Institute of Medical Physics (IMP)

Friedrich-Alexander-University of Erlangen-Nürnberg
Henkestr. 91, 91052 Erlangen, Germany

4D Generalized Thorax Phantom

Based on the FORBILD Thorax Phantom
**Author:** Frank Bergner, Marc Kachelrieß

April 6th, 2009

The phantom was designed to verify the auto-adaptive phase-correlation (AAPC) algorithm[1].

Phantom Body:

The phantom is based on the thorax phantom proposed by Sourbelle et al. (http://www.imp.uni-erlangen.de/phantoms/thorax/thorax.htm). The phantom was modified for 4D imaging. This document only describes the modifications. For the main phantom design see the original phantom description.

The respiration phase $c(t) \in [0, 100\%)$ is used for a motion-function $f(c(t))$ which is used to scale the different objects. The function was derived from a real motion function detected from the deviations of a patient's abdominal wall. The artificial function consists of a truncated trigonometric series.

$f = m(c(t)) = 0.1608$
$\quad + 0.936 \cos(2 \pi c(t) - \pi)$
$\quad + 0.2808 \cos(4 \pi c(t) - \pi 3 / 4)$
$\quad + 0.03744 \cos(6 \pi c(t) - \pi / 3)$
$\quad + 0.03744 \cos(8 \pi c(t) + \pi / 2)$
$\quad + 0.013104 \cos(10 \pi c(t) + \pi)$
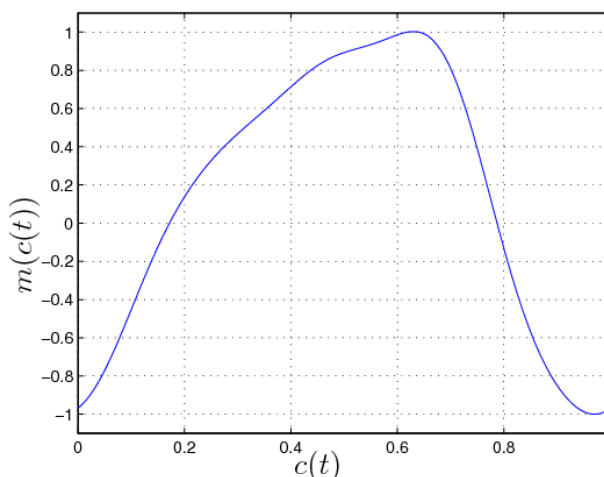
The following modifications were made to simulate pseudo respiratory motion (length units are cm, densities g/cm^3):

The ellipsoid "Lunge L" was changed to

	Object	Center	Axis	Parameters	Density
Lunge L	Ellipsoid	-105.0, 0.0, -55.0		70 + 5* f, 50 + 5* f, 160	0.260

The "Lunge L" CSG object is subtracted with the ellipsoid

	Object	Center	Axis	Parameters	Density
Lung L -	Ellipsoid	-35+5·f, 0.0, -315.0		400, 300, 160 - 20* f	0.260

The ellipsoid "Lunge R" was changed to

	Object	Center	Axis	Parameters	Density
Lunge R	Ellipsoid	105.0, 0.0, -55.0		70 + 5* f, 50 + 5* f, 160	0.260

The "Lunge R" CSG object is subtracted with the ellipsoid

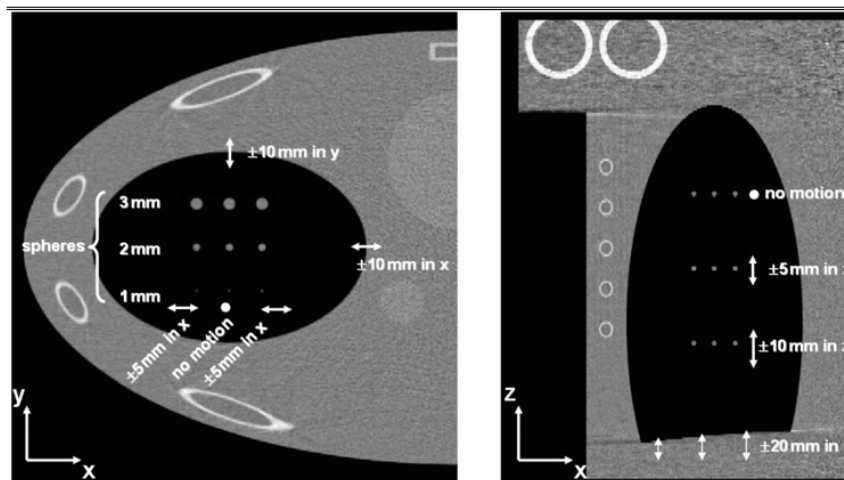|	Object	Center	Axis	Parameters	Density
Lung R -	Ellipsoid	-5*ct + 35.0, 0.0, -315.0		400, 300, 160 - 20*f	0.260

