Removal of camera overlap artifacts in the Lodox system

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Abstract

The Lodox system, developed by Debtech in South Africa, is a medical digital x-ray scanner. In this system multiple cameras are used to acquire a large high-resolution image. However, camera overlap artifacts persist in the image despite calibration and hence devalue the quality of the image. This paper describes the properties of the artifacts and proposes an algorithm to be used for their removal without loss of image detail.

1. Introduction

Figure 1 shows a Lodox image with camera overlap artifacts that appear as vertical lines. These artifacts are marked with downward pointing arrows and are a consequence of the manner by which the outputs of multiple cameras are merged into a single image. Although simple gain compensation based on low absorption calibration data is performed, the artifacts remain visible for a large range of x-ray absorption levels. It is of great interest to remove the artifacts because they obscure details in the image.

As described in [1], absorption level based methods fail to eliminate the artifacts at places in the image because the artifacts are not only a function of absorption level. In this paper a new method is introduced which appreciates that the artifacts change in accordance with the shape of the imaged object.

In the next section, the nature of the artifacts is described. An automatic absorption level algorithm is discussed in section 3 and the proposed image-dynamic algorithm is explained in section 4. Finally, results are provided in section 5.

2. Artifact properties

The most evident quality of the artifacts is that they occur in certain pixel columns only. These columns can be identified *a priori* because they are determined by the geometry of the scanner.

Image intensity profiles of Lodox images of 6 different metal bars are shown in figure 2. Since the metal bars are of constant density, straight lines are expected in the absence of the artifacts. The downward pointing arrow marks the position in the profiles where the artifacts can be seen. Both the size and shape of the artifacts change at different absorption levels.

Figure 3 shows a close-up Lodox scan of a metal bar. It is evident that the shape of the artifact is significantly different in the three indicated regions. Regions A and C show transient artifacts near the edges of the metal bar while region B shows a steady state artifact at the given absorption level.

3. Absorption level based algorithm

The method discussed in this section simply ignores the fact that the artifacts change shape near absorption level steps. It is assumed that the artifact shape is dependent only on the mean absorption level at that point. Consequently the method fails to remove the artifacts in certain places where there are abrupt, large changes in image intensity.

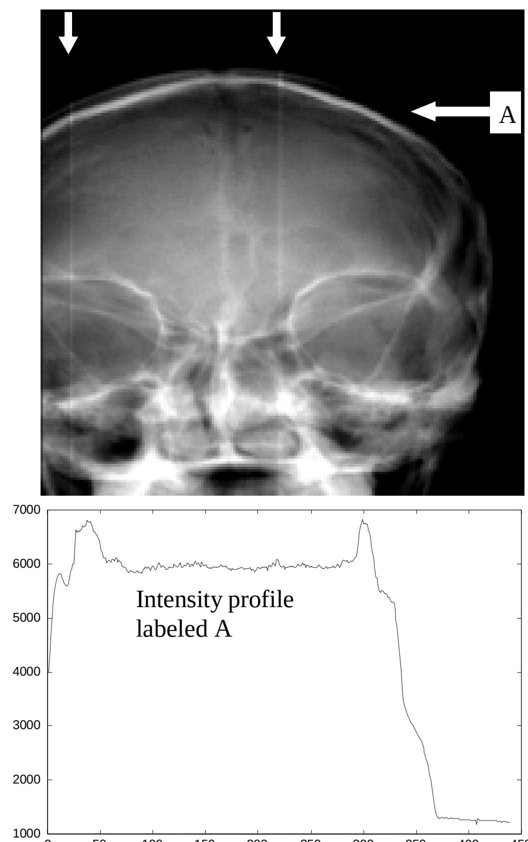


Figure 1: Lodox image with camera overlap artifacts marked with arrows.

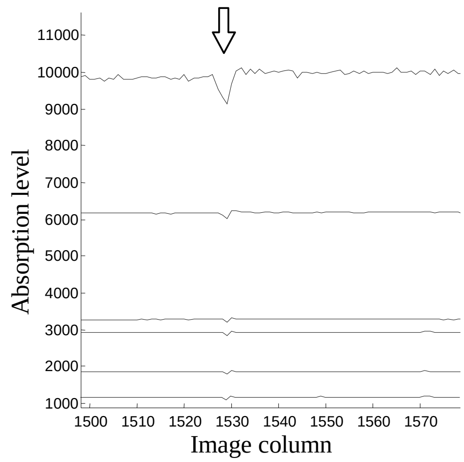


Figure 2: Image intensity profiles for different metal bars.

