TeamSoc21
The ICT Engineer of the 21st Century

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Guided tour from real objects to 3D models

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Lecture outline

- Introduction (Usage of 3D models)
- Model creation based on CT images
  - CT images
  - Segmentation
- 3D scanning
  - Passive scanning (Photogrammety)
  - Active scanning (Structured light scanning, TOF)
- Key takeaways

Introduction

Usage of 3D models

3D models

- 3D modeling:

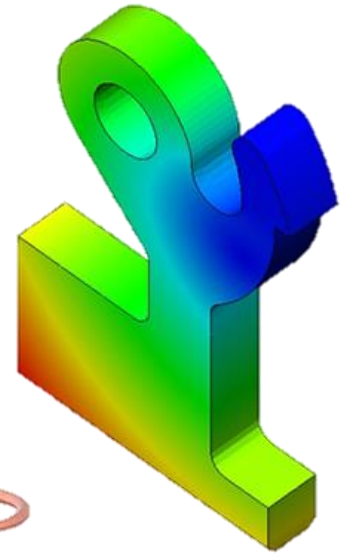
  Process of developing a mathematical representation of any surface of an object in three dimensions.

- 3D models represent a shape using a collection of points in 3D space, connected by various geometric entities (triangles, lines, curved surfaces, etc.)
- 3D models can be created by designing process or algorithmical methods or scanned.

3D models

Applications of 3D models:

- Displaying the model in 2D through a process 3D rendering
  (e.g. computer games or virtual environments)
- Documentation of an object
  (e.g. architectural or mechanical designs, art works)
- Animated and real-life motion pictures
- Computer simulations of a physical phenomena
- Creating physical things
  (3D printing, CNC manufacturing or any other manufacturing technology)

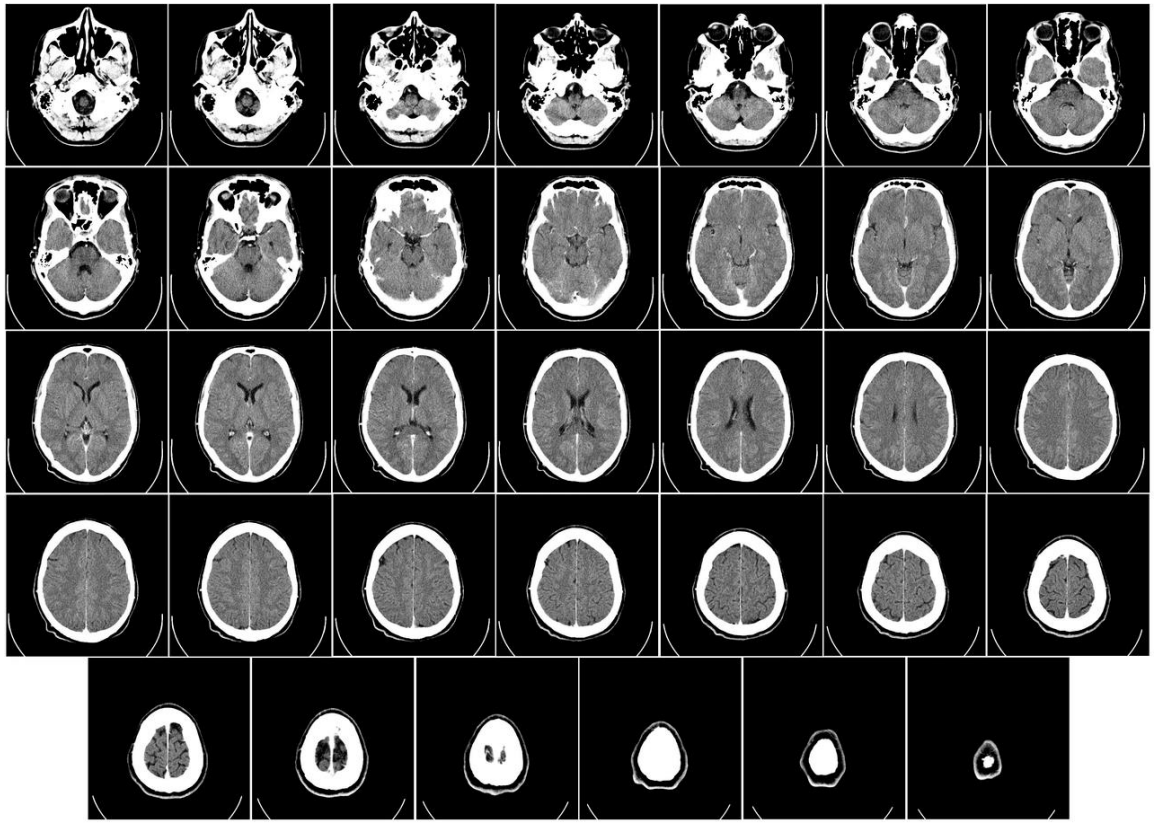


Model creation based on CT images

CT images

CT scan = Computed Tomography scan

- Combination of many X-ray measurements and cross-sectional images
- It allows the user to see inside the object without cutting.

