On-Demand Teleradiology Using Smartphone Photographs as Proxies for DICOM Images

S. Pachhai[2], R. Warfsman[2], C. Podilchuk[1], R, Mammone[1,2]

1. Sonavista, Warren, New Jersey, USA
2. Master of Business & Science, Rutgers University Piscataway, New Jersey USA
{sp1667,rjw167}@scarletmail.rutgers.edu, cpodilchuk@sonavistahealth.com, rmammone@rutgers.edu

Teleradiology is the transmission of radiographic images from one location to another for interpretation. Teleradiology service providers help to fill the need for sub-specialty expert consultants, vacation leaves, and overflow gaps in the onsite radiology facilities. Teleradiology has become a large and growing industry [1]. The integration standard called the Integrating of Healthcare Enterprise (IHE) [2] have been developed to address communication issues between medical imaging sites. However, the IHE standard allows different vendors to implement the standard in different ways [3] which significantly limits the ability to transmit and receive images between organizations in practice.

We explore the possibility of transferring images by using a photograph of the image from the display as an alternative to transferring the DICOM image using the IHE standard. Photographs of the displayed image will differ from the original DICOM image. In this paper we explore the possibility of using a neural network to transform the photographic image to an Image which is equivalent to the original DICOM image.

A total of 2862 ultrasound images of suspect breast cancers are used for the experiment. The region of interest for each image is extracted and displayed onto an LCD screen and an iPhone is used to capture the images. The images are then cropped and adjusted so they resemble the original images, then split into two groups, 2700 are put into train and the rest of the images are put into test. A deep convolutional neural network is trained on samples of photographs as inputs and original images as ground truth. The photographs are then corrected by using the deep neural network to map the photo images to the DICOM images. The average PSNR and SSSIM are calculated for both train and test samples to record the change in the values before and after the transformation.

The proposed photographic method is investigated for the use case of transmission of an image to an off-site human expert. The PSNR is typically used to compare image quality. Other metrics such as the structural similarity index (SSIM) have also been proposed as another perceptual metric [4] and will be used here as well. Some works have shown that a PSNR of 30 dB indicates a reasonable quality for an ultrasound image. [5-7] Similarly, it has been found that an SSIM score above 0.8 is correlated with mean opinion score (MOS)[8].

The use of the proposed system has shown to increase the PSNR by 15 dB on both training and test sets, while there is a noticeable improvement to the SSIM as well. On the training set, the PSNR and SSIM averages prior to using the neural network are 14.5065 dB with a s.d.(standard deviation) of 2.6806 dB and 0.7118 with a s.d. of 0.1102. After using the neural network, the observed scores on the training set are 30.4565 dB with a s.d. of 3.4801 dB and 0.9455 with a s.d. of 0.0279. On the test set, the same metrics prior to using the neural network are 13.5711 dB with a s.d. of 1.1226 dB and 0.7040 with a s.d. of 0.0931, after using the neural network the improvements we get are 29.0058 dB with a s.d. of 2.6748 dB and 0.9352 with a s.d. of 0.0292. The results demonstrate that the use of smartphone/tablet computer can be used to input medical images directly from the display screen and communicated via a separate image sharing system.

ACKNOWLEDGMENTS

Research reported in this publication was supported by Sonavista Inc.

REFERENCES

[1] Teleradiology Market Size, Share & Trends Analysis Report By Product (Ultrasound, MRI, CT, X-ray), By Region (North America, Asia Pacific, Europe, Middle East & Africa, Latin America), And Segment Forecasts, 2019 – 2026 Published Date: May, 2019 Copyright © 2019 Grand View Research, *Inc https://www.grandviewresearch.com/industry-analysis/teleradiology-market*

[2] Fernandez-Bayo, J., 2010. *European journal of radiology*, IHE Profiles Applied to Regional PACS, [e-journal] 78(11), Available through:ScienceDirectwebsite <*http://www.elsevier.com/locate/ejrad*> [Accessed 12 December 2012]

[3] Seonho Kim,"Interoperability remains challenging as HIE approaches 20",Sunday,May29,2016 *https://parcaenews.blogspot.com/2016/05/interoperability-remains-challenging-as.html*

