Local Correction of Non-Periodic Motion in Computed Tomography

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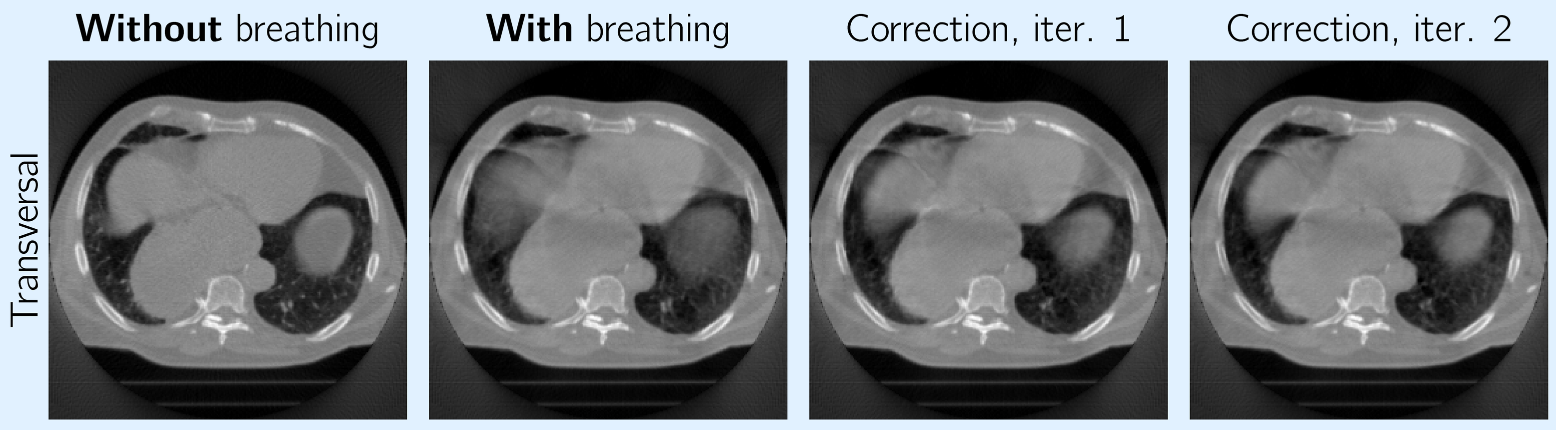
In computed tomography (CT), the reconstructed image is frequently degraded by uncontrolled patient motion during data acquisition. To improve image quality, we developed a method for joint motion estimation and motion segmentation from projection data. The segmentation is used within the image reconstruction algorithm to compensate the motion only locally.



Contrast improves for the liver and the stomach with local motion correction.