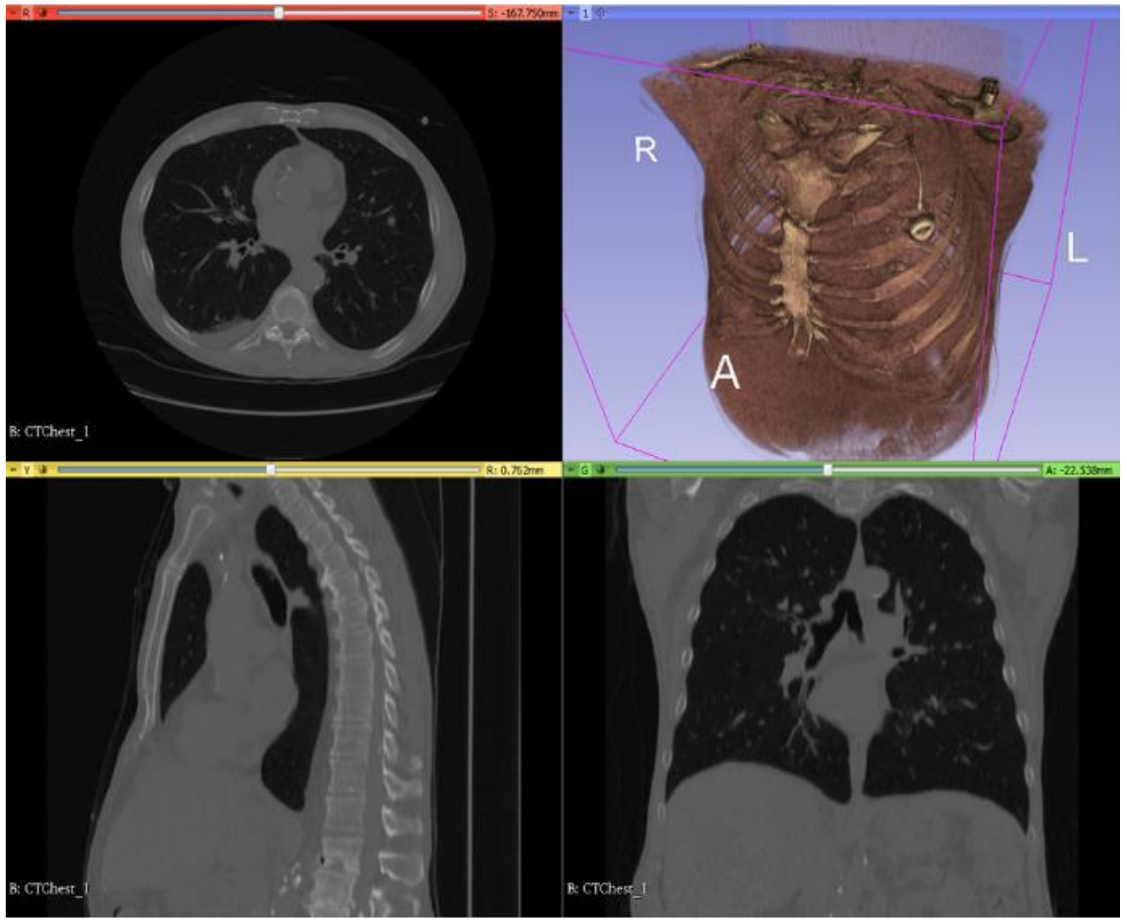


CT image series of human brain taken in axial direction from base of the skull to top.
(https://en.wikipedia.org/wiki/CT_scan#/media/File:Computed_tomography_of_human_brain_-_large.png)

3D model from CT images

Medical image processing software packages:

- 3DSlicer (https://www.slicer.org/)
- InVesalius (http://www.cti.gov.br/invesalius/)
- 4Quant Bone Segmenter (https://4quant.com/)
- Osirix (https://www.osirix-viewer.com/)



