# Homomorphic Alpha Blending of Long Bone Digital Radiography Images

Đorđe Starčević, Vladimir Ostojić and Vladimir Petrović

*Abstract*—**Radiography image merging is used to present anatomies which are larger than the available x-ray detector. Merging is utilized to obtain long bone anatomy images composed of two or more individual images. A homomorphic approach is introduced in order to equalize statistical properties of composing images. Alpha blending is employed to perform merging and achieve gradual transition between the composites. Clinical medical images were used for proposed algorithm evaluation. Experimental results show merging which can be used as a part of long bone image acquisition systems.**

***Index Terms***—**Alpha blending, digital radiography, image merging, image stitching, medical images.**

## I. Introduction

RADIOGRAPHY image merging is a common issue used to depict anatomies whose size exceeds acquisition possibilities of used digital radiography detector. Composing two or more individual images into one without loss of useful information or introducing artefacts is required in several radiography techniques such as diagnostic radiography [1-3], fluoroscopy [4-6] and is even used with infrared imaging [7].

Due to the nature of the acquisition methods used in medical imaging, images or image sections that are to be merged differ in terms of intensity, contrast etc. These differences vary in prominence yet need to be overcome in order to achieve quality merging. Quality of the merged image can be defined by its similarity to its composing parts, meaning that the resulting image should not affect detail visibility or introduce merging artefacts.

When it comes to diagnostic digital radiography image, the most common need for image merging occurs during imaging of long bone anatomies, such as legs, arms or spine. Composing images, depicting parts of the anatomy, are combined into one larger image providing a complete overview of the anatomy. It should be noted that the image combining process is performed after the individual images are acquired, not during the acquisition process. This process can also be referred to as image stitching [1-7]. An example of image stitching is shown in Fig. 1.

Đorđe Starčević is with the University of Novi Sad, Faculty of technical sciences, trg D. Obradovica 6, 21000 Novi Sad, Serbia (e-mail: djordje.starcevic@uns.ac.rs).

Vladimir Ostojić is with the University of Novi Sad, Faculty of technical sciences, trg D. Obradovica 6, 21000 Novi Sad, Serbia (e-mail: vladimir.ostojic@uns.ac.rs).

Vladimir Petrović is with the University of Novi Sad, Faculty of technical sciences, trg D. Obradovica 6, 21000 Novi Sad, Serbia (e-mail: vladimir.petrovic@uns.ac.rs).

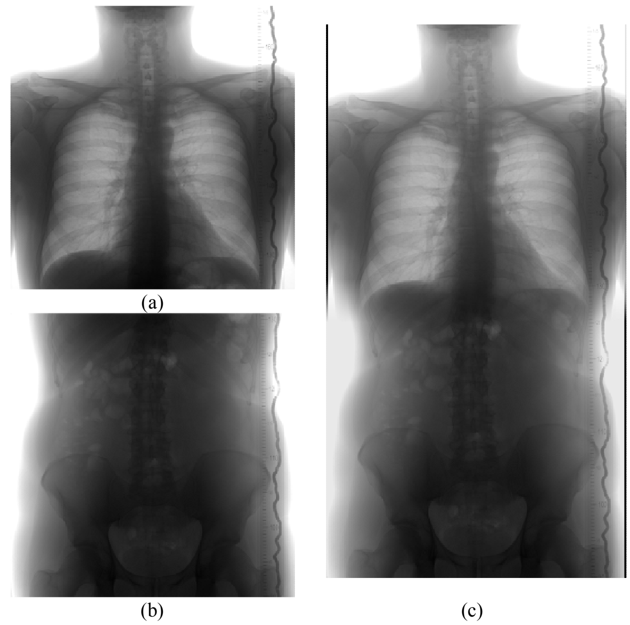



Fig. 1. Example of combining two successive exposures (a) and (b) into one long bone anatomy image (c).

A technique using homography and blending for x-ray image stitching is presented in [1]. Authors of [2] present a method for automatic determination of the order, orientation, and overlap arrangement of the composing computed radiography images. Fast automatic registration of multiple digital radiography exposures based on image feature interpretation is presented in [3]. Radiolucent ruler placed alongside long bone was used as a common feature in fluoroscopic image stitching in [4]. Issue of correct alignment of fragments in fluoroscopy long bone images is presented in [5]. An approach to efficient stitching of intra-operative x-ray images is described in [6]. Infrared medical image stitching technique is presented in [7].

In this paper we propose an approach for x-ray image merging that uses alpha blending of preprocessed images. The preprocessing step is performed in homomorphic domain to reduce differences between the composing images.

