A “KWIC” and dirty look at dose reduction and perfusion metrics in simulated CT neuro perfusion

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Introduction

- The potential uses of **perfusion CT may be limited by radiation dose**.
- In CT perfusion imaging, dose reduction is typically achieved via reduction in temporal sampling or x-ray tube current. Another method is to **reduce the number of projections acquired per rotation**, however when this approach is used with standard reconstruction methods, this will lead to sampling artifacts and degraded image quality.
- In this work, we investigate a novel adaptation of an existing acquisition and view-sharing reconstruction algorithm – “k-space weighted image contrast” or KWIC – allowing for reduced dose through fewer views while preserving diagnostic image quality.
- **This work reports our initial tests using a simulated time-varying head phantom to evaluate CT-KWIC's ability to preserve image quality and extracted perfusion metrics at reduced dos**e.

Background

- Traditional reconstruction methods in CT utilize filtered backprojection or some variation thereof, which reconstructs an image directly into the spatial domain. MRI acquires images in the Fourier domain, "K-space," and then utilizes a 2D Fourier transform to obtain an image in the spatial domain.
- Projection imaging (CT) is related to K-space through the central-slice theorem depicted visually in figure 1.

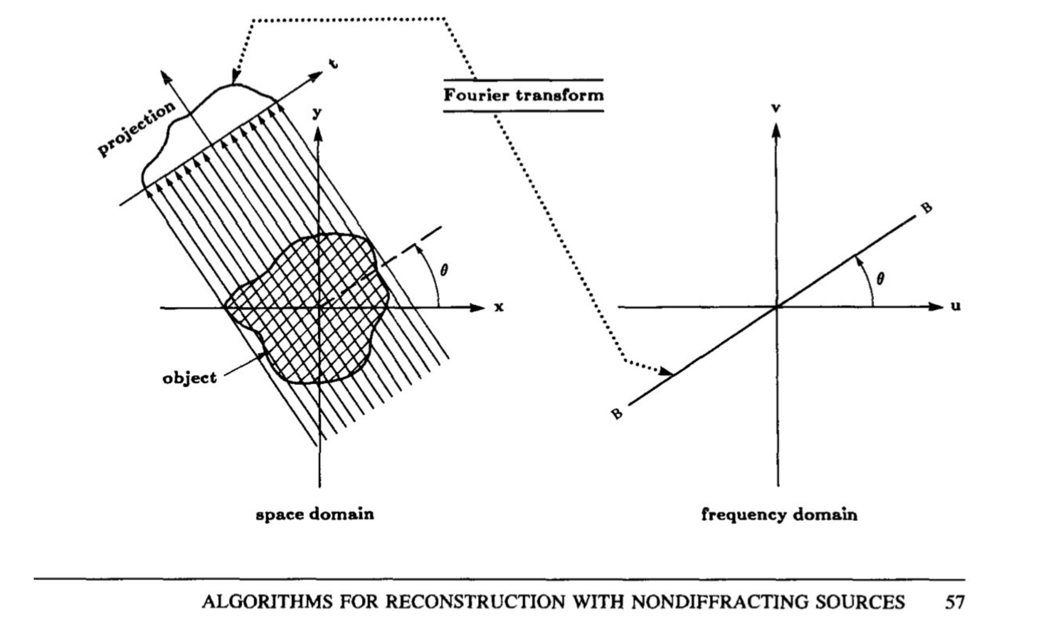

Figure 1: Illustration of the central slice theorem. Projections can be mapped into K-space (the Fourier domain) via the Fourier transform.

- KWIC makes use of the fact that in projection imaging, the central regions of K-space, which dominate image contrast, are oversampled, allowing us to select which views/projections we would like to contribute to the primary image contrast.
- In perfusion imaging this **allows the user to select the bulk of the contrast information to come from a desired time point**, while preserving image quality through the use of views from other time points for mid-range and edge information. This minimizes sampling artifacts.
- The views contributing to the primary contrast information (center of k-space) comprise the **“view-core.”** This can be seen in fig. 2 as the band of the KWIC mask that spans from the top of the sinogram to the bottom. All projections in the view core come from a single time point, reducing the effects of view-sharing on perfusion metrics.
- Outside of the view core, proper sampling is achieved via **“sub-apertures.”** Sub-apertures represent regions of view-sharing, and sampling doubles in each sub-aperture, depicted in fig. 2.

Materials and Methods

- A FORBILD head phantom containing simulated time-varying objects was developed and a set of parallel-beam CT projection data was created.
- Simulated scans were 60 seconds long, 1152 projections per turn, with a rotation time of one second.
- Reduced-dose cases were simulated by down-sampling the number of projections per turn from 1152 to 576 (50% dose), 288 (25%), and 144 (12.5%). KWIC was further evaluated at 72 projections per rotation (6.25%). One image per second was reconstructed using FBP and KWIC.
- KWIC reconstructions utilized view cores of 36, 72, 144, and 288 views and 16, 8, 4, and 2 sub-apertures, respectively.
- From both sets of reconstructed images, an ROI was placed on the time-varying object and time to peak (TTP), cerebral blood flow (CBF) and the FWHM of the corresponding perfusion curve were calculated and compared against reference values from the "full-dose" FBP data.