Screens of 3DSlicer with an opened CT image series

3D model from CT images

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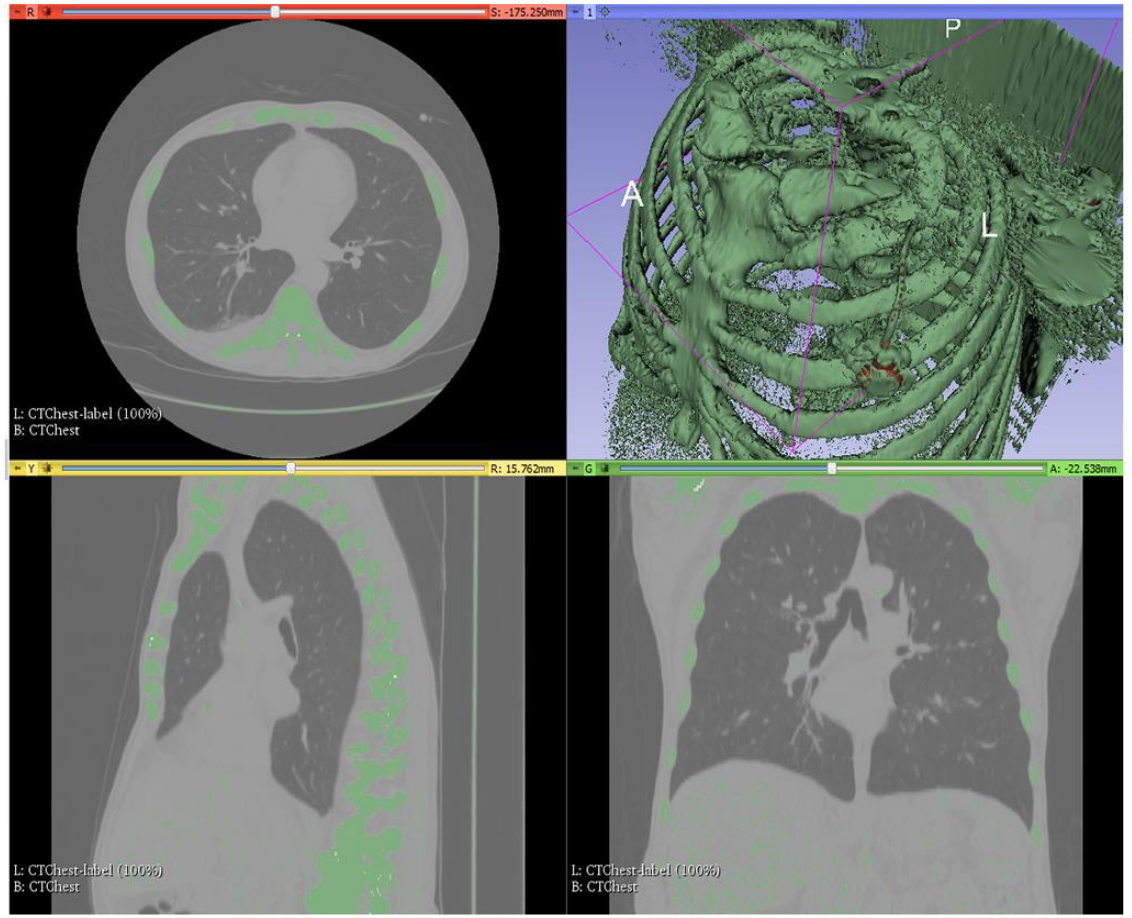
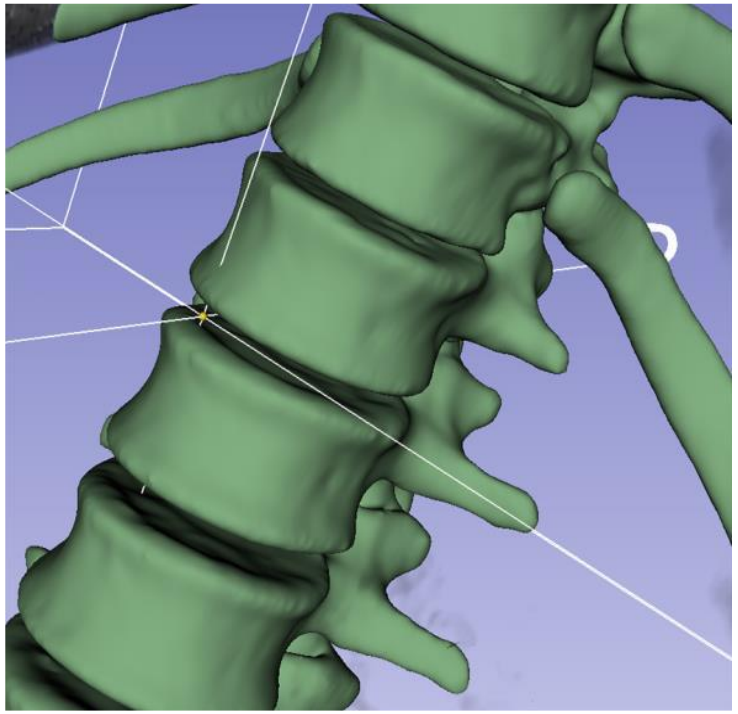


