Testbed for flow analysis using 3D-printed models of individual nasal cavity

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http://rhinodiagnost.eu

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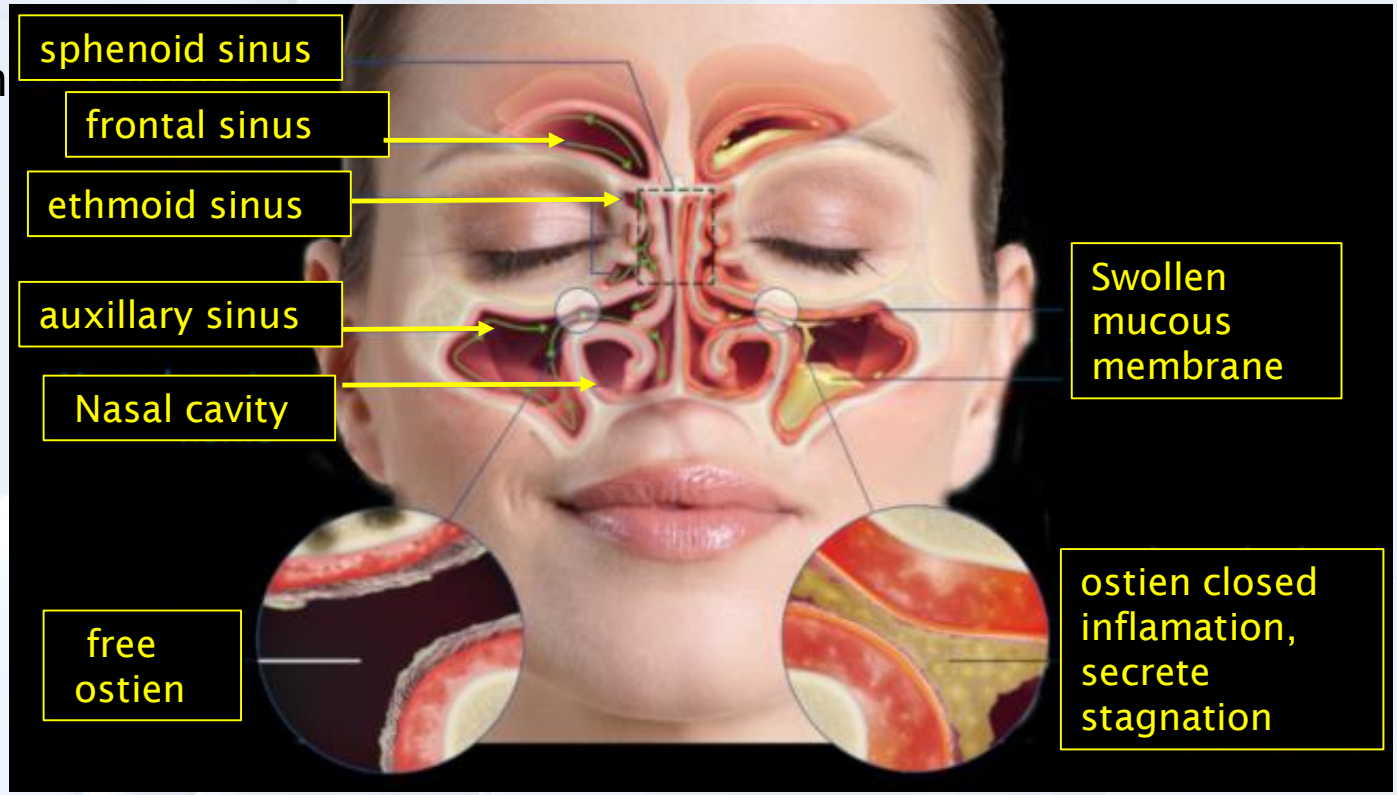
The medical problem

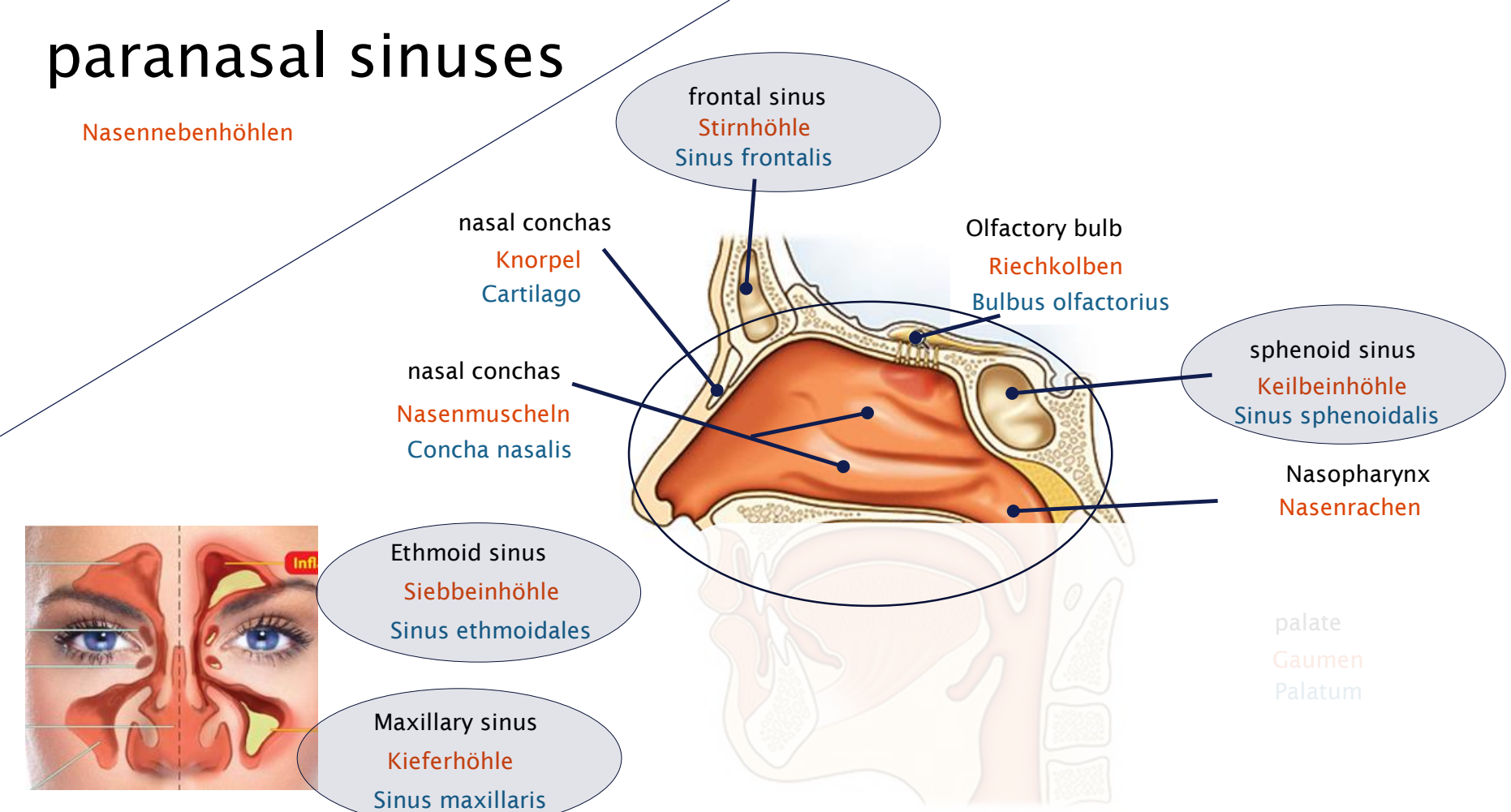
Nasal disorders are among the most common health problems

Chronic sinusitis is the most common **chronic disease** in the Western world



paranasal sinuses

Nasennebenhöhlen



sagital view

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Treatment of chronic sinusities ?

Pharmalocical measures

Surgical interventions to re-open the ostium from a sinus to the main nasal cavity

Serious ENT specialist: „ >20% of surgeries … for nothing “

(so the estimated number may be much higher)

Iatrogen: the term that is not very popular in a Hospital

names all the injuries and deseases that are produced inside a hospital

1. after enlargement - due to swelling and regrow of tissue the ostium could be smaller than before - pain remains or even get more worse

2. straight cutting tools (for a curved path) destroy everything blocking the way!

