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Differential Image Compression for Telemedicine: A Novel Approach

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ABSTRACT

Telemedicine is one of the most emerging technologies of applied medical sciences. Medical information related to patients is transmitted and stored for references and consultations. Medical images occupy huge space; in order to transmit these images may delay the process of image transmission in critical times. Image compression techniques provide a better solution to combat bandwidth scarcity problems, and transmit same image in a much lower bandwidth requirements, more faster and at the same time maintain quality. In this paper a differential image compression method is developed in which medical images are taken from a wounded patient and are compressed to reduce the bit rate of these images. Results indicate that on average 25% compression on images is achieved with 3.5 MOS taken from medical doctors and other paramedical staff the ultimately user of the images.

1. INTRODUCTION

The 'Tele' is a Greek word that means 'distance' and the word 'medicine' means ' the science of diagnosing, treating, or preventing disease using different techniques'. This field of science has the potential to make a difference in the lives of many medically impaired and distorted people. For example, telemedicine can improve the delivery of health care in any country by bringing a wider range of services such as cardiology, radiology, mental health services, and dermatology to communities and individuals in underserved urban and rural areas [1]. Today, telemedicine systems are supported by State of the Art Technologies like Interactive video, high resolution monitors, high speed computer networks, switching systems, and telecommunications superhighways including fiber optics, satellites and cellular telephony [2]. In the field of Information theory the standard data compression codes are designed by Shannon, Fano and Huffman. Shannon and Fano codes based on prefix code based on a set of symbols and their estimated or measured probabilities [3]. Bandwidth saving is an eminent approach in this regards and the best example is Huffman compression or coding. Huffman compression is a lossless compression which determines the most frequent occurring pattern in the image to be transmitted via the telemedicine network [4].Medical and patient related information can be transmitted from patient to doctors or specialist. Doctors can judge the patient health condition; can examine medical reports, X-ray image, video

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clips and ECG reports. In critical situations such as natural disasters or accidents victims need quick and immediate first aid, on the spot or way to the hospitals. In such condition paramedic staff or nurses want to share wounded patient condition with the doctor. Doctors can help the paramedic staff only when they see images or reports. To resolve this issue different countries have bought an advanced ambulance that contains X-Ray, MRI, Electric shock machine and oxygen supply. In severe cases paramedic staff needs urgent advice from the doctor; they can take X-Ray or MRI in few seconds but cannot share this report with the doctor. In most surgical cases paramedic staff wants to share patient video with the doctor but it is different due to telecommunication infrastructure and bandwidth limitations. In such a typical scenario where bandwidth of a system is not enough to carry out transmissions there is a way to handle the situation. This is through the compression/decompression of the information especially for bandwidth hungry image or video data types. In this paper an efficient method of medical image compression is developed. This technique operates upon differential image coding approach. In this approach initially the original (real) image is captured and transmitted while the second image that follows, and transmitted is the difference image of the first and the second image. At the receiver side difference image is added to the first image or image before the difference image to reproduce the second image. In this paper the methodology is given in Section III. The Section IV details the results. In section V conclusion are given and in section VI the future work directions are provided.

2. METHODOLOGY

Images: Two dimensional images of a medical patient with wound will be considered. The images will be taken such that second image is a subsequent of first image of the same patient with same injury. Each image having 378*268 pixels sizes. All the images are digital images. Total 8 different images or 4 different pairs will be used for experimental purpose.

Simulation Tool: For this experimental purpose MATLAB version 7 release 14 will be used. Various function of image processing built in the MATLAB, such as “IMAGE-READ”, “IMAGE-SUBTRACT”, and IMAGE-ADD” will be used to process original image and reproduce the reconstructed image for comparison purpose.

Image quality Assessment: image quality will assessed through subjective means. There are various ways to perform the quality assessment tests. However, for our experimental purpose Mean Opinion Score (MOS) test will be used. This is a popular subjective measure used for different types of Media quality assessment such as voice, video and images. In this test a pair comparison test will be performed, where two images, original and reconstructed image are tests by placing them side by side. Medical doctors and professional will be chosen to perform this test, because they are ultimate end users. At least 30 users are going to be involved in this test so that an average opinion about the quality may be build.

Differential image compression: The proposed algorithm will be working as follows:
Initially two images will be taken in a pair. For example, Image A and Image B. The difference between these both images A and B will be obtained and is called difference or error image. Assuming that image A and B are subsequent images for the same patient and same injury; therefore their difference will be minimal. That also means that one of the initial images can be reconstructed by adding error image or difference image with any one of the pair images.

