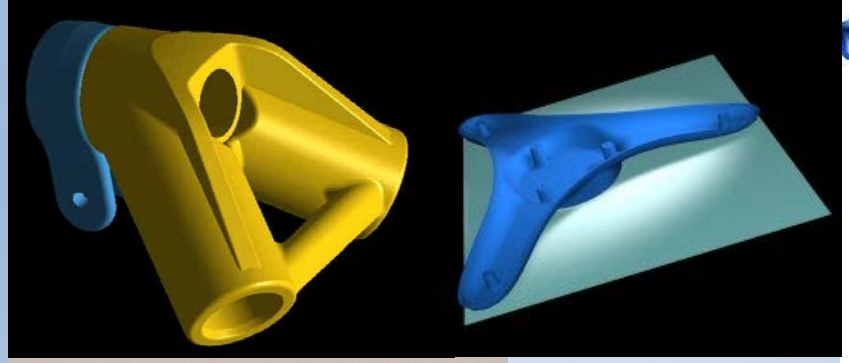
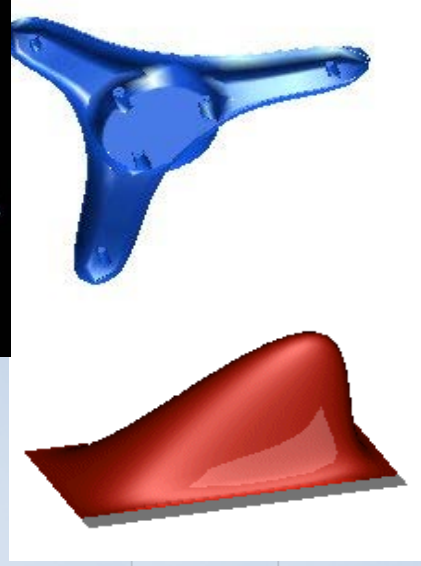
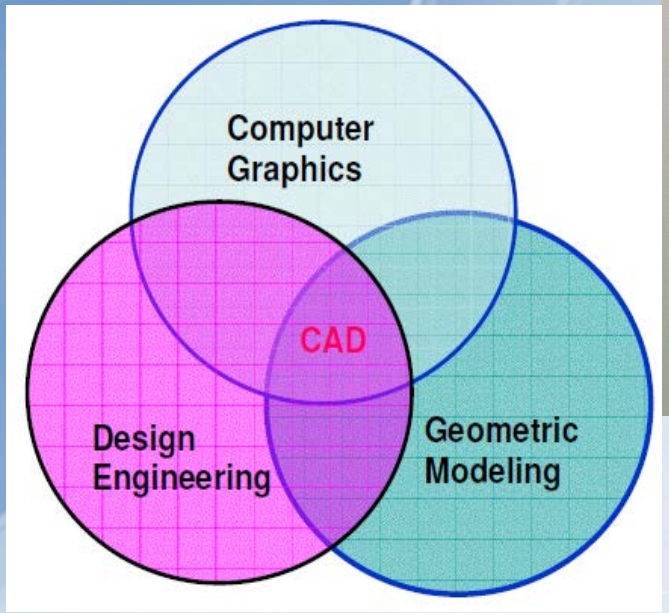
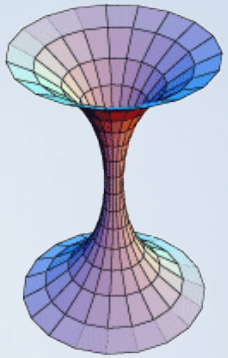
Computer Graphics Programming:
Surface and Solid Modeling, Projections, Light Ray Tracing, Shading, Painting, Mapping, CORE (ACM), GKS, PHIGS (ISO), OpenGL, DirectX









Graduate Course: Advanced Computer Aided Design

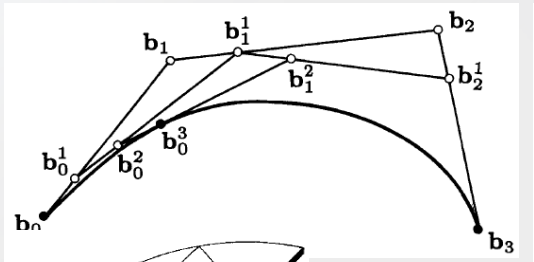
Product Developing, Innovation, Assembly, Simulation, Analysis, Optimization

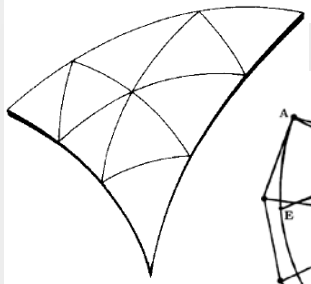
Geometric Modeling: Transformations, Parametric Curves, Splines, NURBS, Parametric Surfaces, Iges, Solid Modeling, Handles, Genus, Manifold Topology, CSG, B-Rep, Step, Parasolid, Euler Operators

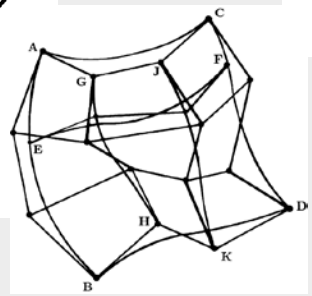
Hikmet Kocabas, Prof., PhD.
Istanbul Technical University

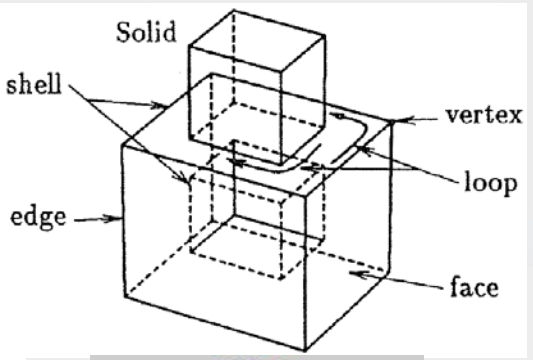
Lectures, Outline of the course

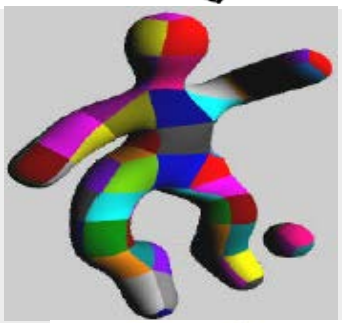
1. Advanced CAD Technologies, Hardwares, Softwares
2. Geometric Modeling
3. Transformations
4. Parametric Curves
5. Splines, NURBS
6. Parametric Surfaces
7. Solid Modeling
8. API programming

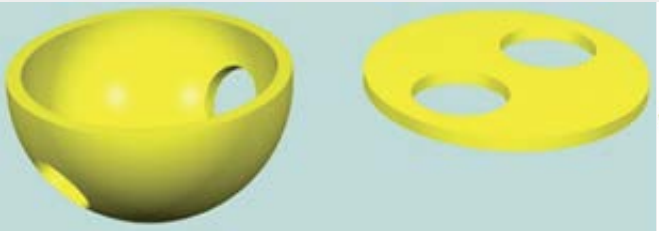


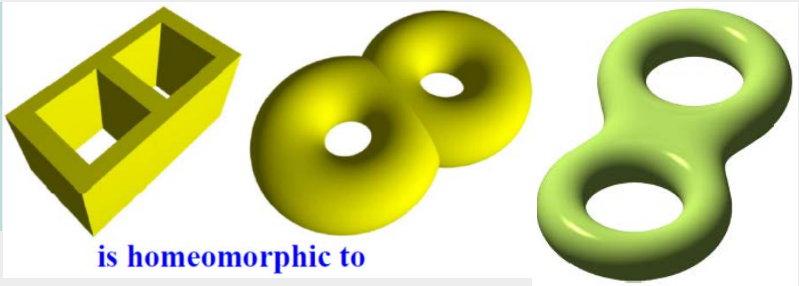




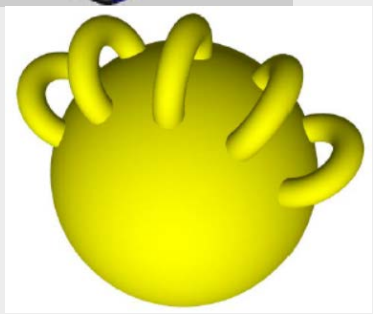








2-manifold meshes, m-handle (genus m)



Course Evaluation

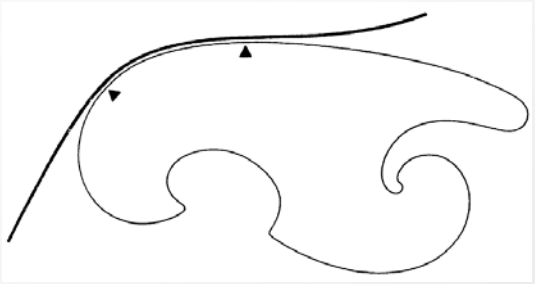
- Midterm exam 30%
- Final exam 40%
- Homework 10%
- API Project 20%

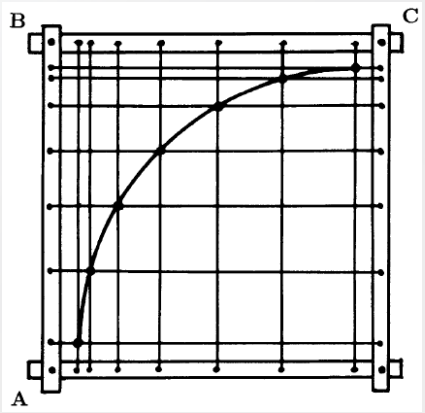
Textbooks

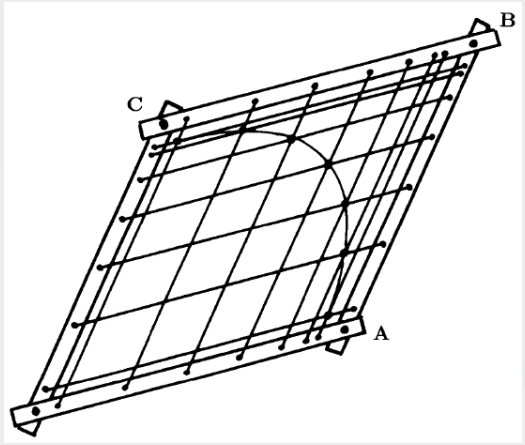
- Computer Aided Engineering Design, Saxena, 2005
- CAD/CAM Theory and Practice , Zeid, 1991
- Mastering CAD/CAM , Ibrahim Zeid, ed. 2004
- The NURBS Book, Les Piegl, 1997
- 3D CAD Principles and Applications, H Toriya, 1991
- Solid Modelling with DESIGNBASE, Chiyokura, 1988

