Reducing Intra Plane Blurring in Dental Panoramas

Christian Hofmann[1], Michael Knaup[1], and Marc Kachelrieß[1,2]

[1]Friedrich-Alexander-University (FAU), Erlangen, Germany

[2]German Cancer Research Center (DKFZ), Heidelberg, Germany

Introduction:

Dental imaging often requires to gather information from a curved plane that covers the upper and lower jaw. To acquire these data one may either use a CT scan followed by extracting the desired curved plane from the volumetric CT data (see bottom figure 2), or one may decide to work at much lower dose levels and acquire a panoramic radiograph (panorama). Due to the small size of specialized panorama x–ray detectors, the cone is collimated such that it is only a few millimeters wide in the fan direction. Assuming an imaging system based on flat detectors the panoramic imaging corresponds to digital x–ray tomosynthesis taken in a curved plane. Panoramic imaging suffers from significant blurring between adjacent planes, as it is inherent to all tomosynthesis techniques. To reduce this intra plane blurring we propose an approach that uses a form filter to simultaneously acquire the data for a typical panorama and data with a significantly increased fan–angle, while the bow–tie takes care to reduce dose in that extended region to about 1% compared to the dose in the central region.

Materials and Methods:

Assume that the curve $\boldsymbol{c}(t)$ with $0 \leq t \leq 1$ is the curve within the plane that shall be imaged in panoramic mode (see figure 1). To do so, the x–ray source shall ideally travel at a constant distance R_F from that curve. Let $\boldsymbol{w}(t)$ be the unit vector normal to the curve pointing towards the source. Then, the source position is given as $\boldsymbol{s}(t) = \boldsymbol{c}(t) + R_F\,\boldsymbol{w}(t)$. Let $\boldsymbol{u}(t)$ be the unit vector tangential to the curve. Now, one can define the position of the virtual flat detector as $\boldsymbol{d}(t,u) = \boldsymbol{c}(t) + u\boldsymbol{u}(t)$ with u being the coordinate along the detector's u–axis. The projection data acquired by the panoramic scan are the line integrals

$$p(t,u) = \int_0^\infty d\lambda\, f(\boldsymbol{s}(t) + \lambda\boldsymbol{\Theta}(t,u))$$

with $f(\boldsymbol{r})$ being the object and with $\boldsymbol{\Theta}(t,u)$ being the unit vector pointing from $\boldsymbol{s}(t)$ towards $\boldsymbol{d}(t,u)$. In dental panoramic imaging the x–ray fan–beam is collimated to be only a few millimeters wide, typically 5.0 mm [1]. The reconstruction of $f(\boldsymbol{r})$ can be done by a shift and add tomosynthesis approach which can also be realized with x–ray films. If large flat detectors are used, the object can be also retrieved at voxel positions other than those described by $\boldsymbol{c}(t)$. Due to the limited fan angle objects behind or in front of the curved plane $\boldsymbol{c}(t)$ tend to show up blurred in the reconstructed plane, especially the cervical vertebrae. We conducted simulations and for that we generated the rawdata we used from a volumetric CT data set of a patient's head (see figure 2). Dedicated systems for panoramic imaging based on x–ray films run a complicated source trajectory to guarantee correct focus and constant magnification [2]. Dedicated systems for panoramic imaging based on x–ray films run a complicated source trajectory to guarantee correct focus and constant magnification [2]. The source–detector trajectory in our simulations is a circle with the center of rotation in the jaw region so that the virtual detector best fits a circle through the patients teeth (see the dashed red circle in figure 2). To generate a panoramic radiograph with a flat detector one has to perform a shift and add tomosynthesis equivalent method which is done by direct backprojection. By sampling along an arbitrary trajectory in this volume one is automatically in focus with this plane as this sampling corresponds to a virtual detector along this trajectory. Our idea now is to take advantage of the flat detector and of the fact that we can acquire low–dose data in a large fan angle and use those to reduce the intra plane blurring. This allows us to compute the undesired background and subtract it from the original panorama. For that w denotes the width of the fan beam in millimeters and f_w is the corresponding panorama image. By using a wider fan angle one increases the depth resolution of the panorama automatically. We therefore propose to perform a frequency split between the original panorama f_5 that is acquired with a 5 mm wide fan beam (see figure 3) but which has a low depth resolution with a panorama f_{70} that uses a 70 mm wide fan beam (see figure 4) and which may be acquired at no additional patient dose if an adequate bow-tie filter is used . Figure 5 illustrates the workflow of the proposed method.

