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Super Resolution Image Reconstruction for Bone Images

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Abstract

Objectives: Images got from image intensifier to assess joint movements during surgery are usually distorted. This paper aims to get exact high resolution image from such low resolution (distorted, blurred) images using super resolution image reconstruction. **Methods/Statistical analysis:** This method uses different images taken from the video of the original procedure of studying a patient with stiff hip to assess his hip movement under image intensifier. The proposed method uses the Singular Value Decomposition (SVD) transformation model for the purpose of reconstruction. In this work two data sets of images extracted as video from a c-arm –image intensifier imaging of a patient with disease of left hip are analysed. **Findings**: While capturing a fast moving object needs a camera with more radiation. Image intensifiers-even with methods like gating have disadvantage of smear phenomenon when capturing fast moving objects. But clear, quick analysis is needed in operation room setting where time is vital. In this method details like the inferior cortex of the neck of femur or proximal end of the trochanter which is absent in captured figures are appreciated in output high resolution image. Thus the outputs generated without omitting essential details. **Application/Improvements:** Distorted images captured during real-time procedures in the operation theatre while patient's part is moving is resolved using Super Resolution Image Reconstruction technique. Thus surgeon understand the patient's bone better. Procedures like placing a screw or passing a guide wire to reduce a fracture can be easily done with such a methodology.

Keywords: Bone Images, Image Intensifier, Image Reconstruction, Moving, Super Resolution

1. Introduction

Imaging is an integral part of management of patients. It is used in three areas viz 1. Before the orthopaedic procedure to select a case, 2. During the procedure to properly guide the surgeon to do the procedure well and 3. After the procedure to assess the effectiveness of the procedure and assess the results of the procedure. Even as the surgery is on, during the procedure movements of the limbs during the procedure happens and sometimes it is necessary. So also passage of the implants within the patient's body also involves movements. Capturing such moving objects and producing them as images is routinely done by machines like image intensifiers[1].

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While assessing the images of a moving limb in the operation theatre the surgeon is left with a set of video images which are blurred and fast in progression. The judgement of the doctor is difficult for example as to what is the limit of the actual bone on which the operation is done and if the position of the implant inside the bone is correct.

The commercially available cameras have steeper gradation which is suitable for fast moving objects. This is useful for faster moving objects like cardiac angiogram etc. the television images are having rich contrast and are free form after glow. However, the disadvantages are that in the imaging intensifier there can be noise high gamma value – high contrast and hence more radiation exposure to the patient and the team which is operating. Price of such image intensifiers are also high e.g. the plumb icon tube. While another device the vidicon is effective in capturing non-moving and slow moving object. Also vidicon is cheap with less radiation [1]. Thus to capture a fast moving object one needs a camera with more radiation. Image intensifiers are having the disadvantage of the smear phenomenon when capturing the objects which are moving fast[2]. Gating is a method employed in the image intensifier to reduce the motion blurr[3]. Even after such employing such methods still there are blur in the images which needed to analyse in the operation room setting, where time is important. It is in this background, we hypotheses that if images of good resolution are available to the surgeon even with moving limbs captured with the same image intensifier, then the result of the surgery will be even better. To our knowledge, there is no such article which discusses the resolution using moving limb recorded as video.

Super resolution image reconstruction is a concept by which images with poor clarity can be used to provide images of good quality for the end user.

In this work we have applied an algorithm to simplify the work of the surgeon in understanding the image captured during the movement of the limb during a procedure.