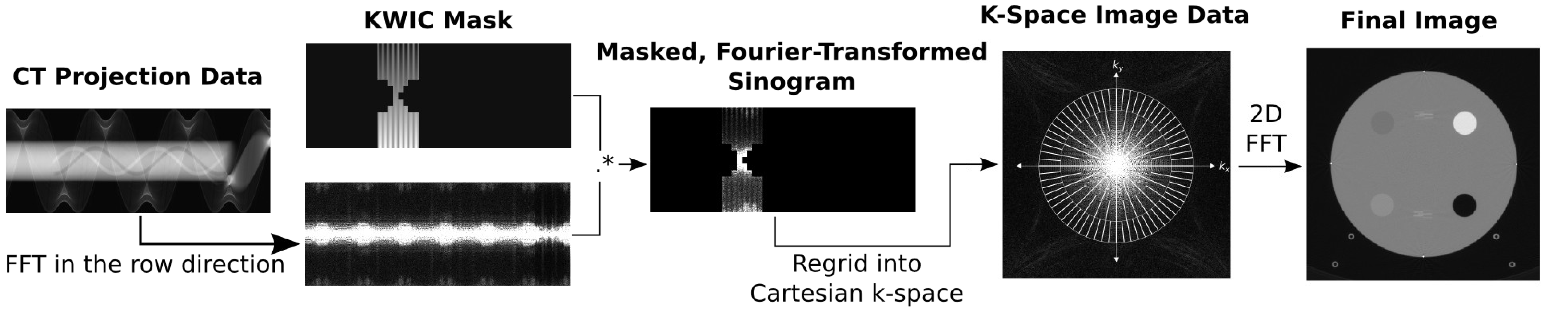

Figure 2: Illustration of the CT-KWIC work flow. Raw CT projection data is Fourier transformed along the detector rows and combined with a KWIC mask which selects and weights projections into sub-apertures. The masked sinogram is then regridded (interpolated) into 2D Cartesian k-space; a grid is overlaid in this diagram to indicate the relative density of projections in each sub-aperture (fewest at the center “view-core,” where contrast info lies, most at the outer, high-frequency regions). The outer sub-apertures will contain the largest amount of view-sharing. Finally, the regridded k-space image will be Fourier transformed into our final 2D image.

