Reducing dOCT imaging time

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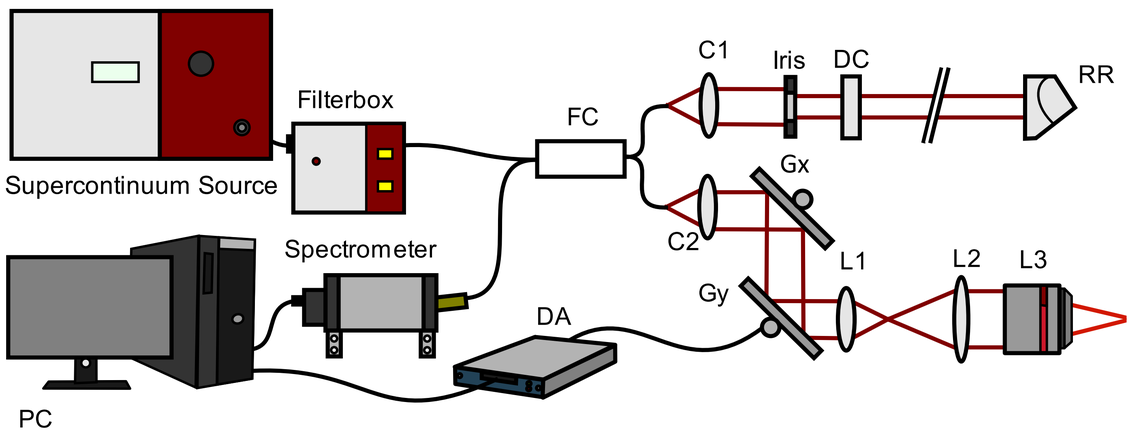
Introduction

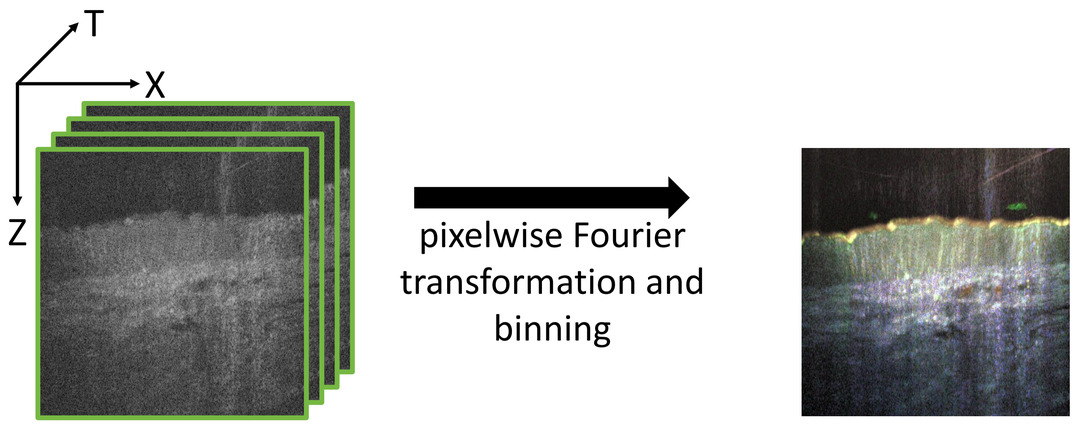
- Dynamic optical coherence tomography (dOCT) can provide functional images with micrometer resolution
- Global motion during acquisition however leads to artifacts, possibly rendering data unusable
- Shorter time series may alleviate this issue as only 4 frames are needed for our dOCT processing

Imaging & Processing



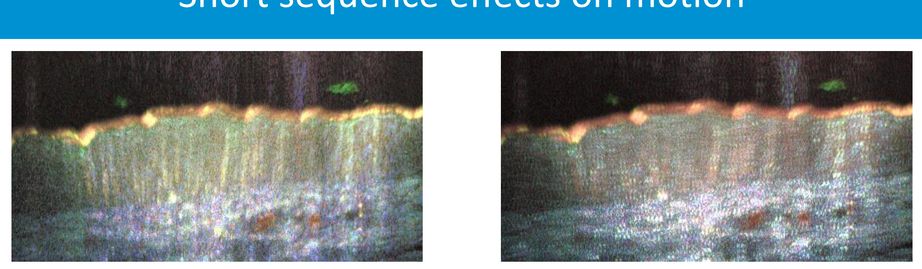
Our custom build OCT setup with microscopical resolution. FC: Fiber-coupler, C: Collimator, DC: Dispersion Correction, RR: Reference Reflector, G: Gyroscopic mirror, L: Lens, DA: Digital-Analog-converter