Brief History of CAD

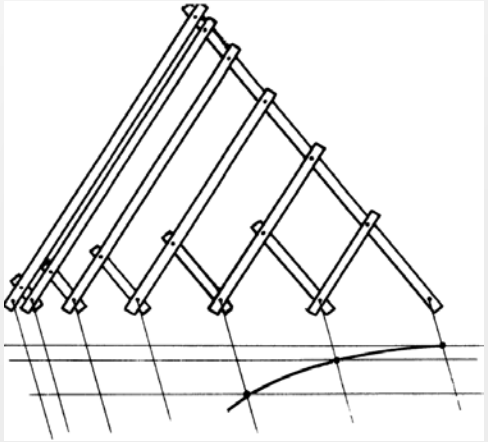
Curve template

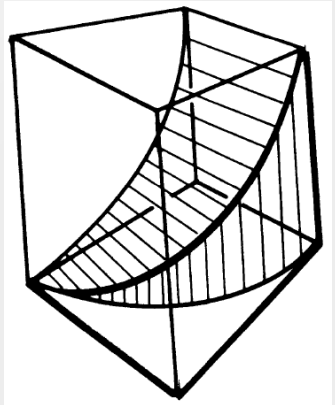


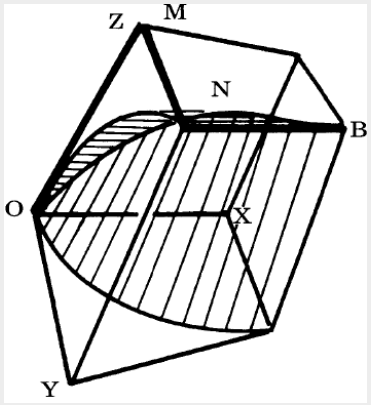


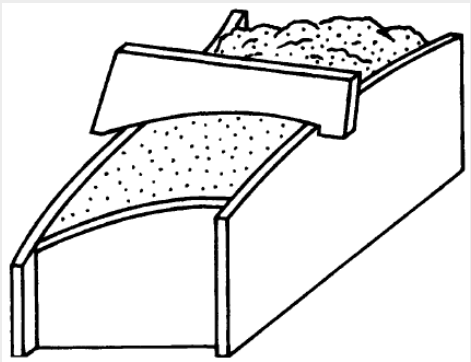


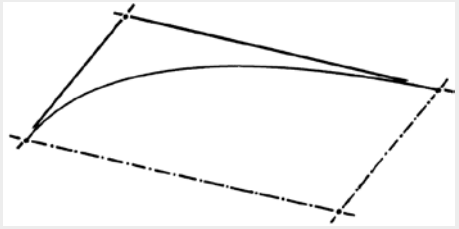
Curve Control polygon

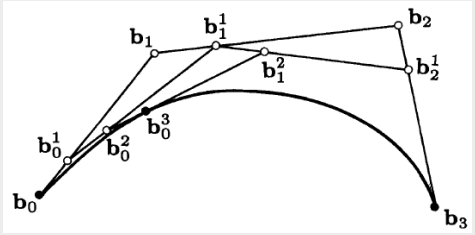






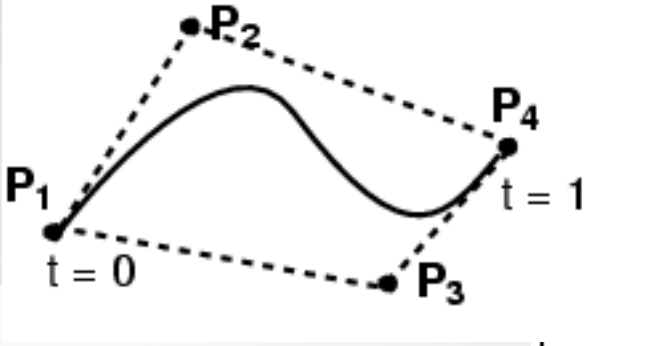




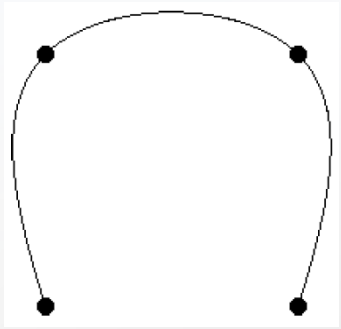


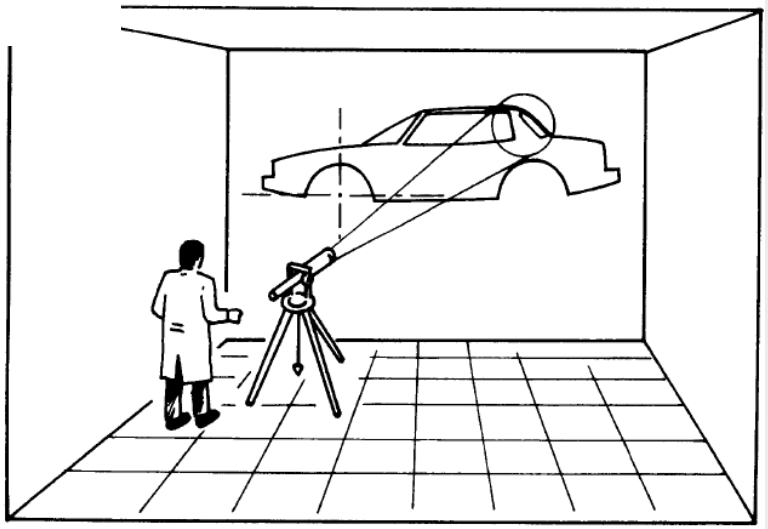
Surface definition

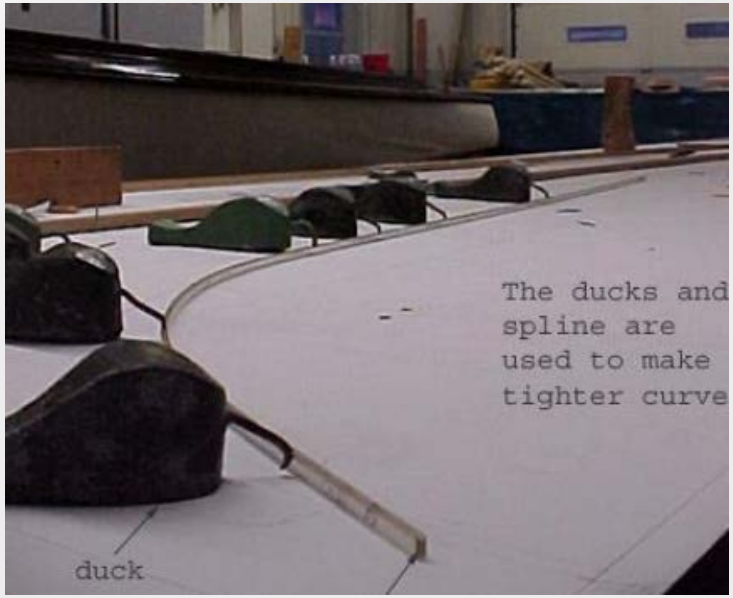
Curve templ

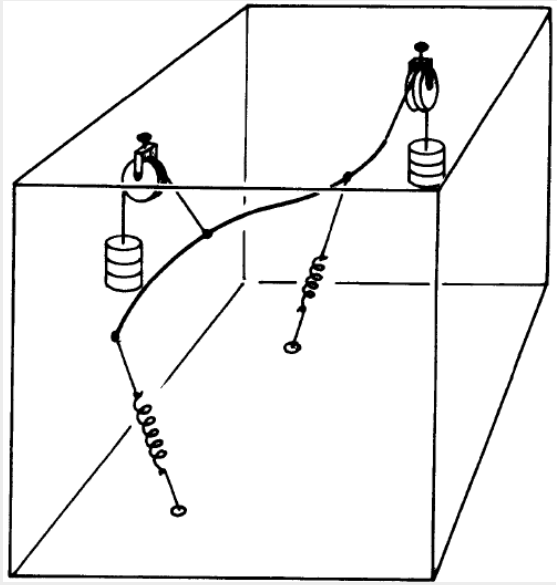


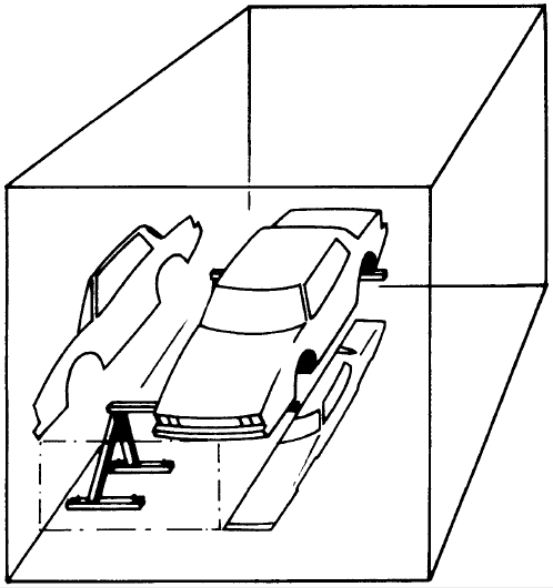
Projections of template curve





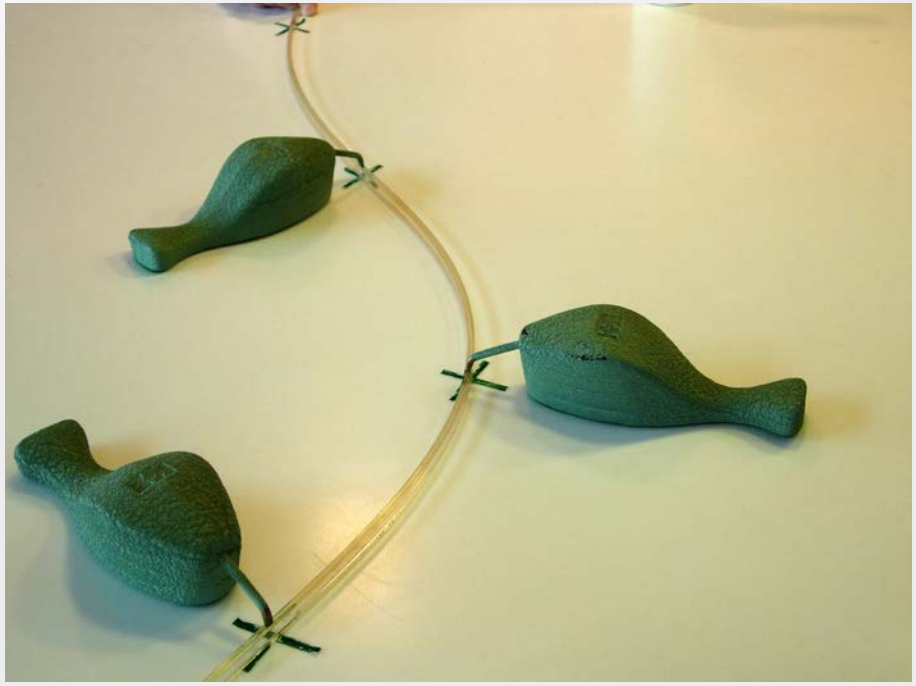




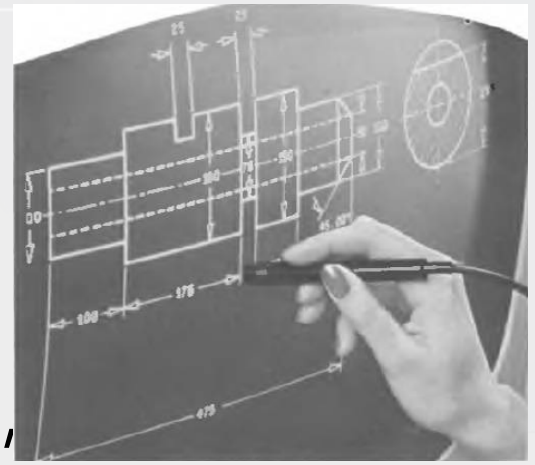


Natural Spline

Natural Spline : mathematical approximation of the spline historically used in naval construction.



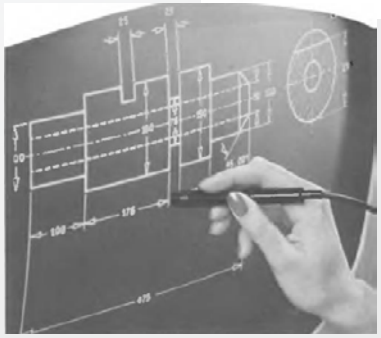
Brief History of CAD technology

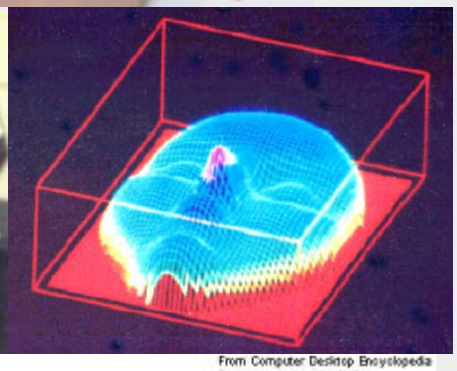


- **1960 SKETCHPAD (MIT Lincoln Labs).**
- **Early 1960's industrial developments .**
- General Motors – DAC (Design Automated by Computer), McDonnell Douglas – CADD
