Medical X-ray images enhancement based on super resolution convolution neural network

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Abstract

Pneumonia is a severe lung infection, chest X-ray (CXR) image preferred to find infection. Real images lost its quality, resolution and other feature due to transmission. So good qualitative datasets are very limited. Quality enhancement in medical images is challenging task for researchers. And quality in clinical diagnosis of any disease in deep learning play a very important role. So, this paper presents an aspect with importance of quality in medical images CXR of a particular dataset and how to enhance and create new images with high quality resolution, that is re-used for classification in deep learning. Super resolution convolutional neural network (SRCNN) is deep learning based method, which is used for improving resolution in image. The objective behind this study is to measure the effect of super resolution with quality index, peak signal-to-noise ratio (PSNR), mean squared error (MSE), and structural similarity index measure (SSIM). This experiment performed on 200 images with 10 batches, each batch has 20 images from Kermany dataset, select LR images and converted into HR with SRCNN. Then we find PSNR value of image is increase up to 2 to 5 DB, and MSE of good quality images is near to zero and MSE decrease up to 20-25, SSIM value have little variation due to same pattern is found in input and output images. Enhancement means highlight or improve the region of interest of pneumonic images. Main goal of this study is to prepare a modified dataset which is further used for classification.

1. INTRODUCTION

Pneumonia is a disease of lungs, in the small air sacs (alveoli) is affected. In this air sacs fill with fluid (pus) which leads cough, high fever, breathing problems and sometime death. And pneumonia can be very dangerous for children and the elder with weak immunity [1]. Mostly the chest X-ray (CXR) is being used all over the world for detection of this infection due to hardware, bandwidth, storage space limitation, under exposure, over exposure, transmitted image degrades their quality and resolution, due to noise and compression techniques Figure 1 shows low quality images (Figures 1(a)-1(f)) and Figure 2 shows high quality images of Kermany dataset (Figures 2(a)-2(f)). Visual observation clearly shows the difference between low quality and high quality.

No doubt deep learning method has great success in the field of medical images diagnosis. But this requires training on large number of images with good quality. Mostly available datasets have low quality
and it became cause of poor performance in deep learning. Calli et al. [2] provide a detailed survey on publicly available dataset of CXR, and suggest that for deep learning more focus on clinical needs in CXR interpretation. Kieu et al. [3] describe four main issues in deep learning w.r.t datasets; i) data imbalance, ii) limited availability, iii) size of image, and iv) high correlation error. And suggested some potential future direction like, use of cloud computing, more datasets availability and more variety of features. Using super convolution neural network (SRCNN) proposed by Dong et al. [4], we construct high resolution (HR) from low resolution (LR) CXR to enhance the quality of dataset. Chaudhari et al. [5] and Park et al. [6] applied super resolution method in medical domain. Rahimi et al. [7] suggested that LR can be converted into high quality. Study involved SR approaches including SRCNN, SR generative adversarial network (SRGAN), U-net and presented that all approaches showed significant improvement in mean opinion score (MOS). Ulhaq et al. [8] recommended that small (less no of images) dataset is barrier and their quality became challenging in healthcare imaging domain.

Author [9]-[11] presented research on chest radiograph with deep learning. Rani et al. [12] compared SRCNN technique with other enhancement method like histogram equalization; contrast limited adaptive histogram equalization (CLAHE), Gamma correction, and other filter techniques. And find this approach is better then other, so it gives an idea to reconstruct a dataset from LR (low quality) to HR (high quality) of CRX images. In the field of super resolution, Zhang et al. [13], Kin et al. [14], Lim et al. [15], Zang et al. [16], provide super restoration of images between LR to HR images.

![Figure 1. Low quality images, (a)-(b) virus, (c)-(d) bacterial, (e)-(f) normal](image1)

![Figure 2. High quality images, (a)-(b) virus, (c)-(d) bacterial, (e)-(f) normal](image2)
Dataset description, pediatric CXRs (PP) labeled pediatric CXRs from the Guangzhou Woman and Children Medical Centre (Guangzhou, China) Kermany et al. [17], which contains 5,856 CXR images from pediatric patients aged 1-5 years. Table 1 shows the distribution of total images for training and testing. In the table, we observe that pneumonia-based images are more than double as compared to normal images. As we know that for binary classification equal numbers of images are desirable for deep neural network, especially for medical imaging domain for specific.