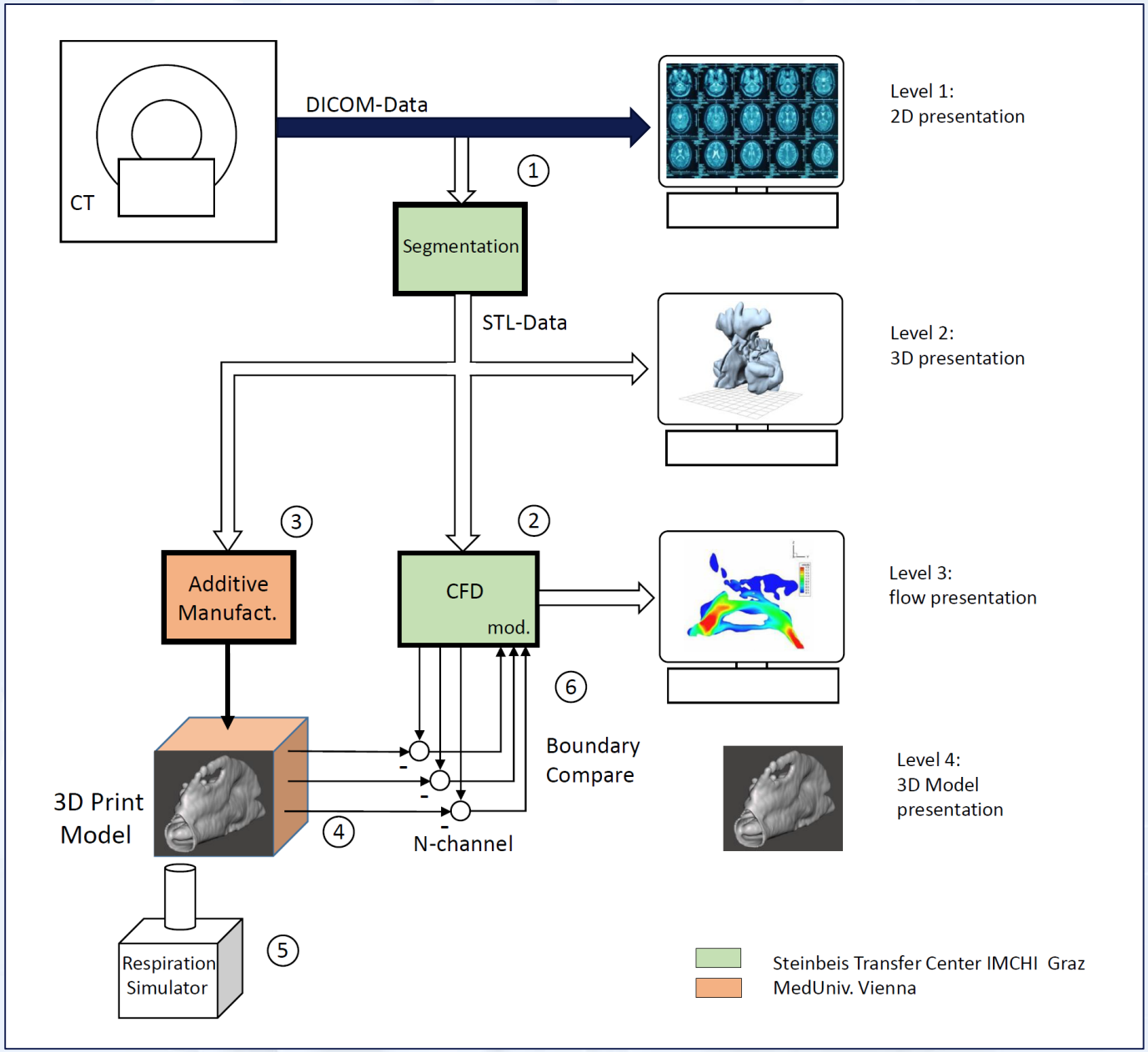
How can we achieve more information and knowledge ?

Improve 3D imagination about (pathological) anatomy:

CAD 3D models on screen
Physical 3models (3D-prints)

CFD - Computational Fluid Dynamics
to recognize reduced flow in specific parts of the air path

Scientific level !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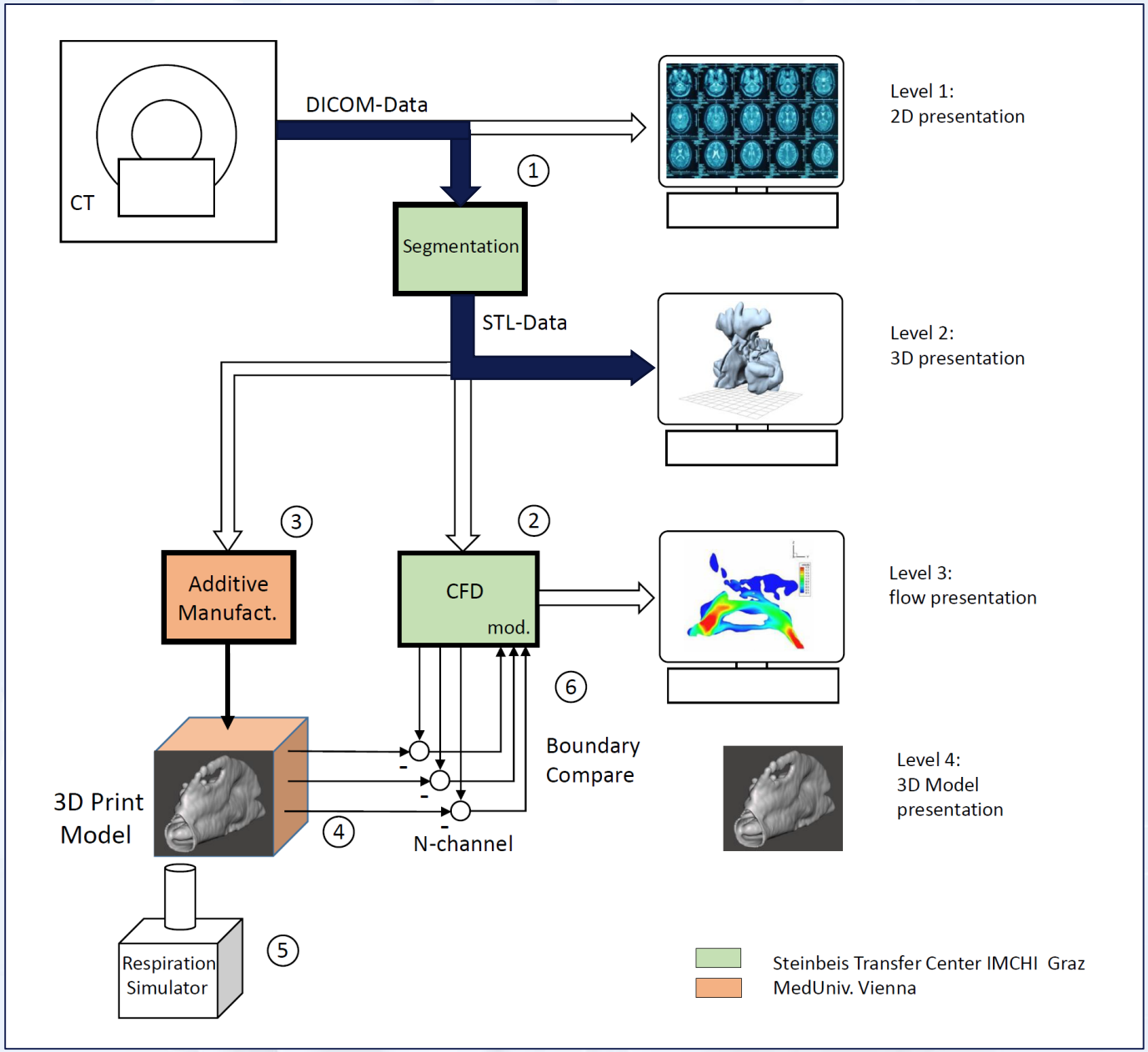
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Comparison: Human vs Neural Network

2000 patients to analyse

CT Image

2x 2 class segmentation

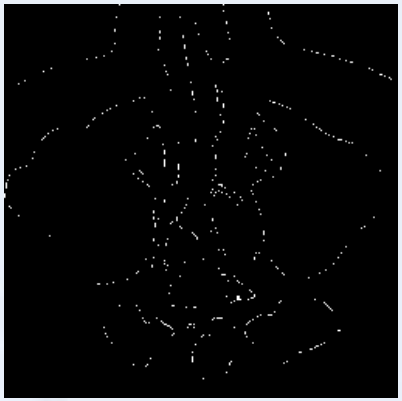
A. air vs. non air
B. bone vs. non bone

C = B – A
soft tissue (mucos, ..)

manuall segmentation

CNN segmentation

difference

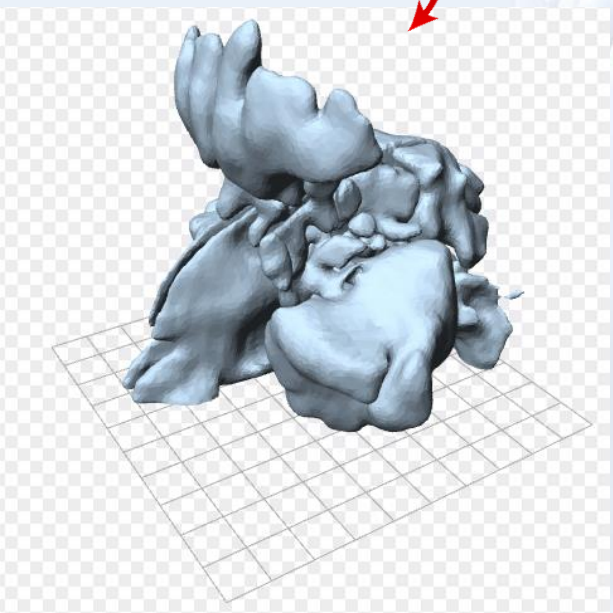


99.43% accuracy with the CNN used

Accuracy = percentage of pixels classified correctly (in comparison to the manual segmentation as reference)

