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F. P. Vidal, P.-F. Villard, M. Garnier, N. Freud, J. M. Létang, N. John, and F. Bello: Joint Simulation of Transmission X-ray Imaging on GPU and Patient's Respiration on CPU. In *Medical Physics*, 37(6):3129, July 2010, American Association of Physicists in Medicine

DOI: 10.1118/1.3468154

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@article{Vidal2010MedPhys-B,
  author = {F. P. Vidal and P. F. Villard and M. Garnier and N. Freud and J. M. L\'etang and N. W. John and
  title = {Joint Simulation of Transmission X-ray Imaging on {GPU} and Patient's Respiration on {CPU}},
  journal = {Medical Physics},
  year = 2010,
  volume = 37,
  pages = {3129},
  number = 6,
  month = jul,
  address = {Philadelphia, Pensilvania, USA},
  annotation = {AAPM Annual Meeting, Jul~18--22, 2010},
  abstract = {Purpose: We previously proposed to compute the X-ray attenuation
from polygons directly on the GPU, using OpenGL, to significantly
increase performance without loss of accuracy. The method has been
deployed into a training simulator for percutaneous transhepatic
cholangiography. The simulations were however restricted to
monochromatic X-rays using a point source. They now take into account
both the geometrical blur and polychromatic X-rays.
Method and Materials: To implement the Beer-Lambert law with a
polychromatic beam, additional loops have been included in the
simulation pipeline. It is split into rendering passes and uses frame
buffer objects to store intermediate results. The source shape is
modeled using a variable number of point sources and the incident beam
is split into discrete energy channels. The respiration model is composed
of ribs, spine, lungs, liver, diaphragm and the external skin. The organ
motion simulation is based on anatomical and physiological studies:
the model is monitored by two independent active components:
the ribs with a kinematics law and the diaphragm tendon with an up and
down translation. Other soft-tissue components are passively deformed
using a 3D extension of the ChainMail algorithm. The respiration rate
is also tunable to modify the respiratory profile.
  Results: We have extended the simulation pipeline to take into account
focal spots that cause geometric unsharpness and polychromatic X-rays,
and dynamic polygon meshes of a breathing patient can be used as input data.
Conclusions: X-ray transmission images can be fully simulated on the GPU,
by using the Beer-Lambert law with polychromatism and taking into account
the shape of the source. The respiration of the patient can be
modeled to produce dynamic meshes. This is a useful development to improve
the level of realism in simulations, when it is needed to retain both speed
and accuracy.},
  doi = {10.1118/1.3468154},
  publisher = {American Association of Physicists in Medicine}
}
```

Joint Simulation of Transmission X-ray Imaging on GPU and Patient's Respiration on CPU

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Purpose

We previously proposed to compute the X-ray attenuation from polygons directly on the GPU, using OpenGL, to significantly increase performance without loss of accuracy. The method has been deployed into a training simulator for percutaneous transhepatic cholangiography. The simulations were however restricted to monochromatic X-rays using a point source. They now take into account both the geometrical blur and polychromatic X-rays.

Method and Materials

To implement the Beer-Lambert law with a polychromatic beam, additional loops have been included in the simulation pipeline. It is split into rendering passes and uses frame buffer objects to store intermediate results. The source shape is modeled using a variable number of point sources and the incident beam is split into discrete energy channels. The respiration model is composed of ribs, spine, lungs, liver, diaphragm and the external skin. The organ motion simulation is based on anatomical and physiological studies: the model is monitored by two independent active components: the ribs with a kinematics law and the diaphragm tendon with an up and down translation. Other soft-tissue components are passively deformed using a 3D extension of the ChainMail algorithm. The respiration rate is also tunable to modify the respiratory profile.

Results

We have extended the simulation pipeline to take into account focal spots that cause geometric unsharpness and polychromatic X-rays, and dynamic polygon meshes of a breathing patient can be used as input data.

Conclusions

X-ray transmission images can be fully simulated on the GPU, by using the Beer-Lambert law with polychromatism and taking into account the shape of the source. The respiration of the patient can be modeled to produce dynamic meshes. This is a useful development to improve the level of realism in simulations, when it is needed to retain both speed and accuracy.

