# Autofocusing panoramic radiographic image by all-in-focus image fusion


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***Abstract*—Digital panoramic radiographic imaging is routinely used by radiologists to assess the structural information about the patient. To minimize the inconvenience to the patient during the image acquisition and to complement for the imperfection of imaging systems, attempts have been made to generate several panoramic radiographic images at a time, each with different focus area. However, this leads to the inconveniences for the radiologists in exploring many panoramic radiographic images at a time. In this paper, we propose to do "autofocus" image fusion by computing an all-in-focus panoramic image from those panoramic radiographic images. This is to ensure the only one all-in-focus panoramic radiographic image is showed to the radiologists. The experimental results confirm the effectiveness of the proposed approach in producing the only one all-in-focus panoramic radiographic image, easing manufacturers, radiographers and radiologists from manually selecting the optimal image to be used in clinical assessment.**



***Keywords — Autofocusing, panoramic radiographic imaging, panoramic radiology, focus measure, all-in-focus.***


## I. Introduction

The purpose of panoramic radiographic imaging systems [1] is to acquire the information about the object from which the decision will be made accordingly. In dental imaging, the panoramic radiographic image shows a two-dimensional view of a nearly half circle from ear to ear of patient. The radiologists will examine this image to find hidden dental structures, malignant or benign masses, bone loss, and cavities.

A panoramic radiographic imaging system consists of an X-ray source, a narrow and long detector, and a central unit to control the movement of X-ray source and detector for a certain panoramic movement so that only the specific layer of interest is shown up in the final image. The raw projection data acquired by the detector will be used to construct a panoramic image of a predefined imaging layer. The formation of panoramic radiographic image is carried via a popular shift-and-add algorithm [2]. However, due to the mismatch between the designated image layer and the actual structure to be focused, the resulting panoramic radiographic image is usually focused on a particular region while the others get blurred.

To overcome this limitation, attempts have been made to perform multi-focus panoramic radiographic imaging where multiple layers are imaged at a time. In particular, the multi-focus function is smartly done by adjusting the internal parameters within the shift-and-add algorithm, from which the multi-focus image layers are constructed [3, 4]. Though these multi-focus images enable the radiologists to freely explore the most focused area by themselves, it is time consuming to do so, especially when the image area is of large size. Therefore, there is a need for the autofocusing from these images.

In this paper, we propose an approach to perform autofocusing for panoramic radiographic imaging by combining multi-focus images (which correspond to different panoramic layers) via an image fusion process as shown in Fig. 1(a). This approach for panoramic radiographic imaging has been drafted in a recent patent [5]. However, while the author in [5] proposed to selectively choose the layers to be used in the final panoramic image so that for a particular region in the final image the information comes from only one layer, our approach uses all-in-focus technique to generate the final all-in-focus panoramic image in which, for a particular region in the resulting panoramic image, the sharpness comes from different layers.

The remainder of this paper is organized as follows. Section II presents the pipeline of generating image stack or well-aligned images from panoramic raw projection data. This section also presents a method to generate an all-in-focus image from the image stack. Section III presents our experimental results. Section IV discusses and concludes.

## II. Autofocusing Panoramic Radiographic Image

### *A. Project Data Acquisition*

In a standard panoramic X-ray system, the X-ray source and the detector are mounted to and fixed in two opposite sides of a suspension arm. The suspension arm is mounted onto a fixing and moving means which allows the suspension arm to rotate and move around the object to be imaged in a special trajectory. The angular speed and linear movement speed of the arm are maintained so that the X-rays from the source to the detector are as perpendicular as possible to the dental arc to be imaged.

### *B. Multifocused Image from a Single Projection Dataset*

The resulting projection data from image acquisition will then go through image reconstruction process that involves the shift-and-add algorithm [2]. With traditional reconstruction scheme, we can generate the only one panoramic radiographic image corresponds to the focus layer at a time. However, if the

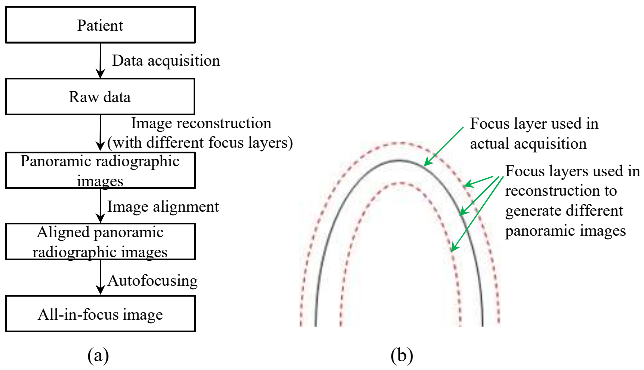



Fig. 1. (a) Flowchart of the proposed method; (b) Illustration of different focus layers (profiles) used in reconstruction from which different multi-focus images are generated (In our experiment, 9 layers were used).

patient's jaws are not close to the central plane of the image layer, the spatial resolution of panoramic radiographic images rapidly decreases and the quality of the image degrades. In addition, due to the differences in the shape and size of the jaws among individuals, some patients may not fit perfectly into a given panoramic unit's image layer. Therefore, the positioning of a patient's jaws to obtain an optimum quality image is burdensome for radiographers.

