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Subjective and Objective Quality Assessment in Wireless TeleUltrasonography Imaging

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Abstract— **Mobile Robotic teleultrasonography is an emerging technology that can be applied in different clinical settings for remote ultrasound scanning without the need of the expert at the point of care. Guaranteed medical image quality for diagnostic purposes and their delivery in bandwidth limited wireless environments is a challenging issue. In this paper we present some of the subjective and objective image analysis acquired from a robotic teleultrasonography system operated remotely by the expert to provide an assessment of these medical imaging measures for such advanced wireless telemedical system.**

Index Terms— **Wireless teleultrasonography, medical video streaming, medical imaging, m-health.**

I. INTRODUCTION

The increasing flow of medical digital imaging within the mobility domain has been assisted by parallel advances in the area of emerging mobile, network and medical robotic technologies. Breakthrough technologies in medical imaging can provide substantial cost savings, efficient healthcare delivery and improved diagnostic accuracy. Remote robotic ultrasound and medical imaging is one of the new technologies that can offer these advantages, and provide a suitable platform for medical experts who want to perform skilled diagnosis from an expert centre to a remotely located patient.

An advanced medical robotic system OTELO (m**O**bile- **T**ele-**E**chography using an ultra-**L**ight r**O**bot) is used here as the robotic teleultrasonography system application. It is a fully integrated end-to-end mobile tele-echography system for population groups that are not served locally, either temporarily or permanently, by medical ultrasound experts [1]. It comprises a fully portable tele-operated robot allowing a specialist sonographer to perform a real-time robotised tele-echography to remote patients. Fig. 1 shows the main operational blocks of the system over wireless communication network. Further details of this system and related work are described elsewhere [1-2].

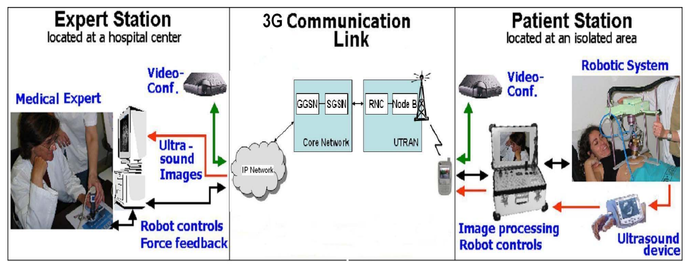

Fig. 1. The OTELO mobile robotic tele-ultrasonography system over 3G wireless network

The transmission of the Ultrasound medical video in bandwidth limited link is the main challenge in such telemedical application.. The transmitted video sequence is compressed at the sender side and transmitted over the wireless channel. Furthermore, a decision on the transmitted image compression parameters is needed at the sender (patient/robotic station) end before transmission. The wireless network condition and the compression of the medical video sequence are the main factors influencing the medical image quality at the receiver end.

Therefore some objective image quality assessment mechanism is essential for both the sender end (in order to choose the best compression parameters) and the receiver end (in order to evaluate the joint effects of the compression and transmission errors). The image quality measures based on objective approaches are less complicated and less expensive especially if these measures are based on Human visual System (HVS) characteristics. In this paper we consider two objective image quality measures, the Peak Signal to Noise Ratio (PSNR) and the Structural SIMilarity (SSIM) metric. A comparison with the subjective evaluation performed by the medical experts is then provided.

The paper is structured as follows: Section II presents details on the objective and subjective methods used. Section III discusses the experimental setup and introduces some of the preliminary image assessment results with relevant discussion. Finally, Section IV presents the conclusion of the paper.

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II. OBJECTIVE AND SUBJECTIVE MEASURES

In this section we present briefly the subjective and objective image quality assessment methods selected here and applied on the received ultrasound images from the robotic system. These are defined next:

1. **PSNR index**, where for Common Intermediate Format (CIF) image resolution a value of 35dB was recommended from earlier clinical evaluation study to give better medical diagnosis quality [2].

$$PSNR = 10.\log\left[\frac{255^2}{\frac{1}{NM}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left(x(i,j)-y(i,j)\right)^2}\right] \quad (1)$$

where $x(i,j)$ refers to the pixel (i,j) in the original image and $y(i,j)$ to the pixel (i,j) in the test image. Both images are of size NM.

