Medical Image Processing for Diagnostic Applications

Artifacts and Preprocessing Problems

Online Course – Unit 15

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Topics

Acquisition Artifacts

Defect Pixel Interpolation

Summary
- Take Home Messages
- Further Readings

Artifacts of flat panel detectors

- Large detectors composed of four detectors $\rightarrow$ butting cross
- Offset in intensities
- Inactive pixels:
  - Single pixels
  - Pixel clusters
  - Image columns
  - Image rows

Typical Preprocessing Problems

- Offset and gain correction
- Defect interpolation
- Butting cross correction

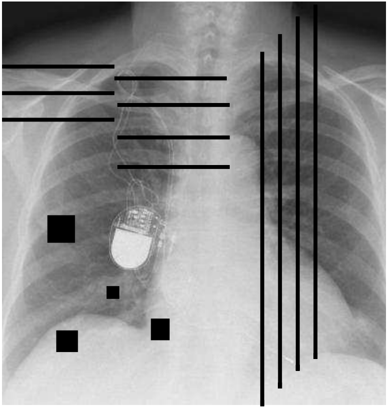

Figure 1: Thorax image with defect pixels

Butting Cross Artifact

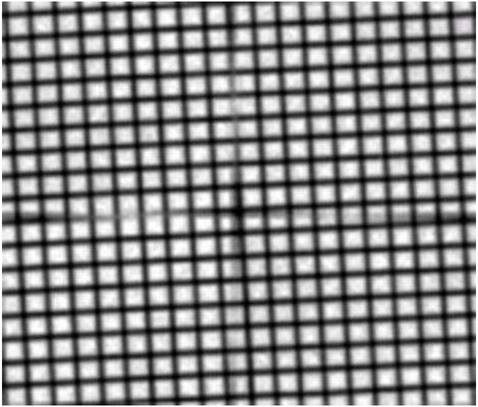

Figure 2: Artifacts appearing after butting cross correction

Butting Cross Artifact

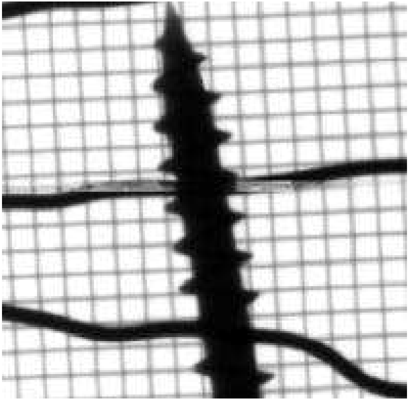

Figure 3: Artifacts caused by an improper correction method

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Defect Pixel Interpolation

There are two general approaches for defect pixel interpolation:

1. **interpolation in spatial domain:**
   - non-adaptive linear filtering,
   - non-linear filtering (like median),
   - suitable for small defect areas,
   - unnatural appearance (amplified by post-processing);
2. **interpolation in frequency domain:**
   - enforce bandlimitation by bandpass filtering,
   - defect interpolation corresponds to the deconvolution of defect and ideal image,
   - binary defect image is computed in a calibration step,
   - ideal image is multiplied with the binary defect image.

In this course, we are introducing the second type.

Mathematical Modeling of Pixel Defects

Defect pixels are caused by defect detector cells. The mathematical model for defect generation is just the multiplication of the original image with a defect mask:

- Let $f_{i,j}$ denote the intensity value at grid point (i,j) of the **ideal image** f that has no defect pixels.
- Let $w_{i,j}$ denote the indicator value at (i,j) where w is the **mask image** that indicates defect and uncorrupted pixels:

$$w_{i,j} = \begin{cases} 0, & \text{if pixel is defect,} \\ 1, & \text{otherwise.} \end{cases}$$

- Let $g_{i,j}$ denote the intensity value at (i,j) of the **observed image** g that is acquired with the flat panel detector and has defect pixels.

Mathematical Modeling of Pixel Defects

By pixelwise multiplication of the ideal image with the mask image, we get the observed image computing

$$f_{i,j} \cdot w_{i,j} = g_{i,j}$$

for a pixel at (i, j), and likewise for all pixels.

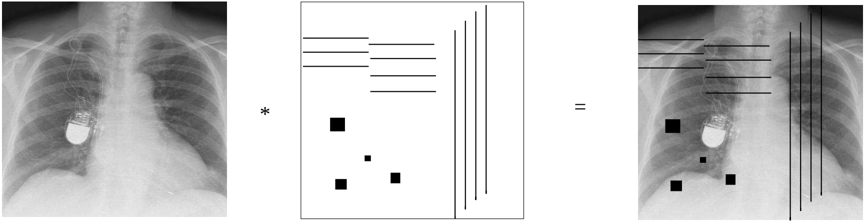

Figure 4: The ideal image (left) is multiplied with the defect mask (middle) which results in the output defect image (right).

Defect Pixel Interpolation in Frequency Domain

In the frequency based algorithms for defect pixel interpolation, three important properties of or related to the Fourier transform are applied:

- the Nyquist-Shannon sampling theorem,
- the convolution theorem, and
- the symmetry property of the Fourier transform of real signals.

We recommend to refresh your memory regarding these topics before going to the next unit.

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Take Home Messages

- An image acquired with a flat panel detector can contain certain types of artifacts.
- Defect pixel interpolation can be done in spatial and frequency domain.
- The pixel defects can be modeled by multiplication of a defect mask and the ideal image.

Further Readings

- The method presented for defect pixel interpolation in the frequency domain was published by Til Aach and Volker Metzler in 2001:

  Til Aach and Volker Metzler. "Defect Interpolation in Digital Radiography: How Object-Oriented Transform Coding Helps". In: *Proc. SPIE 4322, Medical Imaging 2001: Image Processing*. Vol. 4322. San Diego, CA: SPIE, Feb. 2001, pp. 824–835. DOI: 10.1117/12.431161

- A recent article about defect pixel interpolation with respect to image quality issues can be found here:

  Jan Kuttig et al. "Effects of Defect Pixel Correction Algorithms for X-ray Detectors on Image Quality in Planar Projection and Volumetric CT Data Sets". In: *Measurement Science and Technology* 26.9 (Aug. 2015), 095406 (14pp). DOI: 10.1088/0957-0233/26/9/095406