[4] Jean-Francois Pambrun, Rita Noumeir., "Limitations of the SSIM quality metric in the context of diagnostic imaging", *2015 IEEE International Conference on Image Processing (ICIP)*

[5] Delgorge, C., Courreges, F., Bassit, L. A. , Novales, C., Rosenberger, C., Smith-Guerin, N., Bru, C., Gilabert, R., Vannoni, M., Poisson, G., and Vieyres, P., 2005, "A Tele-Operated Mobile Ultrasound Scanner Using a Light Weight Robot," *IEEE Trans. Inf. Technol. Biomed. 1089-7771*, 9(1), pp. 50–58

[6] Kenneth R. Persons, Patrice M. Palisson, Armando Manduca, William J. Charboneau, E. Meredith James, Nick T. Charboneau, Nicholas J. Hangiandreou, Bradley J. Erickson M.D., "JPEG/wavelet ultrasound compression study," *Proc. SPIE 3662, Medical Imaging 1999: PACS Design and Evaluation: Engineering and Clinical Issues*, (18 July 1999); doi: 10.1117/12.352750

[7] N. R. Wanigasekara, Shenghao Ding, Zhuangzhi Yan and Yongqin Zeng, "Quality evaluation for JPEG 2000 based medical image compression," *Proceedings of the Second Joint 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society* [Engineering in Medicine and Biology, Houston, TX, USA, 2002, pp. 1019-1020 vol.2.doi: 10.1109/IEMBS.2002.1106255

[8] Kumar, Basant & Singh, Surya Pal & Mohan, Anand & Anand, Animesh. (2012). Performance of Quality Metrics for Compressed Medical Images Through Mean Opinion Score Prediction. *Journal of Medical Imaging and Health Informatics*. 2. 188-194. 10.1166/jmihi.2012.1083.

On-Demand Teleradiology Using Smartphone Photographs as Proxies for DICOM Images

S. Pachhai, R. Warfsman, C. Podilchuk, R, Mammone

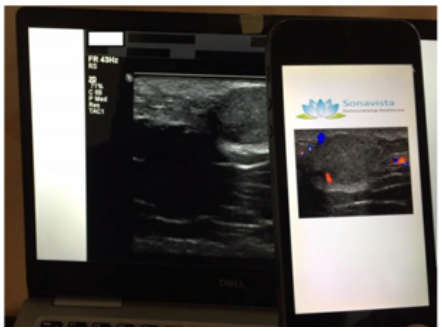
Master of Business & Science, Rutgers University

Abstract

- We explore the possibility of transferring images by using a photograph of the image from the display as an alternative to transferring the DICOM image using the IHE standard.
- Photographs of the displayed image will differ from the original DICOM image.
- We explore the possibility of using a CNN to transform the photographic image to an image which is equivalent to the original DICOM image.
- The proposed photographic method is investigated for the use case of transmission of an image to an off-site human expert.

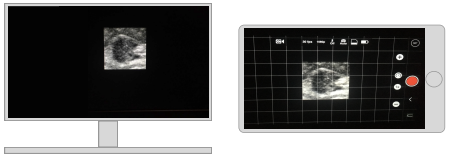
Overview of Teleradiology

- Teleradiology is the transmission of radiographic images from one location to another for interpretation.
- A shortage of radiologists, an increase in the use of advanced imaging methods with associated larger data files, the consolidation of hospitals into regional delivery systems, and high expectations of patients and referring physicians for timely service are among the factors that have encouraged the increasing use of teleradiology.
- The Integrating of Healthcare Enterprise (IHE) was formed to address communication issues between medical imaging sites.
- However, the IHE allows different vendors to implement the standard in different ways which significantly limits the ability to transmit and receive images between organizations in practice.
- The photo approach is an alternative to IHE-based teleradiology applications while avoiding the problems inherit in navigating the proprietary and security barriers that limit DICOM communication between PACS in practice.



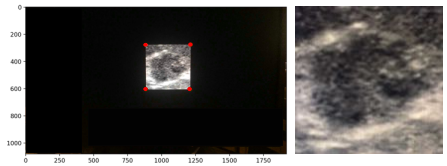
Data Collection

- 2862 ultrasound images of breast lesions displayed on an LCD monitor are captured using the camera from an iPhone 6s.
- The original DICOM images were captured by radiologists with varying levels of experience and different ultrasound devices.