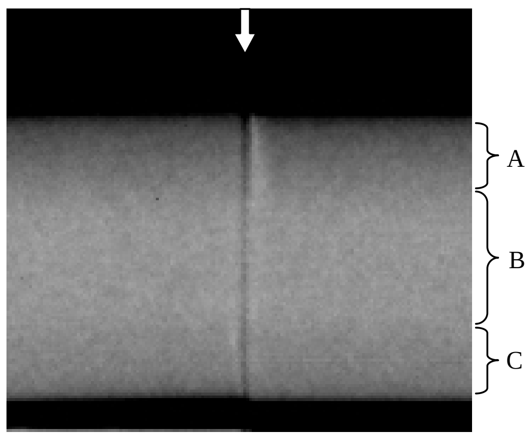


Figure 3: Lodox image of metal bar shows how artifact change near edges of metal bar.

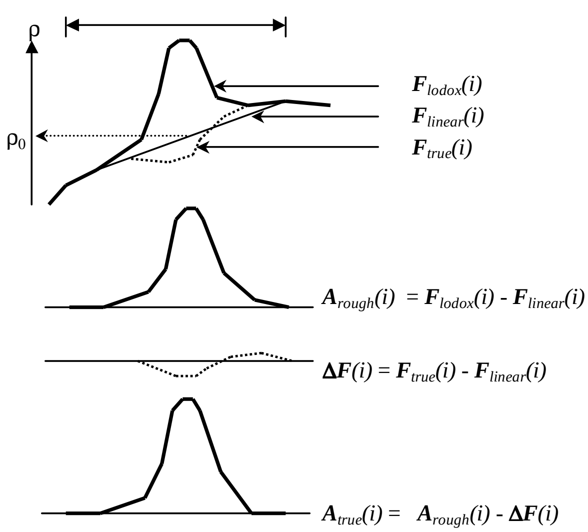


Figure 4: Visual representation of terms used.

Firstly, linear interpolation is performed horizontally across the artifact. A rough estimate of the artifact, $\boldsymbol{A}_{rough}(i)$, for each row, i, is obtained by subtracting the relevant columns of the original Lodox image, $\boldsymbol{F}_{lodox}(i)$, from the linear interpolations, $\boldsymbol{F}_{linear}(i)$. Each of these rough estimates $\boldsymbol{A}_{rough}(i)$ are associated with the mean absorption level, ρ_0=mean($\boldsymbol{F}_{linear}(i)$) of the linear interpolation at that row. See figure 4 for a visual representation of various terms.

The true shape of the artifact $\boldsymbol{A}_{true}(i)$ at row i can be written as

$$\boldsymbol{A}_{true}(i)= \boldsymbol{A}_{rough}(i)- \Delta\boldsymbol{F}(i)$$

where $\Delta\boldsymbol{F}(i)$ is detail of the true image profile that is clipped off by the linear interpolation. If there are N rows with the same absorption level tag ρ_0, indexed with k, the expected true artifact for this set of rows can now be calculated as

$$\begin{aligned}\boldsymbol{A}_{true}(\rho_0) \equiv \langle \boldsymbol{A}_{true}(k)\rangle &= \langle\boldsymbol{A}_{rough}(k)\rangle - \langle\Delta\boldsymbol{F}(k)\rangle \\ &= \langle\boldsymbol{A}_{rough}(k)\rangle - 0 \\ &= 1/N \textstyle\sum_k \boldsymbol{A}_{rough}(k).\end{aligned}$$

The expected value of $\Delta\boldsymbol{F}(k)$ is zero because it is assumed that there is no correlation in the clipped off detail amongst the rows in the underlying image.

In practice the absorption level tags ρ_0 are quantized and a linear interpolation scheme is used to build a lookup table of artifact shape versus absorption level. This lookup table is then used to predict the artifact shape at an arbitrary absorption level in the image which can then be subtracted out of the image.

4. Image-dynamic algorithm

The assumption on which the image-dynamic algorithm discussed here is based is that the artifacts change slower than the image detail in the vertical direction. Therefore, blurring the image in the vertical direction will not have a significant effect on the artifact yet it will smooth out image detail.

In this implementation of the algorithm, the amount of image detail at a point is assessed using the blurred magnitude of the gradient of the result of the absorption level based algorithm.

Figure 5 shows the result of blurring the image in figure 1 with a fixed kernel size in the vertical direction only. Except for the artifacts, the image appears to be blurred in *both* the horizontal and vertical directions in regions where there are predominantly horizontal edges such as at the top of the skull. However, at the right hand side of the skull, the image appears less blurred since there are mostly vertical edges. The horizontal blurring is perhaps easier seen in the intensity profiles also provided in the figures.

