It also has been found very useful in the locking system, as the image has been scanned first, and the image sensing capabilities have made it possible to authenticate the identity of the person. The advancement in the robotics wasn't been possible if there won't be the enhancement in the image sensing capabilities. Therefore, the important role has been played by the image sensing in various applications of daily life. This paper reviews the past researches for the CMOS image sensing. As in image sensing, the image processing has to be done, therefore, in this paper, the Huffman Coding has been implemented for the image processing i.e. for compression and decompression. In the results, it has been found that the image compression has taken place in such a way so that there is less degradation in the quality of the image. The validation of the results have been done and they are found to be true to the objectives.

KEYWORDS: *CMOS image sensor, CCD, Test System, Image Processing, Image Sensing.*

1. INTRODUCTION
The image sensing is used in various applications like biomedical applications, mobile devices, personal computers and in videos [1]. The demand for the sensing devices that have the high resolution and integrated image processing capabilities and requires low power is increasing. The use of the CMOS technology is making it possible and increasing the overall performance of the system [1].

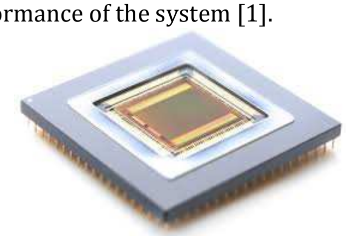


Figure 1: Image Sensor (Source: CMOS Sensor) Ref:- http://https://www.embedded-/vision.com/ sites/default/files/industry-analysis/cmos-ccd-

Image Sensors are the important component for any machine that contains the camera. The function of the sensor is to convert the photons i.e. light into the electrical signals which help everyone in various applications in the daily life. They are classified on the basis of the various factors like resolution, frame rate, pixel size, and sensor format, structure, etc. The image sensors are the solid-state devices which analyze and store the information that has been derived from the conversion of the light signal into the electrical signal [9]. The generally used image sensors are CCD and CMOS, but this research will be focusing on the CMOS image sensors for future enhancements.

1.1. Image Sensing using CMOS
There is explosive growth in the market of the solid-state image sensors because of the increased demand of the mobile imaging digital still and video cameras, surveillance, Internet-based video conferencing, and biometrics. Because of the advancement in the design of the image sensors implemented in the technologies of the complementary metal oxide semiconductor (CMOS), it has led to the adoption in the various high-volume products like optical mouse, mobile phones, PC cameras, and high-end digital cameras.

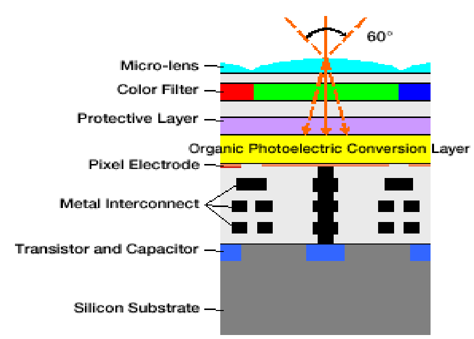


Figure 2: CMOS Image Sensor Ref:- https://3c1703fe8d.site.internapcdn.net/newman/gfx/news/hires/2013/

It has the ability for the integrated sensing along with the analog and digital processing which can be done to the pixel level. Among the semiconductor industry, CMOS image sensors are the fastest growing segment [3]. The CMOS image sensors, sometimes, also referred to as the "electronic eye" of the device [10]. The image sensing with the CMOS resulted into the faster execution because, in this, there is the direct conversion of the light into the electrical signals, which helps in avoiding the other transfers which can take more time and can increase the execution time [11].

1.2. Sensor Testing with Image Processing Technique

In the various practical applications, the sensors are consisting of the very small cameras which used to trace the particular object so that it can capture the image and can process it for various purpose. They have to continuously monitor the change in the environment. Because of the high costings, the GPS is not installed in them.