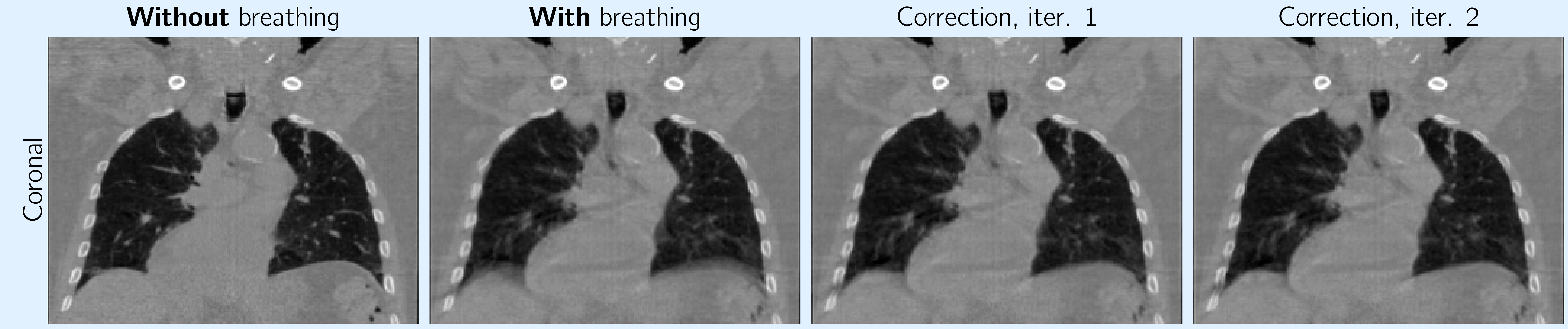


Image reconstructions from 360 parallel-beam projections, simulated for a free breathing acquisition of 12 seconds.
The border of the diaphragm becomes progressively sharper with local motion correction.

Experiment from simulated acquisition

Philips Allura Xper FD20

Digital flat detectors mounted on C-arm systems allow volumetric soft tissue imaging with computed tomography (CT).

Simulation of projection data

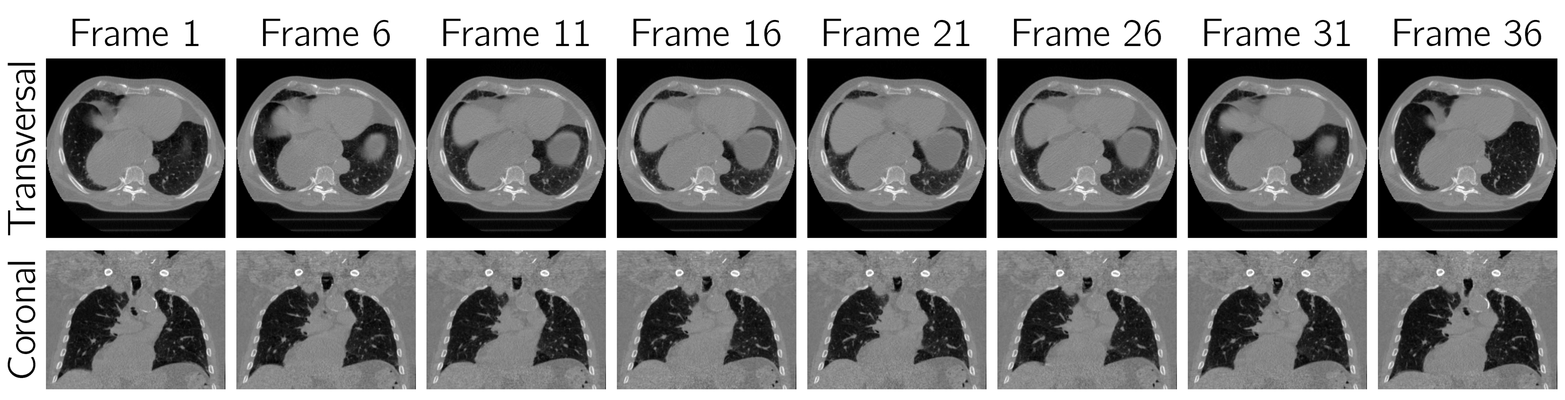
The arm rotates around the object and X-ray projections are acquired sequentially, along a full **circular trajectory**.

- A parallel-beam geometry is considered
- The data acquisition lasts for 12 seconds
- The frame rate is 30 projections per second

Image reconstruction

A volumetric anatomical image is reconstructed from acquired data with filtered-backprojection (FBP). Patient motion might introduce **motion blur** artifacts in the reconstruction.

Dynamic phantom from clinical patient data



The dynamic phantom: 40 frames of $256 \times 256 \times 198$ voxels, for one breathing cycle.
Frames are reconstructed from a respiratory-gated helical CT acquisition.

- 360 projections of 256×198 pixels are sampled from the free breathing dynamic phantom.
- Each projection uses a different frame from the phantom to simulate an acquisition of 12 seconds.
- Frames still contain some blurring due to helical artifacts and residual motion within each gate.