- **Since 1981: programs** CATIA, Enovia, IDEAS, DesignCAD, SurfCam, Unigraphics,NX, ProEngineer,Creo, 3DStudio MAX, Rhino, ThinkDesign, Solid Edge, SolidWorks
- **1986 AutoCAD** included the full **AutoLISP** API program
- **1989 STEP**-compatible Parasolid 3-D modelers introduced.
- **1990 ACIS 1.0** ships. Since **1991** Microsoft developed **Open GL**. **1967 founds SDRC in Cincinnati, IDEAS**
- **1979 Boeing, General Electric and NIST develop IGES** (Initial Graphic Exchange Standards), for NURBS

Hardwares - **Input Devices**

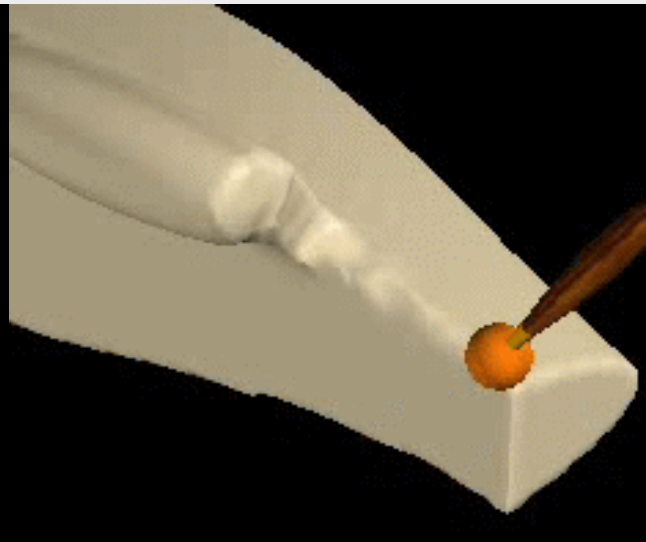
- Keyboard
- Mouse
- Joystick
- Lightpen
- Scanner
- Digitizer
- Camera
- Leap Motion
- Glove
- Microphone





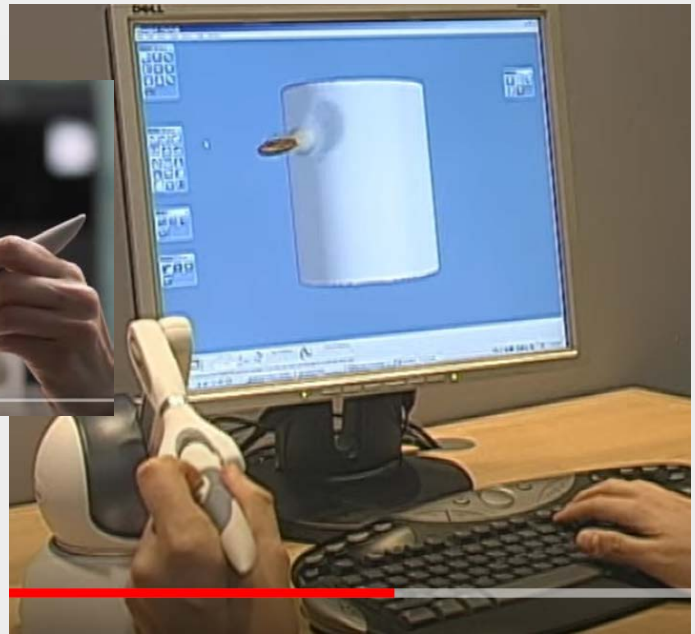
Advanced CAD Technologies

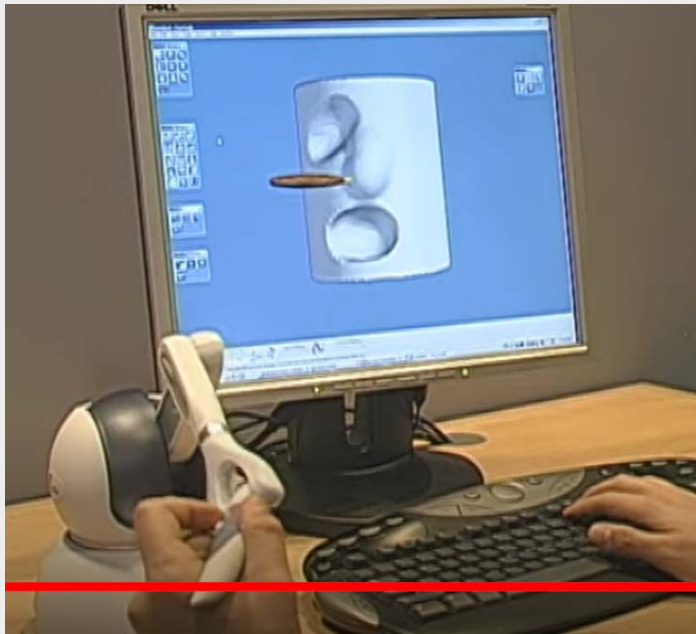
Phantom omni haptic device
3D Systems haptic device
provides precision force feedback
SensAble Freeform Phantom Arm
https://www.youtube.com/watch?v=REA97hRXoWQ
Designing by sculpturing 3D Clay



Phantom omni haptic device

https://www.youtube.com/watch?v=REA97hRXoWQ
https://www.youtube.com/watch?v=C_rHAbJJggM
Geomagic Freeform and Geomagic Sculpt 3D haptic device can measure the 3D spatial position (x, y, z-axis) and the orientation (roll, pitch and yaw) of its handheld stylus.