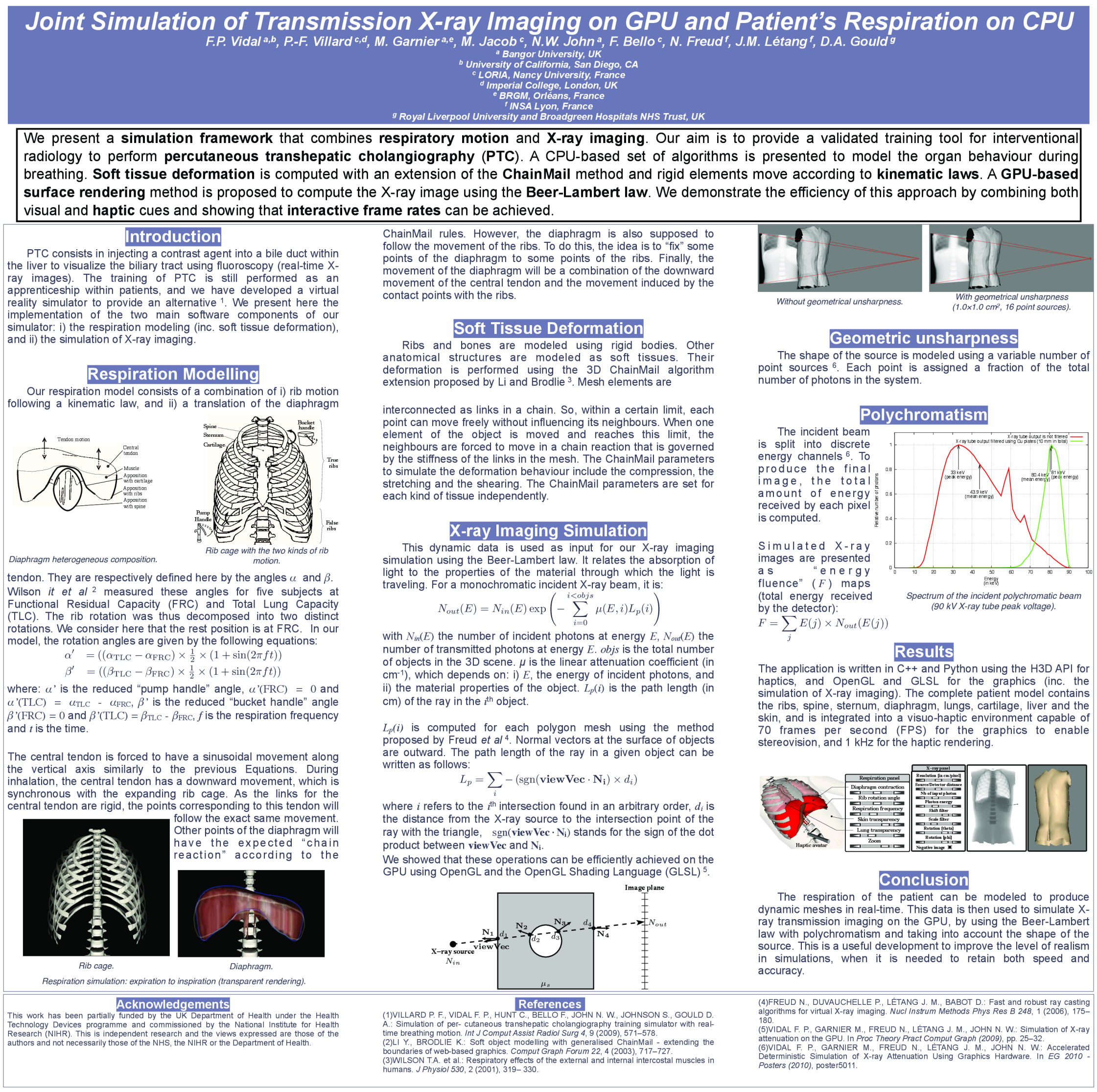

Figure 1: Poster presented at AAPM Annual Meeting, Philadelphia, Pensilvania, USA, Jul 18–22, 2010.