2. Methodology

A patient with suspected disease of left hip is taken for the study. In this disease, the head of femur bone (thigh bone) will be deformed and hence a mechanical block of the hip movements is expected. To check the range of movements objectively, a c-arm –image intensifier is routinely used. During this procedure, for comparison, the normal side hip was also imaged and its videos were recorded for dynamic assessment of the hip movements of normal side. The videos were in mp4 format. The current study is done on the images taken from these videos recorded using Surgico Hfx of Medtronics –Philips. In

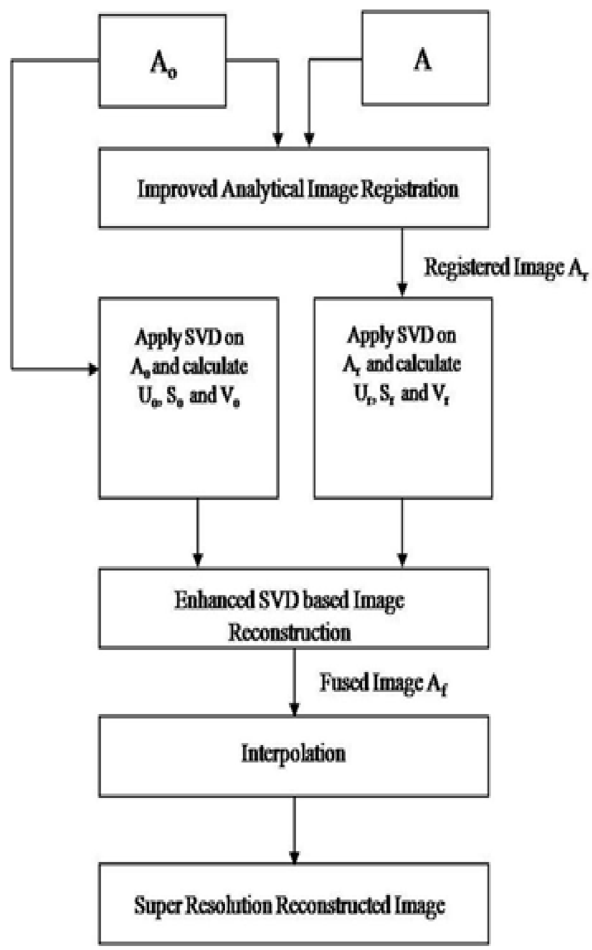

Figure 1. SVD based super resolution image reconstruction flowchart.

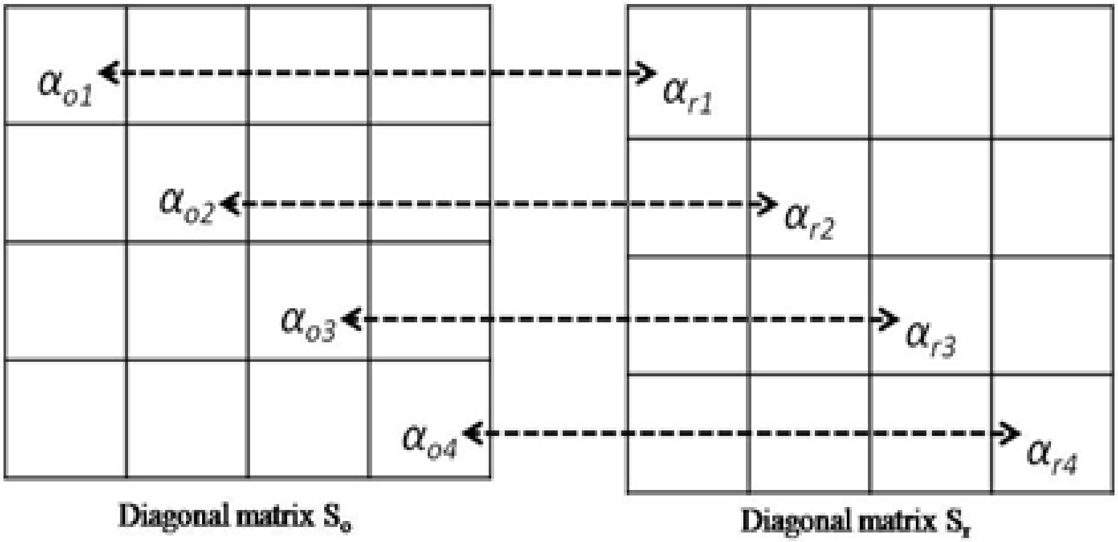

Figure 2. Element wise comparison of singular values in diagonal matrices So and Sr.