Homomorphic approach to improve image merging is introduced in Section II. Section III describes alpha blending technique. Experimental results are presented and discussed in Section IV. Section V concludes the paper.

## II. Homomorphic Approach

An intentional spatial overlap between images composing the long bone anatomy is introduced, which ensures there is common information through which the images can connect. However, even though the images depict the same anatomy, irradiation parameters used for individual acquisitions may not be the same, leading to different signal statistics in the overlapping region. Additionally contributing to the previous issue are phenomena such as scattered radiation, noise and involuntary patient motion. These differences between the composing images should be reduced if quality merging is to be achieved.

Let us denote the composing images as $I_1$ and $I_2$. We can then present the sections of these two images corresponding to the overlapping region as:

$$\begin{aligned} R_1 &= I_{01} \cdot e^{-\int \mu(t)dt} \\ R_2 &= I_{02} \cdot e^{-\int \mu(t)dt} \end{aligned} \tag{1}$$

where $\mu$ represents linear attenuation coefficient of the irradiated anatomy, $I_{01}$ and $I_{02}$ represent irradiation intensities used for acquisitions while $R_1$ and $R_2$ represent incident signals detected by the detector [8] for images $I_1$ and $I_2$, respectively. In (1), for simplicity, we assume that the attenuation coefficient is independent of the irradiation characteristics.

Establishing a simple relation between $R_1$ and $R_2$ is not straightforward. We therefore propose a homomorphic approach which performs a linear to logarithmic domain conversion of pixel intensities. Upon applying the logarithmic function to (1), we reach:

$$\begin{aligned} \log R_1 &= \log I_{01} - \int \mu(t)dt \\ \log R_2 &= \log I_{02} - \int \mu(t)dt \end{aligned} \tag{2}$$

Subtracting the previous equations leads to:

$$\log R_1 - \log R_2 = \log I_{01} - \log I_{02} = C \tag{3}$$

where $C$ represent a constant.

This leads to the conclusion that the difference between the regions in logarithmic domain is constant. Based on this, we propose a global mean value equalization of the images. It should be noted that such equalization should be performed on the entire image, not just the section corresponding to the overlapping region. This can be done by adding the constant $C$ to the image log $I_2$, which represents the image $I_2$ in the logarithmic domain. This is a preprocessing step which ensures similar image statistics leading to better quality merging as shown in Section IV.

Usefulness of the logarithmic transformation is not reflected only in providing the simpler relation between the overlapping regions. As stated in [9], this conversion is an important part of medical image processing frameworks with the aim of dynamic value range compression. Purpose of the previous is to provide a suitable domain for image processing due to the fact that values presented in the logarithmic domain are inversely proportional to the anatomy thickness [10]. What is more, transformation into logarithmic domain does not substantially add to complexity of the image processing pipeline, as it can easily be implemented through a look-up-table.

## III. Alpha Blending

Merged image is a result of combining two composing images and it depicts the entire long bone anatomy. This image consists of three regions. Two of them correspond to sections of the composing images that are complementary to the section of the overlap, while the third is the product of merging $R_1$ and $R_2$.

After alleviating intensity differences in the logarithmic domain, values of pixels in the section of the merged image which corresponds to the overlapping region should be determined. These values can, for example, be obtained by taking the mean value of corresponding pixels from each composing image. This approach, appealing due to its simplicity, does not produce satisfactory results, as the merging algorithm should provide gradual transition from one image to another. As shown in Fig. 2, taking the mean value of the pixels representing the overlapping region fails to provide the desired transition.

Fig. 2. Merging images by taking mean pixel values in the overlapping region.

In our approach, we employ alpha blending (also known as alpha composition), which utilizes the linear combination of image pixel values [1], [7].

Let us suppose that $x$-axis corresponds to the horizontal and $y$-axis to the vertical image axis, with the coordinate origin positioned in the top left corner of the merged image. Suppose that the composing images $I_1$ and $I_2$ are vertically aligned, and that their vertical dimensions are $D_{1y}$ and $D_{2y}$ respectively.