improvement for smoothing the surface nessesary

The Marching Cubes Algorithm

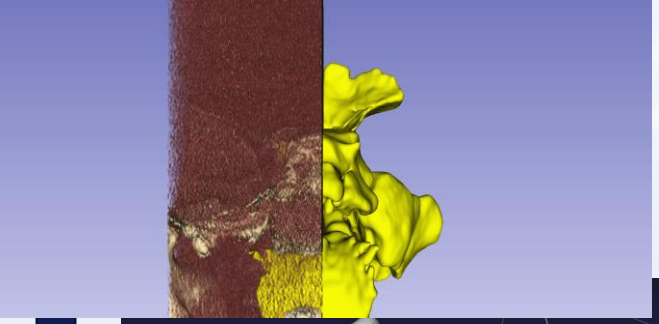


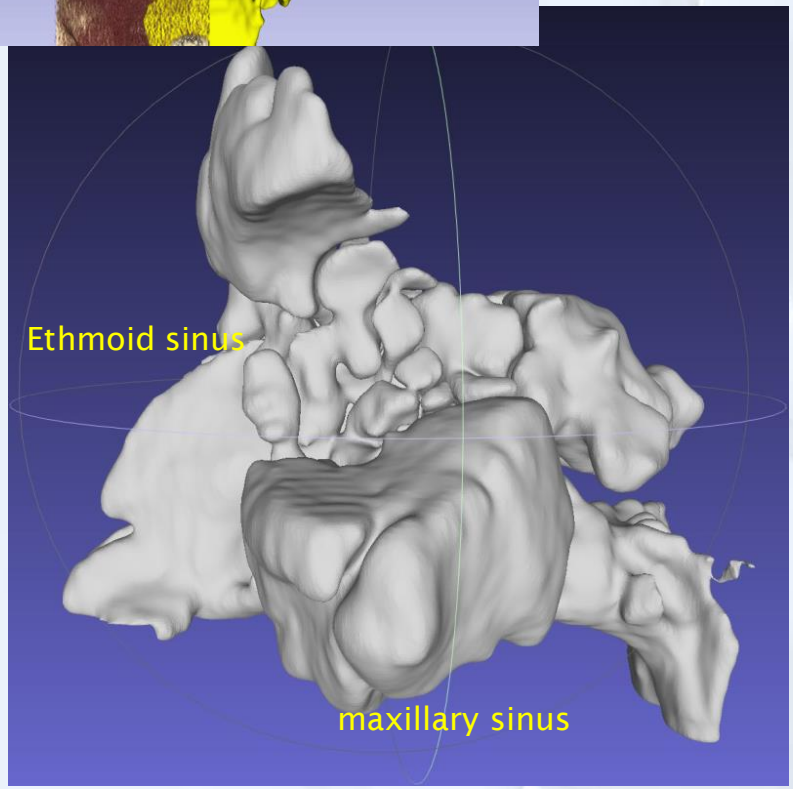
The **Marching Cubes** algorithm is used to extracts polygonal mesh from an input isosurface. Using this algorithm, one can generate 3D surface triangulations, from the 2D segmentations of air and bone.

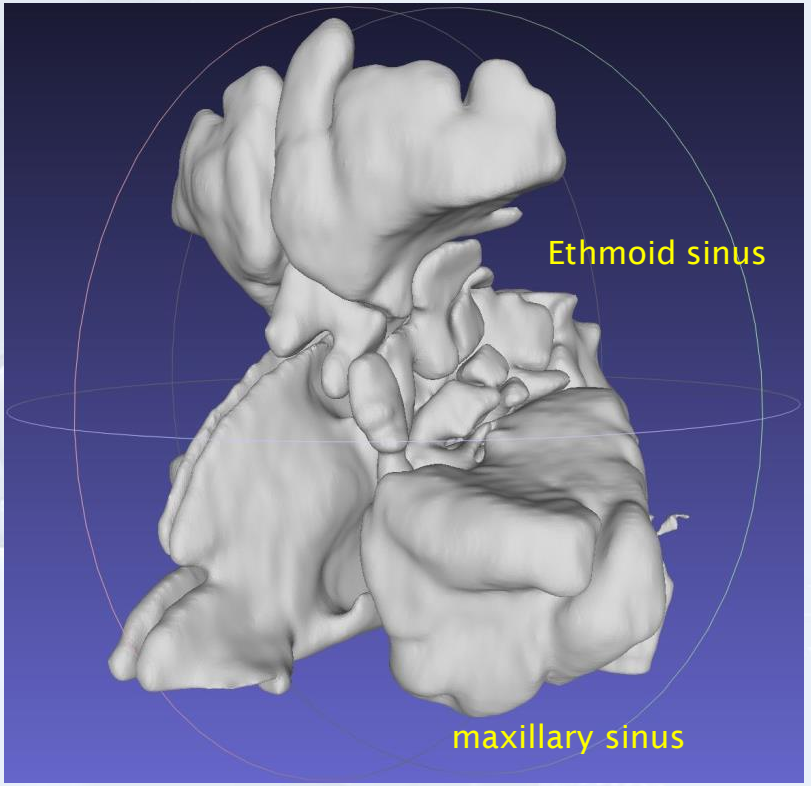
The algorithm is accurate and well suited for surface reconstruction. The total time needed increases linearly with the increase of area.

Further application:

- 3D printing
- CFD simulations
- fluid dynamics measurements with an artificial lung
- classify and distinguish different anatomical structures (i.e. different sinuses, left and right), etc.







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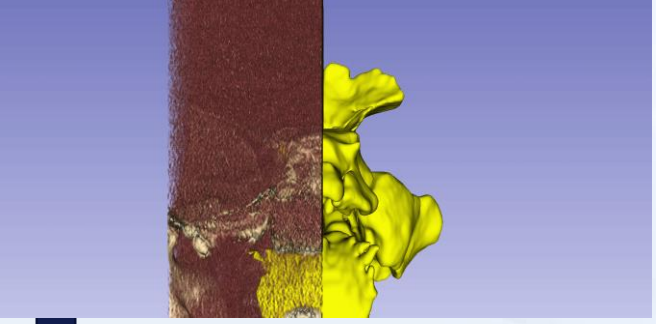