Screens of 3DSlicer with an opened CT image series

Result of segmentation

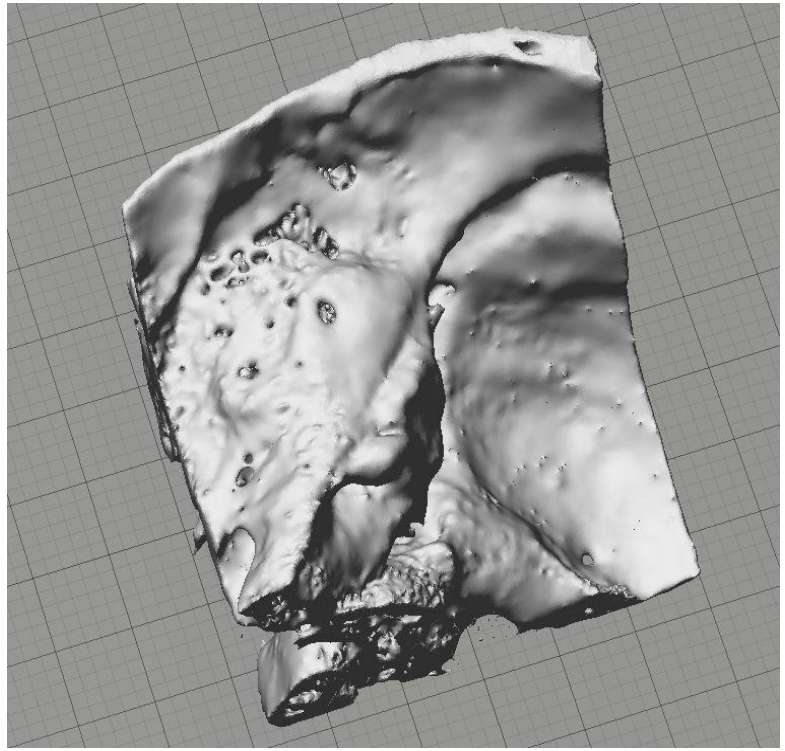
Segmented area of a chest part



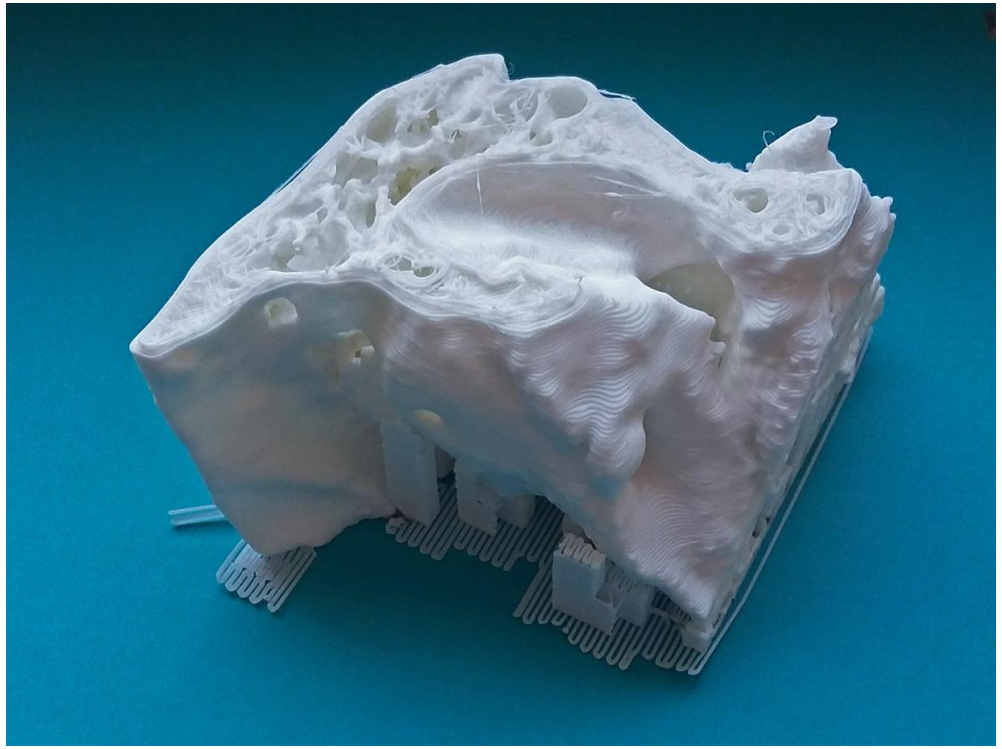
Generated surface of the same chest part

Solid model of the chest part in STL format

Result of segmentation



Solid model of a skull part



3D printed skull part

3D scanning

3D scanning

A device analyses a real-world object or environment to collect data on its shape.

Collected data:

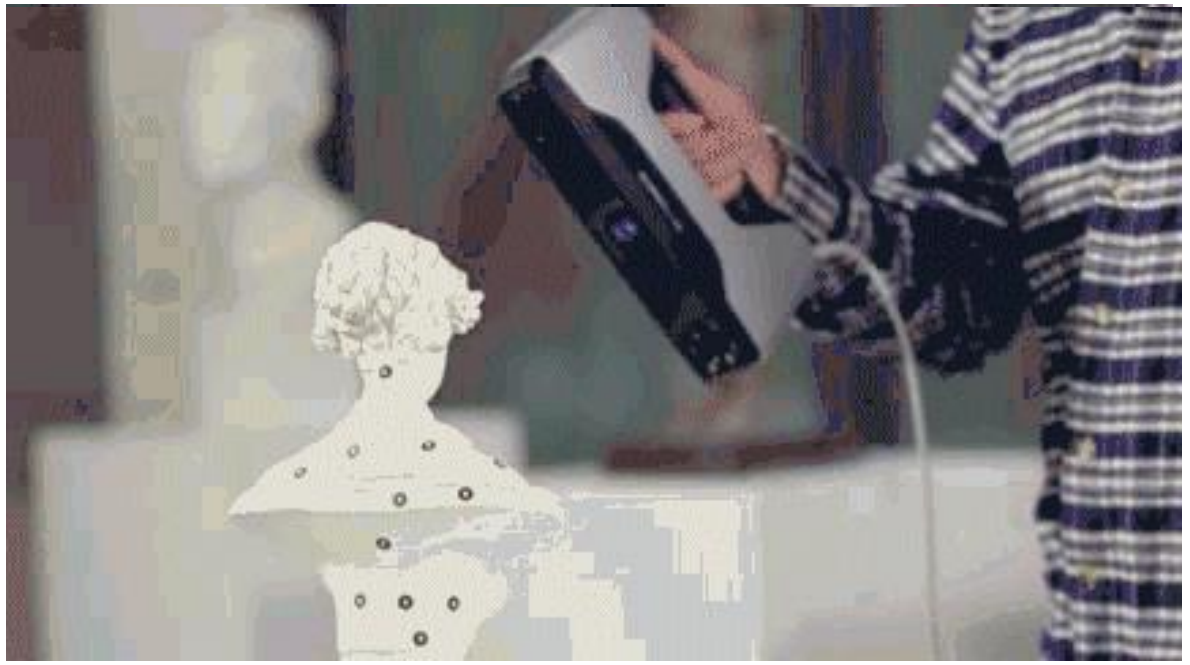
- points with coordinates
- color (not always).

The collected data can be used to construct digital 3D models.