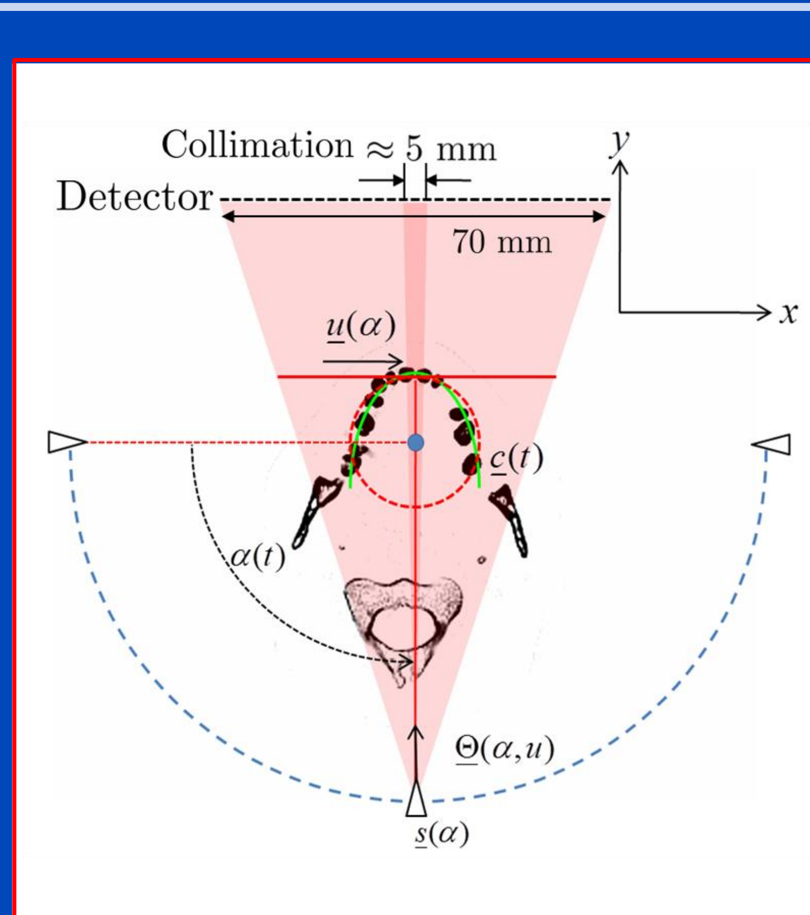

Fig. 1. Geometry of a panorama scan. The desired curve $\boldsymbol{c}(t)$ is the solid (green) curve. The dashed (red) circle approximates the solid (green) curve.