2. **SSIM** index, which can be defined as in the following equation [3]:

$$SSIM = \frac{(2\bar{y}\bar{x}+c_1)(2\sigma_{xy}+c_2)}{(\bar{y}^2+\bar{x}^2+c_1)(\sigma_y^2+\sigma_x^2+c_2)}, \quad (2)$$

Where

$$\bar{x} = \frac{1}{L}\sum_{i=1}^{L} x_i \,, \quad \bar{y} = \frac{1}{L}\sum_{i=1}^{L} y_i \,,$$

$$\sigma_x^2 = \frac{1}{L-1}\sum_{i=1}^{L}(x_i-\bar{x})^2 \,,$$

$$\sigma_y^2 = \frac{1}{L-1}\sum_{i=1}^{L}(y_i-\bar{y})^2 \,,$$

$$\sigma_{xy} = \frac{1}{L-1}\sum_{i=1}^{L}(x_i-\bar{x})(y_i-\bar{y}),$$

x, y and L represent the original image, the test image and the number of pixels in the portion of the image under processing respectively.
c_1 and c_2 are constant values used to calculate the SSIM metric. The mean value of the proper number of image sub-windows is then calculated [3]. The dynamic range of SSIM is [-1, 1]. The best value 1 is achieved if and only if $y=x$.

3. **MOS** (Mean Opinion Score). This measures the subjective quality of the medical image and how well it provides diagnostic information to the medical expert. This is usually done by tests or questionnaires with numerical ratings. A suitably randomized set of images can be presented to experts or typical users who rate them, often on a scale of 1 to 5, where 1 is Bad and 5 is Excellent. Subsequent statistical analysis can then highlight averages, variability, and other trends in the data [4].

$$MOS(k) = \frac{1}{M}\sum_{i=1}^{M} S(i,k) \quad (3)$$

Where $S(i,k)$, is evaluation score of image k by viewer i, M is the number of observers

III. EXPERIMENTAL SETUP AND RESULTS

In this study a sample of 11 medical images has been used in the evaluation process with three medical experts involved.

The artifact effects considered are: compression using JPEG2000 (Joint Photographic Experts Group 2000), blur effect type motion, speckle noise, and transmission over a wireless network. Images have been processed through a MATLAB™ based software. The 3G wireless communication network link has been considered for the real-time image transmission.

Earlier experimental tests and clinical evaluation studies concluded that the quality evaluation of the ultrasound images transmitted by the OTELO system suggested that the minimum threshold for acceptable medical US image quality is PSNR > 35 dB for CIF image format and PSNR>36dB for Quarter CIF (QCIF) respectively [2].

Fig. 2 illustrates the effect of the selected PSNR bound of 35dB on the sample image. The JPEG2000 compression technique was used, as this technique provides better compression efficiency than other well known compression techniques, e.g. JPEG. Images compressed with different PSNR values are shown in the figure. Fig. 2(c) shows an acceptable image quality with PSNR value of 35.1 dB for this particular application.

However, the subjective evaluation of the compressed image is not necessarily proportional to the objective evaluation measures defined in (1) and (2). Images with a close PSNR value may have a drastically different perceptual quality [5]. The SSIM quality index measurement technique had proven to be well matched to the perceived visual quality of the image [3]. Fig. 3 shows an ultrasound image with different distortion levels, each adjusted to give the required PSNR of the selected 35dB. The distortion factors considered here are compression, blurring and speckle noise effects. The SSIM quality index is also measured. The results show SSIM index values lower than 0.9.

Fig. 4 shows example ultrasound images under the same type of distortion as in Fig 3. These results show that SSIM value of 0.9 gives good perceptual and diagnostic image quality.