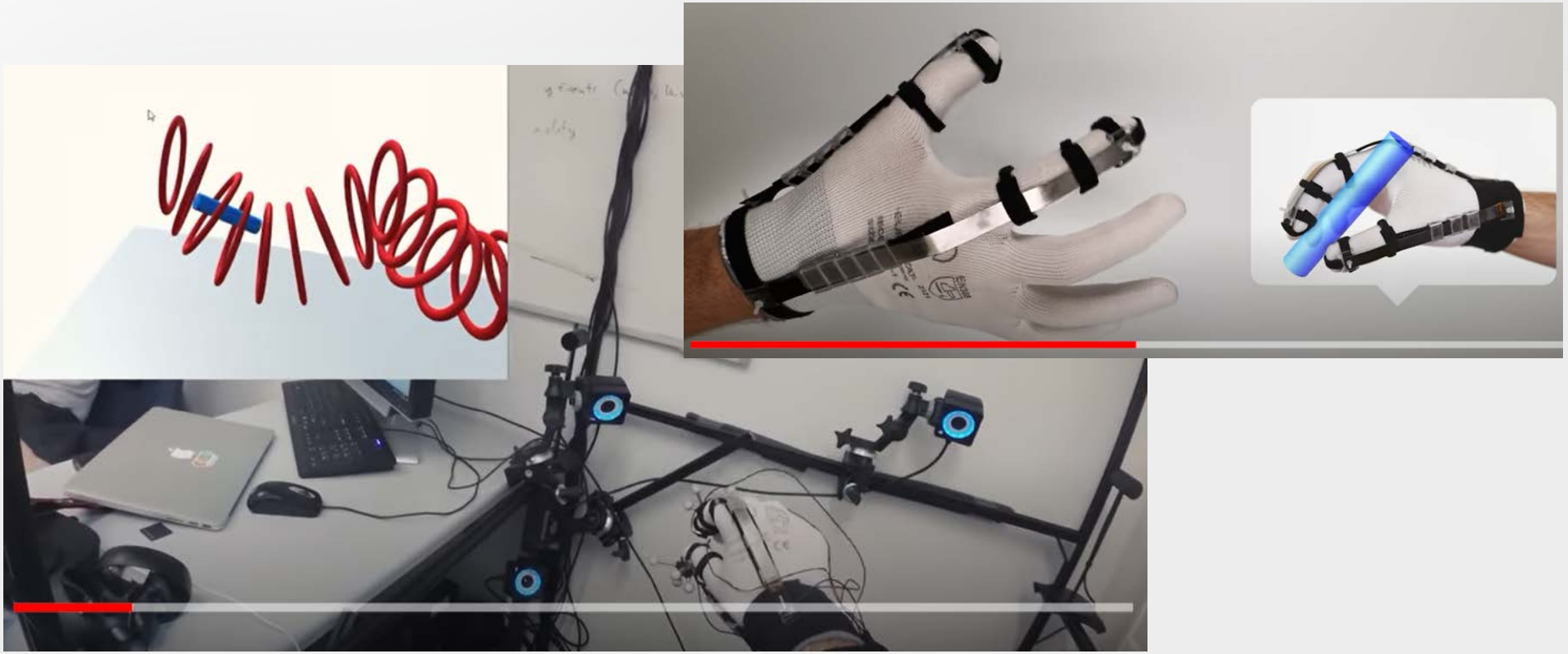




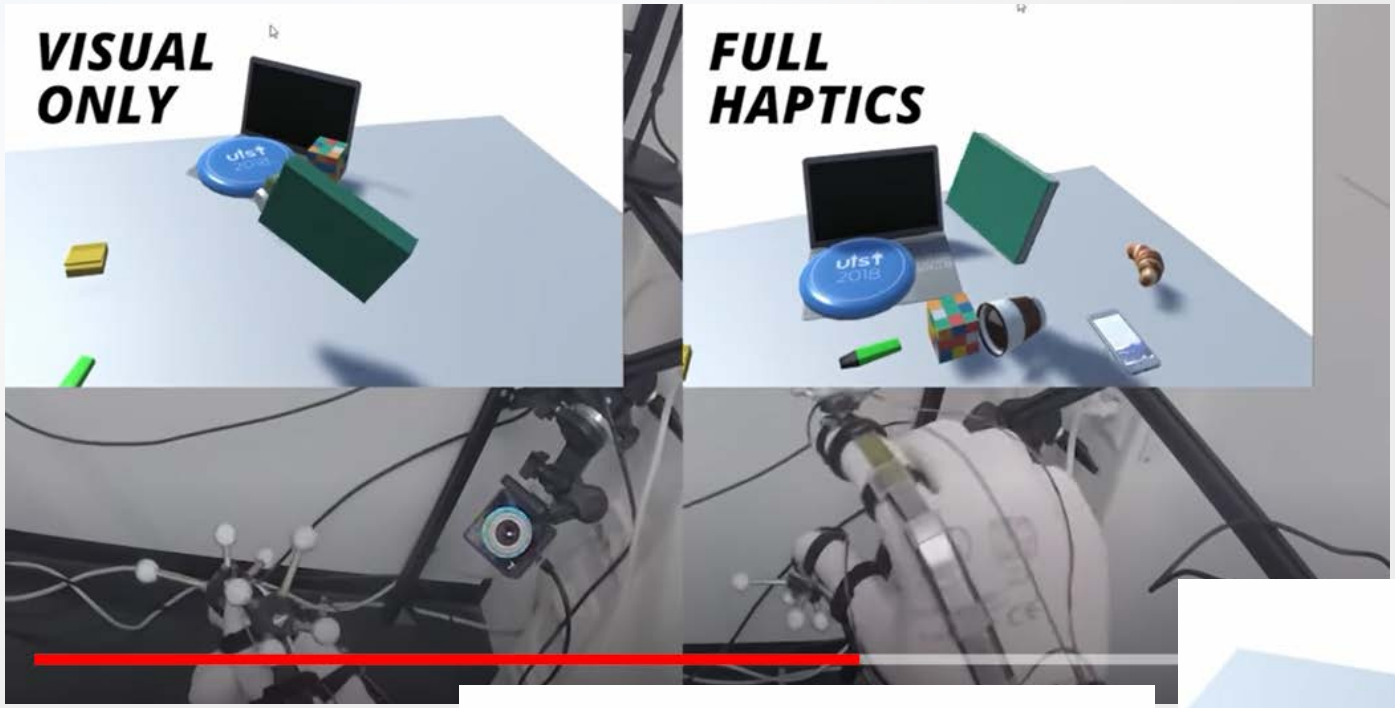
DextrES : Wearable Haptic Glove

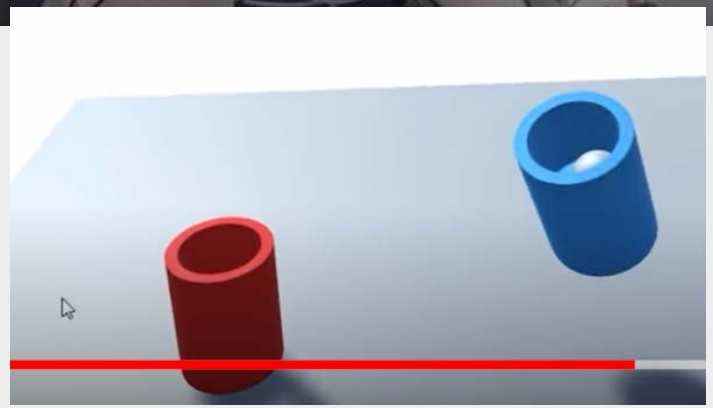
DextrES : Wearable Haptic Glove for Grasping in VR via a Thin Form-Factor Electrostatic Brake

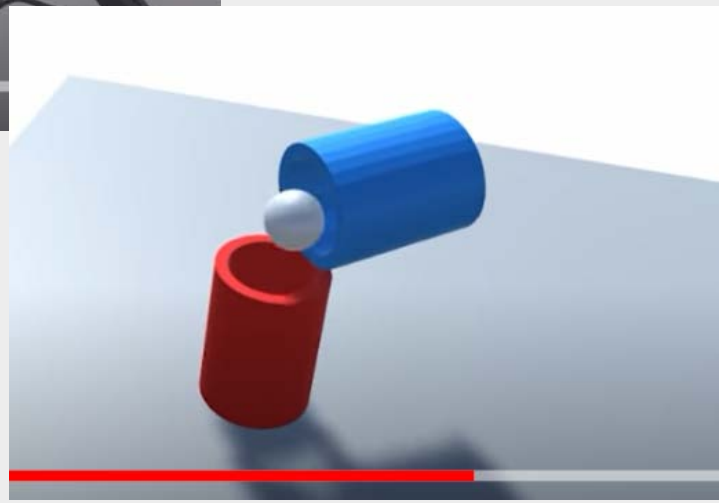
https://www.youtube.com/watch?v=deqn2cYf1EM



DextrES : Wearable Haptic Glove







LandingPad Virtual Collaboration in 3D

Technology that allows designers to invite decision makers into a virtual collaboration room to present directly in 3D. Feedback in real-time is available.

3D Camera Scanner, Digitizer, CMM

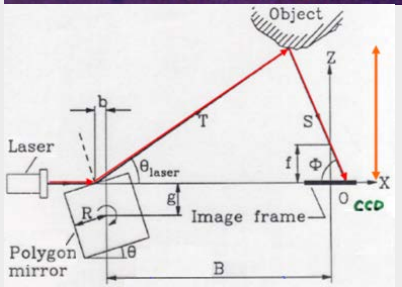
(CMM)
Coordinate
Measuring
Machine

Digitizer
attached to robot

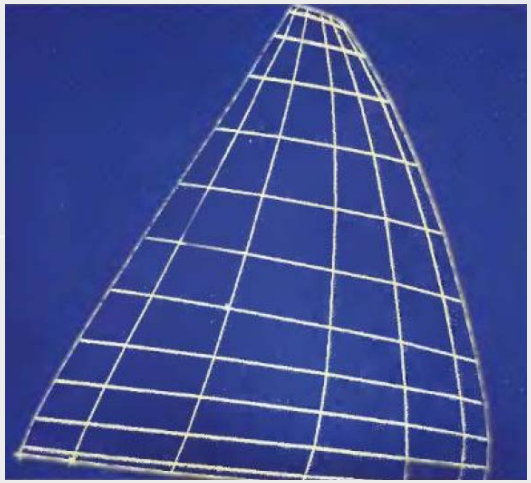
3D Range Data Acquisition and Its Applications

2D Image: (for each pixel: X and Y coordinates and light intensity)
3D Range Image/Data from Range Sensing Devices and 3D Camera – data points defined by their X, Y, and Z coordinates (cloud point data) – added Depth.

