Gestural 3D Interaction with a Beating Left Heart
Simulation, Visualization and Interaction

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Introduction

SimVisInt: Platform in Simulation-Visualization-Interaction

Goal:

- Bring together CSC core competences and research
- Establish interdisciplinary projects within the theme of computational human modeling and visualization
  - Interactive virtual biomedicine (HEART):
    A public showcase to aid the perception and understanding of the heart simulation data
  - Simulation of human motion (MOTION)
  - Virtual prototyping of human hand prostheses (HAND)

Components of HEART

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Simulation

Mathematical model and numerical simulation

Visualization

Visualization of pressure and velocity in VTK

Interaction

Gesture interaction (orientation, zoom) using Kinect depth-sensing camera, OpenNI and OpenCV

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Simulation

From a patient specific ultra sound measurement to the geometric model of the left ventricle

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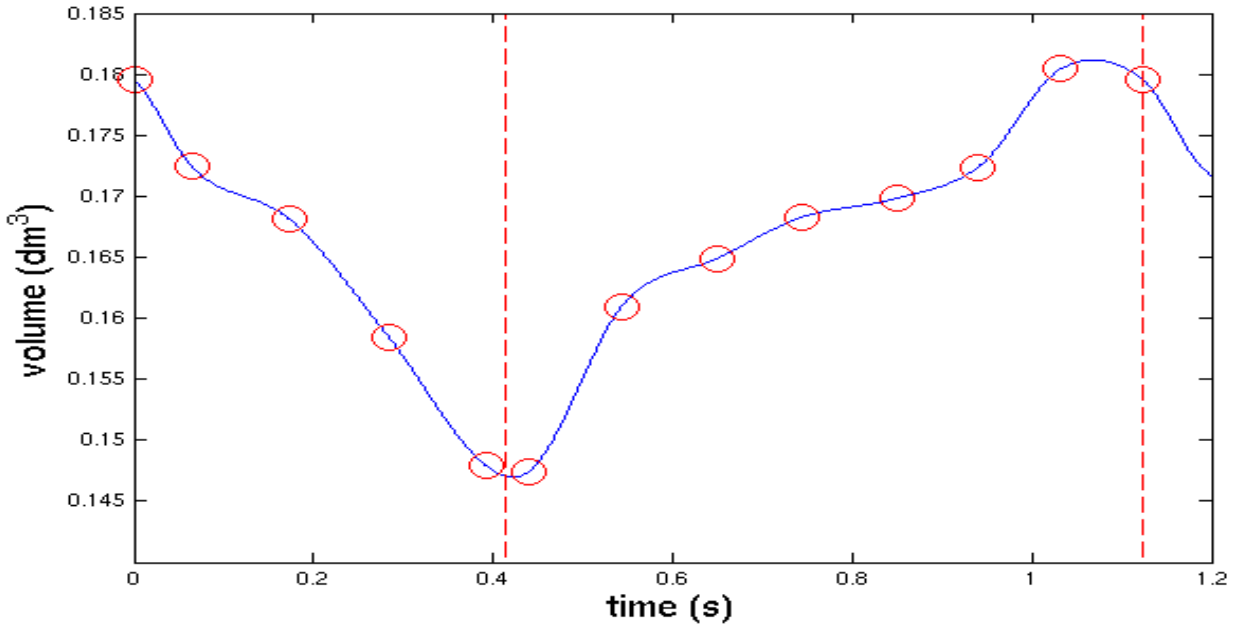

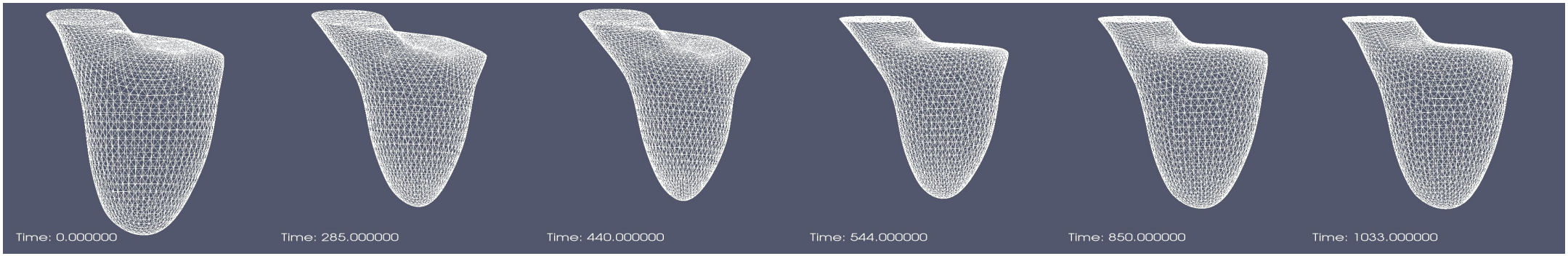

Mathematical Model

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- Incompressible Navier-Stokes equation

$$\dot{u} + (u \cdot \nabla) u - \nu \Delta u + \nabla p = f$$

$$\nabla \cdot u = 0$$

- Boundary conditions for the pressure and the velocity at the valves are changing during the cardiac cycle
- Maximal Reynolds number of $2 \cdot 10^4$

$$\mu = 2.7 \cdot 10^{-3} \frac{kg}{m \cdot s} \quad \rho = 1.06 \cdot 10^3 \frac{kg}{m^3}$$