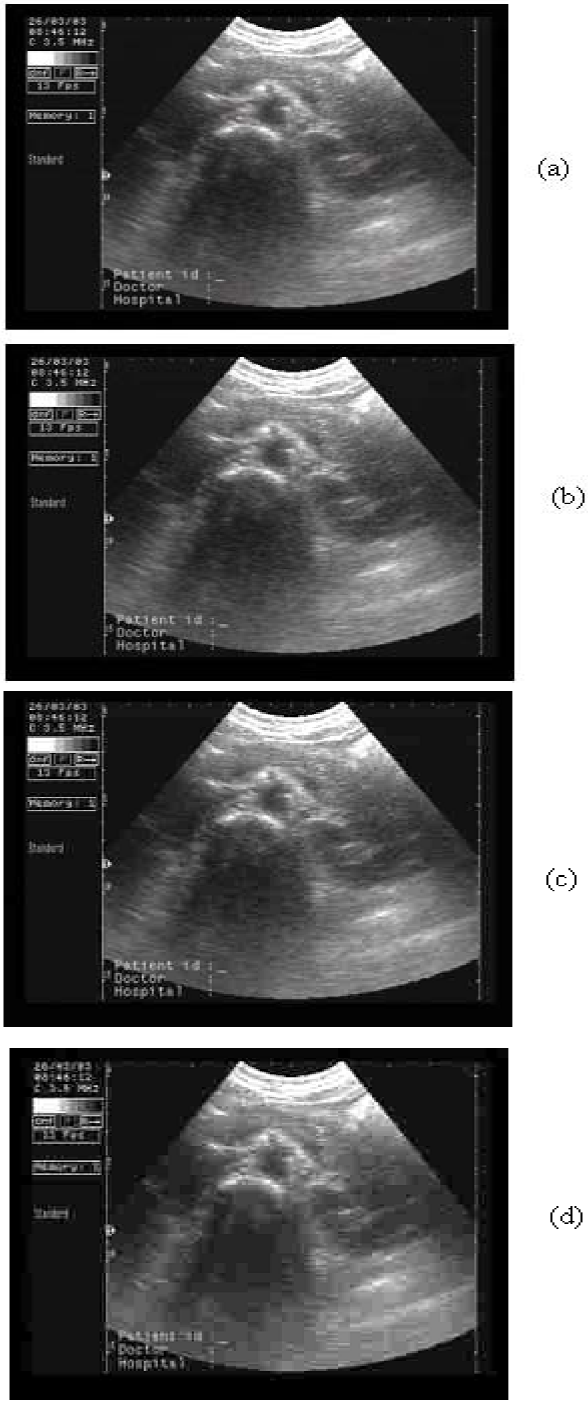


Fig 2. Ultrasound Images for abdomen, acquired by the OTELO system. (a) Original, uncompressed; (b) compressed with PSNR = 38 dB; (c) compressed with PSNR = 35.1 dB; (d) compressed with PSNR = 33.6 dB.

In order to further validate these results for SSIM index of 0.9 as an indication of good quality, value, the subjective quality measure Mean Opinion Score (MOS) has been used to assess the visual quality of the processed images shown in Figs. 3 and 4 as evaluated by the experts.