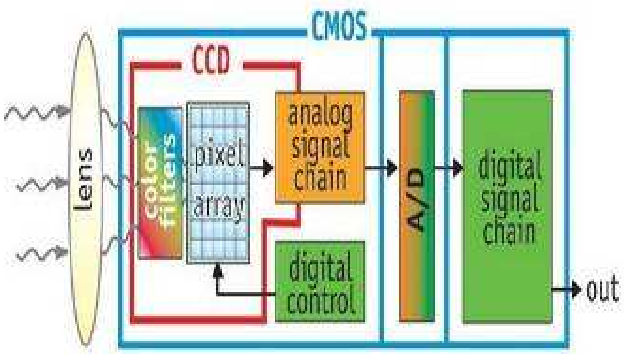


Figure 3: Working of Image Sensor Ref:- http://brickwood.co/wp-content/uploads/2018/08/CCD-CMOS-

In the wireless systems, there may be the case, in which there will be the convergence of the various images, which may lead to the disturbance in the actual quality of the image. To retrieve the actual image, so that sensing could take place in a proper way, the image processing technique is used. The image processing helps in retaining the actual quality of the image. For this purpose, the values for the PSNR, QL, and CR are specified, so that the required image can be obtained after the application of the image processing method for the sensor. It also provides the flexibility at the different processing levels on the various parameters which also results in the better quality of the image [13].

1.3. Advantages/Disadvantages

No doubt, image sensing has been proved very useful for the various applications. Sometimes, CCD is used over the CMOS, and vice-versa. There are some advantages that lead to the usage of the CMOS image sensors over the CCD image sensors. The main advantage of the CMOS over CCD is the ability for integrating sensing along with the analog and digital processing which can be done to the pixel level [3]. Each pixel in the CMOS have their own amplifier, hence there is no need of the separate shift registers, which results in the saving of the execution time. There is no complex clocking system for the CMOS. There is the direct conversion during the transfer, which results in the savings of the power as well [11]. The data rate is faster for the CMOS image sensors than the CCD image sensors which leads to the faster execution. This makes them cheaper from the CCD image sensors [10].

Along with the advantages, there are some disadvantages as well, which inhibits the adoption of the CMOS image sensors over the CCD. The disadvantage is that there is a limit on the minimum pixel size [7]. Because of the greater sensitivity, it results in the strong color noise, which can destroy the quality of the image. They also have significant low fill factor for the images, which result in the noise in the images [6].

Though the adoption in the CMOS technology is recent these days, still a lot of improvement work can be done for the CMOS image sensors, because still there is resistance in the people to adopt the CMOS over the CCD. The architectures could be designed which could lead to the increase in the frames per second. The various architectures can be designed which would lead to the easy and cheap on-chip integration. There is also another important factor and i.e. the power consumption. Therefore, these are the points on which the further work can be done, so that the CMOS image sensing technology can be adopted over the CCD image sensors.

2. Literature Review

Zhang & Bermak (2010), reviewed the on-chip image compression using the CMOS image sensor. They have also provided the review of the new design paradigm where image processing was performed during the phase of the image capture before the storage phase and known as the compressive acquisition. As compression is the most important task for image processing, CMOS has enabled the integration of the sensors and image processing capabilities to fulfill the future image system's needs. The integration of the architecture of the image sensor array and the array-pixel level processor was used for the improvement of the overall system. Also, a new paradigm has been reviewed which resulted in the reduction of the storage requirement. The proposed on-chip image compression sensors were great in every aspect like high performance, such as high resolution, high frame rate, high throughput, or low power consumption, that was required to fulfill the future imager system needs [1].

Maddalena et al. (2005), showed the two CMOS image sensors which have been developed by the Melexis for targeting the market of the automotive safety, and automotive imagers. As cameras play an important role as a sensor in automobiles and also increase the safety. They provide the dynamic assistance and comfort in driving. Because of all these reasons, automotive sensors need to be different from the market sensors. This paper has defined the criteria with the image sensor that should be compiled for the highly automotive world by keeping all the parameters in consideration like image quality, cost, size, and reliability, etc. So that it could be integrated into the present automotive safety system [2].

El-Desouki et al. (2009), presented the review of the CMOS-based high-speed imager design. They had also described the various implementations which target the ultrahigh-speed imaging. They had discussed the design, layout, and results of the simulation for an ultrahigh acquisition rate CMOS active-pixel sensor imager which could take 8 frames at a rate of more than a billion frames per second (fps). By the combination of the different methods, researchers had managed to push the frame rates to the 10 thousand frames per second (fps). It was found that a 2-D image could couple to the 1-D line-scan imager by using fiber coupling to achieve the ultrahigh-speed imaging without the sacrifice of the array fill-factor [7].