A portable 3D scanner (Sense 3D) in practice

Application fields of 3D scanning

- Industrial design
- Quality control
- Reverse engineering
- Prototyping
- Robotics
- Documentation of cultural artifacts
- Display real 3D objects in a Virtual Reality
- Healthcare
- …

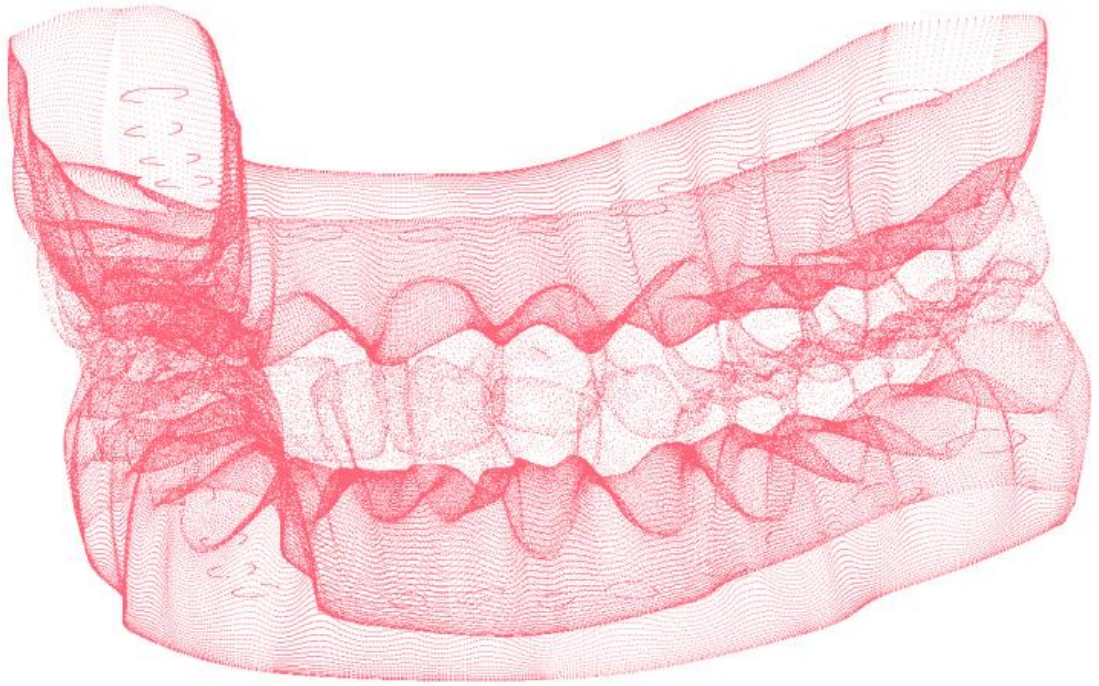


EinScan Pro 3D Scanner

The results of 3D scanning

Primary result is a point cloud.

- Point could = an unstructured set of 3D point samples (only a collection without any rules, connections)
- A point is represented by its coordinates is a Cartesian coordinate system.

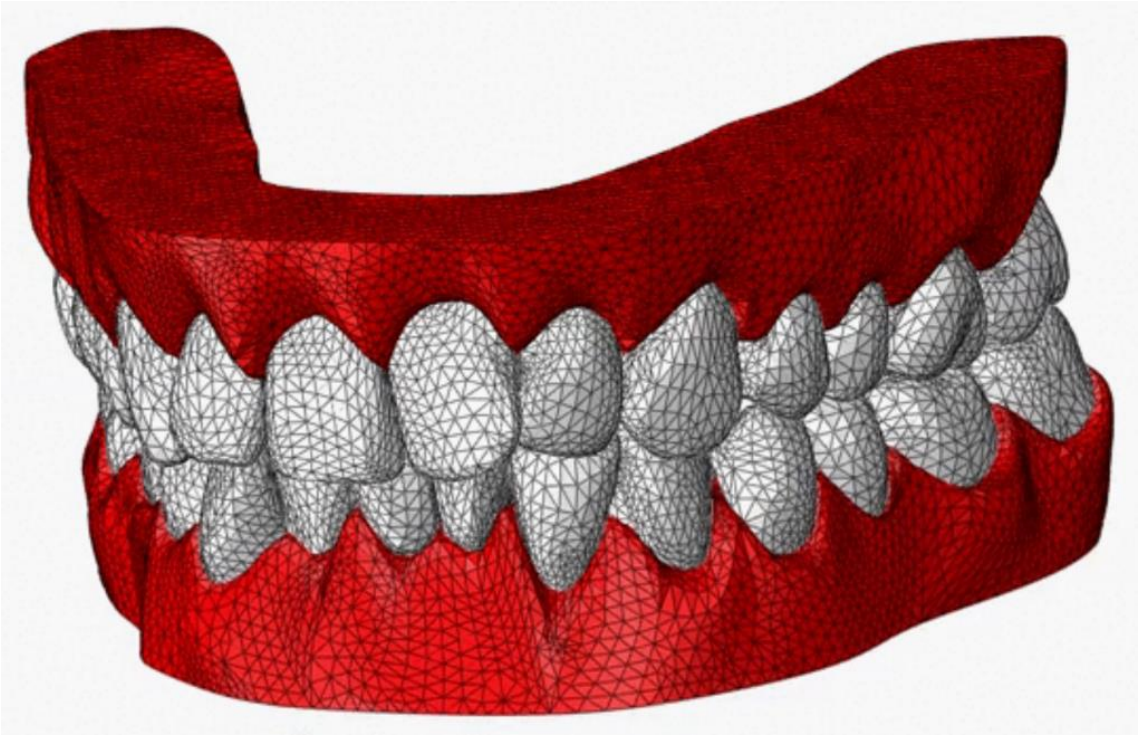


Point cloud of dental arches

The results of 3D scanning

Secondary result is polygonal mesh.

- Polygonal mesh creates connection between the collected points.
- Stored in STL and/or OBJ formats.
- STL consists of only triangles.
- OBJ can consist other planar polygonal facets as well. Color data may be associated with it.