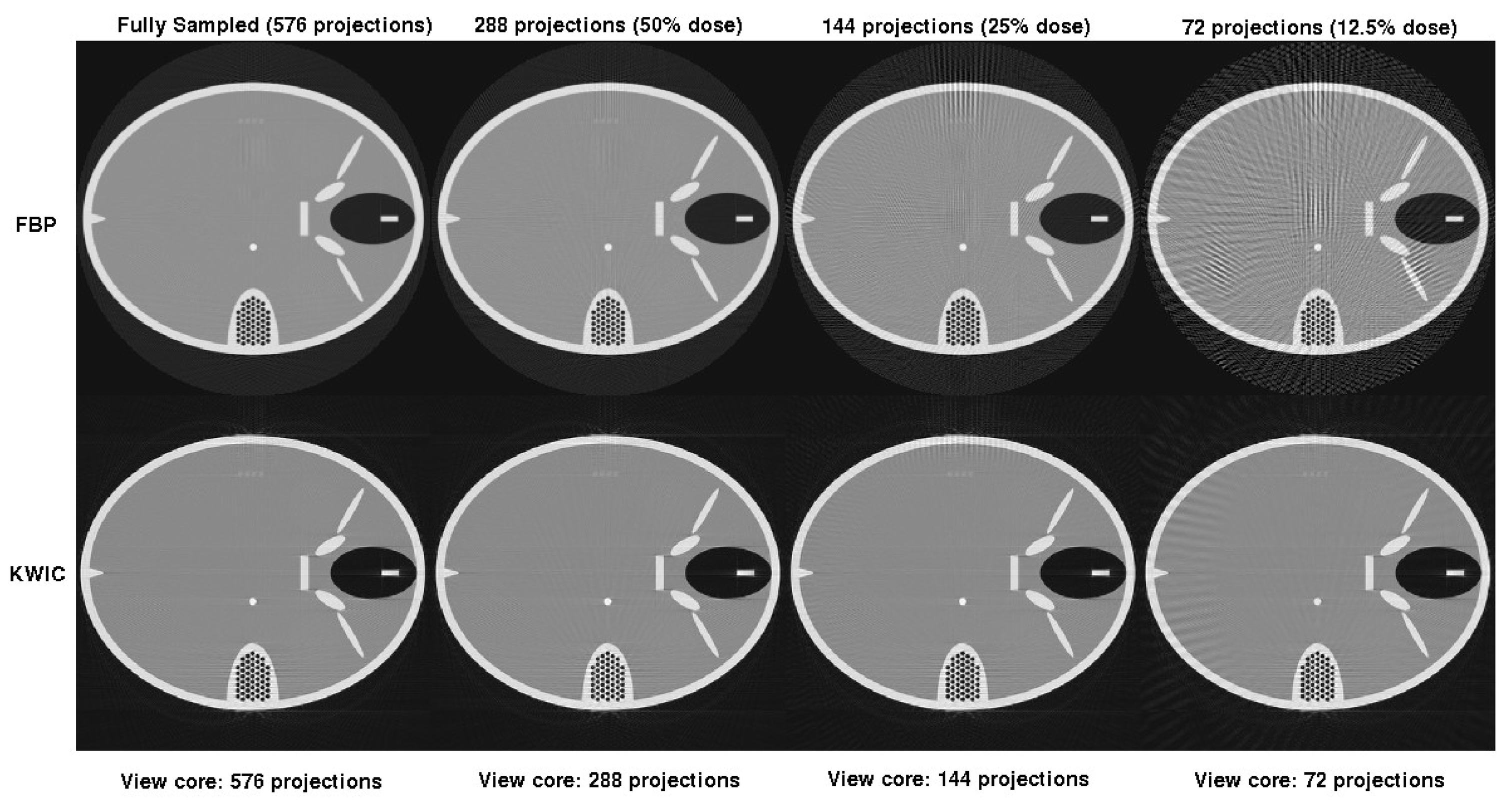

Figure 3: Reconstruction samples for 5 mm object at peak intensity. Note that image quality is preserved using CT-KWIC while aliasing artifacts begin to obscure the FBP image at reduced projections

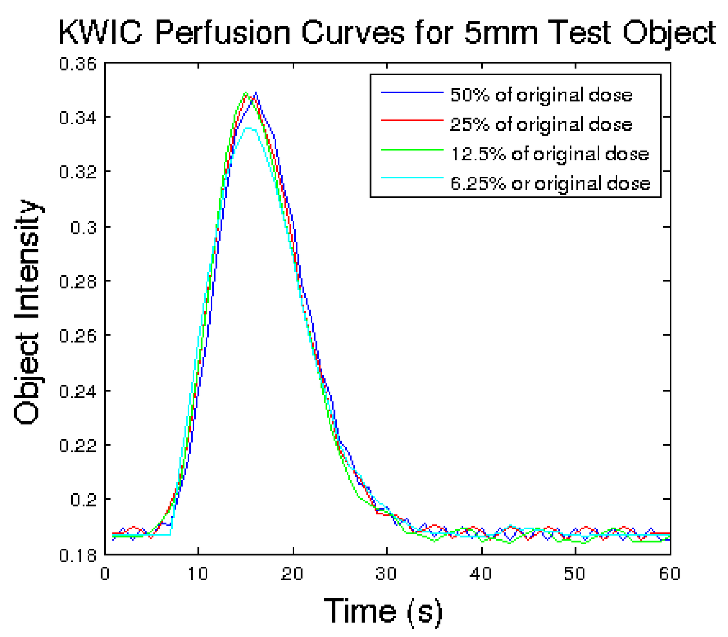

Figure 4: Plot of perfusion curves derived from CT-KWIC reconstructions. KWIC's use of sub-apertures to select contrast data from a single time point and then share views to fill in edge data allows us to preserve image quality while having an extremely minimal impact on the measured perfusion curves.

	FBP 100%	KWIC 50%	KWIC 25%	KWIC 12.5%	KWIC 6.25%
TTP (s)					
5mm	15	15	14	14	14
10mm	15	15	15	14	14
50mm	15	15	15	15	15
CBF (intensity/s)					
5mm	0.0253	0.0310	0.0285	0.0294	0.0266
10mm	0.0253	0.0271	0.0271	0.0264	0.0266
50mm	0.0253	0.0270	0.0271	0.0272	0.0266
FWHM (s)					
5mm	10.712	10.732	10.729	10.696	11.556
10mm	10.712	10.705	10.703	10.785	10.809
50mm	10.712	10.712	10.712	10.708	10.705

Table 1: Summary of perfusion metric calculations. Even at the most aggressive dose reductions, KWIC has a minimal impact on the results.

Results

- In CT data reconstructed with FBP, as the number of projections decrease, the perfusion curves are overpowered by the noise and artifacts in the image leading to near complete obfuscation of the original perfusion data. CT-KWIC however preserved the metrics and provided comparable image quality to the fully sampled images in even the "lowest dose" cases.
- As seen in figs. 3 and 4 as well as tab. 1, **perfusion metrics were not affected by simulated dose reduction**, however **image quality in the KWIC reconstructions was superior to the FBP reconstructions** with a notable decrease in sampling artifacts.

Conclusions

- **The KWIC reconstruction method can be successfully applied to simulated CT data** via the depicted work flow in fig. 2.
- The **view-sharing in KWIC** (i.e. borrowing projection data from other time points for higher spatial frequency information) **does not appear to negatively impact common perfusion metrics, and greatly enhances image quality in reduced projections studies.**
- The results of this study suggest that KWIC applied to CT could provide dramatic radiation dose reduction in perfusion studies. Such dose reduction could allow for repeat perfusion studies in organs such as the brain, or perhaps even body perfusion for the liver or kidneys.