Adaptation of Image Quality Using Various Filter Setups in the Filtered Backprojection Approach for Digital Breast Tomosynthesis

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Abstract. The main limitations of conventional projection mammography consist in tissue overlap and missing depth information. These deficiencies are intended to be reduced by the new technique of digital breast tomosynthesis. From a set of radiographic projections, acquired at different view angles in a linear tomosynthesis research system setup, 3-D slices of the scanned breast region are reconstructed. As the method of choice for the reconstruction we use filtered backprojection. By applying different filters with task-adapted parameters this method allows to control the image quality regarding noise, spatial resolution and artifacts. In order to investigate the basic effects of the various settings in the filtering step the method is first applied to simulated data. The impact of the selected filter functions is then demonstrated with clinical data.

1 Introduction

To overcome the limitations of tissue overlap and missing depth information in conventional (digital) mammography, the application of 3-D imaging methods to the breast seems appropriate. Digital breast tomosynthesis benefited by the progress in several key technologies such as flat detectors, reconstruction and post-processing algorithms, has become an interesting research topic within the last few years. Initial investigations on this technique have been promising and provide the opportunity to overcome drawbacks of conventional mammography by acquiring several views of the breast from different angles and reconstructing a 3-D data set. Separating lesions from overlapping dense fibroglandular tissue, tomosynthesis is expected to improve both detectability and characterization, while the applied dose can be kept comparable to mammography.

In Ref. [1] Grant described 1972 a type of geometric tomography he called tomosynthesis, which uses a conventional X-ray source and a digital detector to produce a virtually unlimited number of tomographic images at arbitrary depth in the patient. To date successful reconstruction and post-processing algorithms have included filtered backprojection, traditional shift-and-add reconstruction coupled with matrix inversion or constrained iterative restoration deblurring methods, and algebraic iterative reconstruction procedures [2-6]. The challenge for reconstruction algorithms consists in optimizing the image quality from the limited, incomplete sampling of the object.

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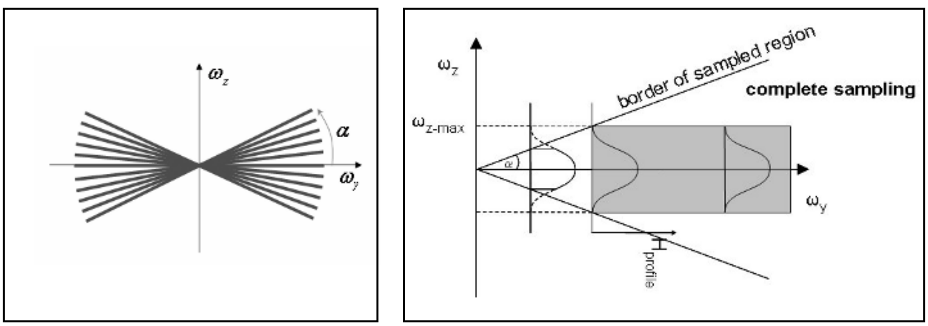
In this paper, we present results of the filtered backprojection with various filtering setups, carried out for a prototype breast tomosynthesis system. In section 2 we describe the optimized filtered backprojection method and the corresponding filter design. The achieved image quality of the reconstruction results for simulated and clinical data is presented in section 3.

2 Filtered Backprojection for Linear Tomosynthesis

The acquisition system we employ is based on the Siemens full-field digital mammography x-ray generator modified for linear tomosynthesis. The X-ray tube moves over an arc of up to ±25° relative to the pivoting point. During a single X-ray scan, multiple X-ray pulses are generated synchronized with the detector read/integrate cycle and X-ray tube motion.

The reconstruction approach described here is based on filtered backprojection [3]. It allows a systematic filter design, an optimized image quality specific to the application and strategies for reducing artifacts caused by inherent incomplete sampling. It can also easily be implemented. Due to its pipelined structure pre- and postprocessing steps can be taken into account as well.



(a) (b)

Fig. 1. (a) Moving the X-ray tube over an arc from angle –α to α the Fourier space data are acquired in a double wedge domain. (b) The introduction of a slice profile filter function $H_{profile}$ (ω_Z) ensures a constant depth resolution over a wide range of spatial frequencies.

The tube motion on an arc over the stationary detector is a linear sampling path in y-orientation with varying magnification and can be treated in parallel beam approximation. This approximation is acceptable for the filter design since the associated inaccuracies are small compared to the effects induced by the incomplete tomosynthetic sampling. The backprojection step for the filtered data is performed with the appropriate high accuracy by using projection matrices for each view, which are determined from the angular information provided by the system [7].

The filtering operations are derived in 3-D Fourier space and can be performed herein. Advantageously, they may be transformed into 2-D projection frequency space by a simple coordinate transformation. The Fourier-Slice theorem states that, in Fourier space, to each projection of the object a plane perpendicular to its beam direction