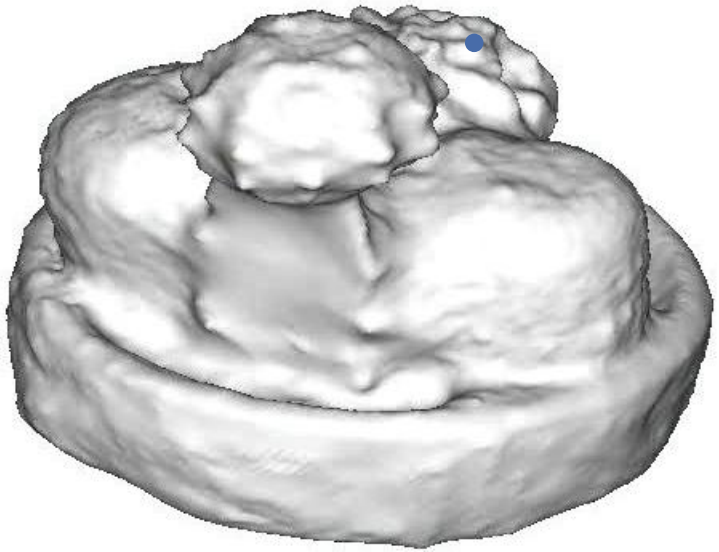
Polygonal mesh of dental arches

Efficiency of 3D scanning

Efficiency of 3D scanning depends on

- the capacity of the device
- lighting conditions
- brightness of the scanned surface
- user's experience

The original scene



Surface model with rendering

Textured surface model

Classification of 3D scanners

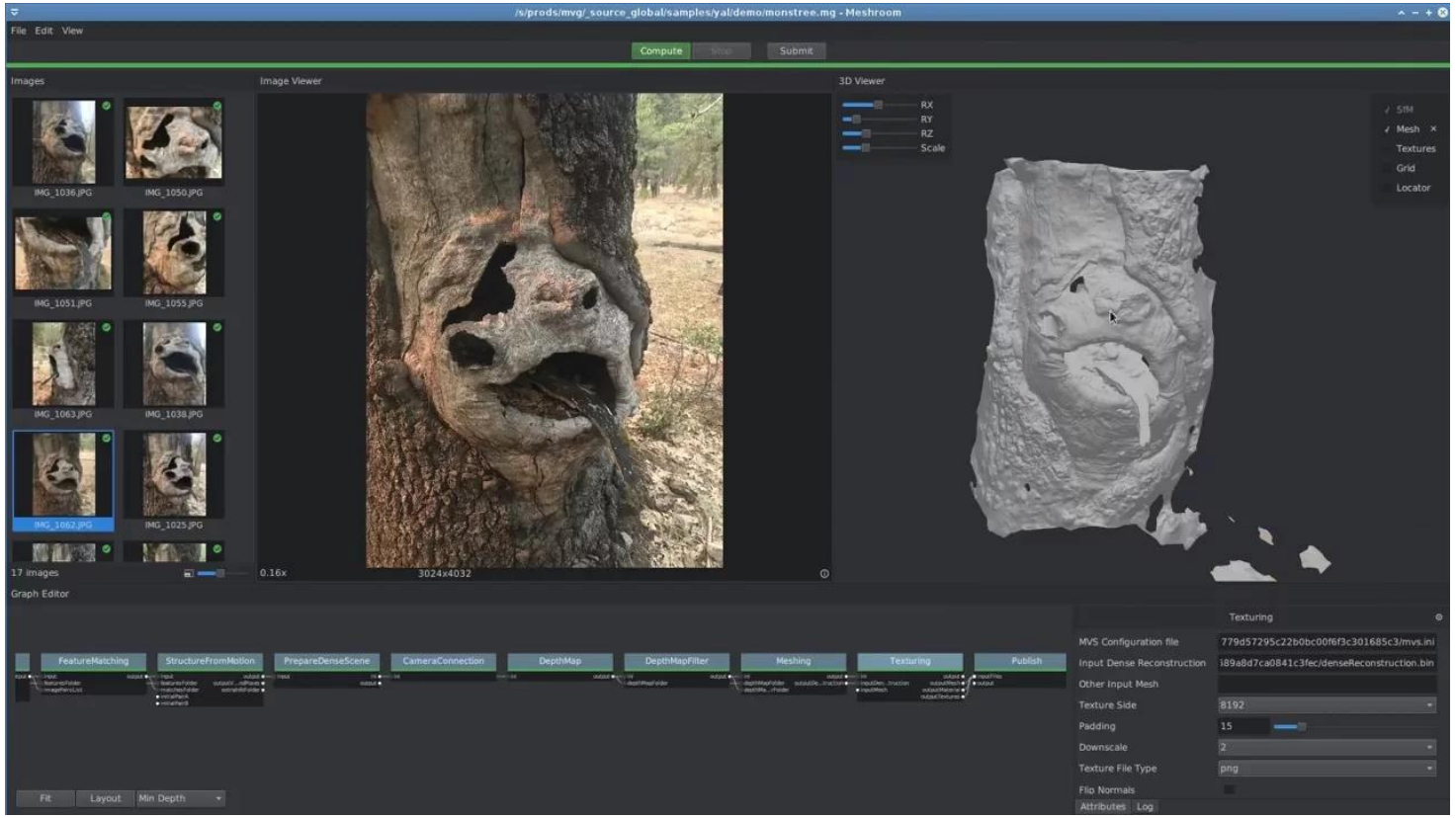
- Passive technologies:
  - mostly based on 2D images
  - it doesn't project anything to the object
  - e.g. Passive triangulation, Photogrammetry
- Active technologies
  - Activity means „using some projections”
  - Projecting light beams, light line or structured pattern its deformation is investigated.
  - Projecting pulsed light waves the time of flight is calculated.
  - e.g. Structured pattern projection, TOF (Time of Flight)

Photogrammetry

- Based on mix of computer vision and computational geometry algorithms.

