Effect of Object Thickness on Resolution of TDI X-ray Detectors

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Abstract: Time Delay Integration (TDI) detectors used in X-ray inspection systems work well when the objects inspected are relatively flat. This is because the scan speed can be synchronized with the object as it moves over the detector. For thicker objects, the speed relative to detector does not appear constant through the height of the object. This can result in blurring or distortion in parts of the acquired image. We created a digital radiography setup using a line scan detector with eight TDI stages and an X-ray source with a fixed source-to-detector distance (SDD). The detector line scan rate was calibrated at a baseline source-to-object distance (SOD). We measured the decrease in the modular transfer function (MTF) by acquiring images of an image quality indicator (IQI) placed at set increments closer to and further away from the X-Ray source. We also measured the distortion of a flat object placed at the same distance. We found the vertical edge MTF drops off proportionally to the change in SOD from where the object was calibrated while the horizontal edge MTF does not drop off until the SDD to SOD ratio is greater than 1.6. The object also becomes distorted in the final image perpendicular to the direction of motion. The apparent width of the object also changes proportionally to the change in SOD from where the object was calibrated.
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Outline

• Background
  • Linear Diode Array (LDA) and motion synchronization
  • Time Delayed Integration (TDI)

• Purpose for the experiment

• Test Setup

• Distortion Results

• MTF10 Results

• Conclusion
Linear Diode Array (LDA)

- Typically used in in-line systems
- Requires motion to create an image
- Motion has to be synchronized to the detector
Synchronizing Motion

1. Using a formula

\[
\text{Line rate (Hz)} = \frac{\text{Object speed (} \frac{\text{mm}}{\text{s}} \text{)}}{\text{Pixel pitch (mm)} \times \text{Magnification}}
\]

2. Scanning a round object

* Only synchronized at one distance

Initial scan where W≠H

Repeat scan with calculated f resulted in W=H

* Only synchronized at one distance
TDI (Time Delayed Integration)
How will a thicker object affect the resolution?

- Part of the object will be outside of the calibration plane
- How does the TDI affect the final image
- We expect a loss from geometric unsharpness
- We expect some distortion
Test Setup

Front View

- X-ray Source
- SDD 824 mm
- SOD 555 mm
- Change the SOD above and below the focal plane and check for change in resolution and image distortion.
- 25.4 mm
- Distance test range
- 0 mm
- Focal Plane
- -152.4 mm
- IQI Object
- TDI Detector

Side View

- X-ray Source
- SDD 824 mm
- SOD 555 mm
- IQI Object
- Direction of motion
- Focal Plane
- TDI Detector
Distortion

• Only apparent in one dimension

• True when using an LDA but TDI can be setup dependent
MTF10 Results

- Calculated using knife edge method
- Horizontal edge corresponds to the direction of motion
- Vertical edge corresponds to fan beam
Conclusion

• There is a height range where the horizontal edge MTF10 is ~2 lp/mm.

• An object whose thickness lies within this range would not lose much horizontal edge resolution.

• An object whose thickness lies outside of this range may see an increase in blurring and resolution loss.

• In general, it is good practice to have the object close to the detector to minimize unsharpness.

• Other factors to consider are spot size, shape and the size of the TDI array.
Thank You!

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