<table>
<thead>
<tr>
<th>Partition</th>
<th>Class</th>
<th>Images</th>
<th>Total Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>Normal</td>
<td>1341</td>
<td>5216</td>
</tr>
<tr>
<td></td>
<td>Pneumonia</td>
<td>3875</td>
<td></td>
</tr>
<tr>
<td>Testing</td>
<td>Normal</td>
<td>234</td>
<td>624</td>
</tr>
<tr>
<td></td>
<td>Pneumonia</td>
<td>390</td>
<td></td>
</tr>
</tbody>
</table>

In Kermany dataset pneumonia images are further divided into two types viral and bacterial. Table 2 describes the second important factor that is quality, the resolution (width and height) of each category normal, viral, and bacterial. Explain low and HR with file size.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Type</th>
<th>Minimum resolution with file size</th>
<th>Maximum resolution with file size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Viral</td>
<td>400×138 (5.31 KB)</td>
<td>1896×1752 (668.5 KB)</td>
</tr>
<tr>
<td>2.</td>
<td>Bacterial</td>
<td>460×157 (5.51 KB)</td>
<td>2334×1956 (400 KB)</td>
</tr>
<tr>
<td>3.</td>
<td>Normal</td>
<td>1416×992 (152 KB)</td>
<td>2482×2570 (2.04 MB)</td>
</tr>
</tbody>
</table>

In the table, we observe there is a big difference in resolution of pneumonia and normal images. Thousand of pneumonia images are less than 50 KB. So, need of reconstruction of the low images to increase structural details.

2. RELATED WORK

In the area of super resolution, author [18] provides an approach to improve resolution in chest X-ray images. Xu et al. [19] proposed supervised generative adversarial net approach to construct HR images from LR. Khishigdelger et al. [20] proposed advance SR approach with residual-in-residual (RIR) structure to diagnostic potential of CXR imaging. Method shows superior performance, delivering enhanced accuracy with visual improvement. Monday et al. [21] proposed an enhanced fast super resolution convolution neural network (EFSRCNN) and obtained peak-signal-to-noise ratio (PSNR) and structural similarity index measure (SSIM) values 32.24 DB and 0.9341 for region of interest. Ahmadian and Alikhani [22] presented X-ray image enhancement based on self-organizing neural network, performance, accuracy, and quality measurement index like PSNR (38.42), SSIM (0.98) gives good result as compared to other medical images enhancement methods. Umehara et al. [23] applied super resolution convolution network on chest CT, high-quality images were constructed from low-quality images, and obtained 41.79± 2.49 DB values of PSNR and 0.947± 0.029 value of SSIM for 2X magnification. The super resolution schemes yielded higher image quality than linear interpolation.

3. RESEARCH METHOD

The dataset used for this study is available on Kaggle. Kermany dataset have 5856 images of two categories, normal and pneumonia (bacterial and viral). This study is performed on Tesla K80 GPU, paid Google Collab platform with sufficient RAM, with extra computing units. Python language is used to implement SRCNN and SciPy open-source scientific computing library is used for statistical analysis. Sequence of steps performed in this experiment is shown in Figure 3 by flow diagram.

With SRCNN technique, construct HR images from LR images to improve spatial resolution of CXR. This experiment is performed on 200 images of mix resolution; with batch size of 20 images. This paper shows the result of one batch. Figure 4 shows the low-resolution input images of each type.
Image quality assessment: Mean squared error (MSE), PSNR, and SSIM are popular and widely used metric for quality assessment.

MSE: this is most common and widely used full reference method, where reference image is available for measurement. It is calculated by squared intensity difference of distorted and reference image pixels and averaging them. It measures the average of the square of the error. And values closer to zero, are better output.

$$MSE = \frac{\sum (y_i - \bar{y}_i)^2}{n}$$

PSNR: commonly used to measure quality of reconstructed images, it is ratio of maximum possible signal power (original image) to the power of noise (reconstruct image) which affects the quality [24]. Ratio between two images is measured in decibel (dB), PSNR value varies from 30 to 50 dB for 8-bit representation and 60 to 80 Db for 16-bit data. In 8-bit unsigned integer data type peakval is 255. Higher PSNR value means better image quality and less distortion.

$$PSNR = 10 \log_{10} (\text{peakval}^2 / MSE)$$

Where peakval is the maximum possible pixel value in the image.
SSIM: SSIM is also type of FR perception-based metric by Wang et al. [25], where it finds how much similarities between perfect reference image and a test image based on factor luminance, contrast, and structure. Structural inform about strongly inter-dependent pixel or spatially closed pixel. Luminance masking is a term which measured by mean intensity of signals, where distortion part of an image is less visible in the edges of an image. Contrast masking is term calculate by using standared deviation, where distortions less visible in texture of an image. Range of SSIM varies -1 to 1, and perfect value is 1.

\[ SSIM(x, y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2))}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \]

Where \( \mu_x, \mu_y, \sigma_x, \sigma_y \) are local means, standard deviations and cross-covariance for image.