Requirements:

- Images are taken from different viewpoints (at least 20-25 pictures)
- Adjacent images should be overlapping for identification point pairs.
- Advantage: Contrasting



Meshroom (https://alicevision.github.io/#meshroom)

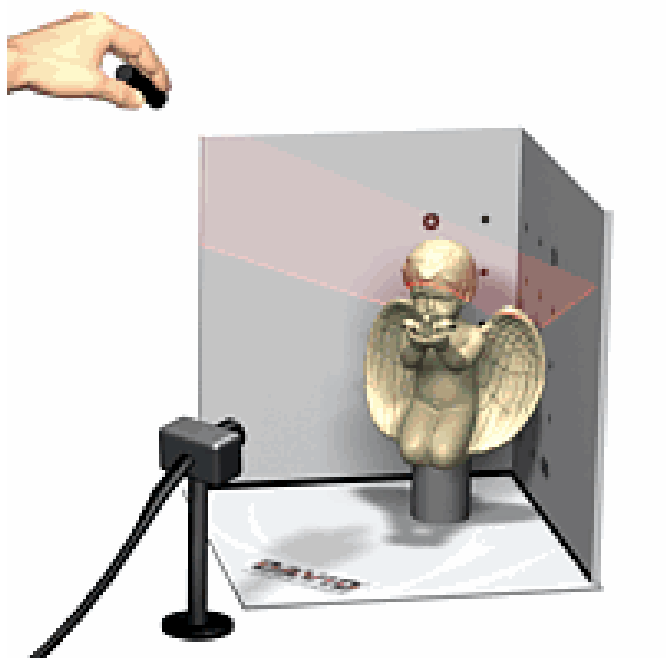
Photogrammetry

http://www.regard3d.org/r3d_demos/demo_sceaux.html

Ceramic snail was scanned by SCANN3D.
http://scann3d.smartmobilevision.com/

Snail's rude model: https://skfb.ly/6wIR8

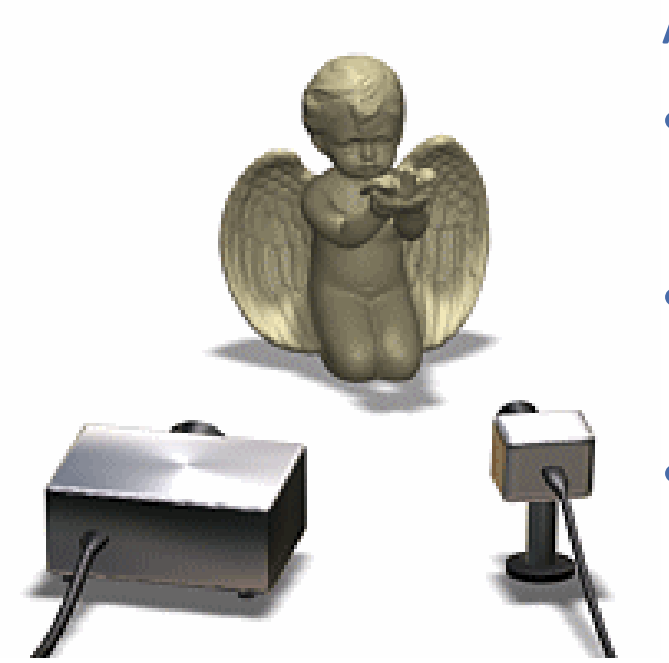
Active scanners (Single line scanning)



- Uses a single line of lasers
- Move it across the surface of the object + take an image in each step
- Time-consuming
- The calculation is based on how the projected line is deformed on the surface.
- Result: high quality surface scan

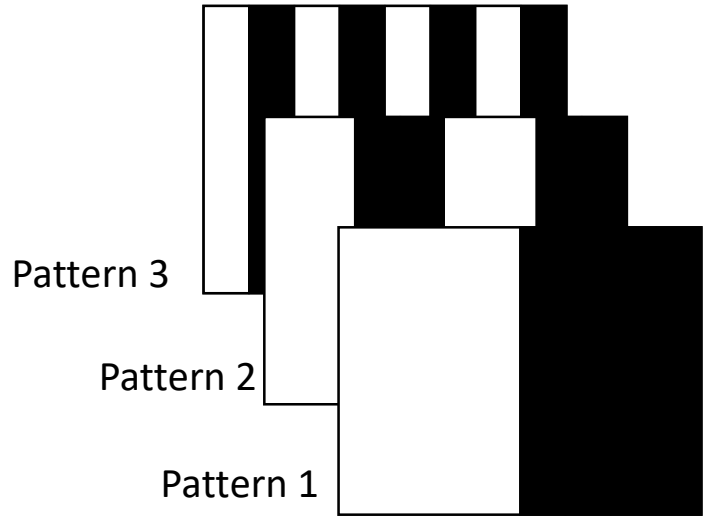
http://wiki.david-3d.com/

Active scanners (Structured light scanning)