- 15 freshly excised human (trachea and bronchus) and mice (colon, liver, spleen, kidney, bladder, ovary, uterus, and cervix) tissues were imaged
- Per sample 150 B-Scans were acquired using a B-Scan rate of about 100 Hz
- Pixelwise Fourier transformation over the time yields the frequencies of the signal fluctuations in each pixel
- These spectra are binned into 3 channels to form an RGB image



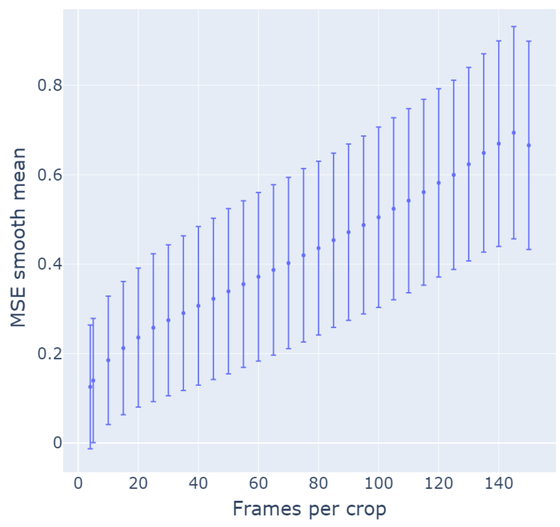
Pixelwise Fourier Transformation over the B-Scan time series yields a frequency spectrum of the signal changes for each pixel. Binning these into 3 channels results in an RGB image.

Short sequence effects on motion



A 1 pixel lateral shift of all frames in the second half of the time series already induces major colouring and resolution artifacts. Left: the time series without global motion. Right: The time series with a 1 pixel lateral motion artifact.

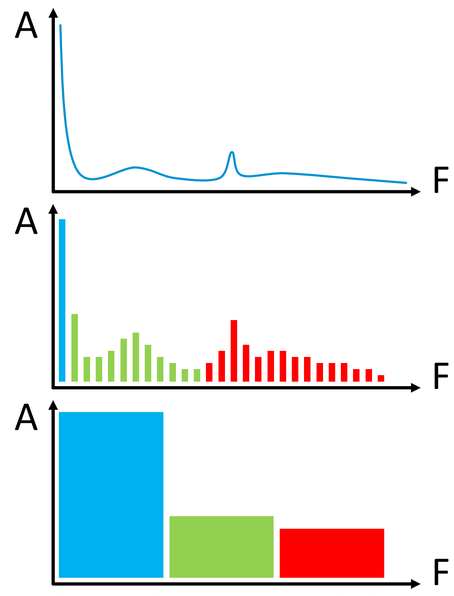
- Registration is not always possible
- Limit global motion by using fewer frames
- The Mean Squared indeed decreases for shorter series
- Registration errors become fewer
- Results are similar for smoothed and regular data