Standard Galerkin Finite Element Method with Streamline Diffusion Stabilization

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- We choose the cG(1)cG(1) ALE FEM method for discretization i.e. piecewise linear elements in time and space

$$((U^n - U^{n-1})k_n^{-1} + (\bar{U}^n - W^{n-1})\cdot\nabla\bar{U}^n, v) + (2\nu\epsilon(\bar{U}^n), \epsilon(v))$$
$$-(P^n, \nabla\cdot v) + (\nabla\cdot\bar{U}^n, q) + SD_\delta(\bar{U}^n, P^n; v, q) = (f, v)\;\forall (v, q)\in V_0^n\times Z^n$$

$$SD_\delta(\bar{U}^n, P^n; v, q) = (\delta_1((\bar{U}^n - W^{n-1})\cdot\nabla\bar{U}^n + \nabla P^n - f), (\bar{U}^n - W^{n-1})\cdot\nabla v + \nabla q) + (\delta_2\nabla\cdot\bar{U}^n, \nabla\cdot v)$$

Software: FEniCS/Unicorn

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- Unicorn is a software tool of the FEniCS platform for automated solution of differential equations
- Unicorn: adaptive finite element solver for fluid and structure mechanics
- http://www.fenics.org/wiki/FEniCS_Project or https://launchpad.net/fenics

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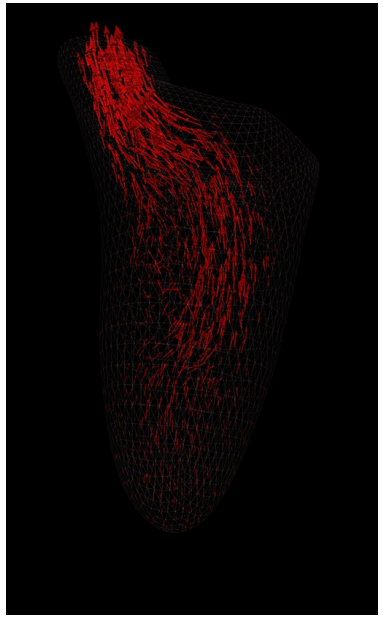
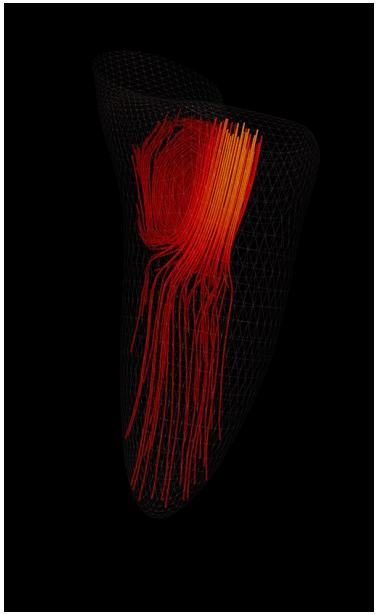
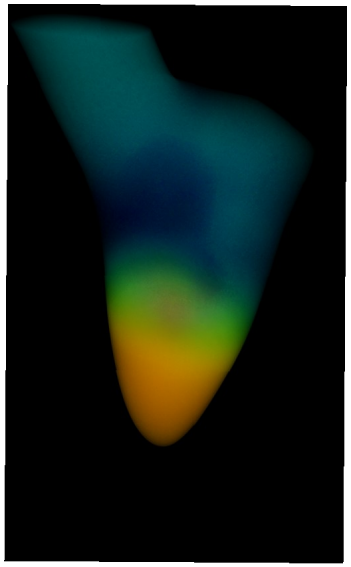
Visualization