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PSEUDOCODE
Step1.Load two Images A and B.
Step2. Calculate Image length and Width.
Step3.Now subtracting the image A from Image B.
Image Difference = Image A-Image B
Step4 RECONSTRUCT IMAGE
Reconstructed image= Image A + Image Difference
Step5 ERROR in Image B and Reconstructed Image
Error=Image B-Reconstructed Image
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Figure 1: Pseudo code of the Algorithm.

Mathematical Explanation of Proposed Algorithm Using Matrix.

Image is composed of minute elements called pixels in other words we can say that image is Matrix. Each matrix contains rows and columns. The Product of m*n matrix within dimensional column vector is a 'm' dimensional columns vector whose i^{th} component is as follows.

$\sum_{j=1}^{n} a_{ij}x_i$ Where as 'aij' as component of an element in the i^{th} row and j^{th} column. In this context we are taking two medical images namely Image A and Image B. Images are as follows:

A= $\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}$ and B= $\begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{pmatrix}$

Medical images are High Definition images and it always consumes higher Bandwidth .It is quite impossible to attach a medical image using less Bandwidth or low data rate. One matrix is replaced by another matrix in a predefined interval of time is technically called video. Fore coming matrix depicts the replacement of coefficient which is as follows:

B {Replaces (A)} = $\begin{pmatrix} a_{11}+b_{11} & a_{12}+b_{12} & a_{13}+b_{13} \\ a_{21}+b_{12} & a_{22}+b_{22} & a_{23}+b_{23} \\ a_{31}+b_{31} & a_{32}+b_{32} & a_{33}+b_{33} \end{pmatrix}$

Medical images are always sequence in nature. Frame of reference must be the same to get the desired results. There is a minute change between two images that can be measured easily. This minute change in images is generally called image difference or 'Δ' Delta which is shown as follows:

Image Difference = $\begin{pmatrix} b_{11}-a_{11}=\Delta_{11} & b_{12}-a_{12}=\Delta_{12} & b_{13}-a_{13}=\Delta_{13} \\ b_{21}-a_{12}=\Delta_{21} & b_{22}-a_{22}=\Delta_{22} & b_{23}-a_{23}=\Delta_{23} \\ b_{31}-a_{31}=\Delta_{31} & b_{32}-a_{32}=\Delta_{32} & b_{33}-a_{33}=\Delta_{33} \end{pmatrix}$ or

$$\Delta = \begin{pmatrix} \Delta_{11} & \Delta_{12} & \Delta_{13} \\ \Delta_{21} & \Delta_{22} & \Delta_{23} \\ \Delta_{31} & \Delta_{32} & \Delta_{33} \end{pmatrix}$$

Image Difference plays a vital role between image A and Image B .If we update or add image A with Image Difference we can easily get Image B or Reconstructed image as shown in fore coming matrix.

$$\text{Image Reconstruction} \begin{pmatrix} a_{11}+\Delta_{11} & a_{12}+\Delta_{12} & a_{13}+\Delta_{13} \\ a_{21}+\Delta_{12} & a_{22}+\Delta_{22} & a_{23}+\Delta_{23} \\ a_{31}+\Delta_{31} & a_{32}+\Delta_{32} & a_{33}+\Delta_{33} \end{pmatrix} \cong \text{ImageB}$$

If a person wants to check the bit level difference between two images namely Image B and Reconstructed Image. This minute difference can be measured using fore coming matrix.

$$\text{Error}=\begin{pmatrix} b_{11}-(a_{11}+\Delta_{11}) & b_{12}-(a_{12}+\Delta_{12}) & b_{13}-(a_{13}+\Delta_{13}) \\ b_{21}-(a_{12}+\Delta_{21}) & b_{22}-(a_{22}+\Delta_{22}) & b_{23}-(a_{23}+\Delta_{23}) \\ b_{31}-(a_{31}+\Delta_{31}) & b_{32}-(a_{32}+\Delta_{32}) & b_{33}-(a_{33}+\Delta_{33}) \end{pmatrix}$$

Mathematical Explanation Using Image.

Image has two dimensions ‘x’ and ‘y’ mathematically Image A has $f_A(x,y)$ and Image B has $f_B(x,y)$.

A= $f_A(x,y)$ and B= $f_B(x,y)$.

Calculating Difference of image ‘Δ’i-e Image (A) – Image(B)= $\{f_A(x,y)\}$-$\{f_B(x,y)\}$.

So,

$\Delta f_{AB}(x,y) = \{f_A(x,y)\}-\{f_B(x,y)\}$.

Reconstruction of Image is the updation of Image A with Image Difference. Mathematically:

$F_R(x,y)=f_A(x,y) + \Delta f_{AB}(x,y)$.