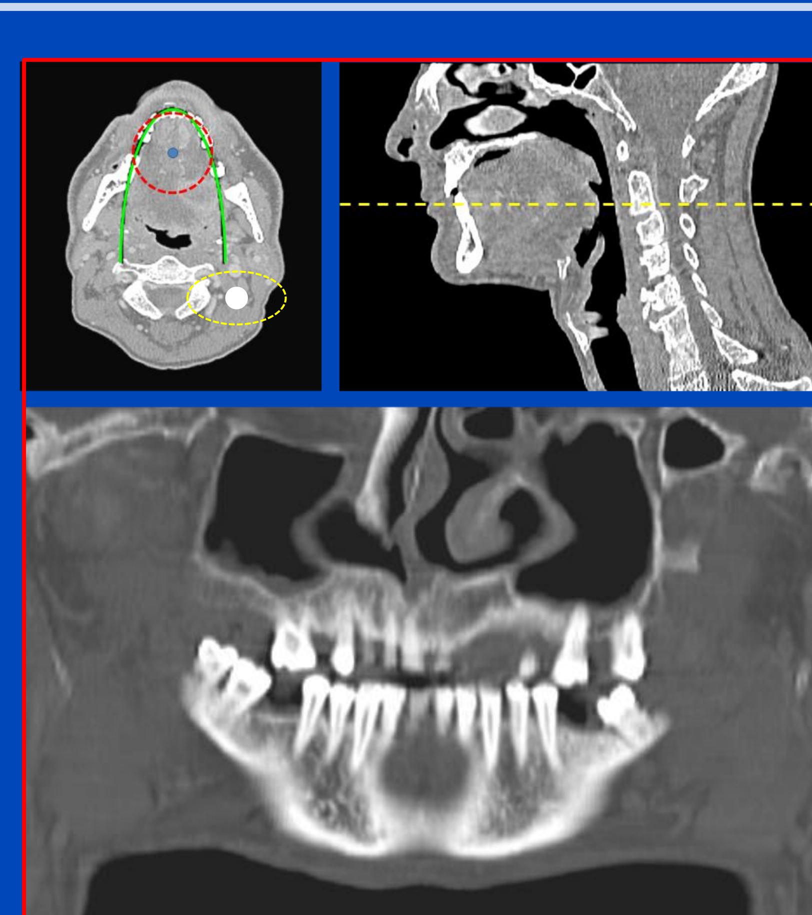

Fig. 2. Top left: Transversal slice of the CT volume used for our simulations. The green ellipse segment indicates the curve $\boldsymbol{c}(t)$. The yellow dashed ellipse shows a high contrast object simulated into the CT volume. Bottom: A curved multiplanar reformation along $\boldsymbol{c}(t)$.

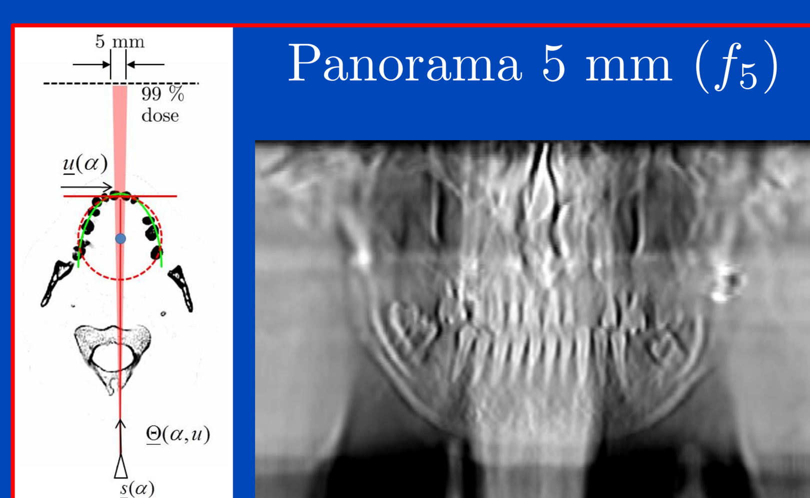

Fig. 3. A panorama image generated from a geometry typically used for panoramic imaging. The fan beam is collimated to 5 mm (f_5).

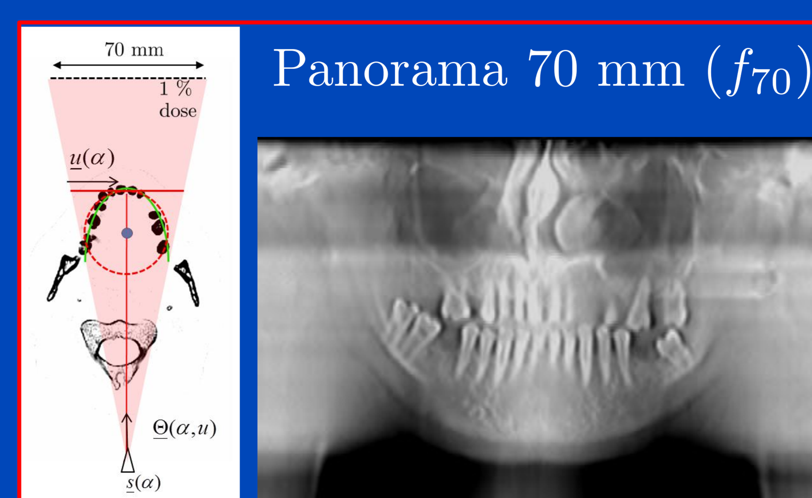

Fig. 4. A panorama image generated from a scan with a collimation resulting in a fan beam width of 70 mm (f_{70}).