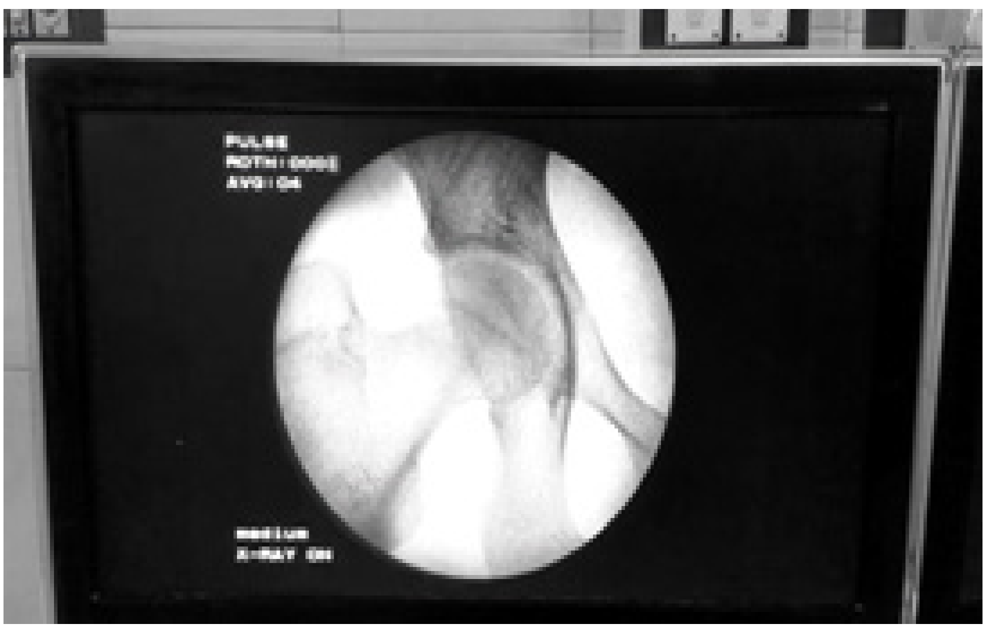

Figure 3. Input image –A0.

this work two data sets of images extracted from the video are analysed and final high resolution images got by using an algorithm shown in Figure 1 and element wise comparison of singular values in diagonal matrices S_o and S_r is done as seen in Figure 2. The images were extracted using Image processing programming are shown in Figures 3 and 4.

Figure 4. Input image– A.

3. Enhanced Singular Value Decomposition Fusion

The original image (A_o) and any subsequent image (A) which is sub-pixel shifted are considered as inputs. The sub-pixel shifted image is subjected to images registration which gives a registered image (A_r). The original image (A_o) and the registered image (A_r) are subjected to singular value decomposition. Performing SVD on the original image (A_o) decomposes the original image