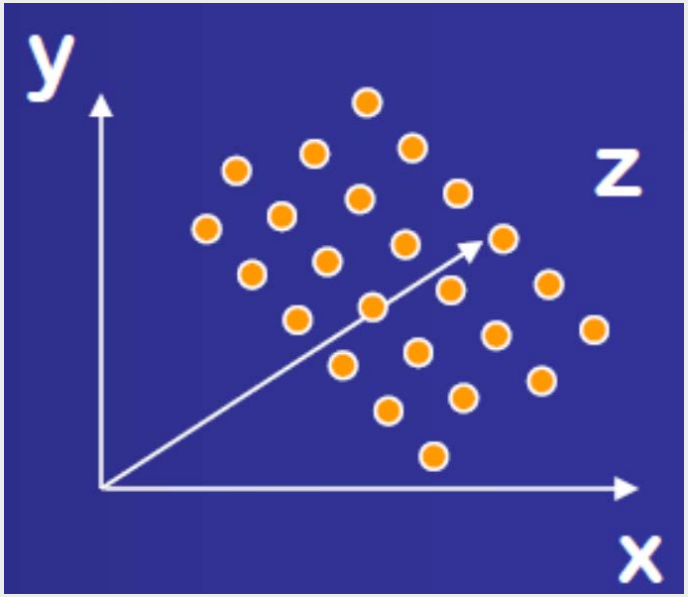
Mechanical probe
(measurement and scanning)
Laser scanning
Triangulation-based range sensing devices
Time-of-flight based range sensing devices
Machine vision based CAD model generation for reverse engineering



Obtaining 3D Cloud Data Points



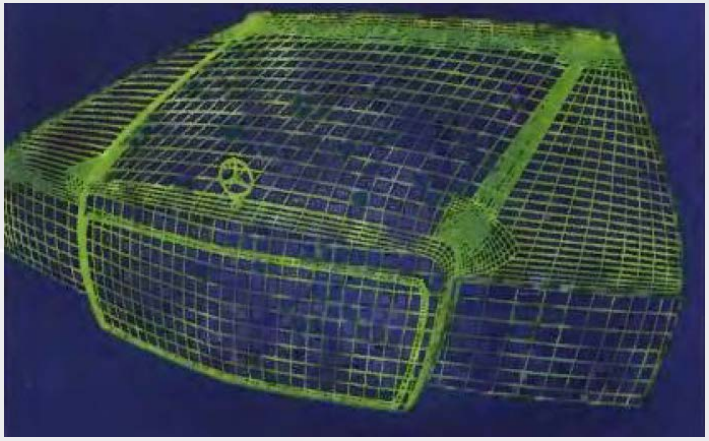
using 3D Range Sensors (3D Cameras):
Two Alternatives:
Triangulation-based: visible laser light, short range, accurate
Time-of-flight-based: laser light & micro wave, long range, less accurate

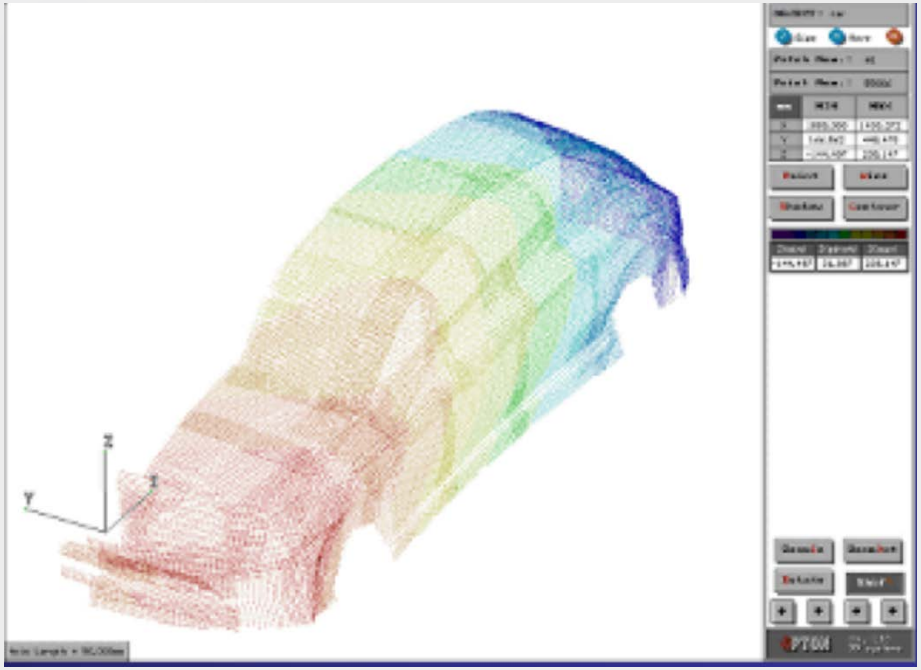


Processing of 3D Range Data
3D Cloud Data Points
-> Cross-section-based CAD Model
Generation of a Complete Model
of Objects and Workspace -- by Sensor Fusion

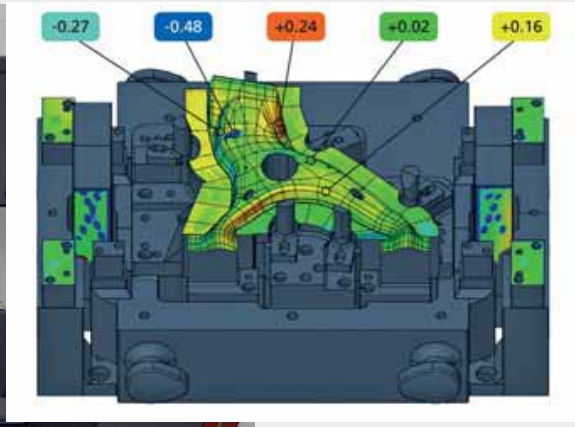
Scanning of full size model

Scanning of full size clay or
foam model to obtain surface data



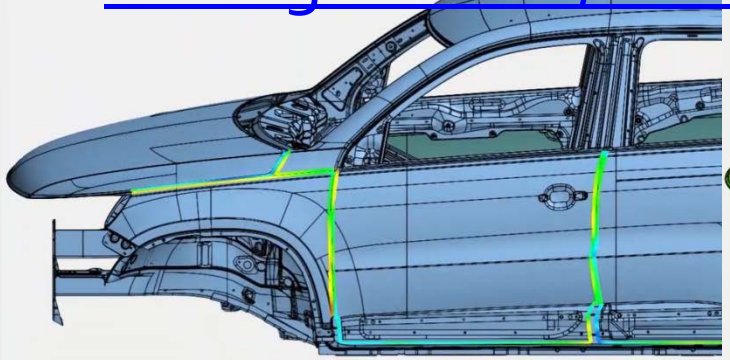


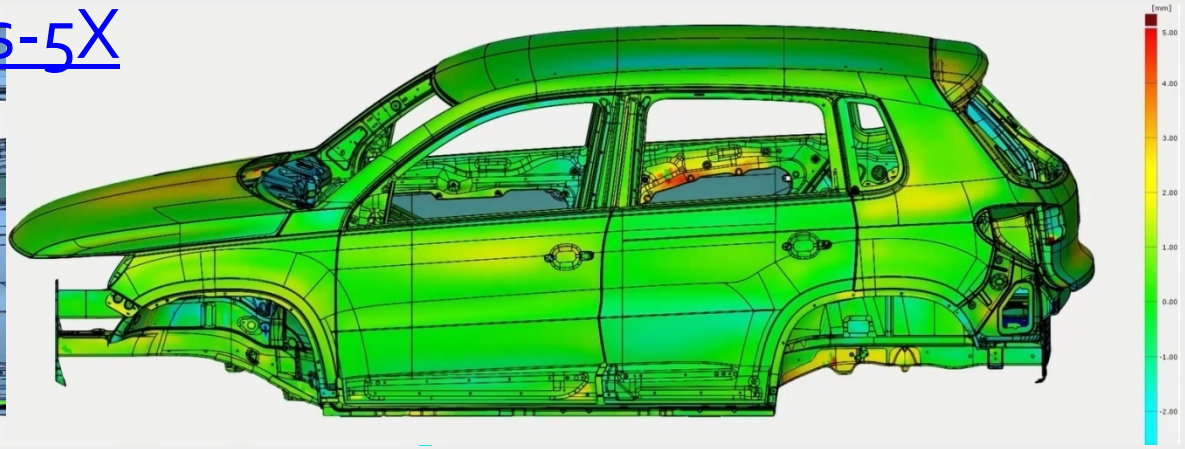
3D Measuring with blue LED light, camera



Complete car body scan takes 30 min.