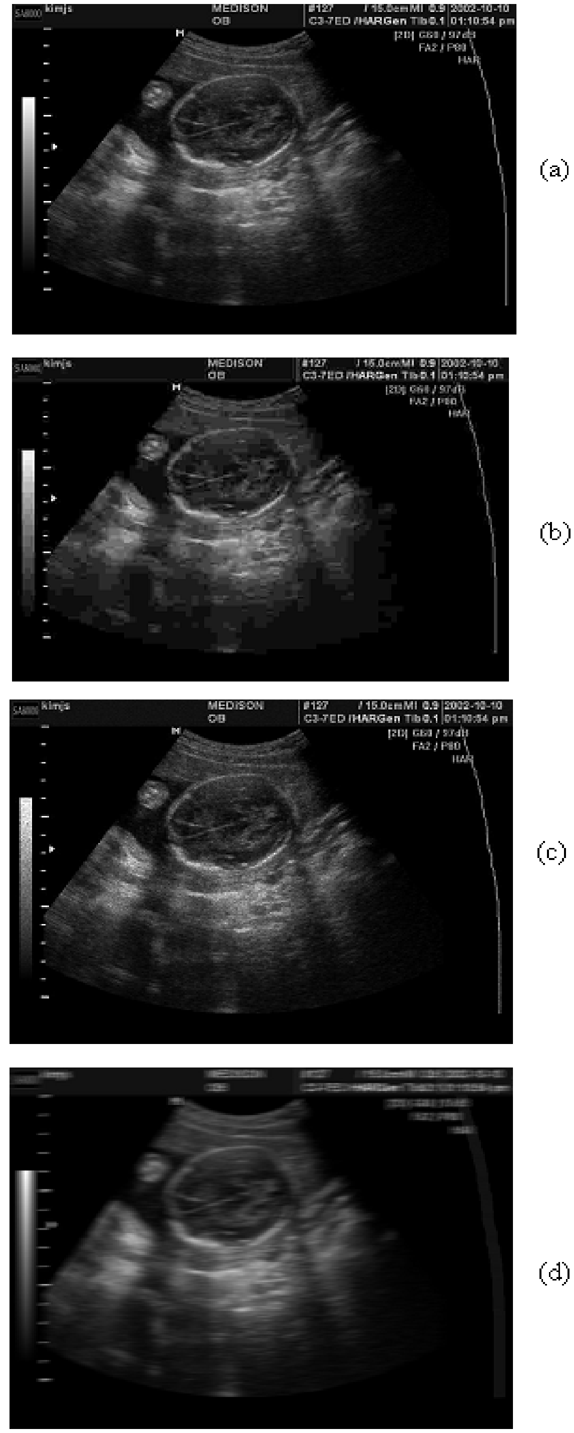
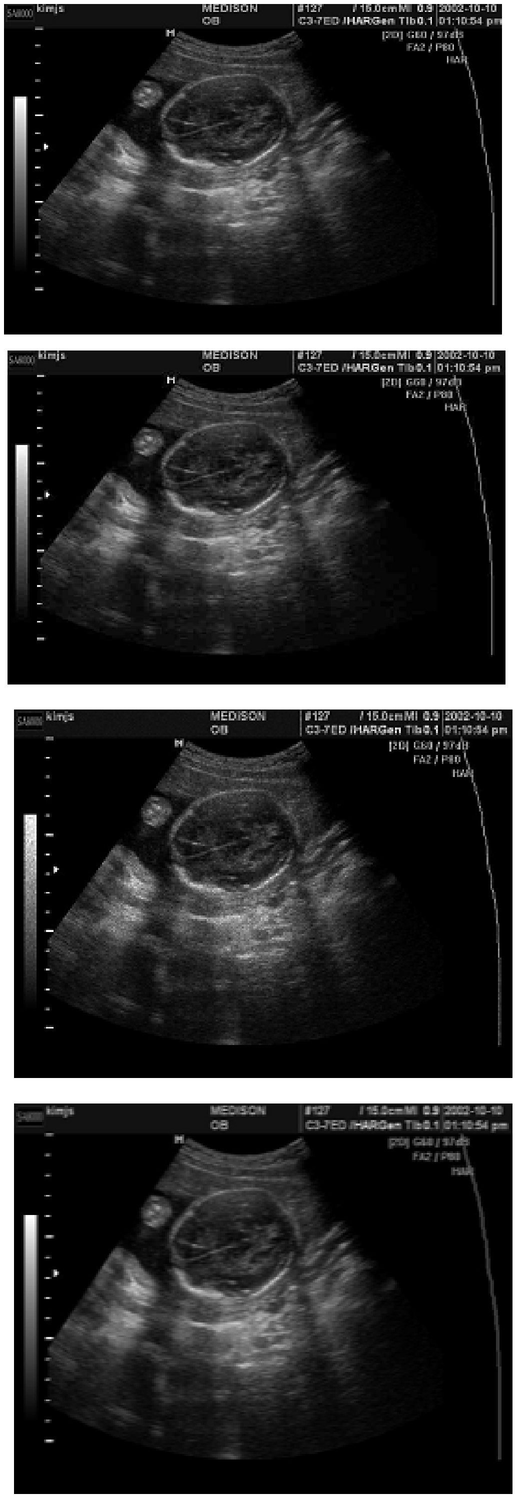