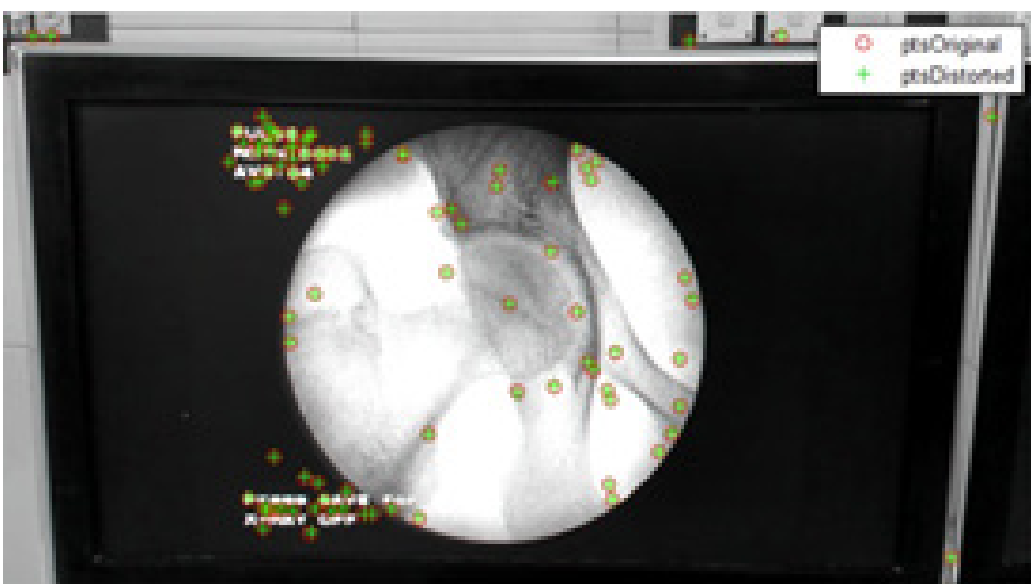

Figure 5. Registered image showing regions of pixels shifted-the image Ar.

Figure 6. Output image – high resolution image.

(A_o) as U_o, S_o and V_o. Similarly performing SVD on registered image decomposes registered image (A_r) as U_r, S_r and V_r. The main objective is during the process of fusion, there should not be loss of any important information. In order to achieve this singular value (α) should be carefully chosen, by comparing them between original and the registered images. The proposed way of choosing the singular values (α) is compare first singular value of original image $A_o(\alpha_{o1})$ with the first singular value of registered image $A_r(\alpha_{r1})$. If value of α_{o1} is greater than α_{r1} choose α_{o1} as the first singular value for the new matrix S_{new}. In case α_{r1} is greater than α_{o1} choose α_{r1} as the first singular value for the new matrix S_{new}. Based on the above statements S_{new} is given by the following equations (1). Figure 2 shows the how element wise comparison is done for singular values contained in S_o and S_r.

Likewise, element wise comparison is done for all the singular values contained in S_o and S_r and the highest among the two singular values is chosen for S_{new}.

$$S_{new} = \begin{cases} \alpha_{oi} \ if \ \alpha_{oi} > \alpha_{ri} \ , i = 1,2,3, \ldots \\ \alpha_{ri} \ if \ \alpha_{oi} < \alpha_{ri} \ , i = 1,2,3, \ldots \end{cases} \tag{1}$$

The S_{new} is combined with left singular vector U_o and complex conjugate of right singular vector V_o to form the fused image A_f which is given by equation below.

$$A_f = U_o S_{new} {V_o}^T \tag{2}$$

This is done prior to the interpolation step because interpolation may cause some loss in the information.

4. Analysis of the Images

The output image has incorporated the details in both first and second input data. The problem of visualising the moving bone while doing a real time procedure is common. This method uses different images taken from the video of the original procedure and the outputs generated without omitting essential details. Procedures like placing a screw or passing a guide wire to reduce a fracture can be easily done with such a methodology.

Consider the Figures 3, 4, 5 and 6; the inferior cortex of the neck of femur (marked with red arrow) which is absent in Figure 4 but present in Figure 3 is appreciated in Figure 6 the output high resolution image.

Also the proximal end of the trochanter (marked with blue arrow) which is prominently seen in Figure 4 is not prominently seen in Figure 3 is appreciated in Figure 6 the output high resolution image.

5. Conclusion

Images even when captured while patient's part is moving can be resolved using Super Resolution Image Reconstruction technique. Clear and exact images thus obtained give good idea on the patient's bone to the surgeon during real-time procedures. This will give the suffering patient a better care.

6. References

1. Van der Plaats GJ, Nijhoff M. Image intensification and X-ray television medical x-ray techniques in diagnostic radiology. A textbook for radiographers and radiological technicians. The Hague/ Boston /London , 4th edition; 1980. p. 184. https://doi.org/10.1007/978-1-349-04630-0_9.
2. Zeljkovic V. Video surveillance techniques and technologies. 1st edition, Information Science Reference; 2013. p. 216. https://doi.org/10.4018/978-1-4666-4896-8
3. Second Generation Image Intensifier [Internet]. [cited 2017 Aug 31]. Available from: http://www.lambertinstruments.com/technologies-1/2014/12/4/second-generation-image-intensifier.