Accelerated SubpiX – A CT Sub-pixel Super Resolution Technique

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Introduction

The resolution of standard CT scans is dictated by the physical constraints of the detector's sampling resolution. Super resolution is a class of techniques used to improve the reconstruction resolution beyond the physical limitations of the detector, via pure computational methods or with novel trajectories to acquire additional data. This work characterizes an improved accelerated super resolution technique that builds upon an existing method, SubpiX [5], and acquires projections along a trajectory of sub-pixel detector translations. The sub-pixel shifts introduce sampling across the spatial domain of each pixel, allowing the resulting images to be combined and upsampled to a higher resolution projection for reconstruction. This technique is shown to be flexible, allowing for different amounts of additional data to improve reconstruction quality at the cost of increased acquisition length.

Methods

4 Tile SubpiX

The current SubpiX technique [5] sub-samples an image by spatially shifting the detector by pre-set sub-pixel intervals and acquiring a complete grid of low-resolution images. Those images are then combined to create the high-resolution image for each angular projection of the CT scan. The set of high-resolution projections is reconstructed creating a high-resolution volume.

2 Tile SubpiX

Much like the 4 Tile, this technique sub-samples an image, but instead of sub-sampling the entire grid, only 2 of the tiles are acquired (Figure 1(b)). The low-resolution data is then upsampled and the remaining data interpolated. The high-resolution volumes are then reconstructed from the constructed high-resolution images.

1 Tile SubpiX

This method is like the 2 Tile, however it only acquires 1 low-resolution image for each projection, continuing to acquire each projection using the sub-pixel shift.

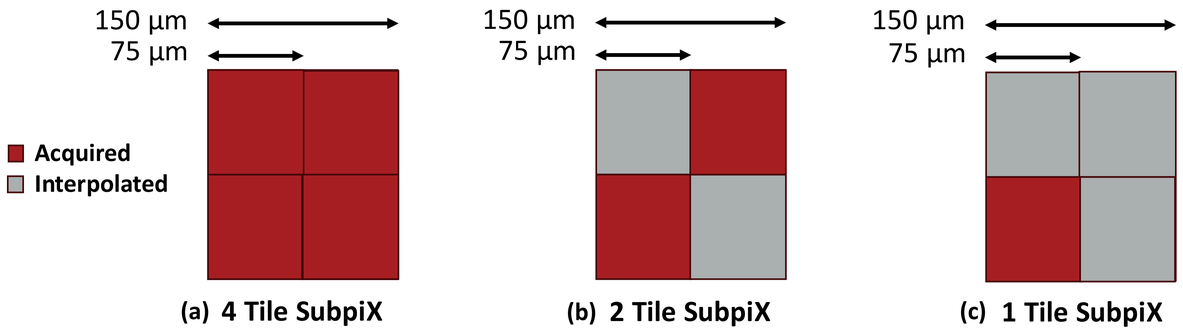

Figure 1: Acquisition technique for the various SubpiX modes splitting a physical detector pixel into sub-pixels.

Experiment & Results

To evaluate the performance of the three variants of super-resolution techniques described above, we scanned several objects with various level of fine details, these included a piston rod, cellphone, aluminum cylinder, and a Lollipop candy. A standard baseline CT scan was also reconstructed for comparison. The ASTM E1695 analysis was performed on the cylinder to evaluate the spatial resolution and contrast to noise ratio performance.

The various scanned objects demonstrated similar results, across all the various scans each SubpiX mode improved the resolution. As more data was used, resolution quality and noise improved at the cost of additional acquisition time.