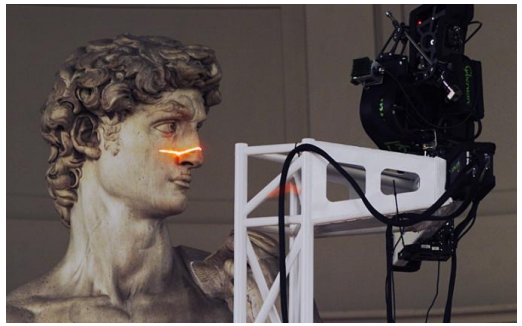


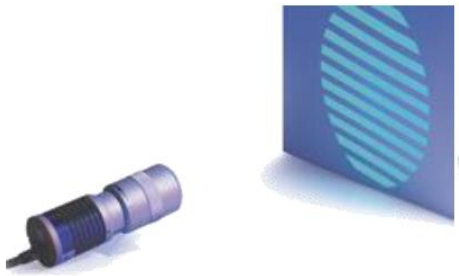
Accelerating the process

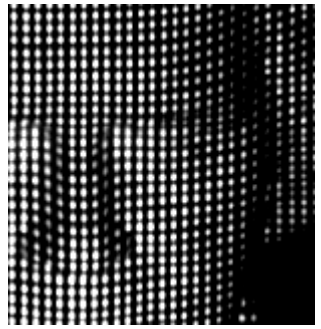
- Stripped pattern is projected to a surface
- More deformed line can be detected on each picture.
- Different solutions are: lines can be contrast and
  - monocolor (black-white) or multicolor
  - constant or variable width



Comparison the structured lightning technologies







- single strip
- lot of pictures
- slow
- model with high accuracy
- produce very high-quality data

- more strips
- more pictures
- middle fast/slow
- medium accuracy

- structured pattern
- single picture
- fast
- model with lower accuracy

Post processed scanned model

Ceramic snail scanned Sense scanner: https://skfb.ly/6wIRo

The basic post-processing can be performed in the scanner software:

- cutting
- demarcation
- solidifying (patching holes)

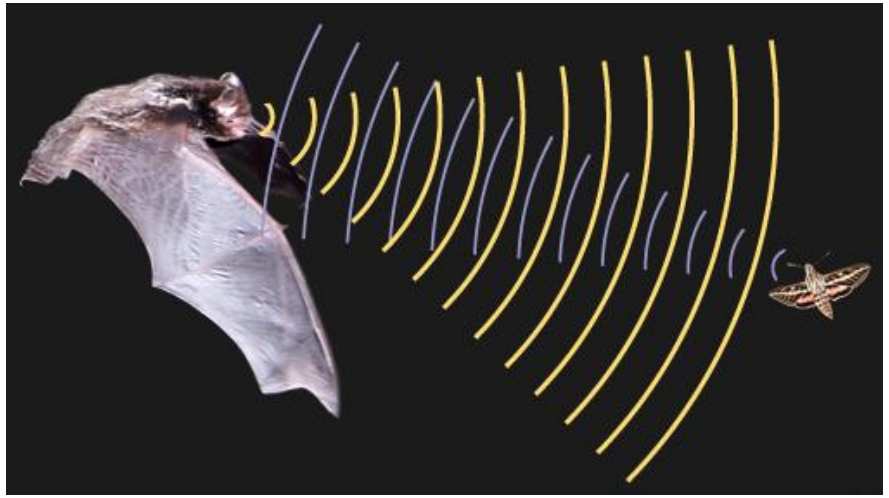
More sophisticated steps are required special mesh-processing applications:

- MeshLab (www.meshlab.net/)
- Meshmixer (www.meshmixer.com/)

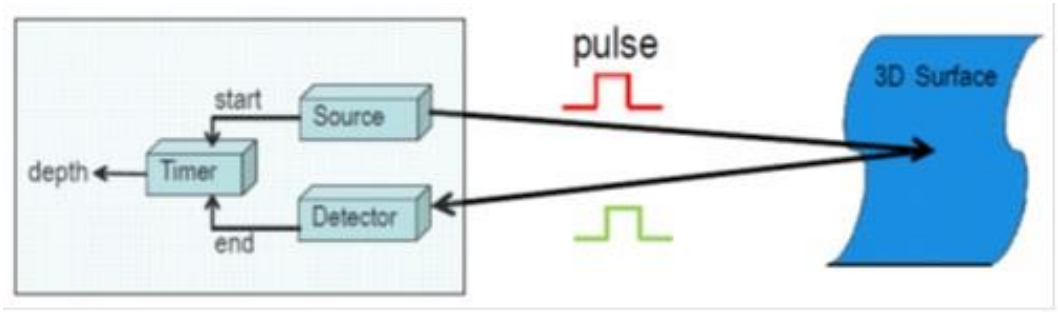
TOF – Time of Flight

The source of idea is in the nature:

- The bats (dolphins) use the reflected sounds to determine location of barriers in front of them or their food. (echolocation)



- For scanning:
  - Pulsed laser light is emitted
  - Reflected light is detected
  - The timer measures „time of flight” from starting to return



Benefits of TOF

- It can capture over 10 000 points in every seconds.
- High quality scans.
- It’s sometimes hard to tell the difference between photographs and scans.
- Import the scan into a CAD software we can take extremely precise measurements.
- This can help to preserve a particular state of a building or any other built environment.

Key takeaways

Key takeaways – Technical aspect

- Model creation based on CT images
  - 3D models are generated by a special software (segmentation)
  - The inner part is generated, not only the border surface.
  - Used in medical applications, surgical preparation, education
- 3D scanning
  - Passive technics (no extra lights, patterns are projected)
  - Active technics (there are extra lights, patterns during the scanning)

Key takeaways – Societal aspect

- Model creation based on CT images
  - 3D models help to develop new surgical methods and prepare to the operations
  - 3D models required to design unique implants.
- 3D scanning
  - With 3D scanning the manufacturing processes are more accurate than the traditional ones.
  - 3D scanning preserve the given status of an object. With scans we can recreate things, make copies of an object, can publish things into VR/AR environment.

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