The algorithm varies the size of the one-dimensional vertical blurring kernel for each row to match the image detail and thereby attempt to achieve uniform horizontal blurring indirectly. Since the artifacts are assumed not to change as rapidly as the image detail in the vertical direction, they are not affected by the vertical smoothing.

As in figure 5, all except the artifact appear smoothed horizontally by vertical blurring and it is possible to predict a smooth profile across the columns affected by the artifact using cubic spline interpolation. The artifact is then taken as the difference between the cubic spline interpolation and the vertically smoothed image. Then the artifact is simply subtracted from the original Lodox image.

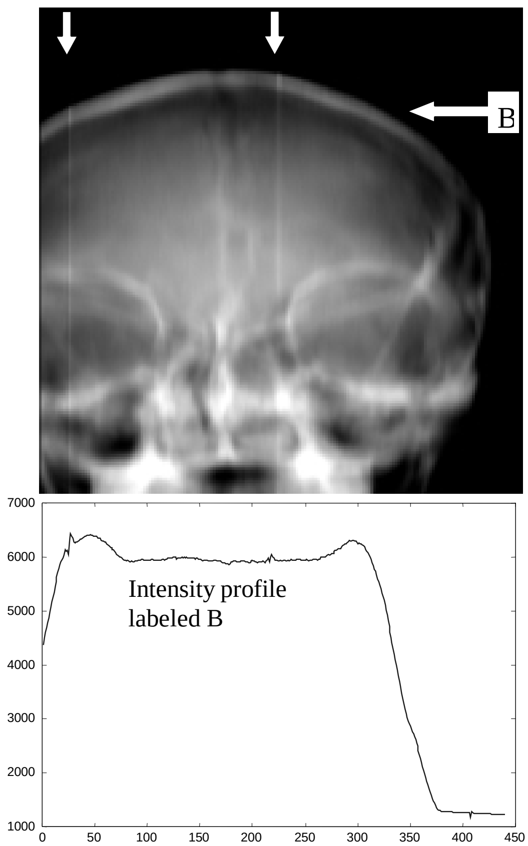


Figure 5: Lodox image blurred in vertical direction by fixed amount.

5. Results

Figure 6 shows the result of the image dynamic algorithm performed on the Lodox image shown in figure 1. Close-up views of a region that is poorly remedied by the absorption level based algorithm are shown in figure 7.

Experimentation with the image dynamic algorithm on Lodox images of high contrast metal test scenes has proven to be less successful in some cases [2] where vertical smoothing does not induce horizontal blurring sufficiently. Fortunately this phenomenon is not found in medical images.

6. Conclusion

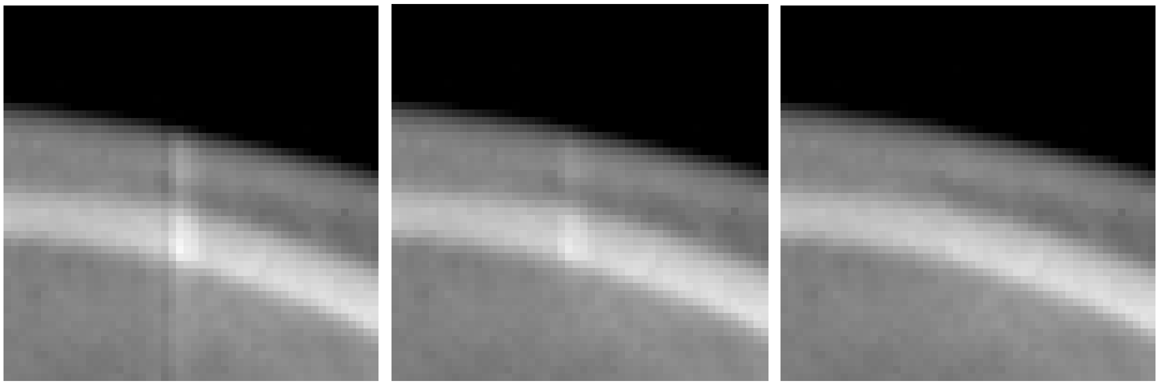
In this paper two methods were presented that can be used to remove artifacts from Lodox images. It is clear from the results that the image dynamic algorithm outperforms the absorption level based algorithm in terms of quality when applied to medical images.

7. References

[1] M. de Villiers, “Investigation of the removal of Lodox Artifacts”, Technical report. Digital Image Processing, University of Cape Town, October 1999.

[2] M. de Villiers, “Removal of Lodox Camera Overlap Artifacts II”. Technical report. Digital Image Processing, University of Cape Town, May 2000.

Figure 6: Result of image dynamic algorithm.



a) Lodox image b) Result of absorption level based algorithm c) Result of image dynamic algorithm

Figure 7: Results of artifact removal algorithms