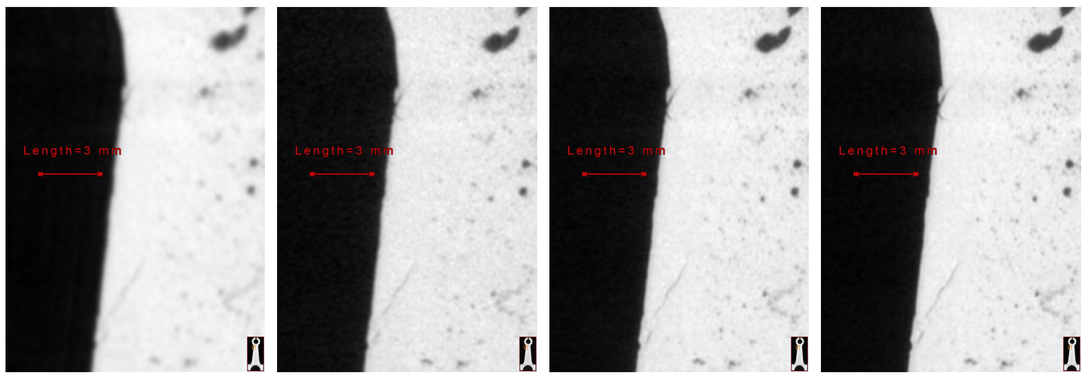

Figure 2: Piston rod scan, **(a)** standard CT, **(b)** 1 Tile SubpiX, **(c)** 2 Tile SubpiX, and **(d)** 4 Tile SubpiX.

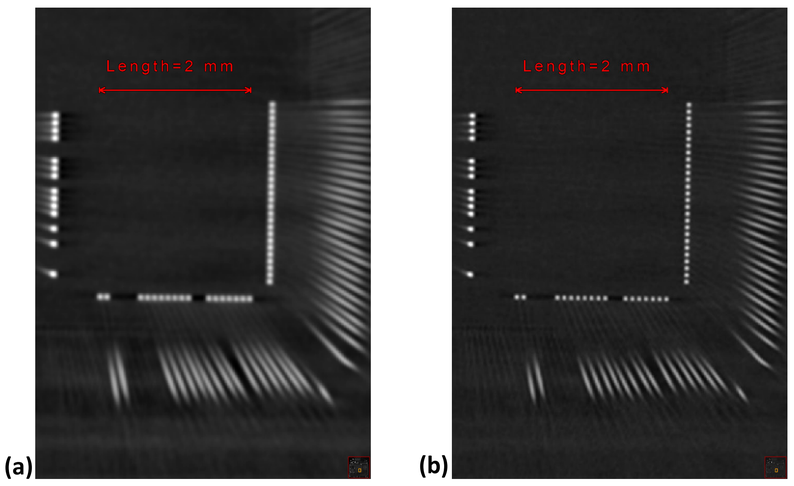

Figure 3: Electronic circuit board, **(a)** a standard CT scan and **(b)** a 1 Tile SubpiX scan.

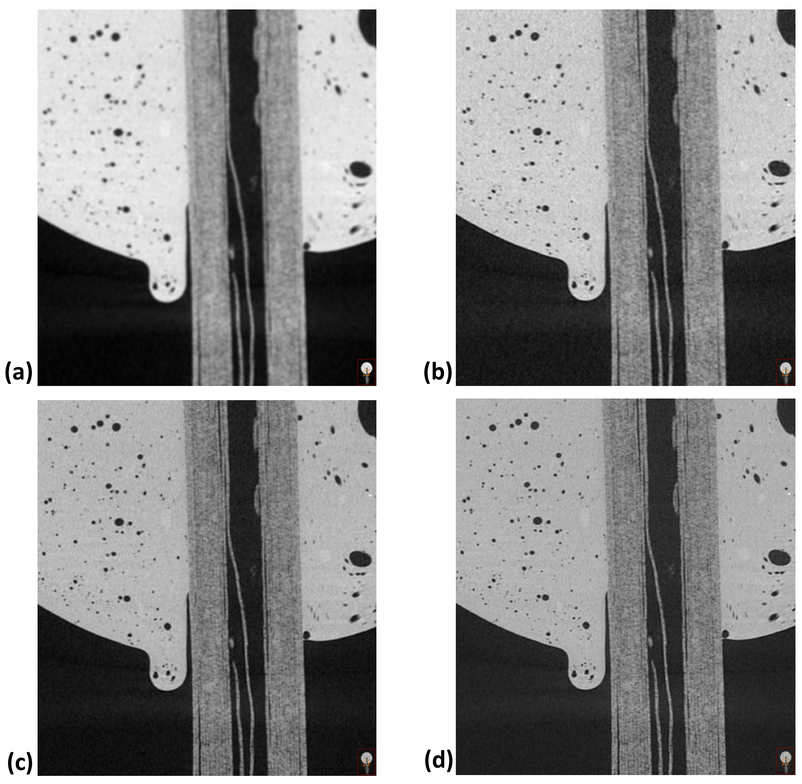

Figure 4: Lollipop scan with **(a)** the standard CT scan, **(b)** 1 Tile SubpiX, **(c)** 2 Tile SubpiX, and **(d)** 4 Tile SubpiX.