4. RESULT

In this section Table 3 represent experimental results of 12 images out of 20 images, of each category. Quality enhancement evaluated by PSNR, MSE, and SSIM. Table 3 also compare the effect of super resolution in CXR before and after apply SRCNN. PSNR value is increase up to 2-5 DB. MSE value is decrease with good ratio. For SSIM, there is little variation, means same pattern is in input and output images. Figure 5 show some screen shot during runtime, first we have to save 20 images then find quality evaluation parameter before apply SRCNN. Figure 6 show output of high resolution with quality index after SRCNN.

| Table 3. Comparisons of LR and HR Image type Source image with LR | Image type SRCNN images with HR Output |
|---|---|---|
| Image type | Source image with LR | SRCNN images with HR Output |
| Viral | Person325_virus_660 | Person8_virus_27 | Person1_virus_72 | Person1699_bacteria_4422 | Person1761_bacteria_4603 | Person904_bacteria_2829 | Person88_bacteria_2812 | NORMAL2-IM-0256-0001 | NORMAL-IM-0219-0001 | NORMAL-IM-1250-0001 | IM-0019-0001 |
| Input | Viral | Person325_virus_660 | Person8_virus_27 | Person1_virus_72 | Person1699_bacteria_4422 | Person1761_bacteria_4603 | Person904_bacteria_2829 | Person88_bacteria_2812 | NORMAL2-IM-0256-0001 | NORMAL-IM-0219-0001 | NORMAL-IM-1250-0001 | IM-0019-0001 |
| Virus | 43.28 | 9.15 | 0.97 | 5.3 KB | 45.13 | 5.97 | 0.98 | 10.3 KB | 38.57 | 27.07 | 0.97 | 49 KB | 43.38 | 8.94 | 0.98 | 120 KB | 36.64 | 42.26 | 0.96 | 44 KB | 41.32 | 14.36 | 0.97 | 99 KB | 36.79 | 40.78 | 0.95 | 47 KB | 41.20 | 14.76 | 0.95 | 98 KB | 42.99 | 9.79 | 0.97 | 9.5 KB | 43.98 | 7.79 | 0.98 | 20 KB | 43.10 | 9.54 | 0.97 | 11 KB | 44.52 | 6.88 | 0.97 | 21 KB | 41.38 | 14.17 | 0.96 | 11 KB | 42.59 | 10.73 | 0.97 | 23 KB |
| Image type | Input | Output | Output | Output | Output | Output | Output | Output | Output | Output | Output | Output |
| Size | 5.3 KB | 10.3 KB | 120 KB | 99 KB | 98 KB | 20 KB | 21 KB | 23 KB | 92 KB | 147 KB | 224 KB | 568 KB |

Figure 5. Input image (virus, bacteria, and normal)
5. CONCLUSION

Objective of the researchers is to create superior quality of clinical images. In this paper, we present compasion of super resolution images HR with LR. Experimental result shows outperformed enhancement factor like PSNR and MSE. LR images rebuild into HR images; it helps us to increase number of images. We create modified dataset which will be used for classification of normal and pneumonia disease in deep learning.

REFERENCES

[1] WHO (http://www.who.int/news-room/fact-sheets/detail/pneumonia)


BIOGRAPHIES OF AUTHORS

Sharda Rani was born on 15-July-1981. She received her B.Sc. in Computer Science from Kurukshetra University Kurukshetra in 2001, MSc in Information Technology from Kurukshetra University in 2003, and M.Tech. in Computer Science from CDL University Sirsa, Haryana in 2007. She qualified UGC-NET (Computer Sc and Application) in June 2014. She currently research scholar with the Department of Computer Science, Sri Guru Granth Sahib World University, FatehgarhSahib (Punjab) India. Her research interests: intelligent systems/machine learning, and deep learning. She is a member of teaching staff at department of computer science and applications, A.S. College, Khanna (Punjab) India. She can be contacted at email: duhan.sharda@gmail.com.

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