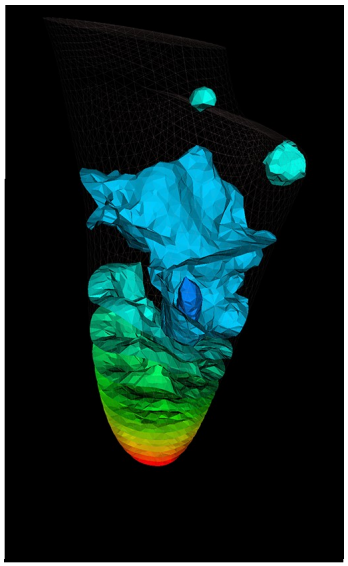
Visualization in VTK

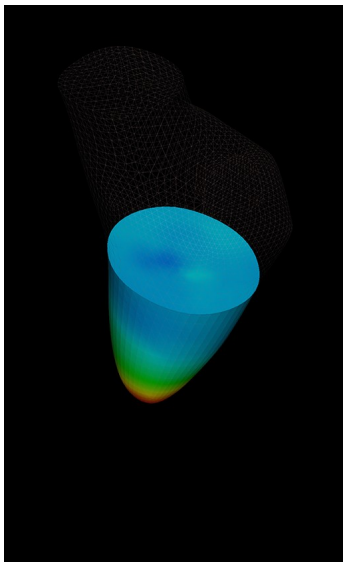




Blood flow velocity
Arrow size is proportional to velocity
Alternative: Animated streamlines







Pressure Data
Volume rendering
Alternative: ISO surfaces or Interactive Cut Plane

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Interaction

Starting

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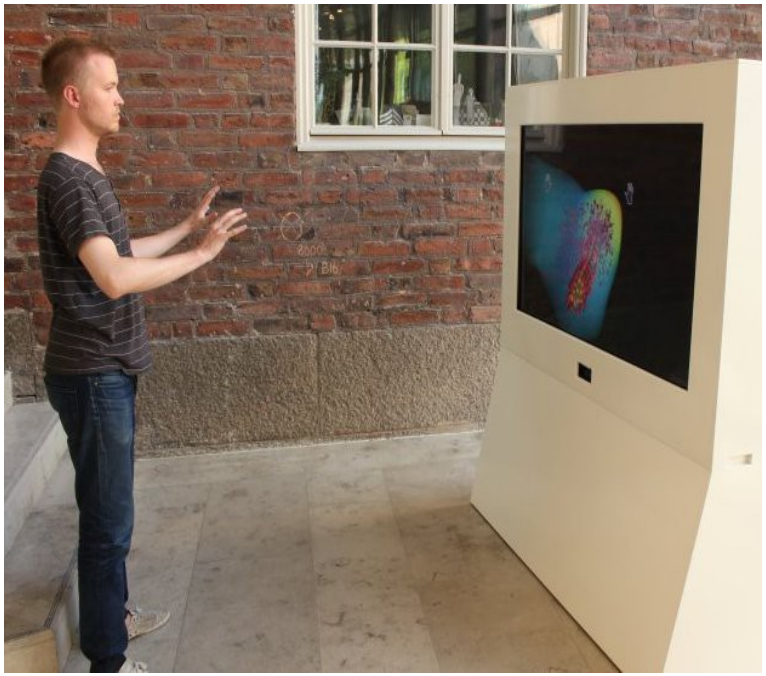
Begins with a calibration pose in order to initiate user tracking