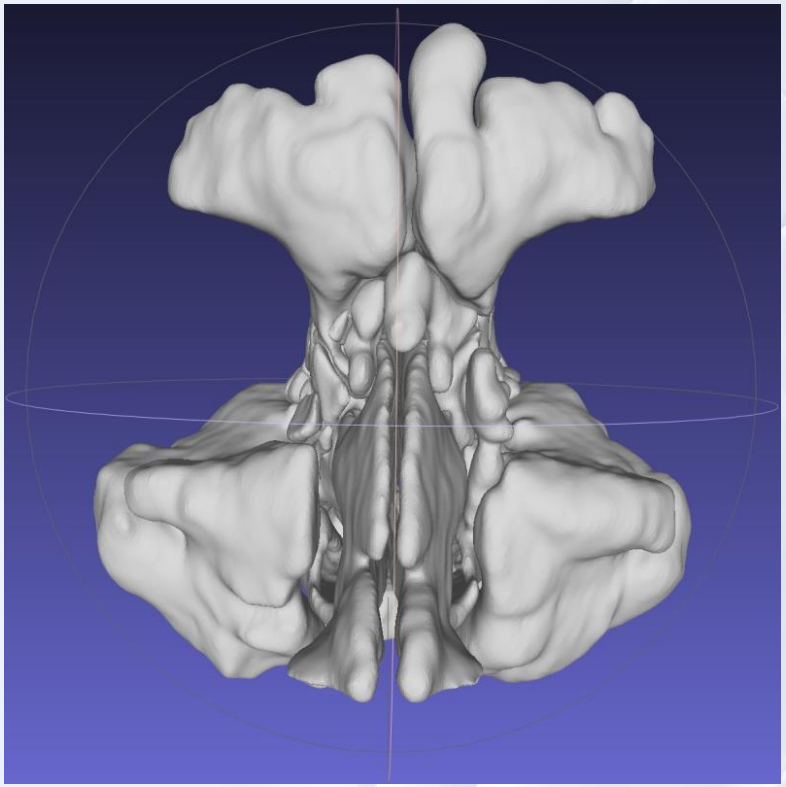

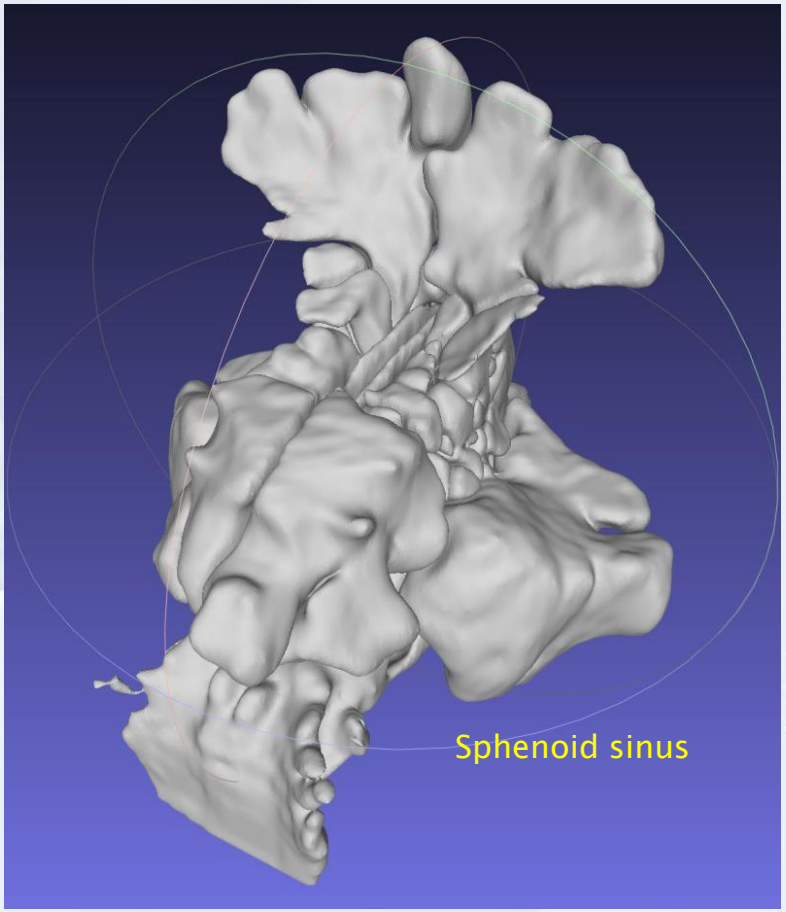

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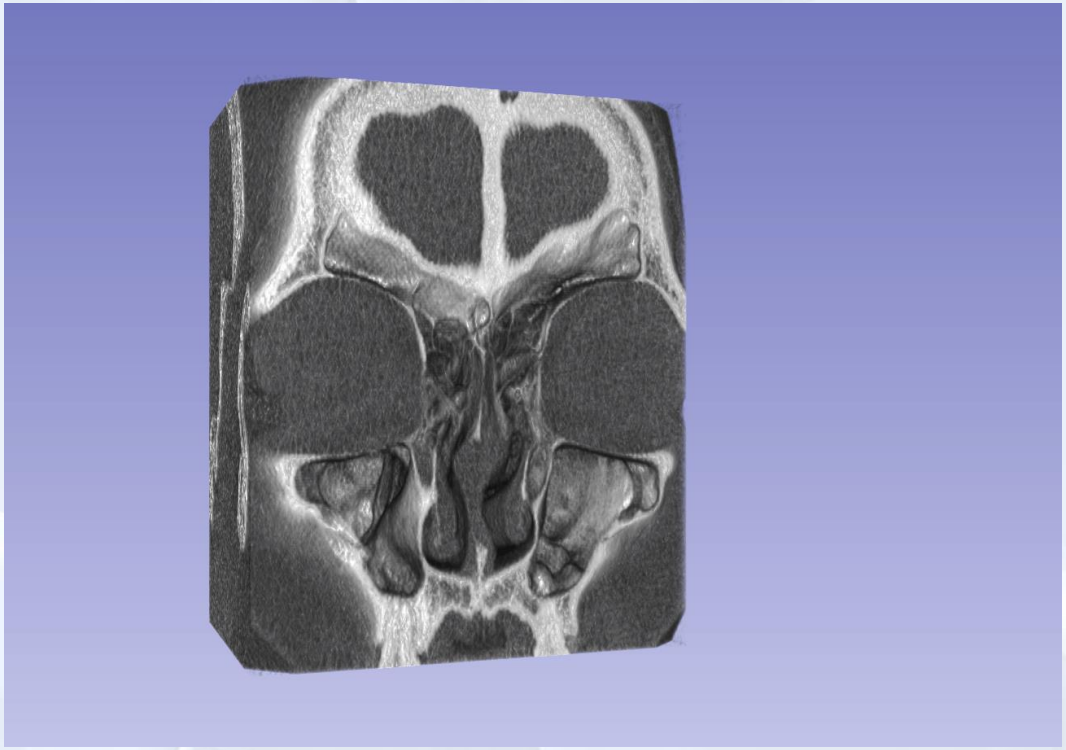
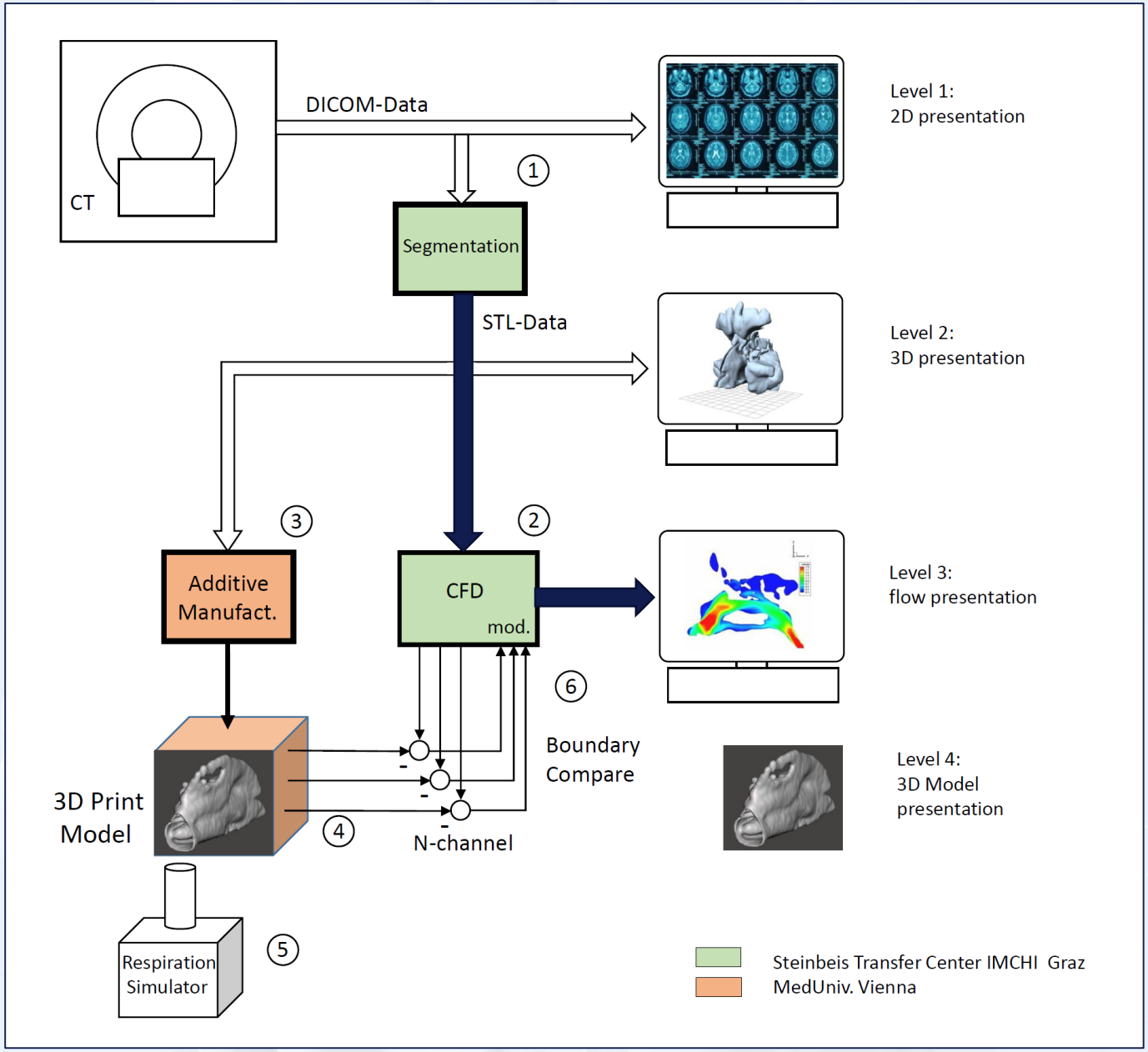


Another more familar view.
(surgeons are use to an endoscopic view)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attempts to understand airflow in the nose

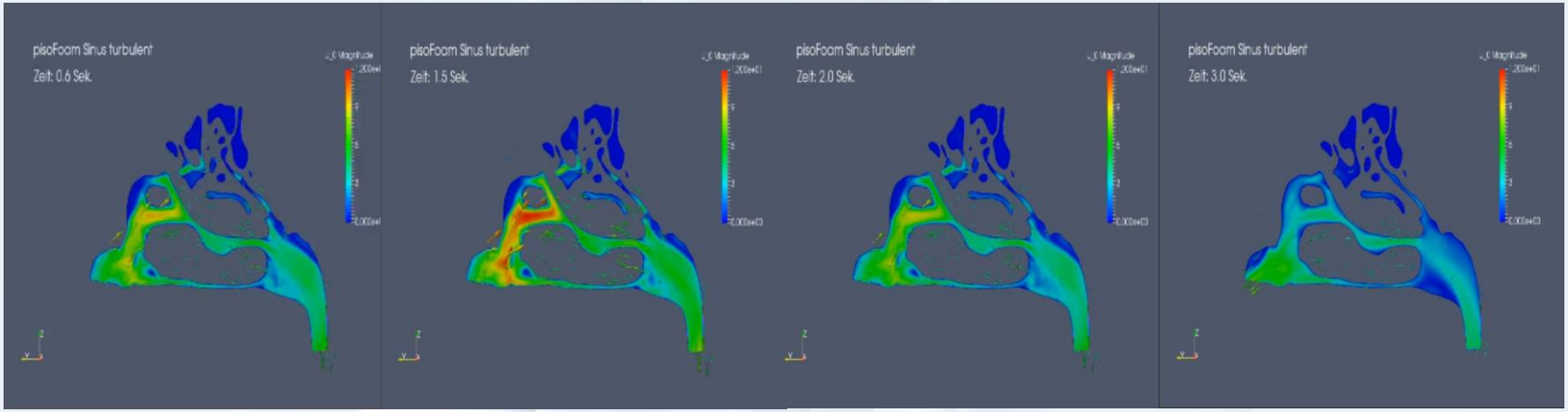
CFD - Computational Fluid Dynamics

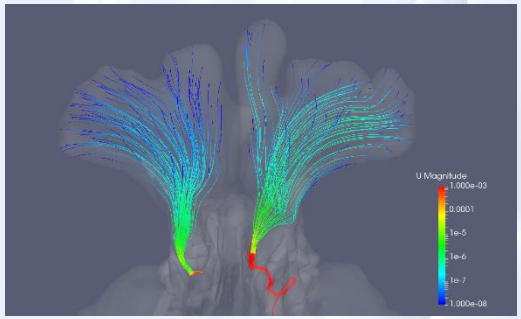
http://rhinodiagnost.eu/2017/09/26/video-stroemungssimulation/

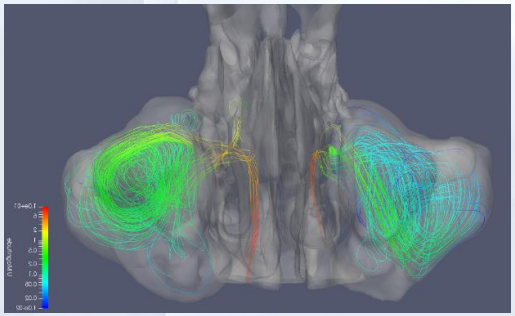
attempts to understand airflow in the nose

Are the results proofed ?