Now comparing the Reconstructed Image with Image B to get the error at bit level. Mathematically we can write as.

Error= $f_B(x,y)-F_R(x,y)$.

Further this technique can be used to compress images. Its mathematical explanation is as follows.

Compression % = $100*[f_A(x,y) + \text{One}\{\Delta f_{AB}(x,y)\}]/\text{Dimension of } [\{ f_A(x,y)\}+ f_B(x,y)]$

Mean Opinion Score (MOS):

MOS is the subjective test used for quality perception and opinions. It is mostly used for audio and video assessment. However same technique can used to determine video or image quality. In this MoS two images ‘Image B’ and ‘Image D’ that is reconstructed and prepared to replace ‘Image B’ were shown to group of 30 Doctors. Images were placed before Doctors to rate against each image at the MOS scale of 1-5, 1 being the worst and 5 being excellent image quality. The Difference between both the images was not informed before the test to any of the participants.

3. RESULT

Image A and its updated version image B are given in figure 1 and 2 respectively. The difference image is obtained by subtracting image B from Image A and in shown in figure 3. The size of the image A is 31.9219 K Byte and the size of the image B is 31.9219 K Bytes this is shown in Table 1. This shows that image A is bit different from image B or vice-versa. The size of the image C is 7.9727 K Byte. The reconstructed image D is an outcome of initial image A and error image C, the image D is given in Figure 1.

Compression Ratio. Since image A is transmitted in original and having size of 31.9219 K Bytes. Second image B is having a size of 31.9219 K Bytes. The sum of two images is 63.8438 K Bytes. If transmitted both separately, that 63.8438 K Bytes are needed to be transmitted. Image A and image C having total size of 63.8438 K Bytes. It is quite obvious that image B can be reconstructed by adding image A and error image. C. This meant, that image C and image A together can reproduce image B. On the receiving side of this image (at the doctors node) image A is sent and then image B is dropped at the transmitter, instead image C is transmitted. Image B is reconstructed from image A and C. the savings in this arrangement is 23.9492 K Bytes. This will save us 37.51% bandwidth of the communication channel. This is just for two images.
A group of 15 Doctors were invited to pass their comments on the quality and similarity of two images B and Image D. Majority of the Doctors Rated these images between Good and Fair and they scaled at MOS of 3.5/5. It means that one can omit Image B with our new reconstructed image and saves precious bandwidth. In medical image transmissions many images are needed by the Doctor sitting at a remote place treating the patient either for the first AID or in emergency, using low bit rate internet channel, will have much benefit over the bandwidth limited channels.

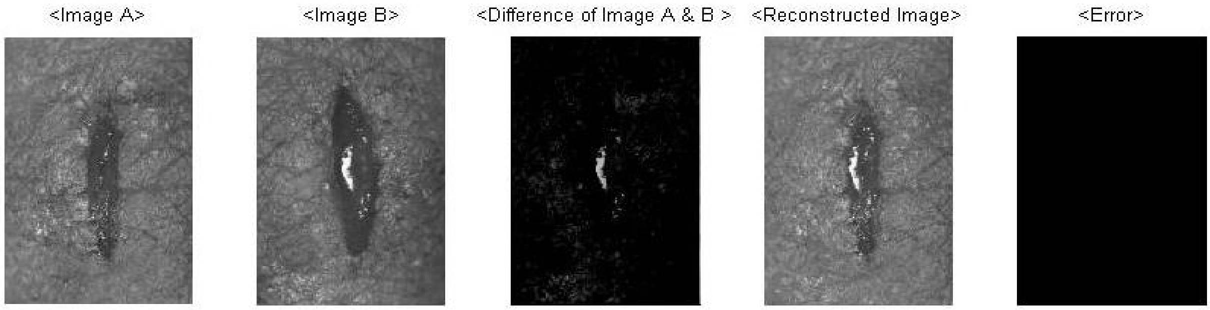

Figure2: Working of Algorithm Set A.

