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    to evaluate CT reconstruction algorithm with motion artefact correction in
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Simulated Motion Artefact in Computed Tomography

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Abstract

We propose a simulation framework to simulate the computed tomography acquisition process. It includes five components: anatomic data, respiration modelling, automatic parametrisation, X-ray simulation, and tomography reconstruction. It is used to generate motion artefacts in reconstructed CT volumes. Our framework can be used to evaluate CT reconstruction algorithm with motion artefact correction in a controlled environment.

1 Respiration Modelling

Anatomical data from 4D CT scans is segmented to provide polygon meshes. The motion due to the respiration is computed in realtime using three different methods [4]. The rib cage motion is simulated by an articulated model of the rib rotations. The diaphragm behaviour is simulated by a deformable model with an intrinsic force to apply contraction and relaxation on its central tendon. The liver behaviour is simulated by a deformable model where boundary conditions are applied by both the rib cage and the diaphragm motion. The 3D Chainmail method is used to deform soft-tissues in real-time [1]. The model includes many parameters, which are automatically tuned using artificial evolution [3].

2 X-ray Simulation

In [2] we proposed a method to compute the X-ray attenuation law on the GPU. The code has been revised and a quantitative validation has been performed. It shows the accuracy of results produced with our implementation. The result is *gVirtualXRay*, *Virtual X-Ray Imaging Library on GPU*, an OpenSource Library available at <http://gvirtualxray.sourceforge.net/>.

Fig. 1 shows the virtual scanning environment. The geometry of the virtual patient is positioned in the

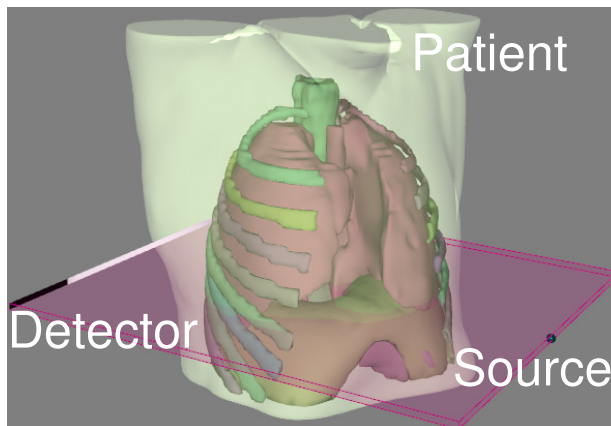


Figure 1: Scanning environment.

centre of the CT scanner. For each anatomical structure (skin, liver, diaphragm, lungs, ribs, and spine), a Hounsfield value is associated to a polygon mesh. The CT scanner is made of a rotation axis, a parallel X-ray source, and a detector. The source and detector rotate around the patient. The source can be monochromatic or polychromatic and it has an initial position. The detector is defined by its initial position and its size (number of pixels and pixel resolution).

3 CT Acquisition

The respiration frequency of the patient and angular frequency of the source/detector couple can be tuned. In the illustrations, we use realistic parameters: 20 breaths per minutes and 15 second to perform a complete circular revolution. Successive projections are then concatenated and finally transformed into a sinogram (i.e. a Radon transform) (see Fig. 2).

