A Framework for Defective Cells Detection on an X-ray Detector Based on 3D Cone-Beam CT

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Abstract. Cone beam 3D CT is widely used for non-destructive inspection. Due to defective cells on an x-ray sensing detector, there must be many calibrations in tomographic image reconstructions. However, only in pre-processing, there must be insufficient calibrated projection images which include defective cell's x-ray sensing intensity. And these projection images result in ring-shaped artefacts.

In this paper, we present a framework for detecting these defective cells on a detector. To do this, we introduce ring artefact reduction technique in posterior processing. With the ring artefact geometric analysis and tracking the projection on 3D coordinate of an object, we find the abnormal pixels on projection images which are defective cells on a detector.

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Introduction

As fast and cost-saving method, cone beam 3D CTis effective reconstruction solution for non-destructive inspection. Using FDK filtered back-projection algorithm, CT volume can be accelerated with recent commodity GPUs.

However, instability of x-ray beam's intensity and its detector's sensibility results in many CT artefacts. Especially, non-equal sensibility of a detector's sensor array gives abnormal pixel values on projection image which is used for BP[1].This gives rise to modulated ring artefact on CT image. Moreover, the abnormal pixel can be regard as defective cell which is critical system error, at least, single projection error to be corrected [1][2].

Traditionally, many calibration methods have been researched in pre-processing level [2]. But these are insufficient to remove ring artefacts because of non-linear properties of sensor array. Also, there are some posterior methods for reduction of the ring artefact [3][4]. Though, these methods need hardly set parameters and reproduce incorrect result.

To resolve this problem, this paper suggests hybrid method using prior and posterior processing with single iteration as a framework. With this iteration, defective cells which correspond to abnormal pixels on projection image can be found. This includes software and hardware corrections.

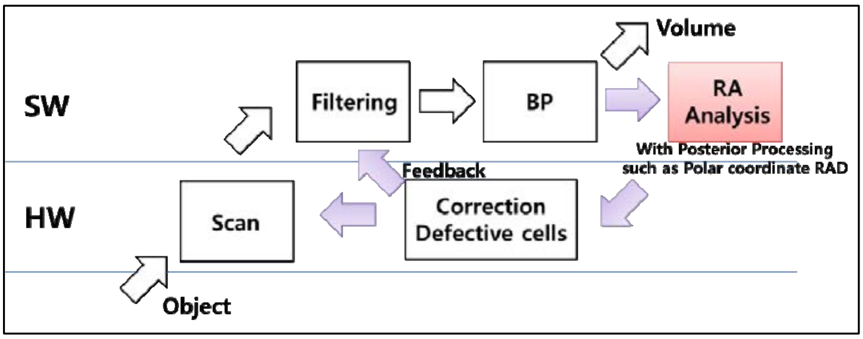
Scheme for defect-cell detection

The framework, suggested in this paper, has software/hardware correction phases<Figure 1>.

Software phase includes FDK filtered back-projection and ring artefact extraction. The ring artefacts need not extract precise result, which is used to locate major ring position. Tracing ring position with simple analytic method, the defective cell's position or abnormal pixel point can be computed.

This result can be used for refinement or adjustment of projection images and detector cells.

Hardware phase makes suspected detector's defective cell to be correct in hardware level. And re-scanning the object, corrected projections induce to be used in filtered back projection.



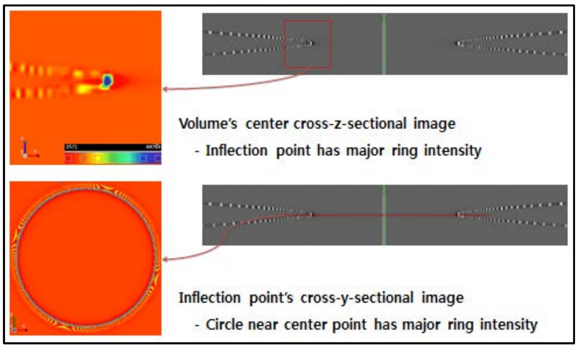
<Figure 1>

1.1Pipeline.

X-ray scanning and producing raw projections.
Attenuation correction and Shepp-Logan filtering for back-projection with initial parameters.
With back-projection, reconstructing CT volume including ring artefacts.
Computing abnormal pixel points by posterior processing.
Correct defective cell on detector in hardware level and filtering-stage refinement in software level.
If hardware correction, re-scanning is needed.
With filtering refinement parameters, reconstructing final volume by filtered back-projection.

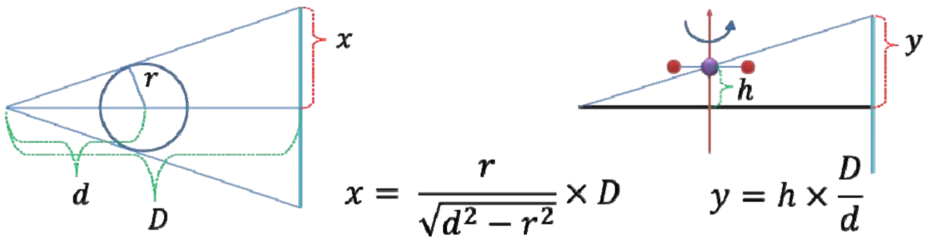
1.2 How to detect the abnormal pixel

An abnormal pixel on projection image makes hyperbola-shape circle on reconstructed volume. The major intensity of the shape is near CT rotation centre-axis. And this results in a ring shape artefact<figure 2>.



<Figure 2>

Through centre-cross section, hyperbola's centre point and ring circle's radius can be computed with simple analytic method. By <figure 3>'s two formula and ring's accumulated order in BP, abnormal pixel's position can be derived.



<Figure 3>

Result

With non-filtered raw projections (from a small size chip), we reconstruct CT volume by FDK filtered back projection based on current GPU, NVIDIA GTX 580. Assuming single pulse noise on a detector, we modulate the corresponding pixel's intensity by 50times multiplication.
Test geometry is below.

- 107.5 × 107.5 mm^2detector with 1.8° per a scan
- 17.5× 17.5 ×15.9mm^3scanned volume
- Source to detector : 550 mm, Source to rotation axis is 90 mm with non-offsets
- Single noise (abnormal) pixel's position : (-32.25, -32.25)mm

The reference defect cell position is (-32.25, -32,25) mm, and the result by proposed method is (-32.16, -32.24) mm. From this result, the error rate is less than 0.01%.

Further works

Through proposed framework, we can easily detect the defect cell on x-ray detector in simple noise experiment. Here, even not referencing the real sample's experiment, the result works well.

However, ring shape segmentation from 1st reconstructed CT is not fully automatic and the correction method of the detector and projection is not well defined. Therefore, more effective method is needed. (We have been researching this work and preparing journal work.)

References

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