The Human Respiratory Pump

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Background: Patients placed in mechanical respirators often suffer from damage of the respiratory muscles.

The longterm goal is to perform realtime simulation to study the effects of mechanical ventilation as well as preventive and therapeutical interventions.

During inspiration the diaphragm moves down by contraction and the ribcage expands up and out. This increases the volume of the thorax and allows air to flow into the lungs.

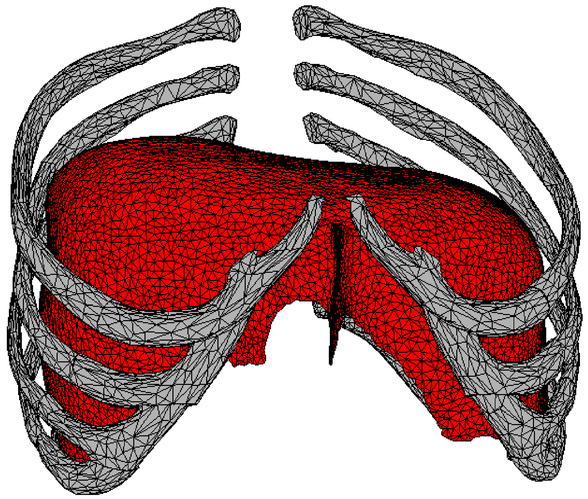
Goal: Continued development of a model of the human respiratory system with focus on achieving muscle contraction in the diaphragm.

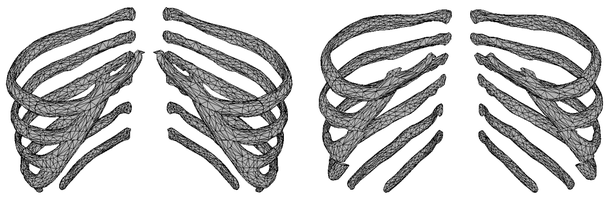
Method: A free 3D model from Anatomography is used for the individual components of the respiratory system.

The mathematical description of the diaphragm is a relaxed mass-spring system, originally used for simulating cloth, which was implemented prior to this project.

The direction of the contracting action is approximated using reference points in thin segments of the diaphragm.

Nodes in the diaphragm attached to the ribcage are assigned based on proximity.

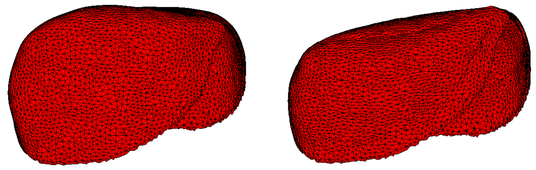




Ribcage at the beginning and end of inspiration. Movement is exhagerated.

Result: A model of the bottom part of the ribcage was made where the movement of each rib can be controlled individually.

Stable contraction of the diaphragm was accomplished by reducing spring resting length with respect to direction of the contracting force. Relaxing the springs, however, leads to instability.



Relaxed and contracted diaphragm

Conclusion: The relaxed mass-spring system is structurally unstable and tends to fold. Increasing spring resting length when relaxing the diaphragm introduces internal forces which leads to structural collapse.

The components of the 3D model used in this project are not well aligned, making it difficult to achieve a realistic description of the diaphragm-ribcage interface. Using a commercial- or patient based model would be preferable for further development.

Future work: Examples of possible improvements of the model are:

- A better description of the pressure and volume changes in the thorax and abdominal compartment.

- Adding contact conditions preventing the diaphragm from exceeding the inner boundary of the chest wall.