Fig 3. Comparison of an ultrasound image with different types of distortions, all with a PSNR value of 35 dB. (a) Original image; (b) JPEG2000 compressed image, SSIM = 0.75; (c) With speckle noise, SSIM = 0.85; (d) Blurred Ultrasound image, SSIM = 0.7.

Table I summarises the results of the percentage average MOS achieved by these experiments. It is clear from this table that SSIM=0.9 attains a good subjective measure with an average of 78%.



(a) (b) (c) (d)

Fig 4. Ultrasound images with different types of distortion, all with SSIM = 0.9. (a) Original; (b) Compressed with JPEG2000; (c) with speckle noise effect; (d) Blurred ultrasound image.

TABLE I. AVERAGED MOS VALUES (IN PERCENTAGE) FOR THE TESTED ULTRASOUND IMAGES

	Images with size QCIF (176x144) And PSNR = 35Db		**Images with size QCIF (176x144) and SSIM = 0.9**	
Image Artifact	**SSIM**	**Subjective measures (MOS)**	**PSNR**	**Subjective measures (MOS)**
Compression with (JPEG2000)	0.75	40%	37 dB	80%
With Speckle Noise	0.85	60%	35.5 dB	73.2%
Blurred image	0.7	40%	38 dB	80%
Transmission effect	0.7	20%	36dB	80%

IV. CONCLUSION

In this paper we presented a study of the use of specific objective and subjective medical imaging measures applied for an advanced mobile robotic tele-ultrasound system. The preliminary tests on the transmitted images in 3G mobile networks indicated that:

1. The earlier PSNR quality measure of 35dB did not qualify for a corresponding acceptable subjective result of the medical experts.
2. An SSIM with value of 0.9 gained 78% of the observers' opinion via the MOS scale application.

Further studies are required to validate the outcome of this work, *i.e.* that SSIM values of ~0.9 can give a good indication of medical acceptability of the received ultrasound images in such mobile tele-ultrasound system.

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REFERENCES

[1] F. Courreges, P Vieyres, RSH Istepanian, P. Arbeille, C. Bru, "Clinical trials and evaluation of a mobile, robotic tele-ultrasound system", *Journal of Telemedicine and Telecare (JTT),* suppl.1, 46-49, 2005.

[2] S. A. Garawi, R. S. H. Istepanian, M. A. Abu-Rgheff, "3G Wireless Communication for Mobile Robotic Tele-ultrasonography Systems", *IEEE Comms. Mag*., vol. 44, no. 4, pp.91-96, Apr. 2006.

[3] Z. Wang, A. Bovik, H. Sheikh and E. Simoncelli, "Image quality assessment: From error measurement to structural similarity", *IEEE Trans. Image Processing*, vol. 13, No. 4, pp. 600-612, 2004.

[4] P. Cosman, R. Gray and R. Olshen, "Evaluating Quality of Compressed Medical Images: SNR, Subjective Rating and Diagnostic Accuracy", *Proceedings of the IEEE*, Vol 82, Issue 6, pp. 919 – 932., 1994.

[5] D. S. Hands, Q. Huynh-Thu, A. W. Rix, A. G. Davis and R. M. Voelcker, "Objective Perceptual Quality Measurement of 3G Video Services", *Fifth IEE International Conference on 3G Mobile Communication Technologies (3G 2004,* pp. 437 -441, 2004.

[6] A. S. Al-Fahoum and A. M. Reza, "Combined Edge Crispiness and Statistical Differencing for Deblocking JPEG Compressed Images", *IEEE Transaction on Image Processing*, Vol. 10, No. 9, September, 2001.