Let the top of the overlapping region in the merged image be set at horizontal profile $y = y_1$, and the bottom of the overlapping region be set at horizontal profile $y = y_2$. Vertical dimension of the merged image, denoted $MD_y$, is determined as:

$$MD_y = D_{1y} + D_{2y} - (y_2 - y_1) \tag{4}$$

We can then calculate the merged image $M$ as:

$$M(x,y) = \alpha(y) I_1(x,y) + (1-\alpha(y)) I_2(x,y) \tag{5}$$

where $x$ and $y$ denote spatial coordinates. $\alpha$ is determined as:

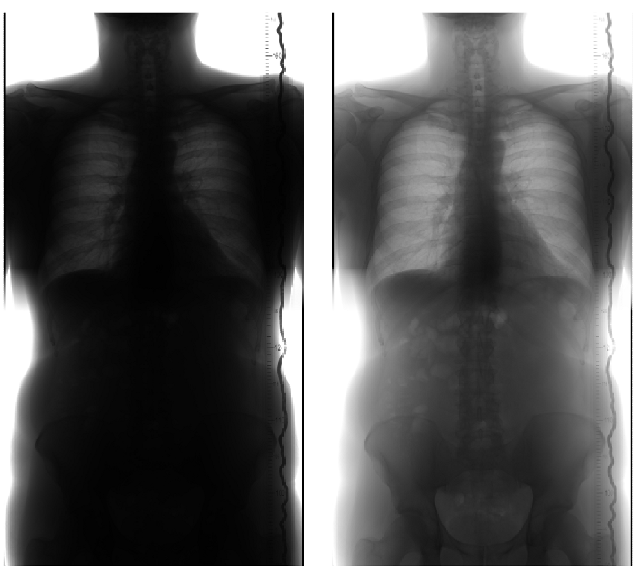
$$\alpha(y) = \begin{cases} 1, & 0 < y < y_1 \\ \dfrac{y - y_2}{y_1 - y_2}, & y_1 < y < y_2 \\ 0, & y_2 < y < MD_y \end{cases} \tag{6}$$

Analogous analysis can be performed for horizontally aligned composing images $I_1$ and $I_2$, by substituting $y$ with $x$.

## IV. Evaluation and Results

For the purpose of verification of the proposed image merging method we used a database consisting of 5 pairs of digital radiography images, obtained during regular clinical routine, as well as 10 pairs of phantom images. The used phantom is especially designed to simulate human torso.

To determine and align overlapping regions in the images, a long ruler with a lead curved line was employed (approach similar to [3] and [4]). The ruler is a planar structure resistant to parallax and is visible on the right side of the images shown in each figure in the paper.

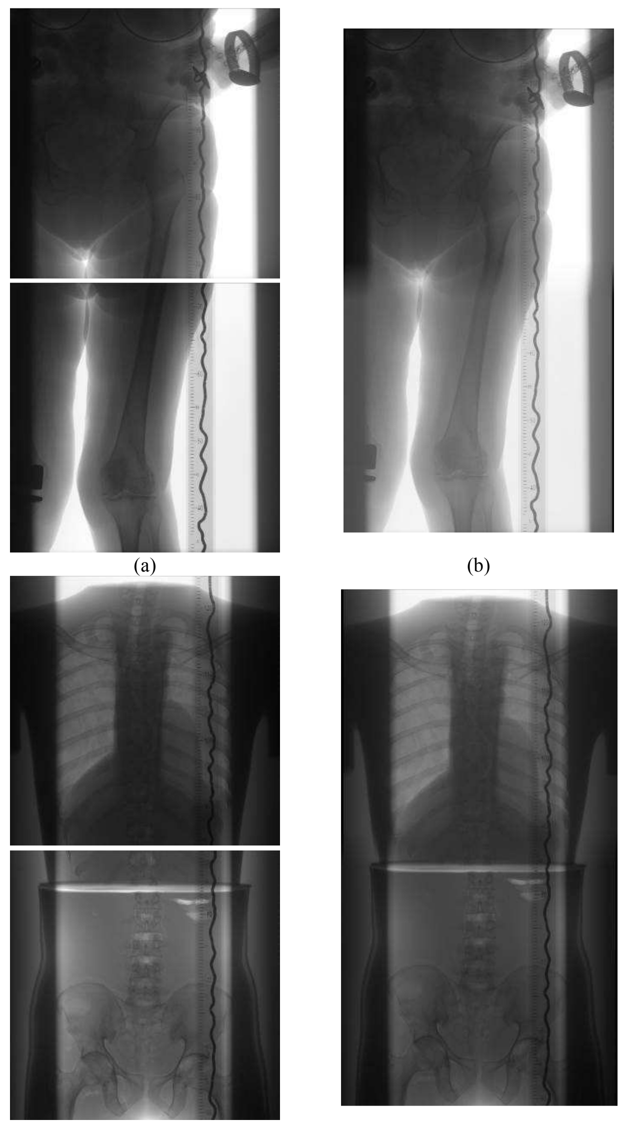


(a) (b)

Fig. 3. (a) Example of image merging in the original domain. (b) Logarithm of the image shown in (a).