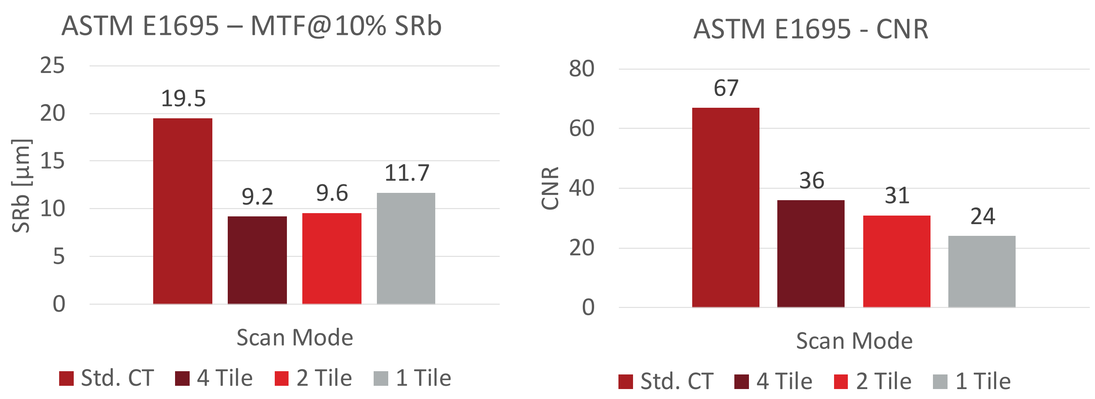

Figure 5: ASTM E1695 analysis of the spatial resolution and CNR of the scanned aluminum cylinder.

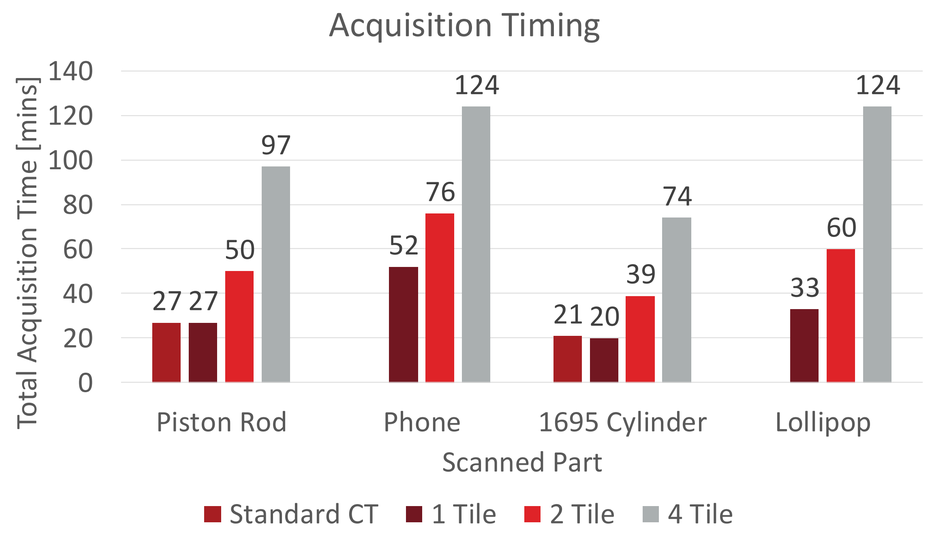

Figure 6: Acquisition timing of the various parts scanned and the different modes.

Discussion & Conclusion

- Accelerated SubpiX, super resolution technique with reduced data:
  - 2 Tile
    - 2x faster than 4 Tile SubpiX
    - ½ the number of images acquired
  - 1 Tile
    - 4x faster than 4 Tile SubpiX, equivalent to standard CT
    - ¼ the number of images acquired, equivalent to standard CT
    - Improved resolution compared to standard CT
  - Spatial resolution and noise improve as additional data is used

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