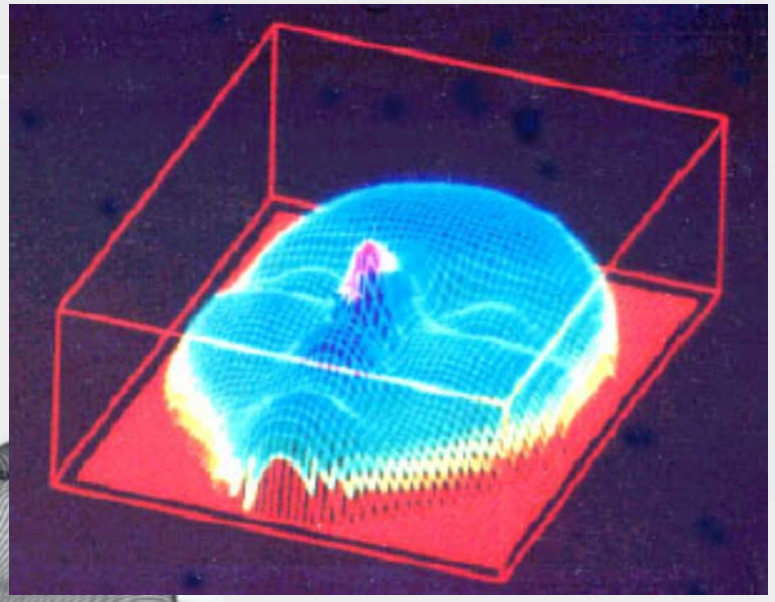
www.gom.com/atos-5X

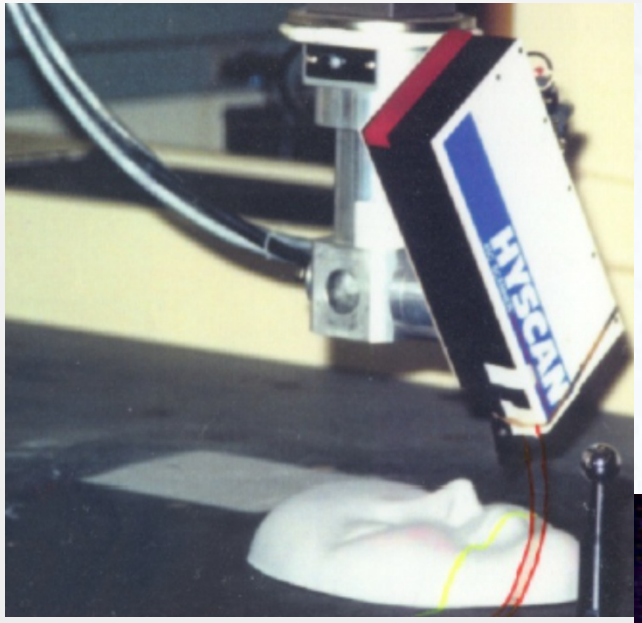


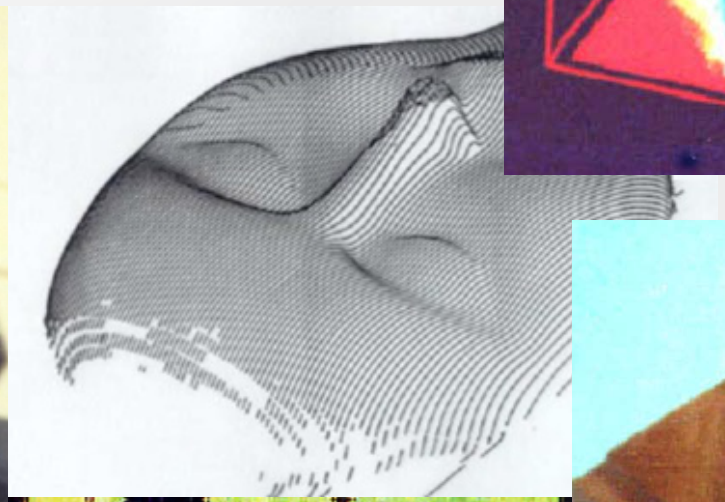


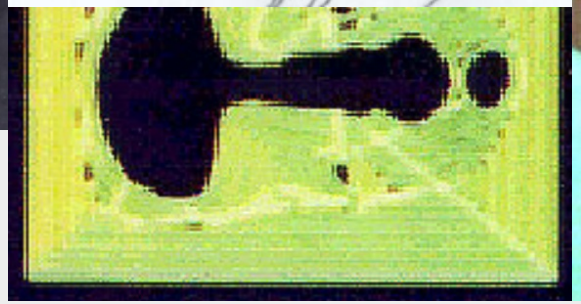
Forming a Surface Model and Carrying out Reverse Engineering

Cross-section-based CAD Model
-> Surface Model
-> CNC Machining; RP; etc.