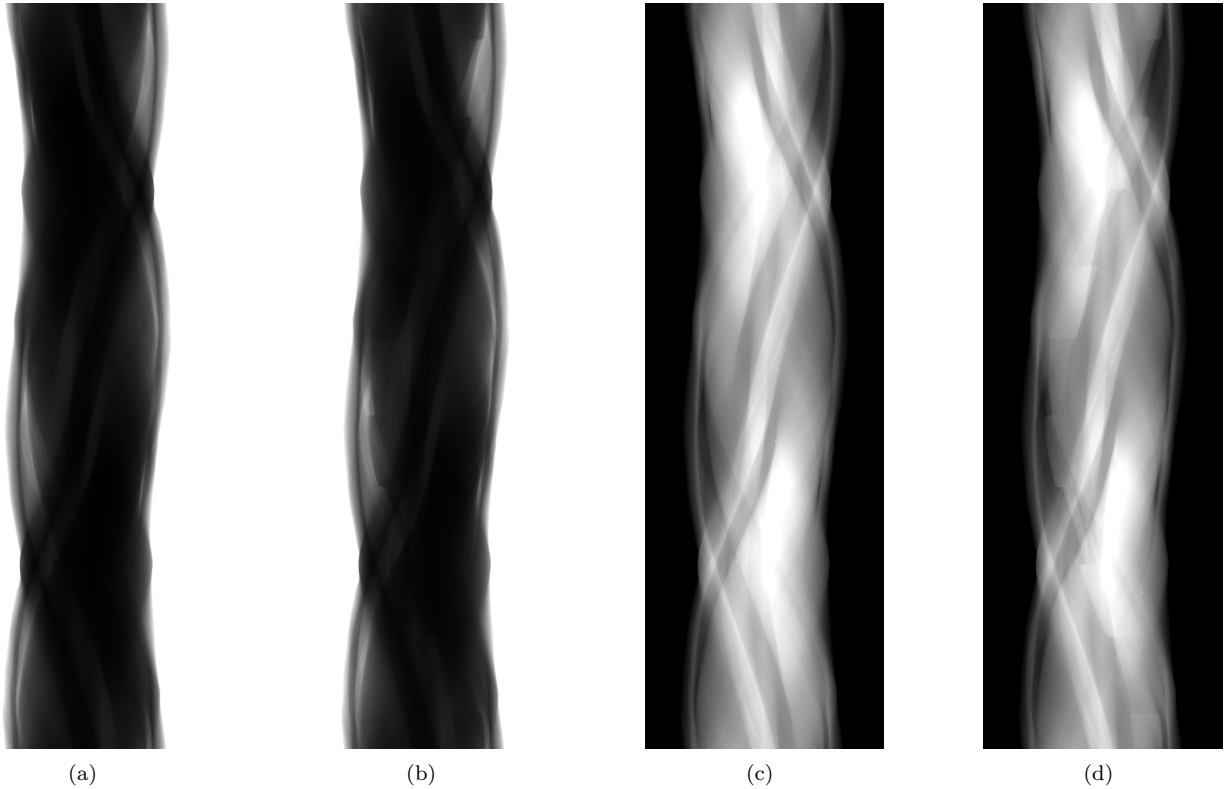


Figure 2: Simulated CT data acquisition; (a) & (b) X-ray projections; (a) without respiration; (b) with respiration; (c) & (d) corresponding sinograms.

4 CT Reconstruction

To reconstruct the CT slices corresponding to Fig. 2, the inverse Radon transform of sinograms needs to be computed. We use the famous filtered back projection (FBP) method. No motion artefact can be seen in the CT slice corresponding to the sinogram simulated without respiration (see Fig. 3(a)). When respiration is used, ghost artefacts can be seen (see Fig. 3(b)).

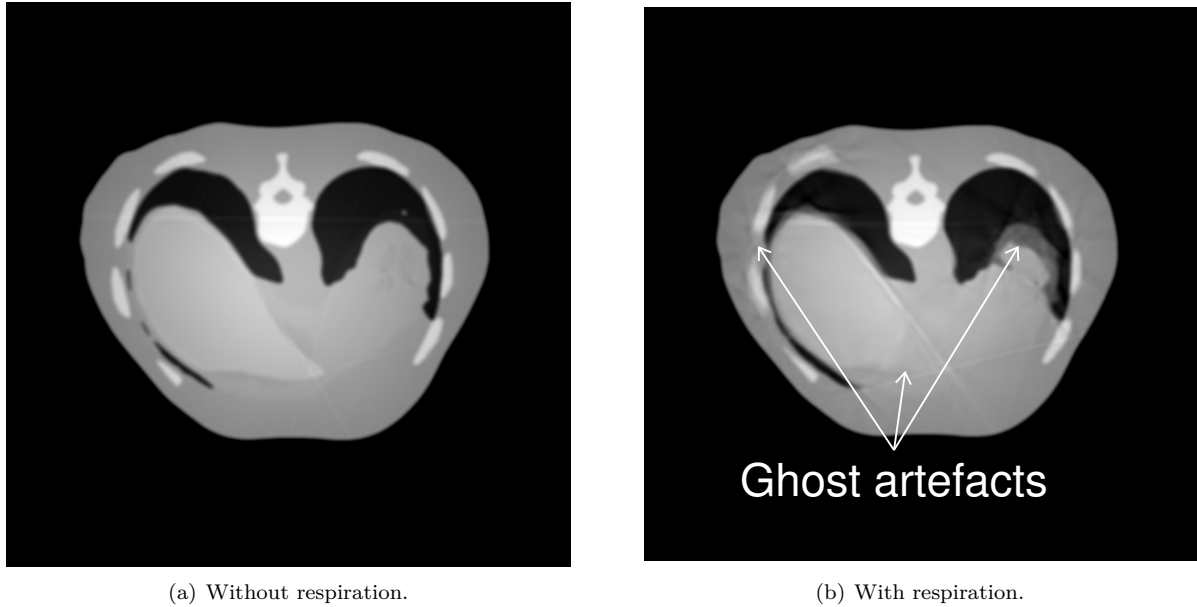


Figure 3: Reconstructed CT slices.

5 Conclusions

This poster focused on the simulation of CT data acquisition with respiration modelling. It involves two simulation components: Respiration and X-ray. Both run with real-time performance. Slices reconstructed with the resulting data include ghosting artefacts due to motion. We demonstrated that realistic data can now be simulated in a controlled environment. Our framework can be used to evaluate motion correction methods in CT reconstruction algorithms.