Perspective transformation of photographs

- The DICOM image is extracted from the photographs by identifying the corner pixels and feeding the images into a perspective transformation algorithm.



Metrics

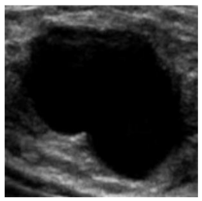
- PSNR is typically used to compare image quality.
- Other metrics such as the structural similarity index (SSIM) have also been proposed as another perceptual metric.
- Some publications have shown that a PSNR of 30 dB indicates a reasonable quality for an ultrasound image.
- Similarly, it has been found that an SSIM score above 0.8 is correlated with high mean opinion score (MOS) for radiologists.

$$PSNR = 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

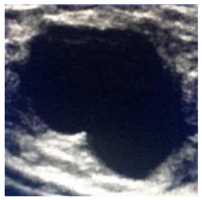
$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

Using CNNs to improve image quality

- The image quality when capturing photographs is quiet low.

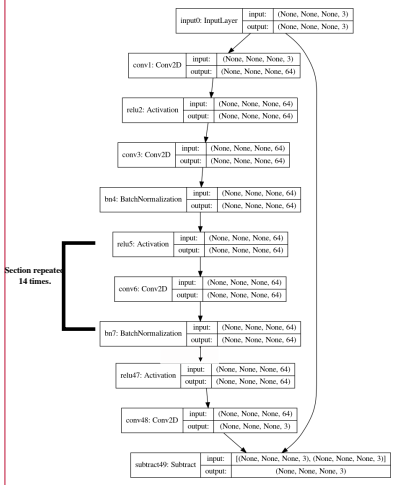


The Original Image



LCD Photgraph of DICOM with PSNR of 13.51 and SSIM of 0.47

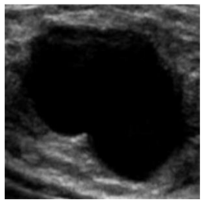
- We train a denoising convolutional neural network (DnCNN) to learn the distortions that are introduced when taking a photograph of the original DICOM image.
- 2700 images are used for training and the rest are used for testing



- Pairs of photographed and original images are formed and batches of random samples processed through the CNN.

Results

- The corrected images produced by the CNN are visually similar to the original DICOM images which are ground truth.
- The bright areas in the distorted images due to capturing photographs from an LCD screen have been corrected



The Original Image

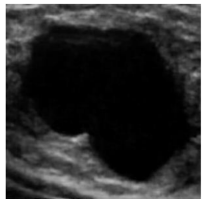


Image restored using neural network with PSNR of 33.39 and SSIM of 0.93

- The improvement in PSNR and SSIM demonstrates that the CNN works very well in the task of quality improvement for low quality images.

Split	Count	Metric	Average Prior Transformation	Standard Deviation Prior Transformation	Average after Transformation	Standard Deviation after Transformation
Train	2700	PSNR	14.5065 dB	2.6806 dB	30.4565 dB	3.4801 dB
		SSIM	0.7118	0.1102	0.94552	0.02795
Test	162	PSNR	13.5711 dB	1.1226 dB	29.0058 dB	2.6748 dB
		SSIM	0.704	0.0931	0.93522	0.02927

Limitations

- The current photographs were taken under ideal conditions. A forthcoming study will show the advantages of the use of an autoencoder to improve photographs under nonideal conditions such as: glare, reflections, geometric distortion. , color balance, greyscale errors, keystone, and motion blur.

Summary

- Teleradiology has become a large and growing industry
- The use of the proposed system has shown to increase the PSNR by 15 dB on both training and test sets, with a similar improvement to the SSIM.
- The results demonstrate that the use of smartphone/tablet computer can be used to input medical images directly from the display screen and communicated via a separate image sharing system.
- The use of photographs of the display in place of IHE/DICOM could also positively impact access and quality of healthcare services in low- and middle-income countries
- This technique was applied to ultrasound images of breast lesions but can be generalized to other imaging modalities and body parts.

Acknowledgements

- Research reported in this publication was supported by Sonavista Inc. [https://www.sonavistahealth.com]