To counter our hypothesis, we tested alpha blending without homomorphic mean value equalization, i.e. in the original image domain (Fig. 3 (a)). It is apparent that this image has very low detail visibility. For comparison, in Fig. 3 (b) we show the logarithm of the image. Note that the purpose of the logarithmic function here is not related to homomorphic approach, but is related to dynamic range compression.

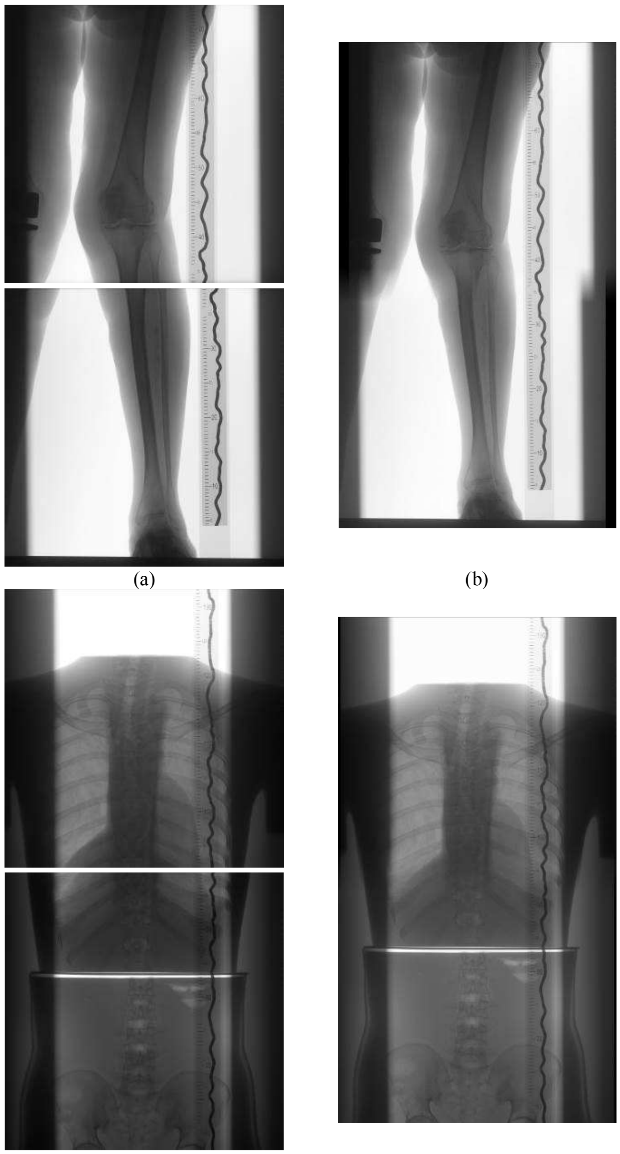
As seen in Fig. 3 (b), the result is better in comparison to calculating mean pixel values for the overlapping region (see Fig. 2). As previously stated, alpha blending has created a gradual transition between images. However, result is still not satisfactory. As visible, image regions depicting shoulders and sternum appear darker than the rest of the anatomical structures, which is contrary to anatomy thickness properties. The proposed approach provides gradual transition and, as can be seen in Fig. 1 (b), produces merged image intensities consistent with the anatomical thickness.



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

Fig. 4. Examples of image merging using homomorphic alpha blending with clinical ((a) and (b)) and phantom images ((c) and (d)).

Examples of image stitching using algorithm proposed in this paper are shown in Fig. 4 and Fig. 5.



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

Fig. 5. Examples of image merging using homomorphic alpha blending with clinical ((a) and (b)) and phantom images ((c) and (d)).

Upon visual inspection of the obtained results presented in Fig. 4 and Fig. 5 it is clear that homomorphic alpha blending approach provides high quality merging. Merged images did not lose composing parts detail visibility and did not introduce merging artefacts.

## V. Conclusion

In this paper we proposed a method to perform merging of digital radiography images. We introduced a homomorphic approach with the purpose of equalizing statistical properties of composing images. Alpha blending was used to perform merging and to achieve gradual transition in the overlapping region. The proposed method was evaluated on a database consisting of phantom and clinical medical images, with the results showing merging that can be employed in medical practice.

Future work should focus on utilizing the proposed homomorphic alpha blending approach for image merging in automated long bone radiography image acquisition systems.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