To ease this difficulty, in the reconstruction process using shift-and-add algorithm, instead of using the only designated focus layer (used in acquisition process), we use several focus layers differ from the designated one to generate the shift profiles used in the shift-and-add algorithm (See Fig. 1(b)). To reduce the confusion, we name these focus layers as "profiles". By doing so, we can generate several panoramic radiographic images from a single projection dataset, each resulting panoramic radiographic image (layer) corresponds to a different profile. Therefore, each panoramic radiographic image has its own profile, thereby, its own focus region.

### C. *Aligning Multifocused Image*

Due to the difference in the viewpoint of each panoramic radiographic image as well as the nature of panoramic radiographic imaging, panoramic radiographic images from different profiles will have different sizes and lightly different content. Therefore, we need to resize and align these images with respect to the reference image which corresponds to the focus layer that was used in the actual data acquisition. Note that resizing these panoramic radiographic images is usually not done in the whole image but with image regions [5].

Having the resized images of theoretically the same image object, the image alignment can be done by using several image registration methods [6]. However, due to the nature of X-ray image, feature-based methods are less stable than direct area-based method. In this work, we use the direct method and employ enhanced correlation coefficient (ECC) algorithm [7] to this parametric image alignment problem. The alignment is made with respect to the panoramic radiographic image in reference profile. (See Fig. 2).

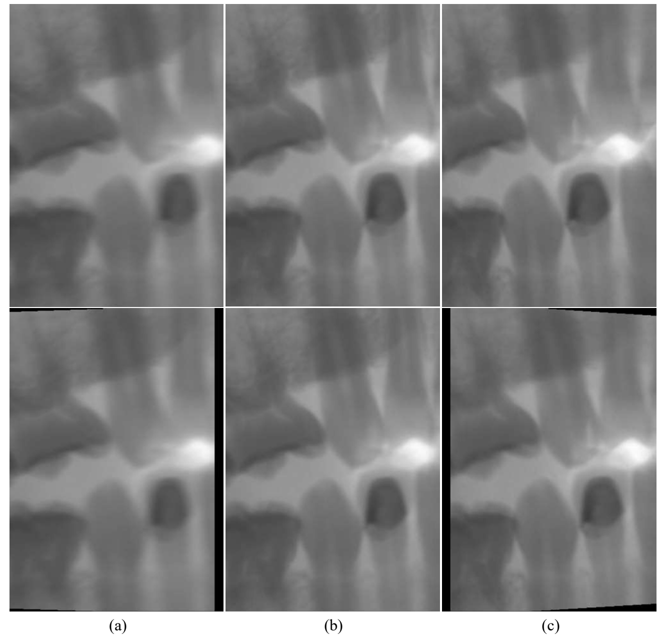



Fig. 2. The images in the first row of (a) , (b), and (c) are results from different profiles. Images in second row are aligned results with respect to the reference image in (b).

### D. *Autofocusing by Computing All-in-focus Image*

Each panoramic radiographic image in the multi-focus images generated in Section II.C focuses on different object and not all visible object in the image are focused. Therefore, it is naturally to use image fusion technique to combine those images to obtain a higher quality image more suitable for human interpretation. In dental imaging field it is called autofocus. In this particular case of panoramic radiographic imaging, it is focus fusion (all-in-focus) where all visible objects are focused.

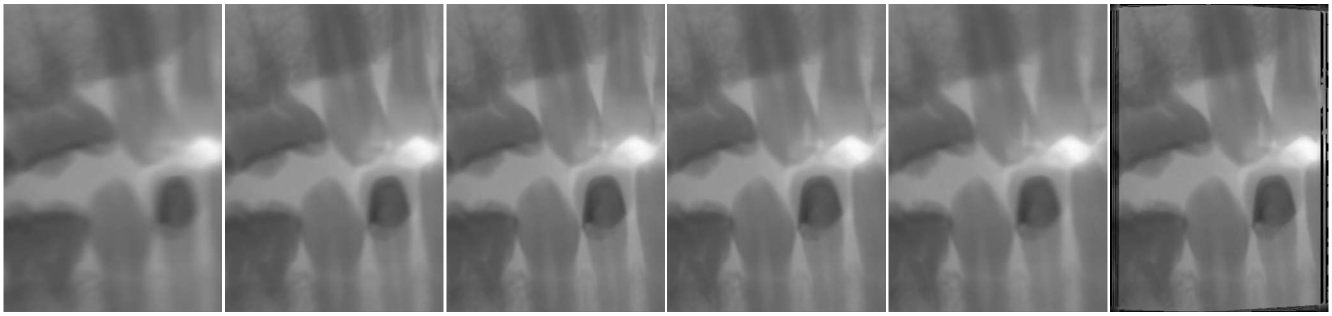
In this work, we use the method in [8] to generate the final all-in-focus panoramic radiographic image. It selectively fuses the different frames of the focus sequence in order to reduce noise while preserving image features. It has three steps and can be summarized as follows. (Details can be found in [8])