CFD - Computational Fluid Dynamics







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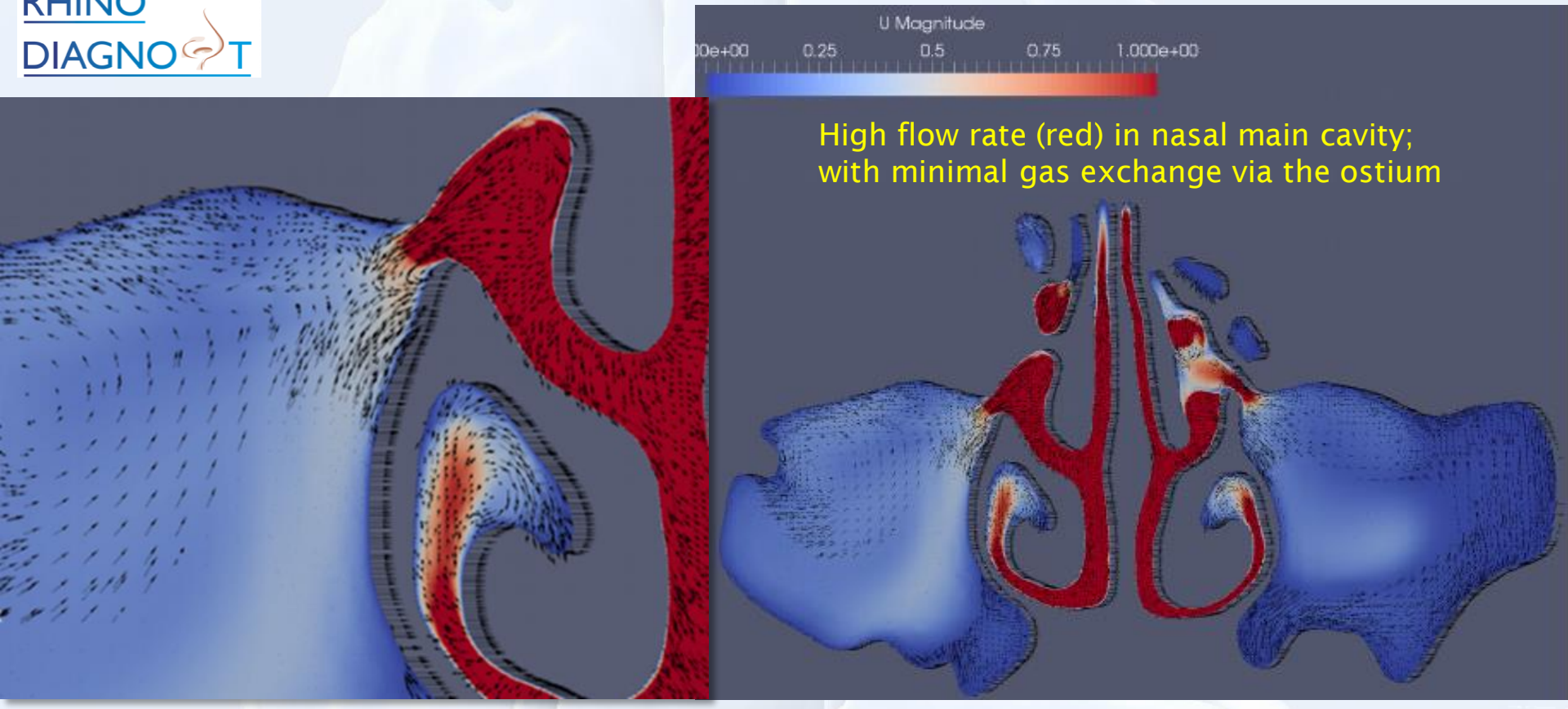

High flow rate (red) in nasal main cavity;
with minimal gas exchange via the ostium

- Extrem complex anatomy needs super computers to perform CFD escpecially if a complete respiration cyle is investigated

- Measures to save computation time:
  simulation of whole breathing by a number of stady state flow simulations at various levels with sequential assembly

M3d+it MEDICAL 3D-PRINTING AND INNOVATIVE TECHNOLOGIES 2019

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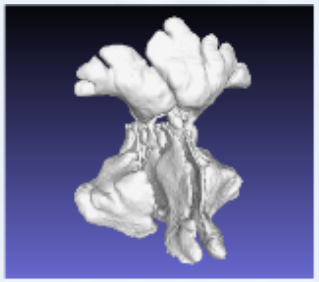
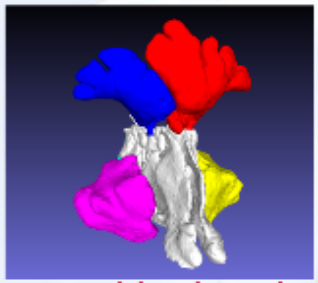
Mesh labeling



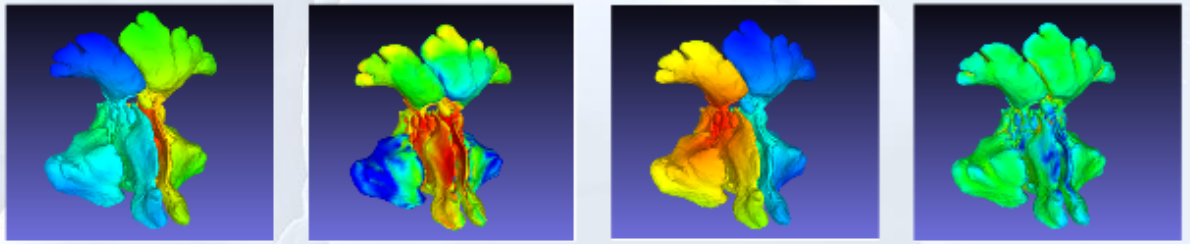
Use surface triangulation algorithm to generate 3D mesh of air segmenation



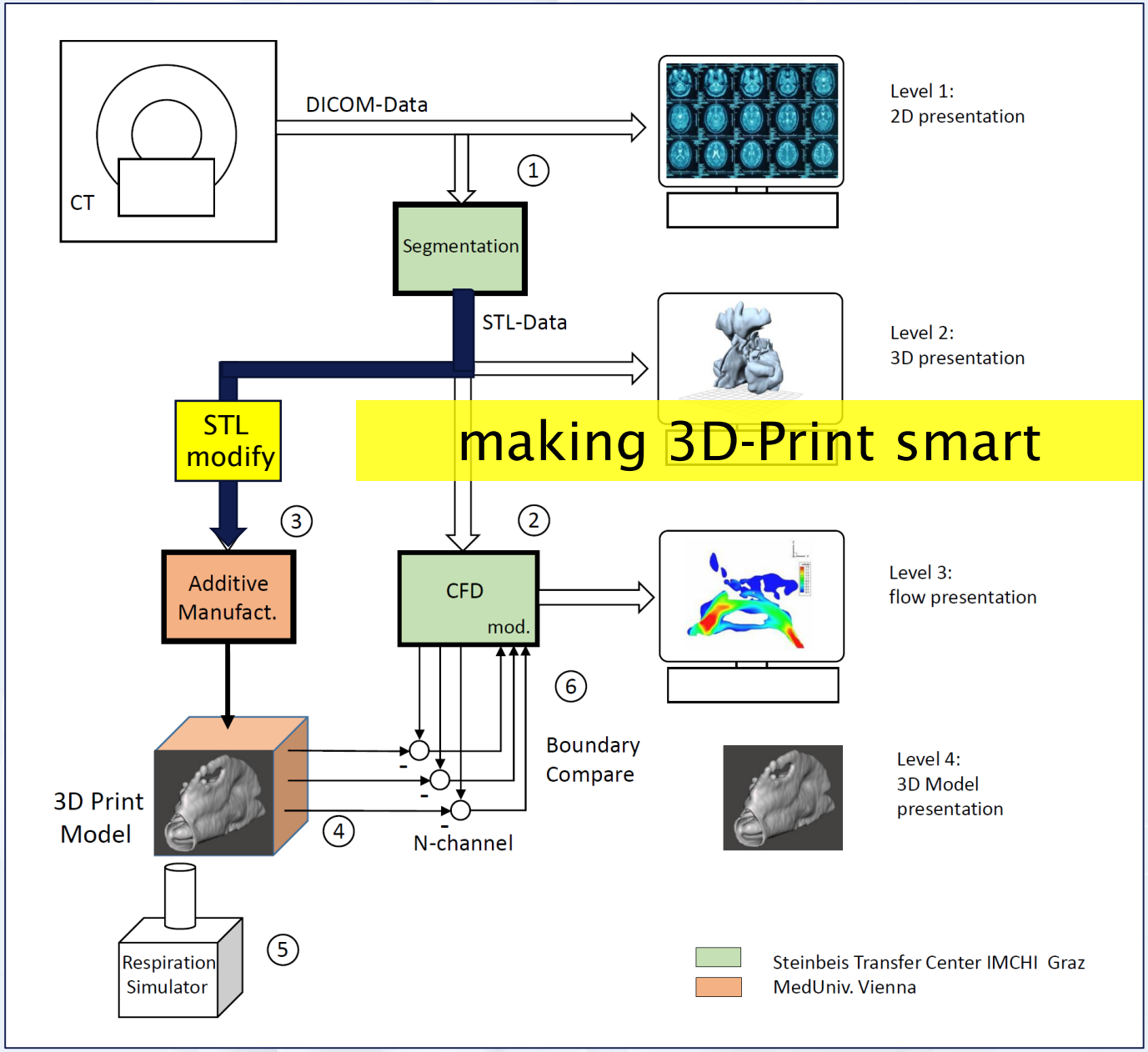
Use machine learning algorithm to label air mesh parts (sinuses)