6 Acknowledgements

This work has been partially funded by FP7-PEOPLE-2012-CIG project Fly4PET – Fly Algorithm in PET Reconstruction for Radiotherapy Treatment Planning (<http://fly4pet.fpvidal.net>).

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- [3] F. P. Vidal, P. Villard, and E. Lutton. Tuning of patient specific deformable models using an adaptive evolutionary optimization strategy. *IEEE Trans Biomed Eng*, 59(10):2942–2949, 2012.
- [4] P. Villard, F. P. Vidal, C. Hunt, F. Bello, N. W. John, S. Johnson, and D. A. Gould. Simulation of percutaneous transhepatic cholangiography training simulator with real-time breathing motion. *Int J Comput Assist Radiol Surg*, 4(9):571–578, 2009.

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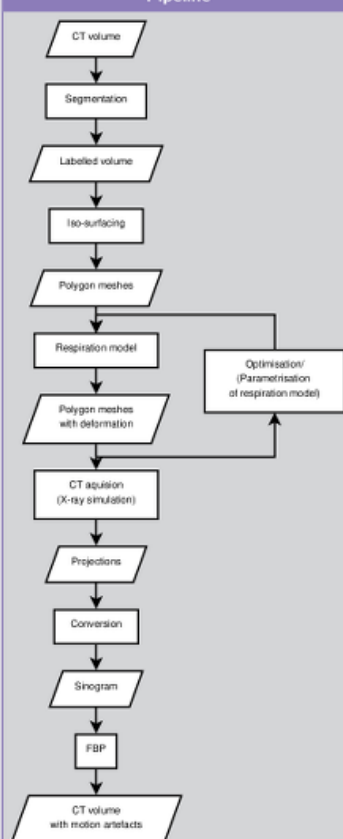
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Contribution

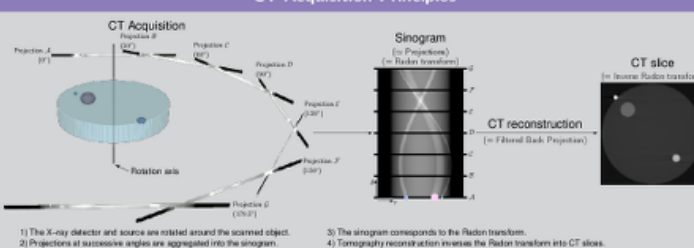
We demonstrate how to simulate the computerised tomography (CT) acquisition process with respiration to generate motion artefacts in reconstructed CT volumes. Our framework can be used to evaluate CT reconstruction algorithms with motion artefact correction in a controlled environment.

Pipeline



1. Anatomical data from 4D CT scans is segmented to provide polygon meshes.
2. The motion due to the respiration is computed in realtime [1].
3. It is a complex model with many parameters. They are finely tuned using an optimisation method based on artificial evolution (AE) [2].
4. It provides realistic data for the simulation of the CT acquisition using X-ray modelling [3].
5. It generate a sinogram that can be reconstructed using the filtered back projection (FBP) method.
6. It creates CT slices that include motion artefacts.

CT Acquisition Principles

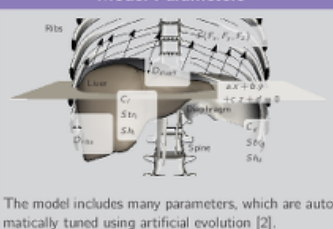


X-ray Simulation on GPU

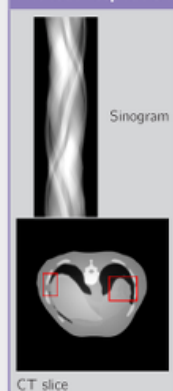
Our X-ray simulation code on graphics processor unit (GPU) is available as an OpenSource Library:



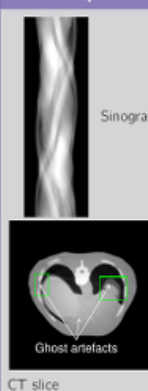
Model Parameters



Without respiration



With respiration



Motion artefacts



References

- [1] P. Villard, F. P. Vidal, C. Hunt, F. Bello, N. W. John, S. Johnson and D. A. Gould, 'Simulation of percutaneous transhepatic cholangiography training simulator with real-time breathing motion', *Int J Comput Assist Radiol Surg*, vol. 4, no. 9, pp. 571–578, 2009.
- [2] F. P. Vidal, P. Villard and E. Lutton, 'Tuning of patient specific deformable models using an adaptive evolutionary optimization strategy', *IEEE Trans Biomed Eng*, vol. 59, no. 10, pp. 2942–2949, 2012.
- [3] F. P. Vidal, M. Garnier, N. Freud, J. M. Létang and N. W. John, 'Simulation of X-ray attenuation on the GPU', in *Proc Theor Pract Comput Graph*, Eurographics Association, 2009, pp. 25–32.

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Figure 4: Poster presented at Eurographics Workshop on Visual Computing for Biology and Medicine, Chester, UK, May 14–15, 2015.