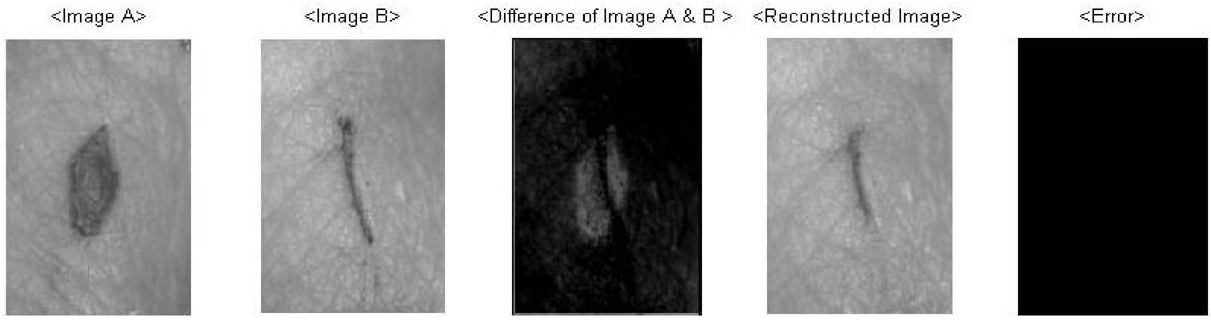

Figure3: Working of Algorithm Set B

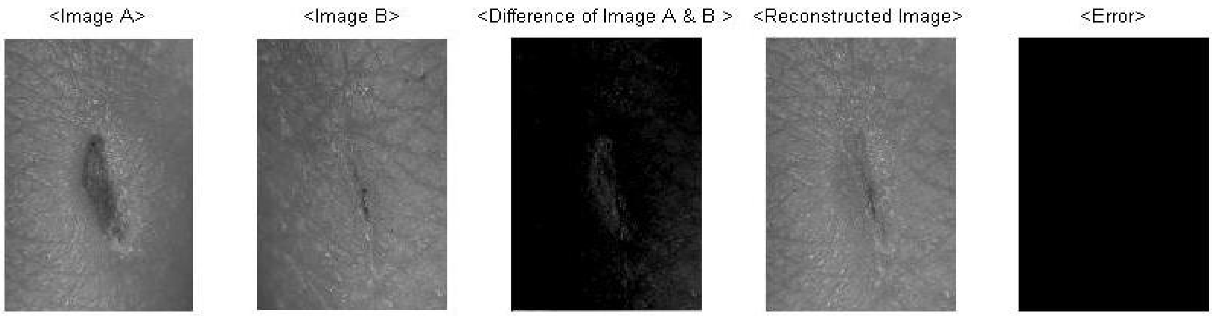

Figure4: Working of Algorithm Set C.

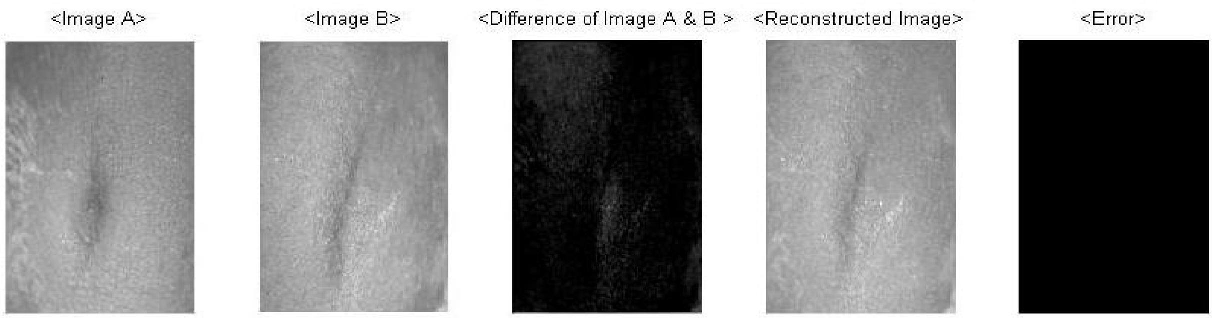

Figure5: Working of Algorithm Set D.

Table1. Differential Image Compression Ratios.

Sno	First Image Image A	Second Image Image B	Difference Image C	Reconstructed Image D	Transmitted Image Size %	Saved Bandwidth or Compression in %
1	32688	32688	8164	32688	62.487	37.5122
2	32688	32688	23275	32688	85.6017	14.3983
3	32688	32688	13043	32688	69.9507	30.0493
4	32688	32688	20575	32688	81.4718	18.5282

The Table1 depicts the compression of a medical image. Here we compare four different sets of image's compression. The first pair is wound image and its compression ratio is 37.5%. Second set of image is taken after 24 Hours and its compression ratio is 14%. After 48Hrs wound is about to heal and its compression ratio is 30% and finally condition of wound after week and its compression ratio is 18%. Over all compression of wound image from day one to a week is about 25% which is quite good in terms of medical imaging.

4. CONCLUSION

The paper is addressing the differential image compression techniques. In order to maintain quality and achieve bandwidth saving Mean Opinion Score test was taken and 30 Doctors were involved to compare these processed images. Each of them was shown a pair of images for comparison. MOS of these two images is rated 3.5 over the scale of 5, on average that shows that they have perceived fair quality of the resultant image. Overall with fair quality images, 25 % bandwidth savings is possible.

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