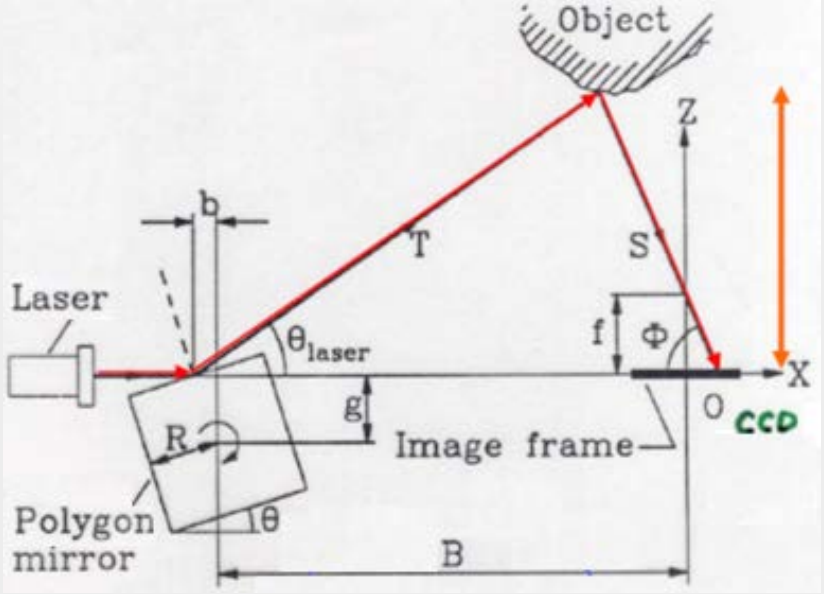


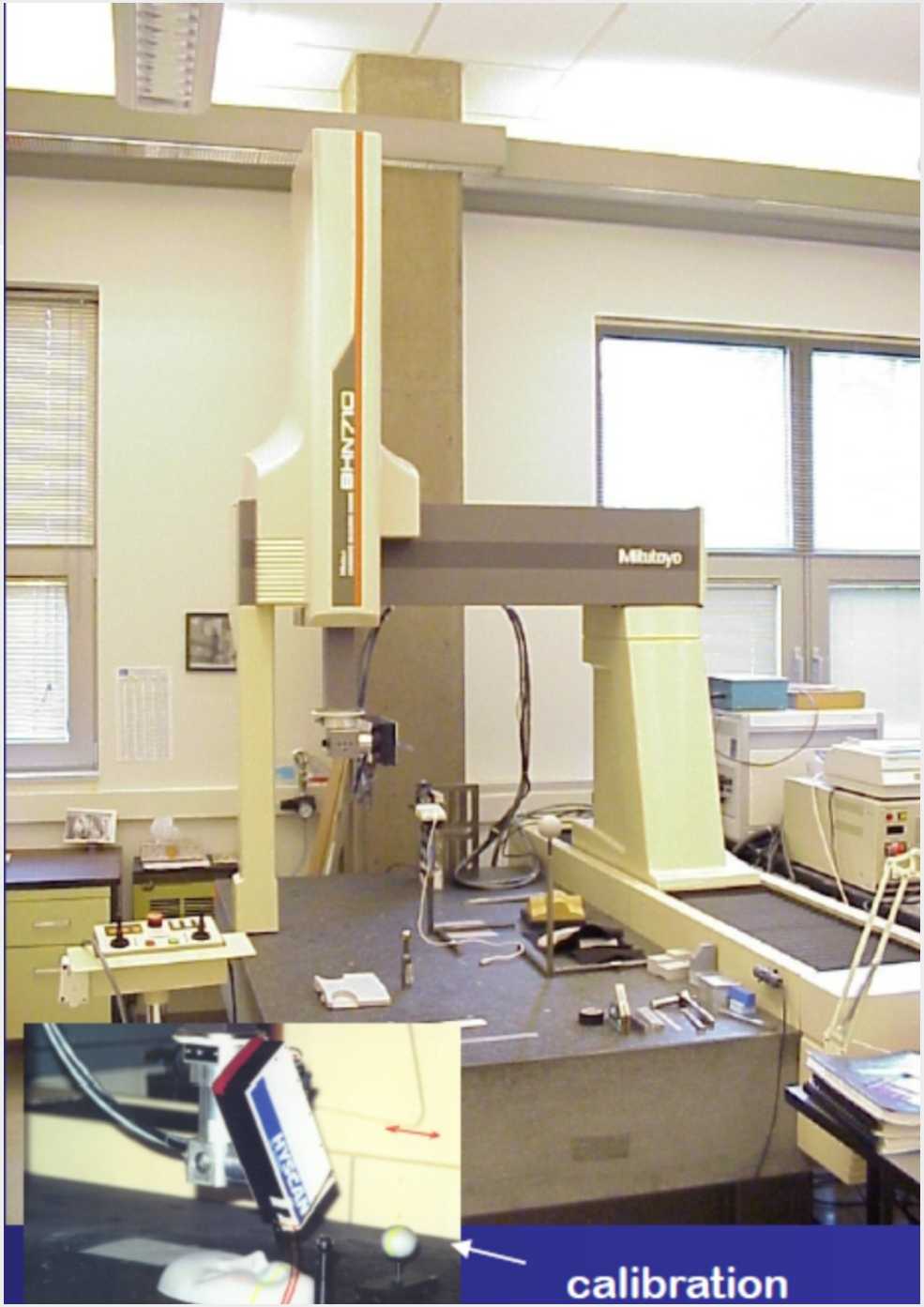




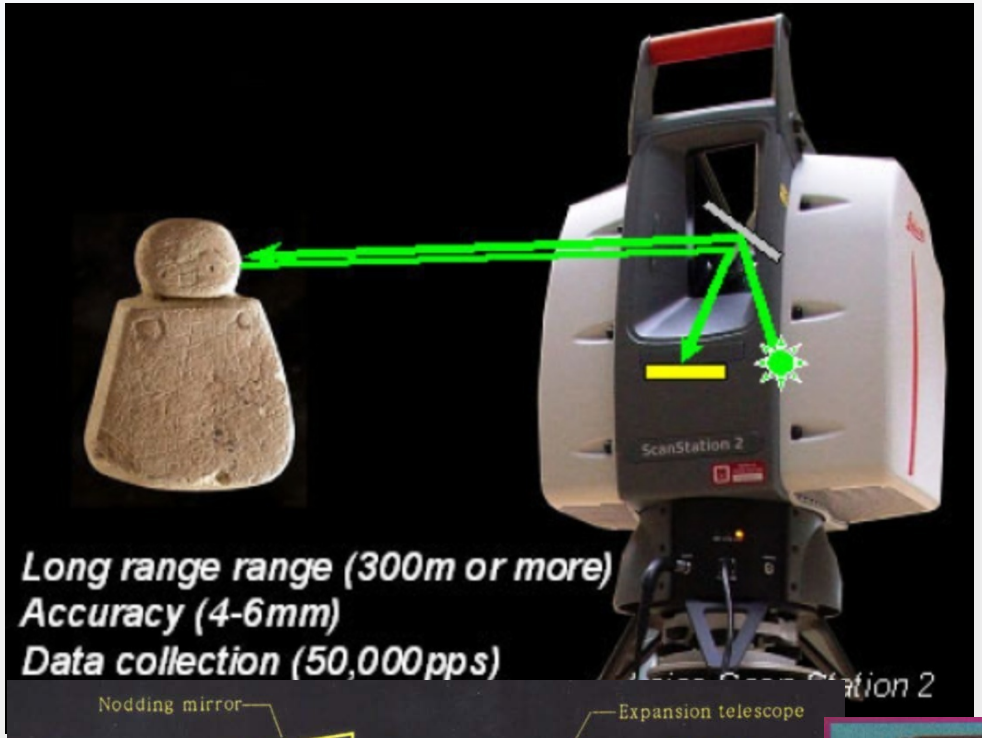
Triangulation-based Range Sensor

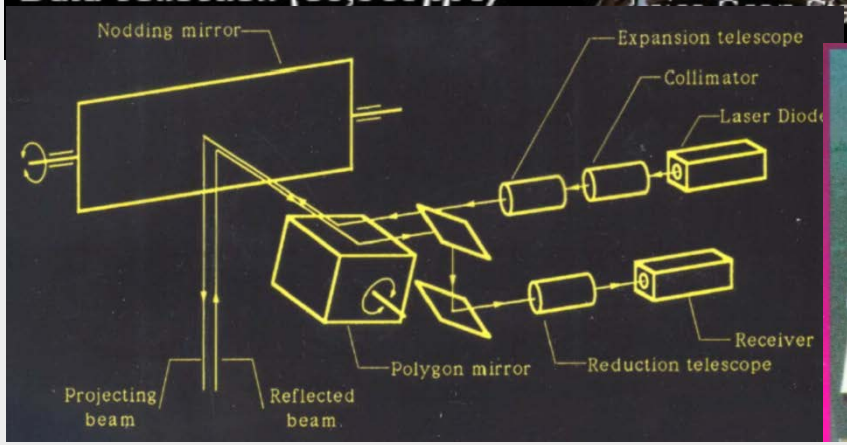
- 

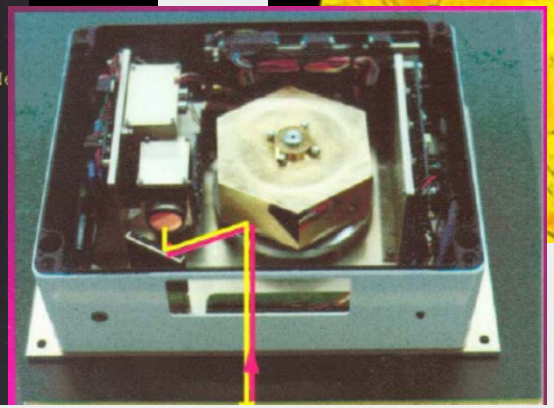




Time of Flight Based Range Sensor







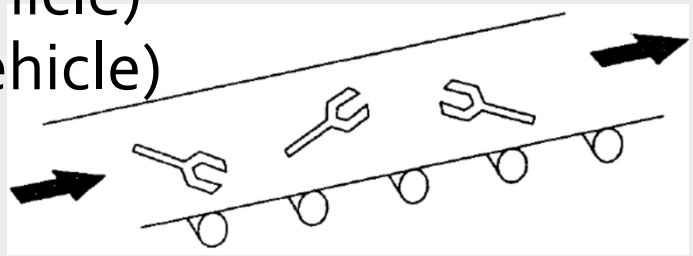
Geometric Modeling Based on 3D Scanning

Challenges:

- Accuracy/Lighting/Range (Selecting Right Sensing Tech)
- Occlusion (Obstruction)/Multiple View Fusion
- Multiple Level Modeling:
  Cloud Data Points -> Cross-sections -> Surfaces -> Solid

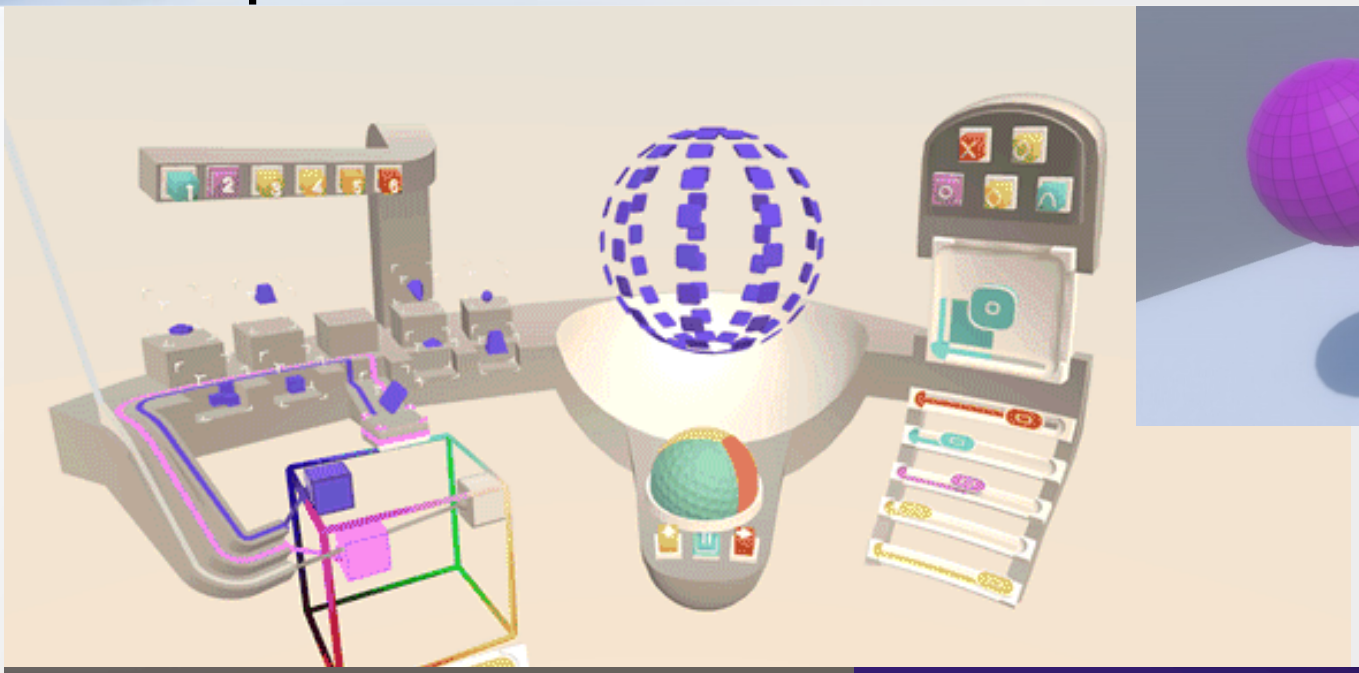
Applications:

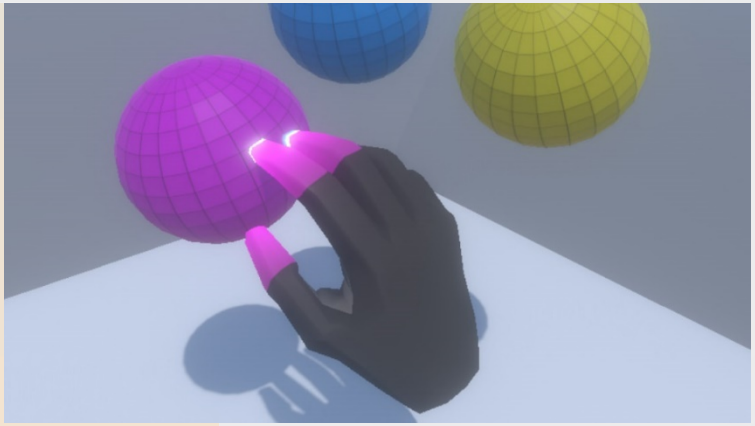
- Reverse Engineering (e.g. Face Mask)
- Size Measurement (e.g. Moving Vehicle)
- Object Recognition (e.g. Moving Vehicle)
- 3D Sculpture Documentation
- Shoe Making
- Character Modeling in Movies/Computer Games