Given image stack $I_k$ ( $k = 1,...,K$ , where $K$ is the number of image layers or "profiles" in the multi-focus step in Section II.B), in step (i) *focus measure*, a transformation is applied to the image $I_k$ ( $k = 1,...,K$ ) to improve its sharpness. The energy of the transformed image over a region of interest is then used as a focus level estimator.

In step (ii) *selective measure*, since the focus measure calculated in step (i) is sensitive to noise, it is complemented with a selection scheme to determine if the focus measurement is reliable or not. Finally, given the selective measure, in step (iii) *image fusion*, the final all-in-focus image is calculated as weighting average of input images. The weights are determined by the image content and selective measure.

## III. EXPERIMENTALRESULTS

We applied our approach to a raw projection dataset acquired from a laboratory dental panoramic X-ray scanner



(a) Layer #1 (b) Layer #3 (c)Layer #5 (d) Layer #7 (e) Layer #9 (f) Autofocused

Fig. 3. Panoramic radiographic images for computing all-in-focus image. First to fifth images are samples from 9 layers used to compute all-in-focus image. The sixth image is the autofocused one. (The intermediate aligned images using ECC algorithm are not included here.). The image for layer #3 corresponds to the reference one (Direct comparison should be made between (b) and (f)).

TABLE I. GLOBAL CONTRAST FACTOR VALUES FOR DIFFERENT MULTI-FOCUS PANORAMIC RADIOGRAPHIC IMAGES AND AUTOFOCUSED IMAGE

| Image layer | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | Autofocused |
|---|---|---|---|---|---|---|---|---|---|---|
| ROI1 | 434.74 | 445.17 | 453.67 | 455.48 | 456.78 | 456.52 | 454.95 | 453.06 | 450.84 | **457.17** |
| ROI2 | 556.73 | 574.53 | 587.48 | 591.31 | 592.83 | 592.01 | 590.50 | 588.36 | 586.08 | **594.31** |

having the following parameter settings: the detector was of the size 202mm×8.7mm (2020×87 detector cells with the bin size of 0.1×0.1mm$^2$). The number of raw projection data file is 2424. We generate 9 profiles for panoramic reconstruction, the gap between two consecutive profiles is 6mm. These profiles will be used to generate 9 panoramic radiographic images, followed by extraction of regions to study the all-in-focus image.

We conducted studies in two different regions of interest (ROI). For each region, we compute the all-in-focus image. To qualitatively evaluate the performance of our approach, we compare the autofocused and non-autofocused results side-by-side. To make quantitative evaluation, we measure the global contrast factor (GCF) [9] of each image. GCF is considered as global focus measure and is strongly correlated to human assessment in term of the degree of focus of the image where the higher the value, the better the degree of focus.

Fig. 3 shows the samples from multi-focus (non-autofocused) images and the all-in-focus (autofocused) image for ROI #1. As shown in Fig. 3(f), the all-in-focus image obtained by our approach shows useful details (and in-focused) of objects instead having only part of the image being focused as in multi-focus images. Note that figs. 3(a)-(e) show images before alignment with respect to the reference image. Due to this alignment, the final all-in-focus image (Fig. 3(f)) contains unwanted region near the border. In practice, the region near the border will be truncated before showing the all-in-focus image to the radiologists.

Finally, Table I shows the global contrast factor calculated from different ROIs in panoramic radiographic images where the all-in-focus image(s) has the best (highest) value.

## IV. DISCUSSIONS AND CONCLUSIONS

We have proposed and validated a new approach to generate an all-in-focus image for panoramic radiographic imaging from a single data acquisition. The approach takes advantages of multi-focus method, which generate different panoramic radiographic images with different focus layers, to produce a single and all-in-focus image to the radiologists. The proposed approach will ease not only the manufacturers in producing the panoramic radiographic image, but also the radiographers and radiologists in exploring the inner structure of the patient from many panoramic radiographic images.

Future work includes using the global focus measure to automatically judge the quality of panoramic radiographic image, thereby automatically select the best all-in-focus image and to fine tune the inner parameters in steps of the algorithm to compute all-in-focus image. Study on the effectiveness of recent all-in-focus methods on the final autofocused panoramic radiographic image is also the subject of future work.

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