Zeffer & Yeargan (2006), proposed the design of the CMOS image sensor array along with the simulation, layout and the test for it. The design consisted of the analog nonlinear circuitry with the onboard photoreceptors which developed and processed the image on a single, compact VLSI chip. The spatial image processing chips that implemented the resistive grid have been properly explored. In the exploration results, the major drawbacks that had been found in this was a large percentage of analog output signal loss because of known low CMOS sensors CD sensitivity and the relatively large offset of the readout amplifier which was caused by the run-to-run and in chip process variations. In the proposed design, the pixel circuit had been modified and it resulted in the gain back of the fifty percent of the photo signal. The test results verified that the circuit smoothed the intensity map of the image and, thus, was able to perform the edge detection. The significant signal loss had been avoided and the offset value has also been decreased [8].

Choi et al. (2016), presented an image sensor for the mobile applications and the wearable devices that also works on the low power. For smart sensing, this sensor used to capture the images continuously like for face detection, eye tracking, and gesture recognition and it has captured the high-resolution images by using the unified sensor. This sensor used to employ the dual switch mode and that is always-on (AO) mode with low power consumption and photo-shooting (PS) mode with a high signal-to-noise ratio. For the high energy efficient dual mode, the dynamic voltage scaling has been implemented, in which 0.9 V analog-digital supply voltage has been provided for the AO mode and 3.3 V analog–1.8 V digital supply voltage has been provided for the PS mode. In AO mode, for low voltage operation, a conventional four-transistor pixel can be operated as a charge-shared pixel. For low voltage and low-frequency operations, some changes in the architecture have been reconfigured which helped in the extending of the battery life while performing the always-on sensing. This sensor has enabled the two functions in the one sensor as explained above. The eye tracking application has also been tested with this sensor, and there were 100% results as the outcome of the testing [14].

Sugawa et al. (2005), described the 100-dB dynamic range CMOS image sensor. This image sensor can achieve the no degradation of the sensitivity for the low light and have kept the sensitivity for the bright light and have realized the high signal to noise ratios in the low and the bright lights. The basic guidelines that have been followed were the introduction to the noise reduction, minimization of circuit elements, and no splitting of the integration time. In the outcomes, the performance of the image sensor has been evaluated, it has been found that the performance of the device has resulted in the high sensitivity and an S/N with 0.15 mVrms random noise and 0.15 mV_{rms} FPN. There was no image lag in the dynamic range and its performance is comparable to the CCD in low lights [15].

Goossens et al. (2017), showed the monolithic integration of the CMOS integrated circuit with graphene which was operating as the high mobility phototransistor and it has been done for the first time. The demonstration of the high-resolution image sensor has been made, in which the image sensor has been operated as the digital camera which was sensitive to the UV, visible and the infrared lights. This integration can be proved as crucial for the incorporation of the 2D materials into the next generation microelectronics while covering the most of the light spectrum frequencies. Therefore, the graphene-based image sensor has been designed which covered the broader wavelength range. In this, the fundamentals limits haven't been encountered for the shrinking of the pixel size and for increasing the image resolution. The lithography of the graphene was the only limiting factor in this. Therefore, the image sensors were competitively performing with the multi-megapixel resolutions and various pixel range i.e. to 1 μm was within the reach. Further development includes the encapsulation and the transfer of the graphene that can increase the uniformity and performance of the graphene-CMOS technologies [16].

3. Problem Formulation

In the literature survey, it can be seen that most of the researchers have focused on the design and architecture of the CMOS image sensors, like the on-chip integration, or the smart CMOS image sensors, or focused on the compact design, so that, its performance can be increased, but no one has told about the using this technology for the various purposes. There is a need to integrate this technology into others so that its full potential can be used. There are various areas present in the CMOS technology for which the research can be done, but in the proposed research, **the focus will be on the compression and decompression of the signals/images in the CMOS image sensor using the image processing techniques.** This research will be very helpful as it would help in the sensing of the images with the high proficiency and the accurate precision because then minute details can also be verified. The concept of the image processing has not been used until now in the image sensors. The focus of the previous researches was on the architecture only. In this paper, the implementation of the concept will be done by using Huffman Coding.