Institute of Medical Physics

The following sphere inserts with radius r and density = 1.0 g/cm^3 were placed into the left lung ellipsoid:

Center	r	Center	r	Center	r
-125 − 5f, 20, 40	0.3	-125 - 5f, 0, 40	0.2	-125 - 5f, -20, 40	0.1
-105, 20, 40	0.3	-105, 0, 40	0.2	-105, -20, 40	0.1
-85 + 5f, 20, 40	0.3	-85 + 5f, 0, 40	0.2	-85 + 5f, -20, 40	0.1
-125 − 5f, 20, -20 − 5f	0.3	-125 - 5f, 0, -20 - 5f	0.2	-125 - 5f, -20, -20 - 5f	0.1
-105, 20, -20 − 5f	0.3	-105, 0, -20 - 5f	0.2	-105, -20, -20 - 5f	0.1
-85 + 5f, 20, -20 − 5f	0.3	-85 + 5f, 0, -20 - 5f	0.2	-85 + 5f, -20, -20 - 5f	0.1
-125 − 5f, 20, -80 - 10f	0.3	-125 - 5f, 0, -80 - 10f	0.2	-125 - 5f, -20, -80 - 10f	0.1
-105, 20, -80 - 10f	0.3	-105, 0, -80 - 10f	0.2	-105, -20, -80 - 10f	0.1
-85 + 5f, 20, -80 - 10f	0.3	-85 + 5f, 0, -80 - 10f	0.2	-85 + 5f, -20, -80 - 10f	0.1

The following sphere inserts with radius r and density = 1.0 g/cm^3 were placed into the right lung ellipsoid:

Center	r	Center	r	Center	r
+125 + 5f, 20, 40	0.3	+125 + 5f, 0, 40	0.2	+125 + 5f, -20, 40	0.1
+105, 20, 40	0.3	+105, 0, 40	0.2	+105, -20, 40	0.1
+85 - 5f, 20, 40	0.3	+85 - 5f, 0, 40	0.2	+85 - 5f, -20, 40	0.1
+125 + 5f, 20, -20 - 5f	0.3	+125 + 5f, 0, -20 - 5f	0.2	+125 + 5f, -20, -20 - 5f	0.1
+105, 20, -20 - 5f	0.3	+105, 0, -20 - 5f	0.2	+105, -20, -20 - 5f	0.1
+85 - 5f, 20, -20 - 5f	0.3	+85 - 5f, 0, -20 - 5f	0.2	+85 - 5f, -20, -20 - 5f	0.1
+125 + 5f, 20, -80 - 10f	0.3	+125 + 5f, 0, -80 - 10f	0.2	+125 + 5f, -20, -80 - 10f	0.1
+105, 20, -80 - 10f	0.3	+105, 0, -80 - 10f	0.2	+105, -20, -80 - 10f	0.1
+85 - 5f, 20, -80 - 10f	0.3	+85 - 5f, 0, -80 - 10f	0.2	+85 - 5f, -20, -80 - 10f	0.1

[1] F. Bergner, T. Berkus, M. Oelhafen, P. Kunz, T. Pan, Kachelrieß, M.,
Voxel-Based Reconstruction Combined with Motion Detection for Slowly Rotating 4D FPD CBCT,
Medical Imaging Conference Record, 2008. MIC '08. IEEE, **2008**, 5107-5112