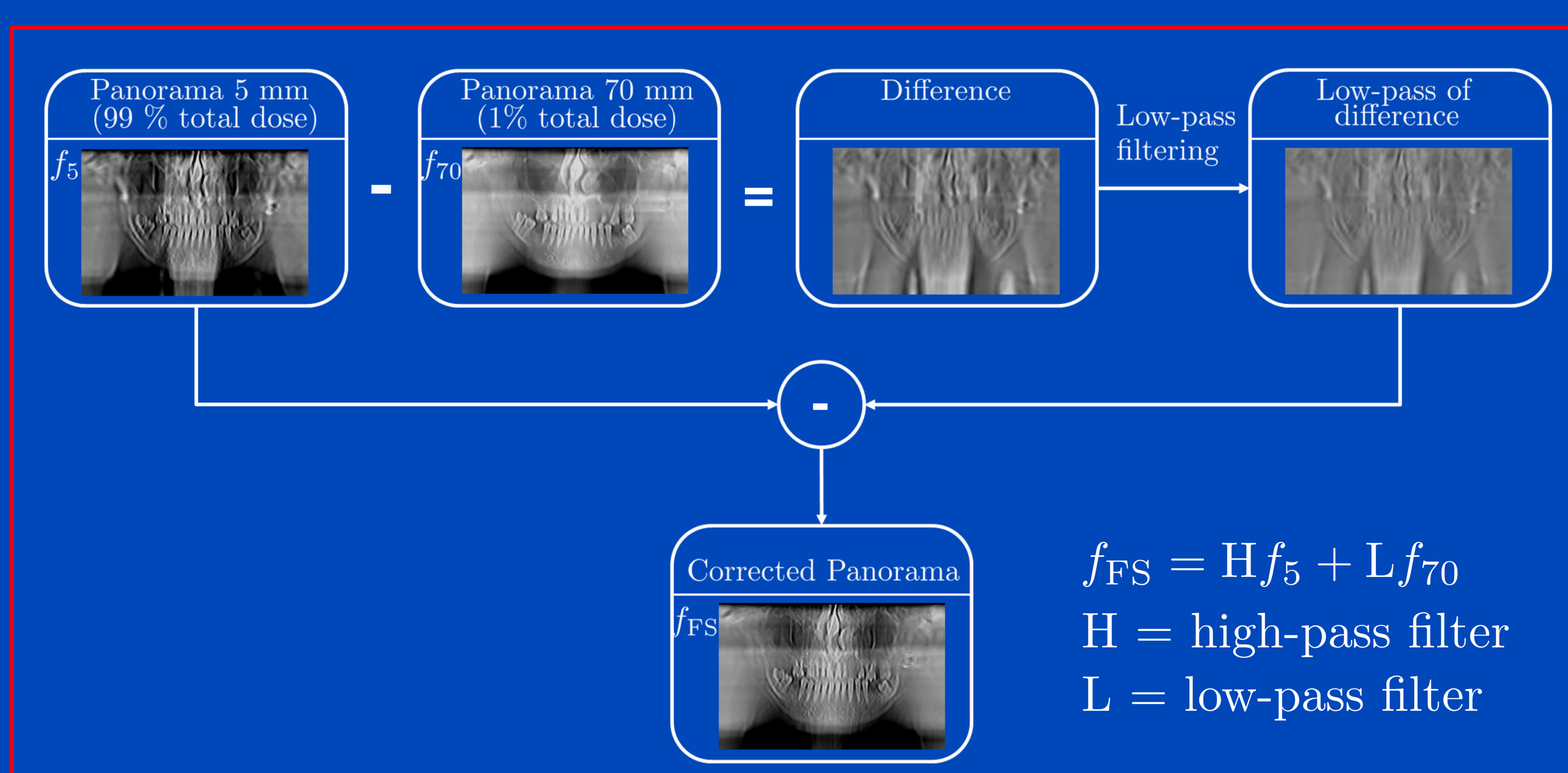

Fig. 5. Workflow of the proposed method. We propose to perform a frequency split between the original panorama f_5 that is acquired with a 5 mm wide fan beam but which has a low depth resolution, with a panorama f_{70} that uses a 70 mm wide fan beam. The difference yields the undesired background information in f_5 which is low-pass filtered before subtraction.