4. Methodology

Digital Image Processing is the part of the digital signal processing and it allows the user to perform the required operations on the images. With the help of the digital image processing, one can modify the features of the image so that they can perform the complex operations on the image and be able to make them more information so that there could be the extraction of the useful information from the image. Image processing used to play an important role in various fields like projection, classification, pattern recognition, feature extraction, and signal analyzation.

There are various techniques that can be utilized for the image processing. Following are the techniques that could help in the image processing:

1. Pixelation.
2. 2.Linear filtering
3. Neural networks
4. Principle components analysis
5. Huffman encoding
6. Hidden Markov models
7. Image Restoration
8. Wavelets

As digital image processing is a very big field and there is a huge number of algorithms which are used in image processing. In this project, we have performed image compression and decompression using image processing techniques. To perform image compression and decompression, we have used the **Huffman coding**.

4.1. Huffman Coding
Huffman coding is the most widely used data compression technique developed by David Huffman. Its procedure is based on two observations:
1. More frequently occurred symbols will have shorter code words than a symbol that occur less frequently.
2. The two symbols that occur least frequently will have the same length.

Huffman coding makes an average number of binary symbol per message nearly equals to the entropy. Huffman coding contains variable length codes and it is a prefix-free coding, it means no code word is a prefix of another code. Those characters get occurred more are assigned to small codes and the least frequent character assigned to the largest code. By using this technique, we can avoid ambiguity.

Example of prefix codes with a counterexample: Suppose there are four characters a, b, c, and d, and their corresponding variable length codes be 00, 01, 0 and 1. This coding leads to ambiguity because code assigned to 'c' is a prefix of codes assigned to a and b. If the compressed bit stream is 0010, the de-compressed output may be "ab" or "ccac" or "ADC".

In Huffman coding, there is no code is a prefix to any other code.

4.2. Huffman Coding: Greedy Algorithm
Huffman algorithm is an example of a **greedy algorithm** because in the Huffman algorithm the two smallest nodes are chosen at each step, and this local decision results in a globally optimal encoding tree. In general, the greedy algorithms use a small grained, or local minimal/maximal choices to result in a global minimum/maximum.

4.3. Steps in Algorithm Used for Compression
1. Read an image from the system.
2. Make a call to a method which finds symbol.
3. Compute probability for each symbol.
4. Perform Huffman coding (encoding).
5. Outputs reconstructed the image.

4.4. Steps in Algorithm Used for Decompression
1. Read compressed Image.
2. Perform Huffman decoding.
3. Convert compressed image to decompressed image.

4.5. Advantages of Used Algorithm
1. Less disk space required.
2. Byte order independent.
3. Faster file transfer.
4. Faster writing and reading.
5. Variable dynamic range.

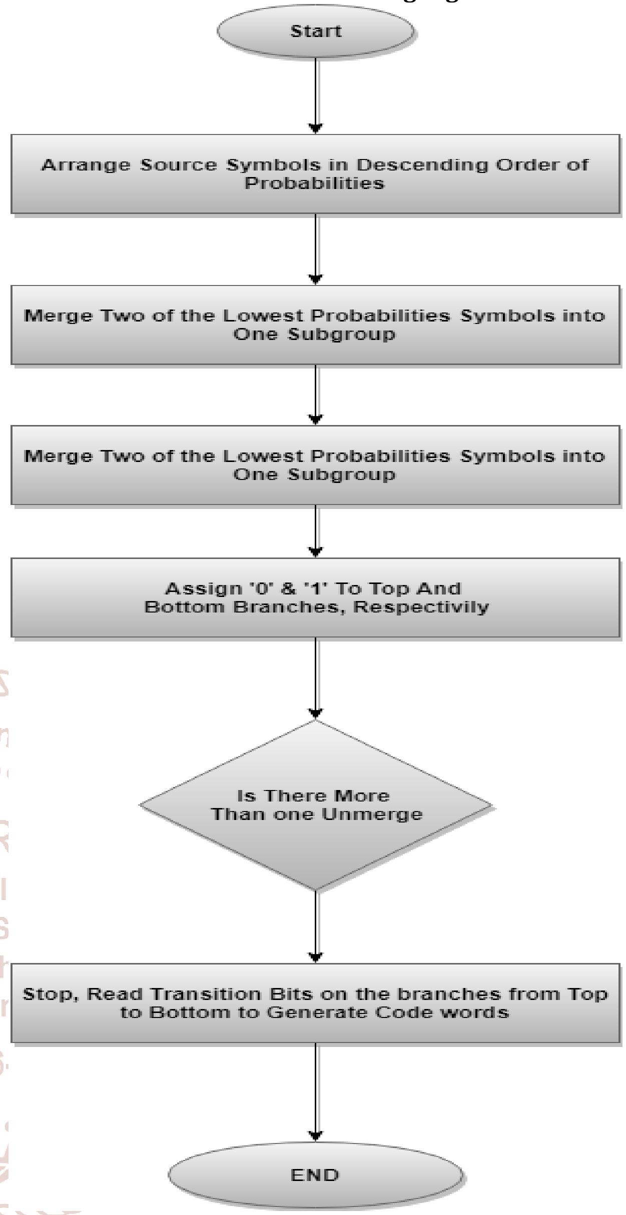
4.6. Flowchart for Huffman Coding Algorithm