Rotating

- - Activation/Deactivation: closed/open hand
- - Rotation: moving 1 closed hand



Zooming

- Scale: distance between 2 closed hands

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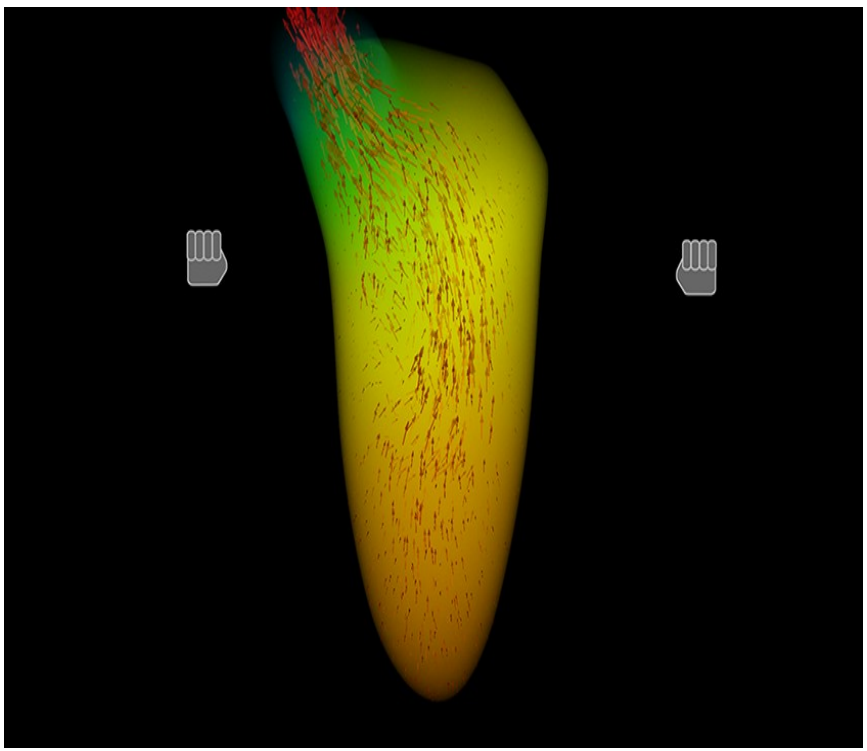
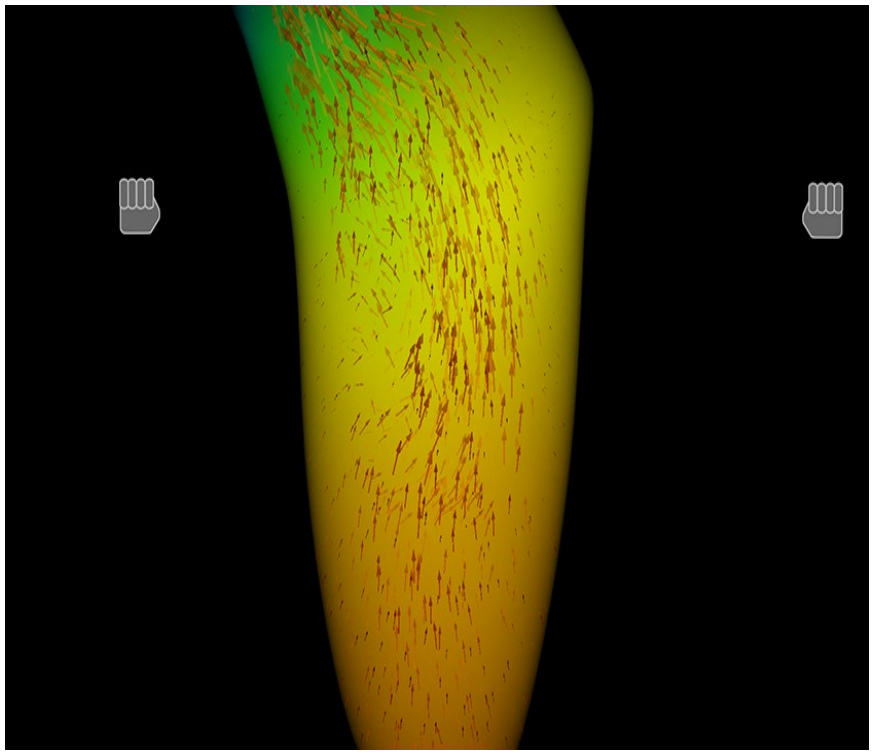




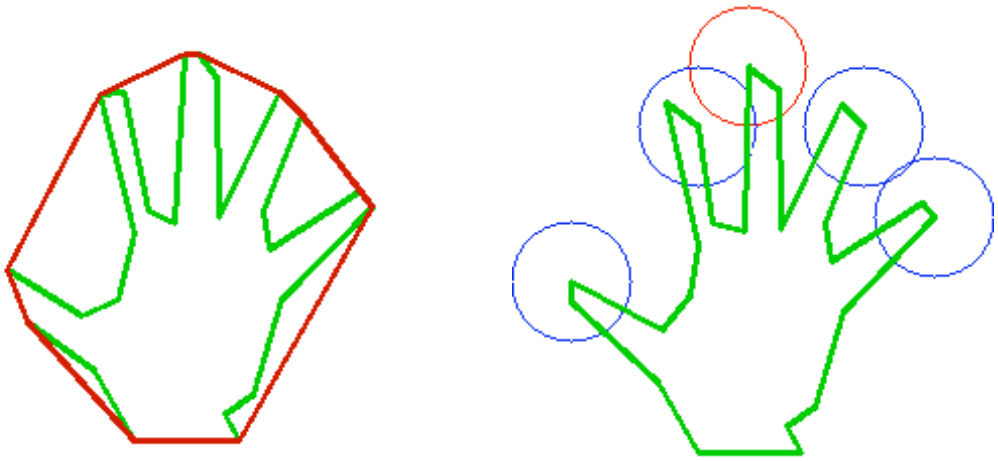
Open\Closed hands detection

1. Locate and isolate the hands in 3D using the information of the tracked joints
2. Create a polygon approximation of the hand contour from the depth camera image
3. Measurements on three important criteria to decide for the state of the hand

Open\Closed hands detection

Criteria

- The similarity of the the hand contour area to the area of its convex hull
- Differences between the contour and hull (convexity defects)
- Sharp consecutive changes of direction along the contour to locate the fingers



Summary /Future work

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- Successful interdisciplinary collaboration
- Showcase at KTHB/ Vetenskapens Hus
- Enhance students interest and understanding of our research fields

- Aim to interactively modify the virtual heart
  - Exchange valves
  - Modify geometry