Our goal now is to separate the 3D mesh of the air segmentation into different parts, i.e. to **distinguish** the **paranasal sinuses** (on each side) from the remaining anatomy (by using a **Convolutional Neural Network**).

We also need these separate parts to define **starting points** for the **raycasting** procedure we will introduce in later slides. This procedure allows us to **extract the inner surface of the bone mesh surrounding the cavity**.



Different triangle properties used for classification (color-coded)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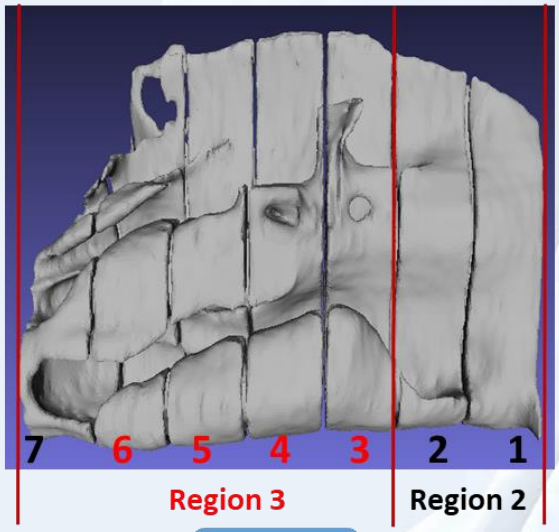
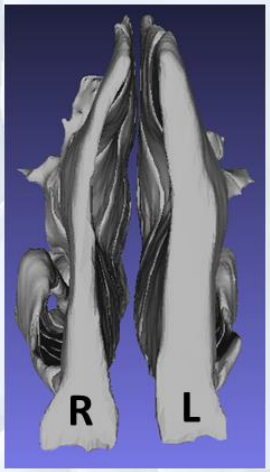
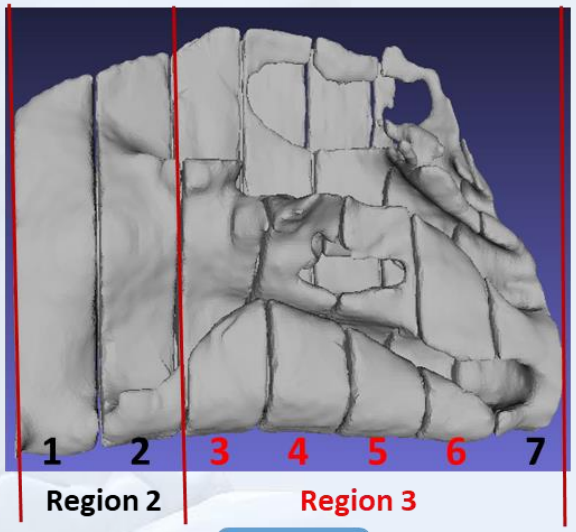
Possible locations of sensors