Figure 4: Flowchart for Huffman Coding Algorithm

4.7. Discrete Cosine Transform
Discrete Cosine Transform method also used to be the part of the image and signal processing. DCT is usually used in lossy compression. This technique separates an image into a discrete number of blocks of pixels with respect to the overall image. The expression of DCT is functioned in the sum of the sinusoidal waveform that varies in frequency and amplitude. It is transforming the image from the spatial domain into the frequency domain. In transform compression, the low-frequency components of a signal are more important than high-frequency components.

Therefore, a reduction in the number of bits used to represent a high-frequency component will degrade the quality of the image only slightly.

4.8. Advantages of DCT
1. Energy Compaction
2. DeCorrelation
3. DCT does a better job of Concentrating Energy into lower order coefficient.

4.9. Disadvantages of DCT

1. Coarse quantization of some of the low spectral coefficients introduces unrefined in the smooth portions of the images.
2. Truncation of higher spectral coefficients results in blurring of the images, especially wherever the details are high.

4.10. Huffman Coding with DCT (Discrete Cosine Transform)

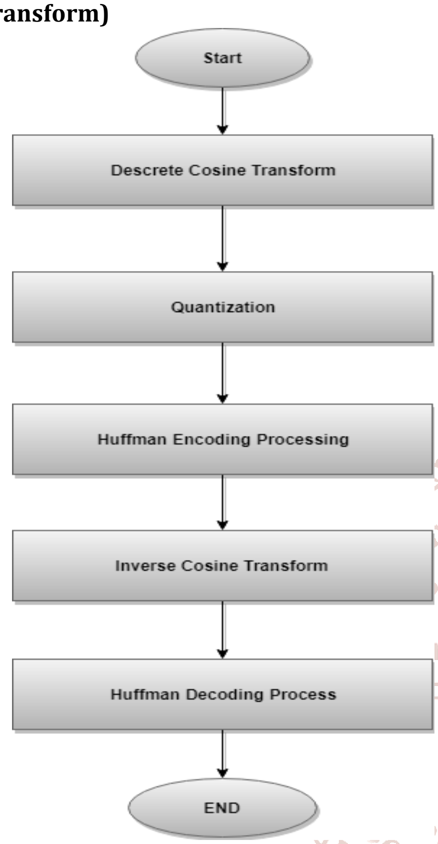