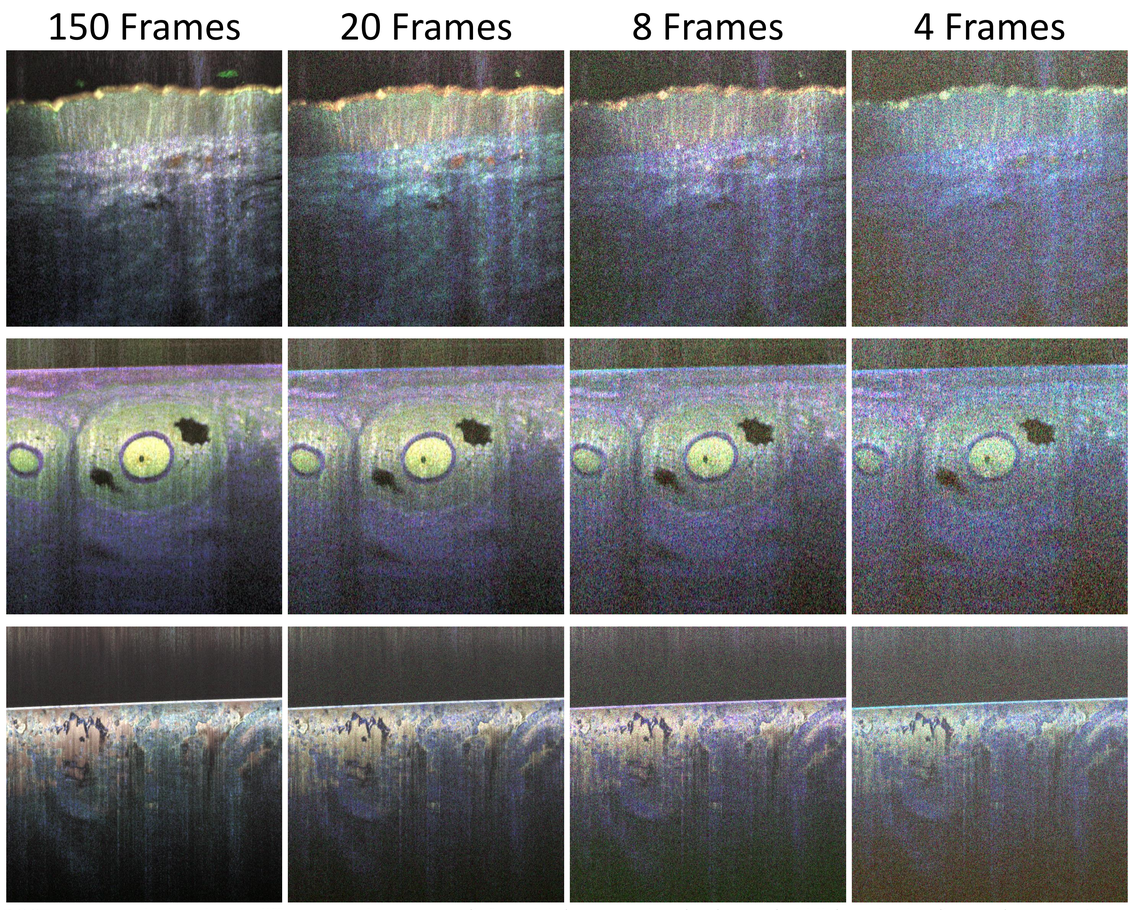
Averaged Mean-Squared-Error (MSE) calculated over all crops of all samples. For each crop the MSE is calculated between the frames after gaussian smoothing to quantify registration errors.

Short sequence effects on image quality

- 4 frames are the numerical limit
- This reduces imaging times from 1.35 s to just 35 ms
- Spectral resolution depends on number of frames
- Fewer frames decrease binning capabilities
- Noise is increased
- This may suffice depending on the sample frequencies

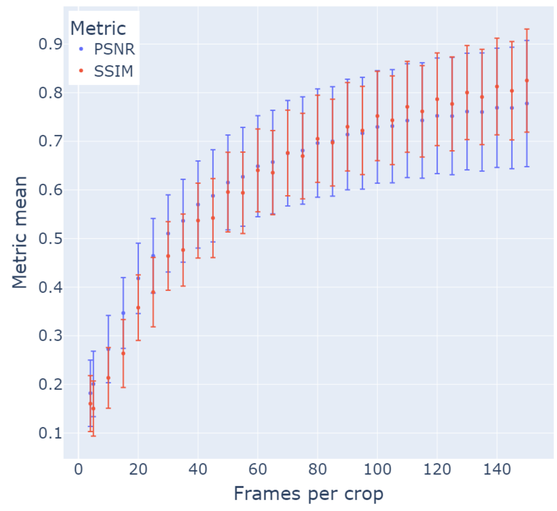


Schematic illustration of how a real spectrum (top) may look like depending on the sampling and how it would be binned (middle and bottom). Fewer frames decrease the spectral resolution.



DOCT contrast calculated with different sized sequences (left to right) on a trachea (top), ovar (middle), and colon (bottom) sample. One can see that even just 4 frames can provide a sufficient dOCT image to distinguish different tissues by activity, even though the images are noticeably noisier.

- Even for just 20 frames the contrast is still very good
- With just 4 frames the noise is very noticeable but dynamic contrast still exists
- This is reflected by the image quality decreasing according to our metrics
- The nonlinear decrease enables many sequence length options



Peak-Signal-to-Noise-Ratio (PSNR) and Structural-Similarity (SSIM) over frames per crop. Both decrease in a similar way for shorter time series, indicating the nonlinear increase of spectral noise.

Conclusion

Short sequences indeed reduce motion artifacts. Though, image quality is lost, just 4 frames were sufficient to differentiate tissues. This work is an important step towards in-vivo application where adaptive sequence lengths based on our metrics could find the best trade-off between artifacts and quality.

Acknowledgement

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