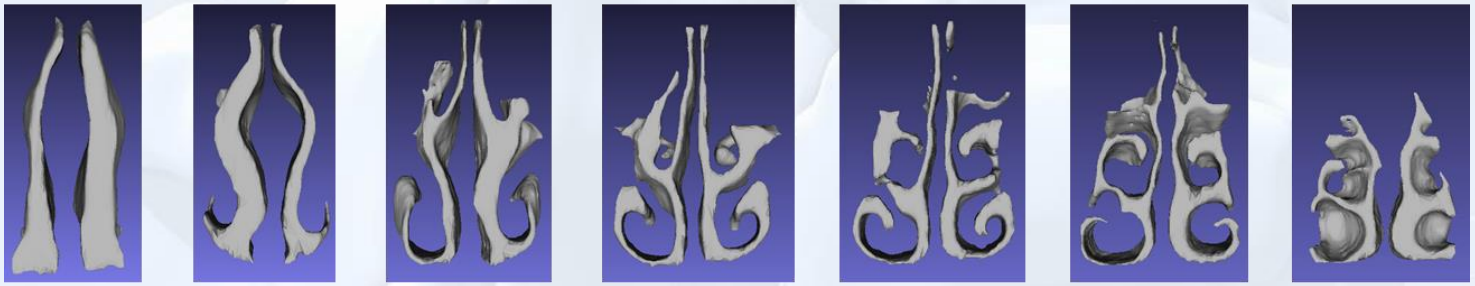


Right

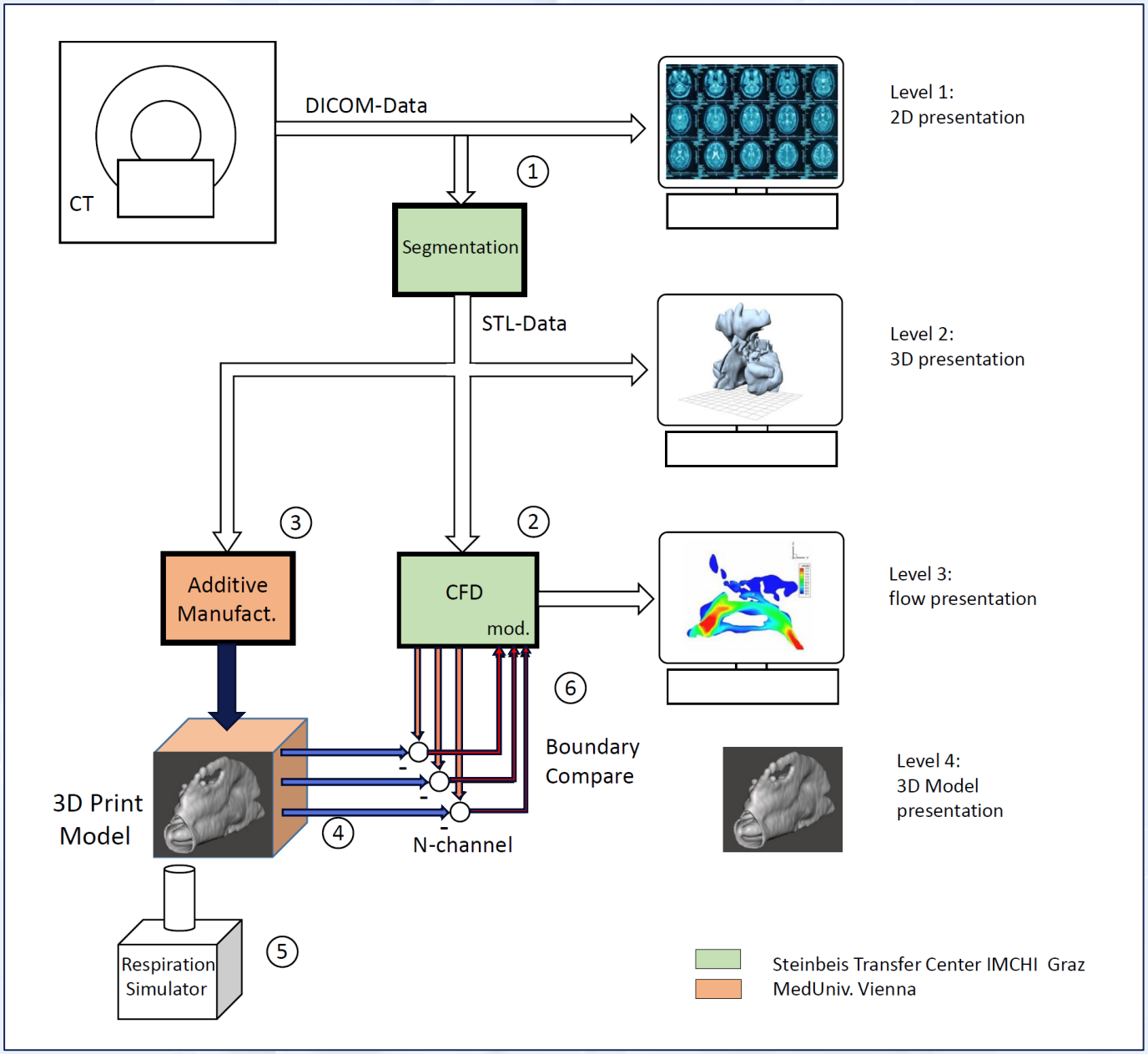




Left



1 2 3 4 5 6 7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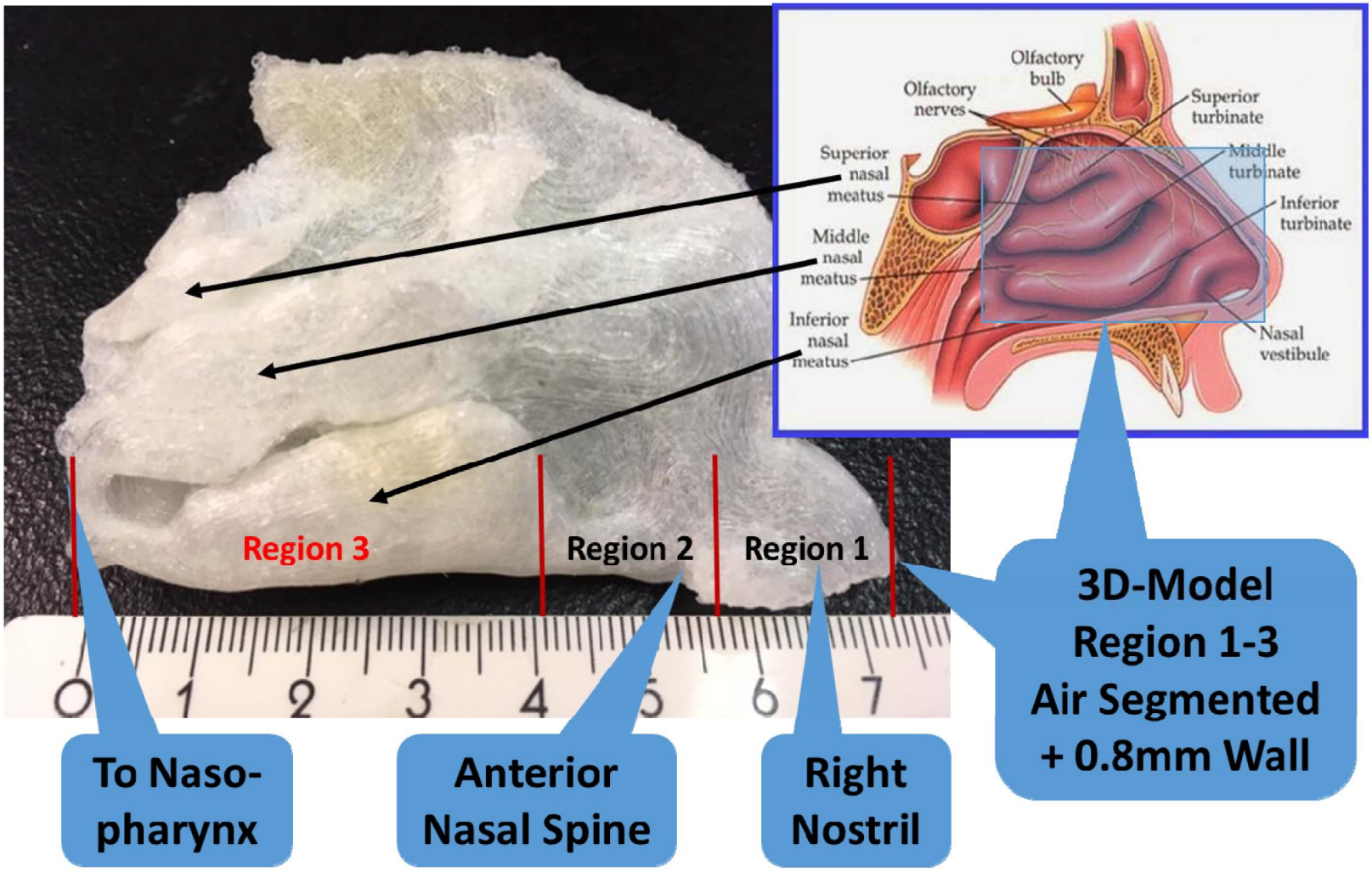
Experiments with different shore hardness to combine materials

Stratasys Connex3 Objet500

ZMPBMT-MUW

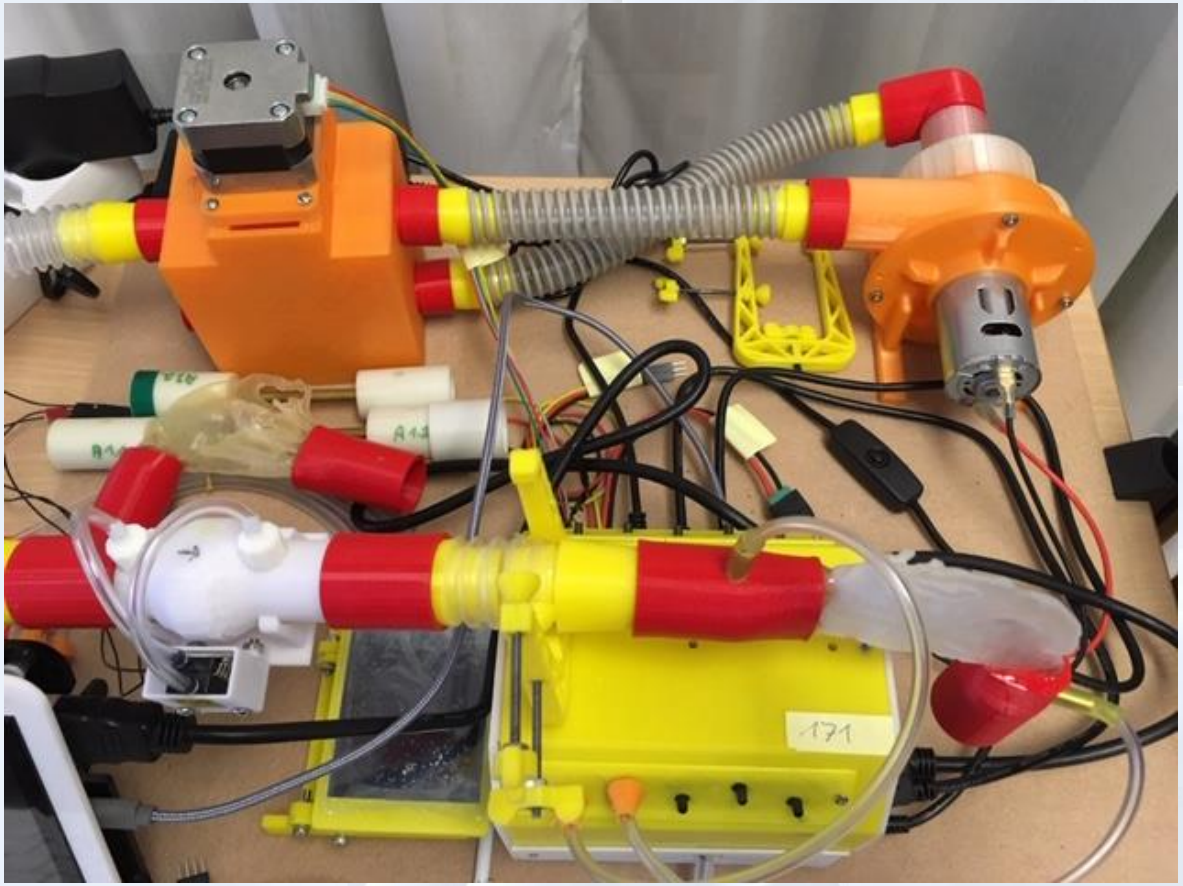
Using featurs of
- combining various shore-hardness
- thin layers
- smooth surfaces

Hard and soft material thinkness 0.2-1 mm


Olfactory bulb
Olfactory nerves
Superior turbinate
Superior nasal meatus
Middle turbinate
Inferior turbinate
Middle nasal meatus
Inferior nasal meatus
Nasal vestibule
Region 3
Region 2
Region 1
0
1
2
3
4
5
6
7
To Naso-pharynx
Anterior Nasal Spine
Right Nostril
3D-Model Region 1-3 Air Segmented + 0.8mm Wall