Figure 5: Flowchart for Huffman coding with DCT

4.11. Application Flowchart

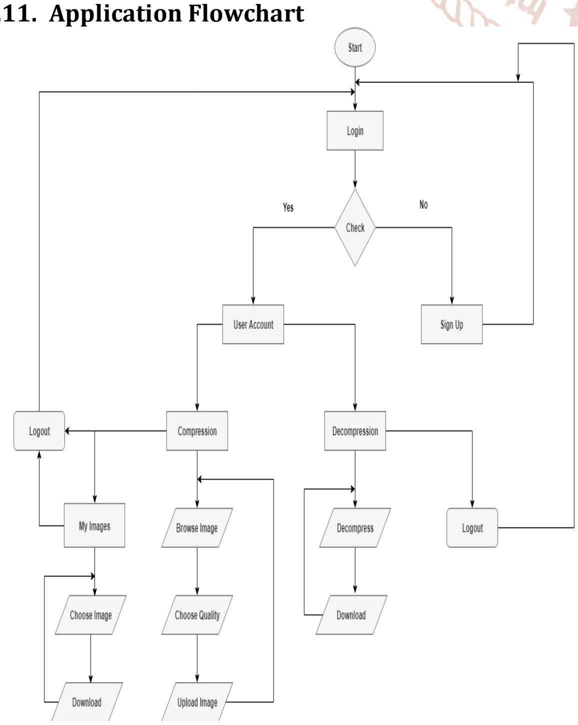


Figure 6: Flowchart for Application of Image Processing

5. Results and Discussions

In this part, the results have discussed which have been obtained after the implementation of the Huffman Coding technique for the image processing. The results have been discussed with the screenshots of the application so that proper validation could be done.

5.1. Log in and Signup Page

Figure 7: Log In page

On the login page, if user not registered than user need to sign up first. If the user is already register than the user can log in directly by providing username and password.

5.2. Sign up Page

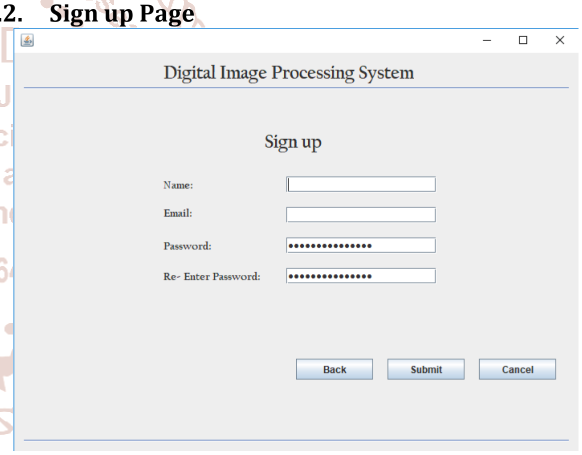


Figure 8: Sign Up Page

When we click on the Signup button a next frame is pop up and ask the user to fill the details like name, email, password, re-enter Password.

5.3. Main Page

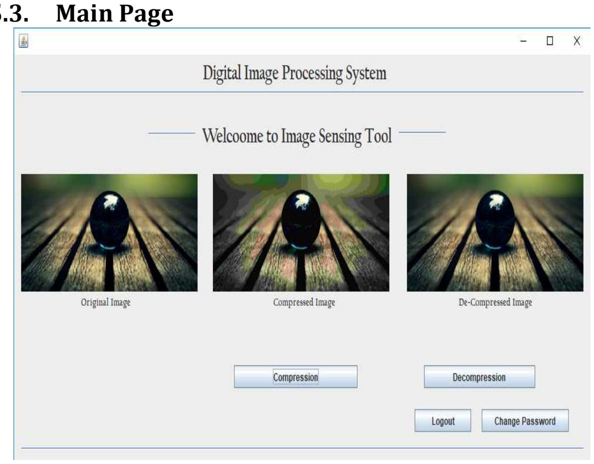


Figure 9: Main Page of Application

Main page consists:

1. Compression Button: For compression of an original Image.
2. Decompress Button: For Decompressed of an Image.
3. Log out: To Logout user.
4. Change password: For changing of the user password.

5.4. Compression Page

Compression Page:

1. First Choose Image that you want to compress.
2. Choose Quality.
3. Click on the upload button.

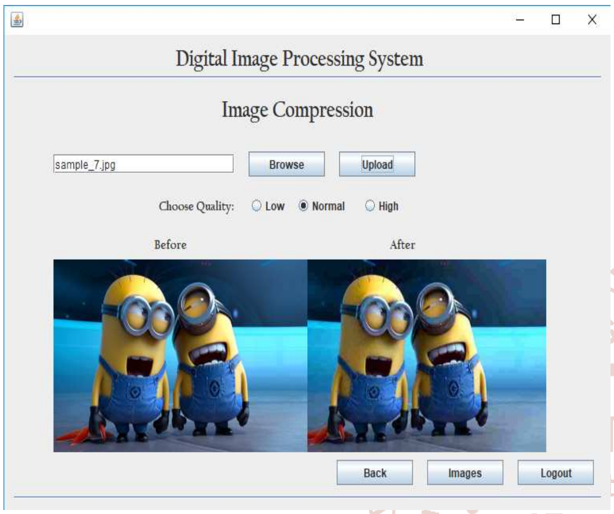


Figure 10: Compression Page of Application

5.5. Decompression Page

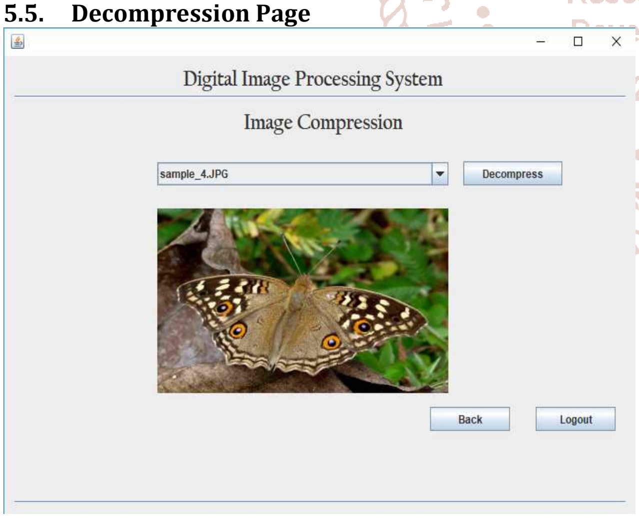


Figure 11: Decompression Page of Application

Decompression of an image:

1. Choose an image from the combo box.
2. Click on Decompress Button.

5.6. Image Gallery

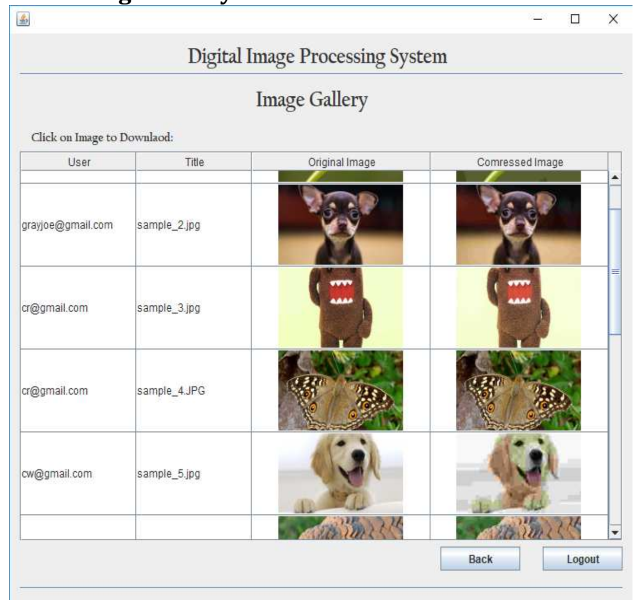


Figure 12: Image Gallery for Application

In Image Gallery, the user can see the Original images, as well as compressed image and user, can also download an image.

6. Conclusion

With the advancement in the technology, the requirements are also increasing, which are increasing the challenges day by day and also making it difficult to meet the challenge. Several card designs have been prepared which requires the 2.5Gbps for the differential pair and the clock speed, but with the changing requirement, now there is the need of the 3 Gbps [12]. The test systems help to identify the various issues that are happening in the CMOS image sensors like a loss in the analog signal and its quality, which may also need to change the structure of the CMOS image sensors. The testing of the systems is required so that the high performances can be achieved. It is found that still there is a lot of research that can be done. As in CMOS Image Sensors, the image processing is also involved. therefore, in this paper, the image processing (compression and decompression) used to be done by the implementation of the Huffman Coding technique along with the Discrete Cosine Transform (DCT). It has been found that the application has performed well for the compression and decompression phases and in the results that are obtained, it is clear that there is less degradation in the quality of the image. The validation for the application has also been done.

7. Future Scope

In the above discussions, there was not a single point about adopting the CMOS technology in the wireless network. As the world is moving towards the wireless digital age, there is a need to develop the various existing technologies for the wireless mode as well, so that they can be used at their full potential. Therefore, the further research topic of the study will include the proposition of the design for the image sensors using CMOS, for the wireless networks which will also involve the image processing technique, so that they can provide with the better results. Further, it will also include the testing of the design that whether it fulfills the performance criteria or not.

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