References

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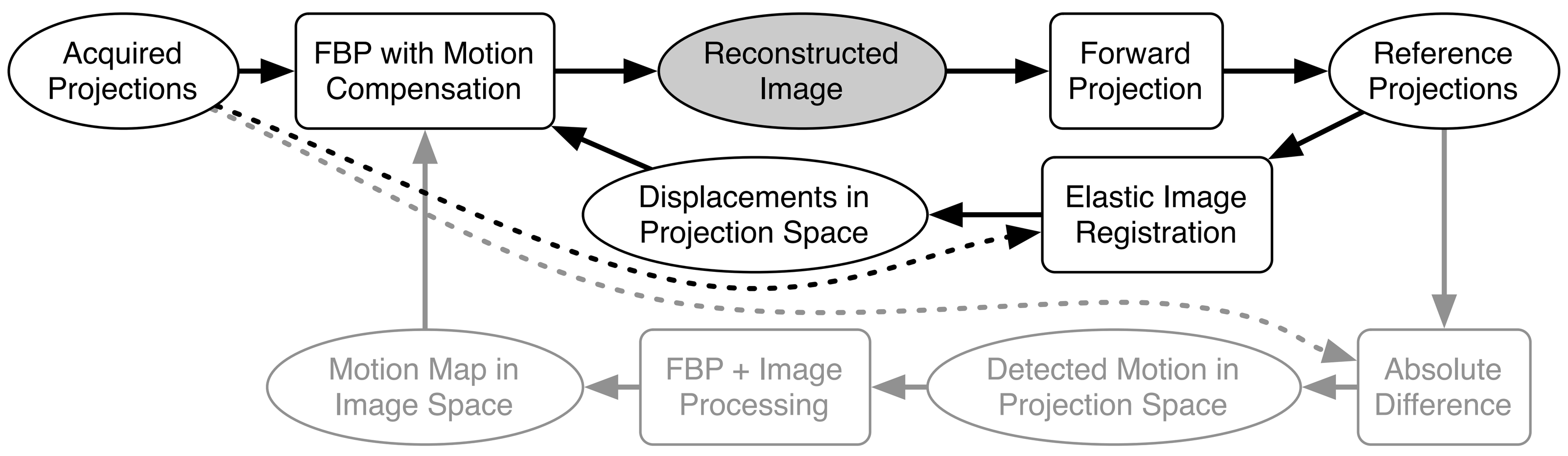
Motion estimation, segmentation, and compensation



Workflow for iterative motion correction. A displacement field is estimated in projection space with elastic image registration [1]. In parallel, the motion is detected and reconstructed in image space. Finally, the image is reconstructed again with local motion compensation.

- The **motion is estimated** in projection space by elastic registration [1] of measured projections on reference projections, forward projected [2] from a previously reconstructed image.
- The **motion is segmented** in image space by thresholding and filtering the reconstruction of line integral differences between acquired and reference projections.
- The **motion is compensated** within FBP image reconstruction by displacing the back-projection of voxel's positions before fetching the filtered line integral.

Motion modeling

A motion estimation technique have been developed [3] for the class of motion represented by a bijective mapping function in projection space [4]. In this work, this motion model is extended by weighting the back-projection of displacement vectors with a normalized motion map.

Iterative estimation

The first reconstructed image does not use any motion compensation but is still considered as a motionless reference for the next iteration. The accuracy of the estimated displacement vector field and the reconstructed motion map are iteratively improved.

Convergence

Reconstructing one static image from the projections of a moving object is a ill-posed problem. Among all the possible solutions, the method experimentally converges to a mean motion state, midway between full inspiration and full expiration.

Conclusion

This work presents a method for local correction of patient motion in CT image reconstruction. The motion is perceived in projection space and is estimated by elastic image registration. Moreover, the regions significantly corrupted by motion artifacts are segmented to apply locally a motion compensation within image reconstruction. The technique relies solely on acquired projections and does not assume periodicity of the underlying motion model. Hence, it can correct for hectic and unstructured patient motion such as nervous movements, breath-hold failures, or intestinal contractions.

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