NAS - Nasal Airflow Simulator

Flow reverser
X-ventil



Pump:
(Francis turbine)

simulates
- Lung
- Respirator

- steady state
- cycles

nose
AM model

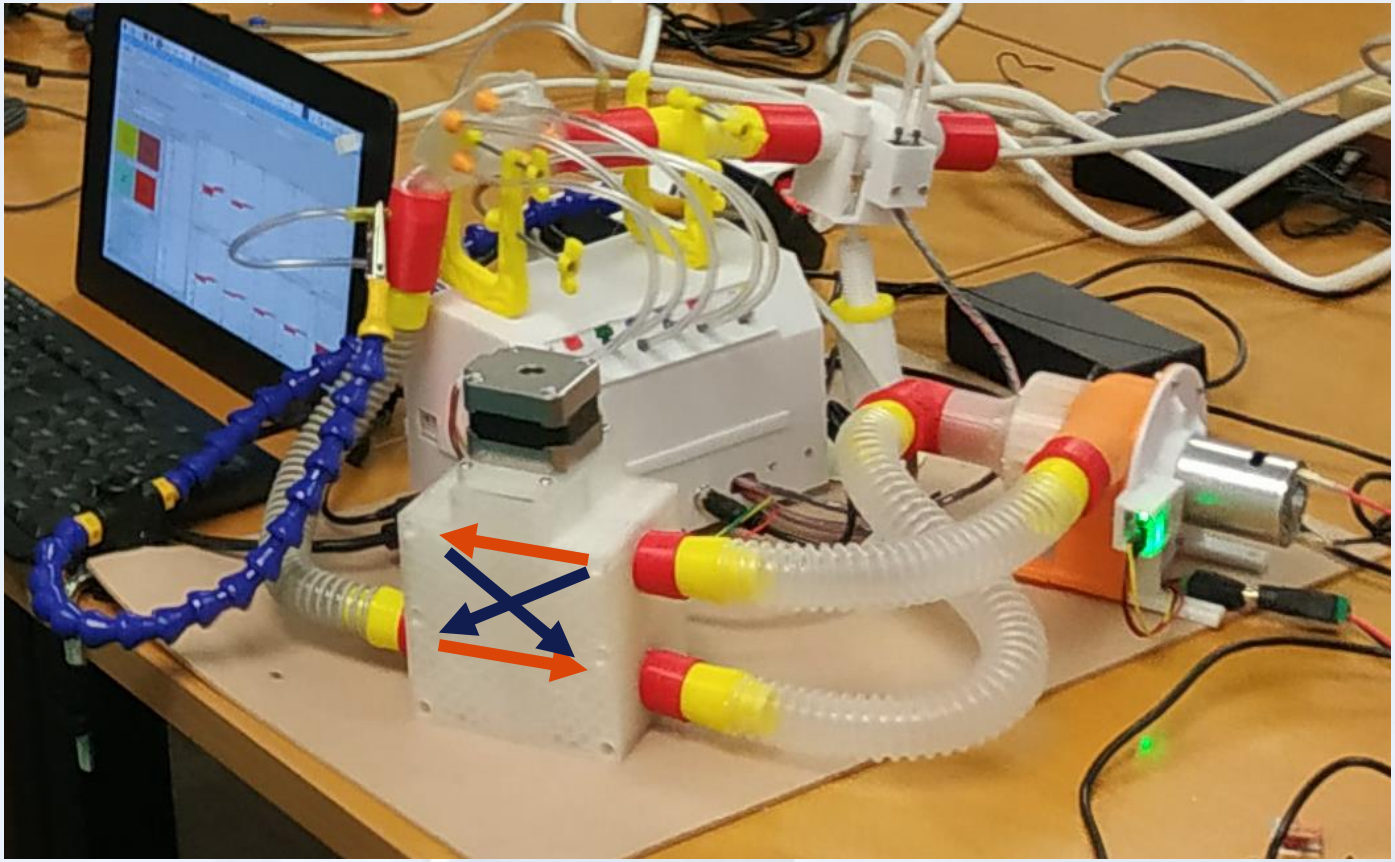
$\Delta P = \pm 200$ Pas
accuracy 1%

Flow sensor

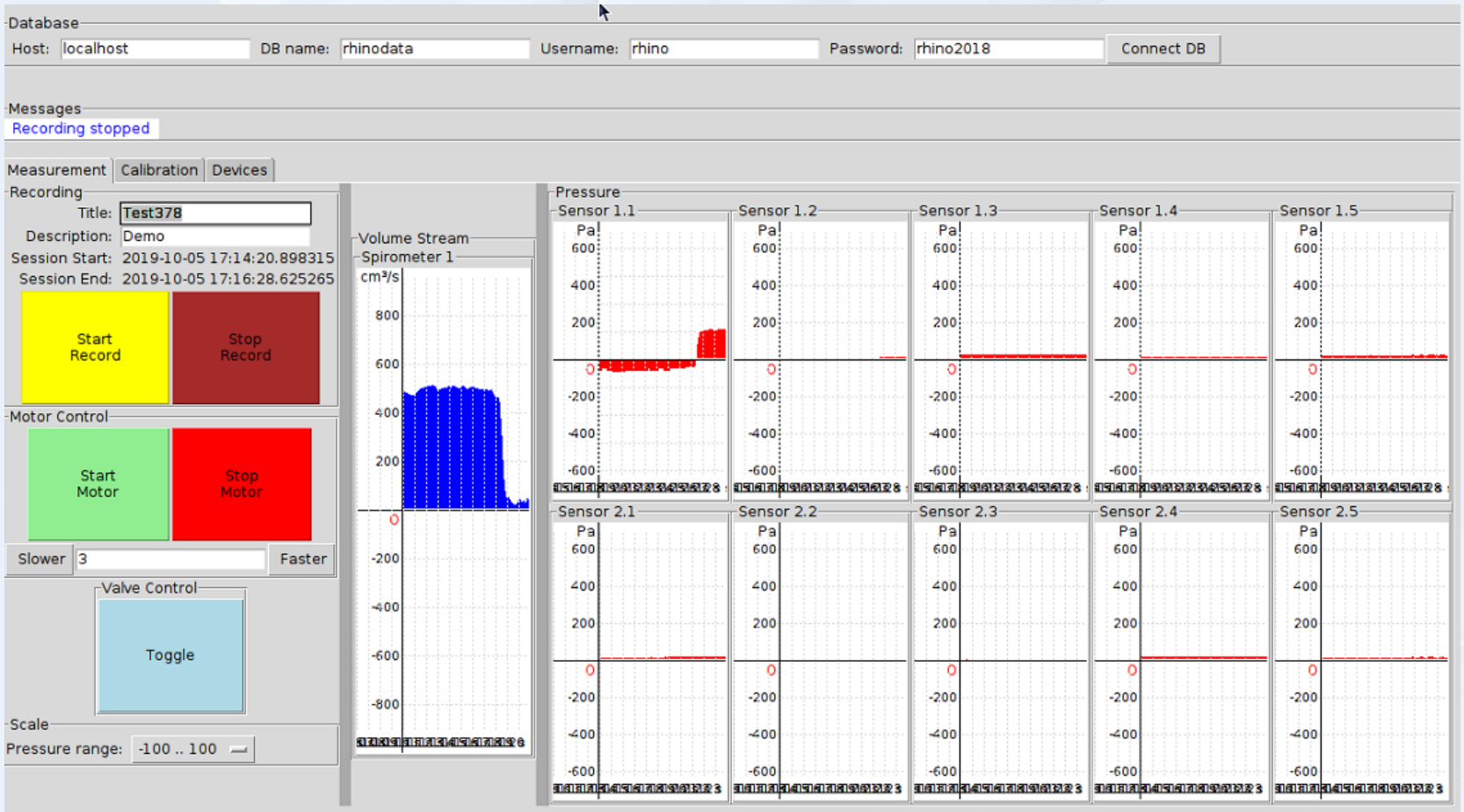
Control unit
24 Bit ADC

p-resolution (Noise):
<2 Pas (0,02mbar)

NAS - Nasal Airflow Simulator



NAS - Nasal Airflow Simulator



$\Delta P = \pm 200$ Pas accuracy 1%

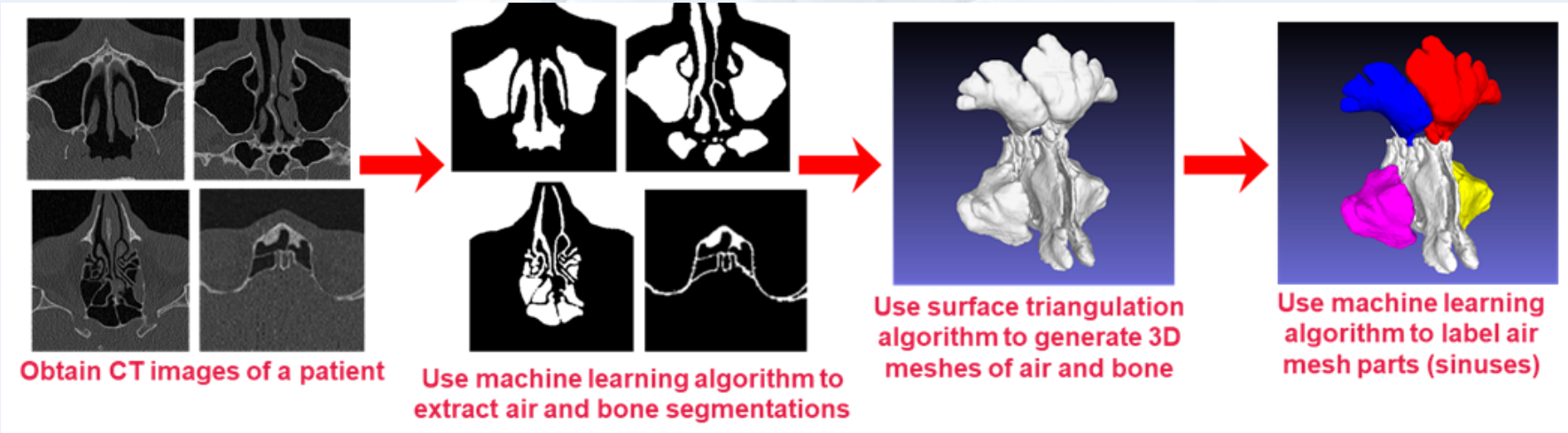
Summary

Reasons to built individual 3D-ploted ENT models:

- Education
- OP-planing
- Training: real haptic feedback eg. using cutting tools due to tissue-like material
- Testbed for individual measurements

Thank you

3D-print technology needs an optimum of data preparation



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