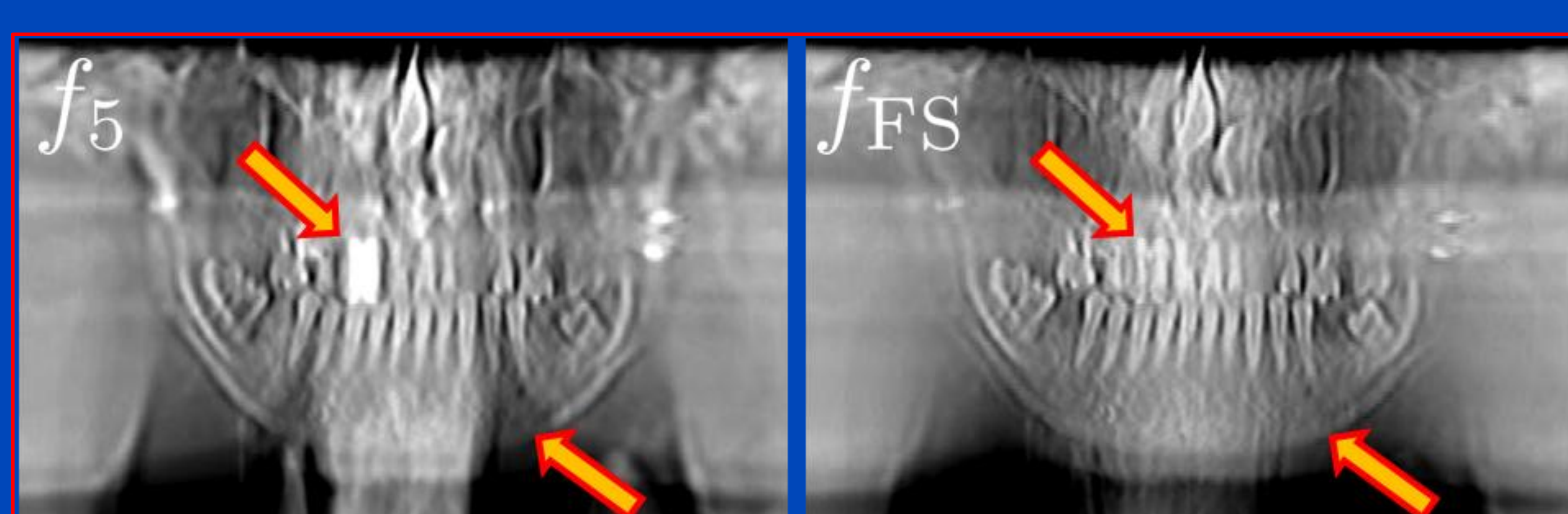

Fig. 6. Left (standard): A typical panorama image as it is obtained with a 5.0 mm wide x–ray fan beam (f_5). Right (frequency split Result f_{FS}): Due to combining low dose low resolution data from a wide fan angle with the standard dose high resolution data of the narrow fan angle the background becomes more homogeneous and details can be seen more clearly while patient dose is not increased.

References:

[1] U. Welander, W. McDavid, and G. Tonje, "Transtomography: a new tomographic scanning technique," Dentomaxillofac. Radiol, vol. 3, no. 33, pp. 188–95, May 2004.

[2] W. McDavid, G. Tronjet, and U. Welander, "A method to maintain a constant magnification factor throughout the exposure of rotational panoramic radiographs," Dentomaxillofac. Radiol., vol. 18, no. 6, pp. 160–168, Nov. 1989.

Results:

Figure 6 compares the original panorama image f_5 with the proposed frequency split panorama f_{FS}. To demonstrate the potential benefit of this method we simulated a high contrast object (see figure 2) which results in a high contrast shadow in f_5 (see figure 6, left image upper arrow). This artifact can be removed. The teeth that were covered by the shadow are now visible. Moreover one can achieve a more consistent image impression with a homogeneous background. Looking at the region indicated with the arrow to the bottom in figure 6 one can see that the inhomogenity in the chaw region in f_5 is now clearly visible in f_{FS}. The overall background bias can be significantly reduced. The shadow of the cervical vertebrae, which is the major cause for an inconsistent impression in panoramic images, can be removed. As f_{70} was generated with 1% of the total dose one has to perform low pass filtering of the difference image before subtraction. Thus the low frequency components can be satisfactorily removed which leads to the homogeneous image impression of f_{FS}. However potential edges arising from background structures will still be visible.

Summary and Conclusion:

Panoramic imaging with a flat detector offers the possibility to improving image quality without additional costs in patient dose.

Send correspondence request to:

Christian Hofmann

christian.hofmann@imp.uni-erlangen.de

Institute of Medical Physics

Henkestraße 91

91052 Erlangen, Germany

MIC 2012