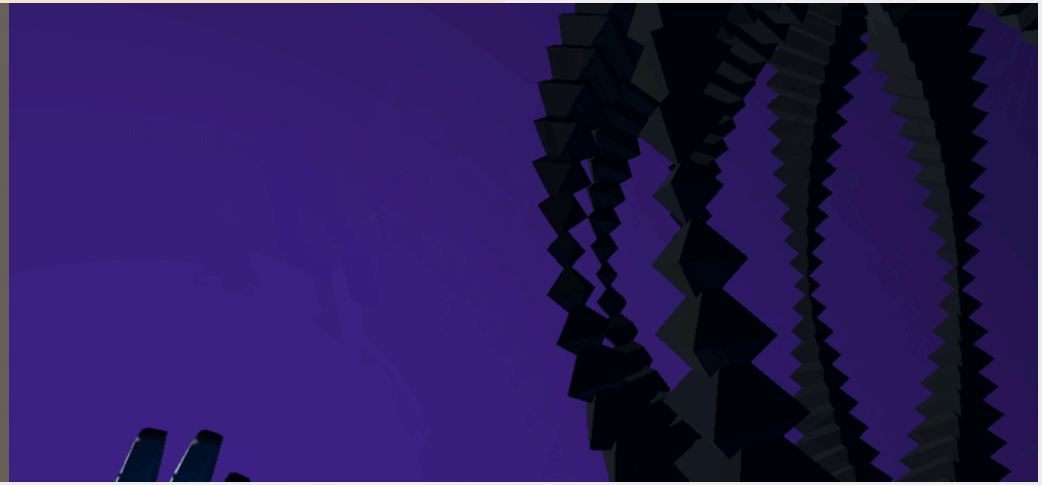


Leap Motion Controller use IR stereo cameras

Leap Motion Controller IR stereo camera

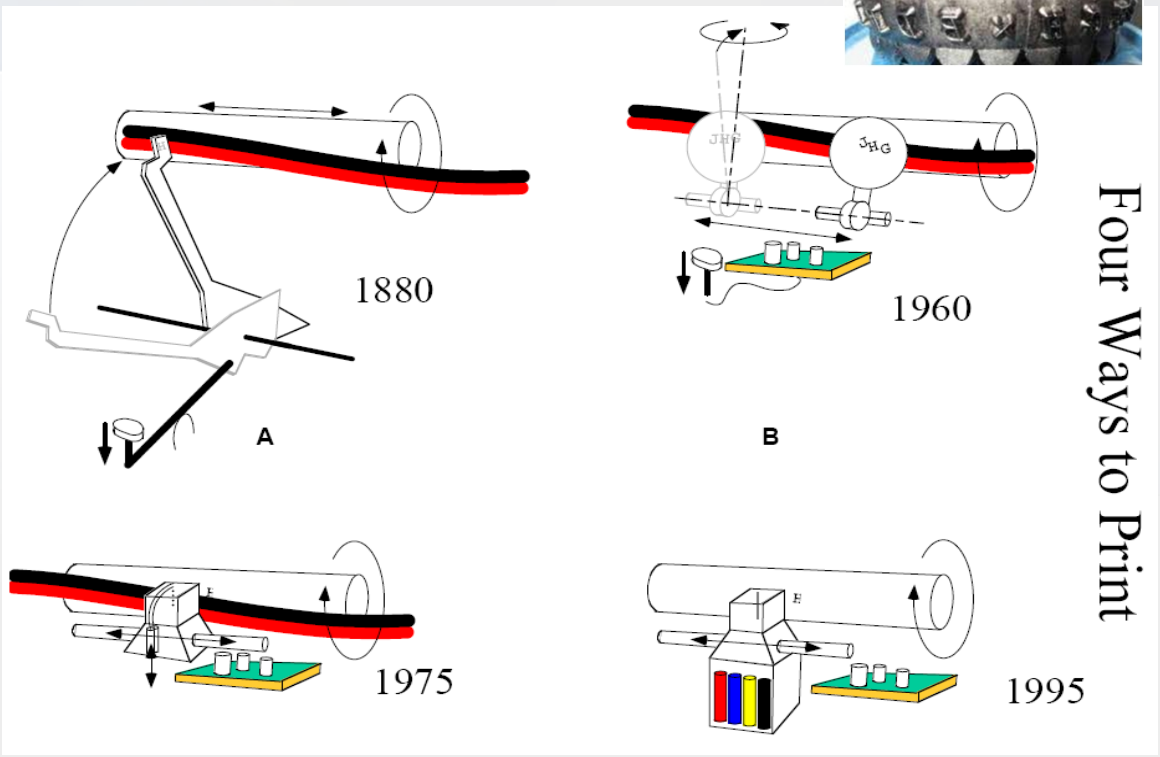




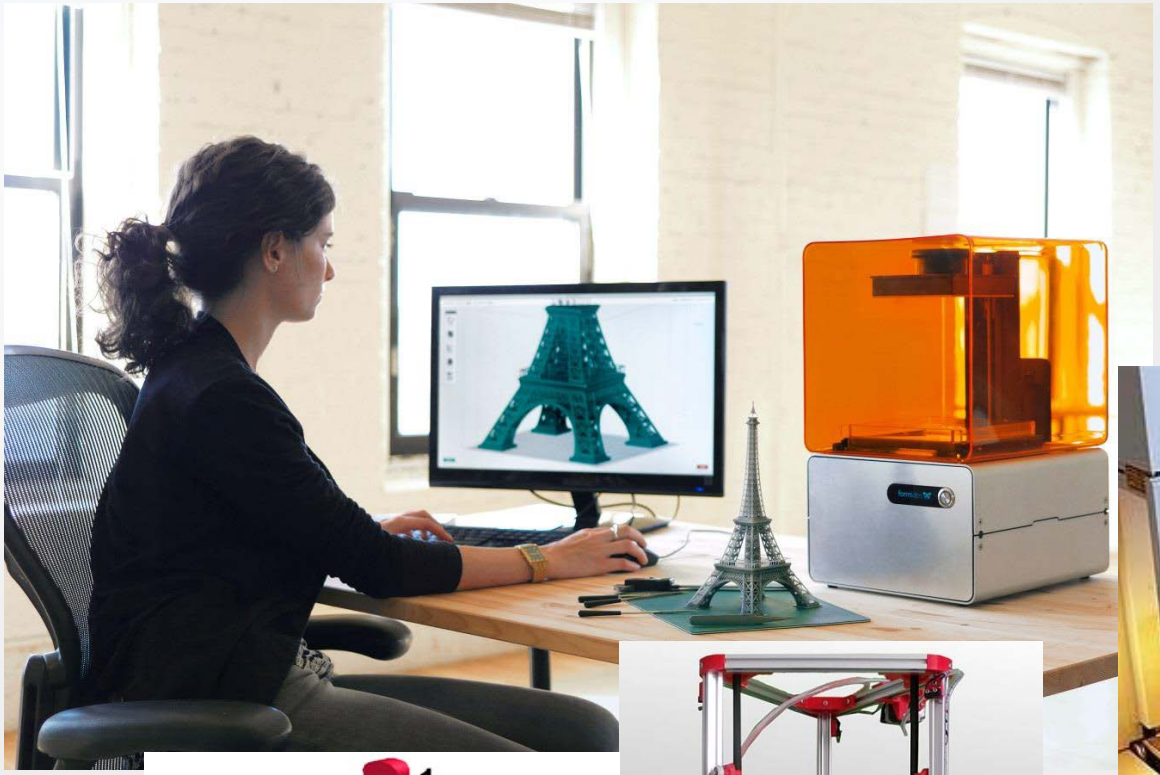


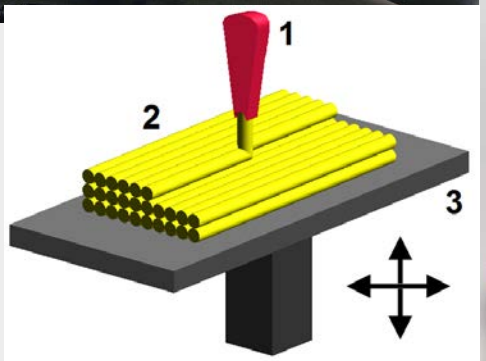
Output Devices

- pin printer
- inkjet printer
- laser printer
- pen plotter
- inkjet plotter



Hardwares - Output Devices - 3D Printers



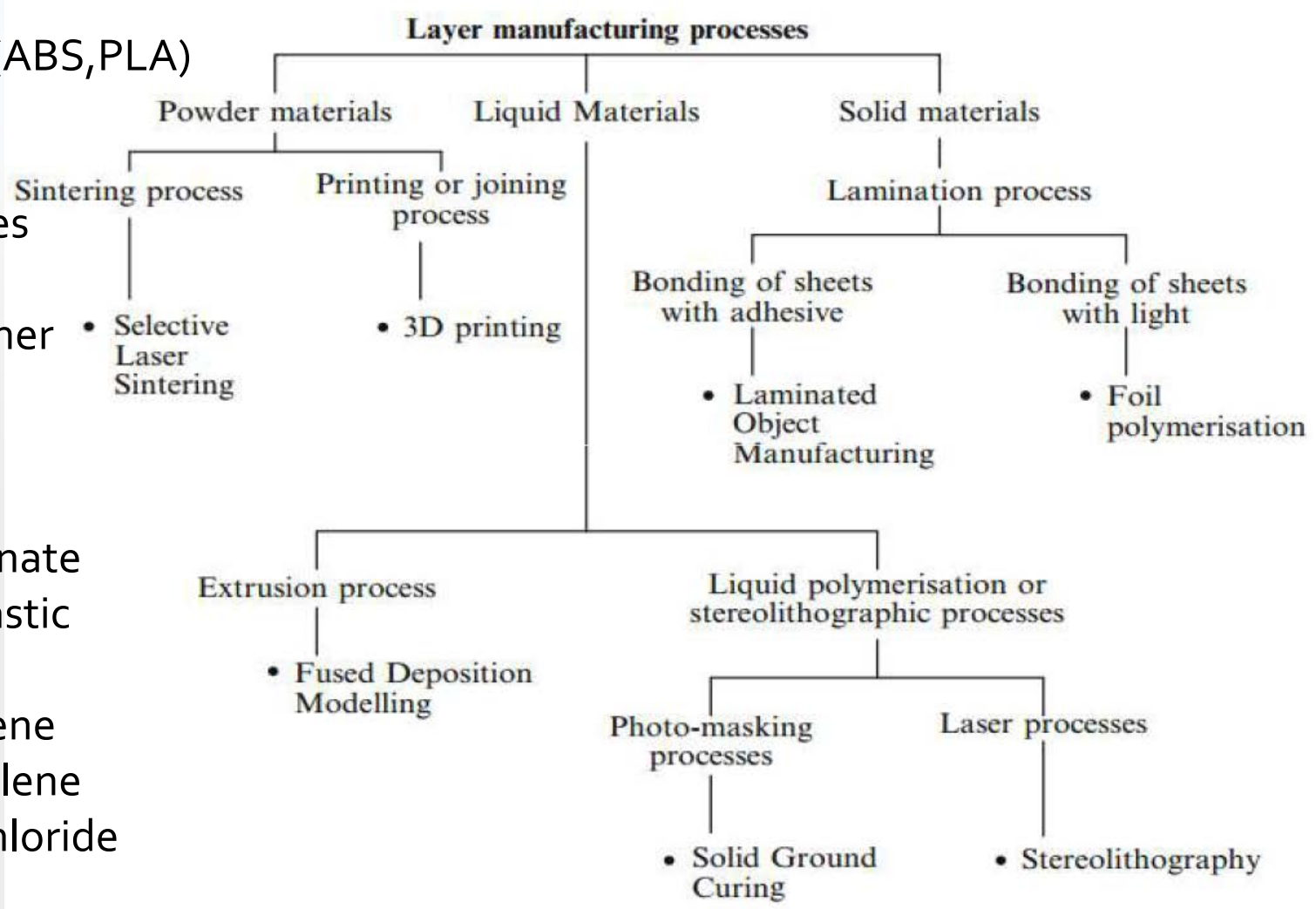


3D Printing Technologies and Materials

1. Polymers (ABS,PLA)
2. Metals
3. Ceramics
4. Composites

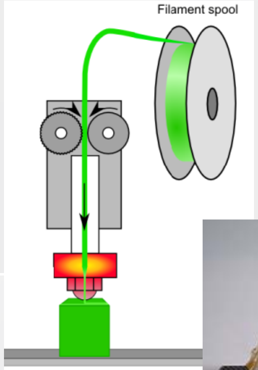
Polymers

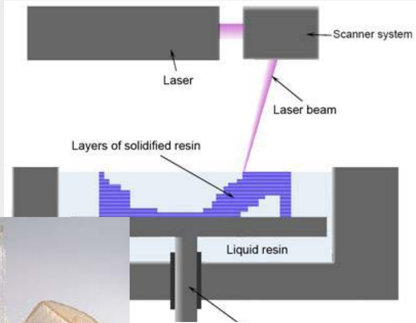
a) ABS polymer
b) Acrylics
c) Cellulose
d) Nylon
e) Polycarbonate
f) Thermoplastic polyester
g) Polyethylene
h) Polypropylene
i) Polyvinylchloride

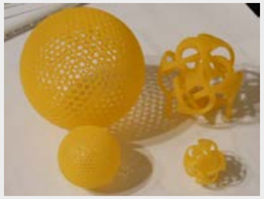


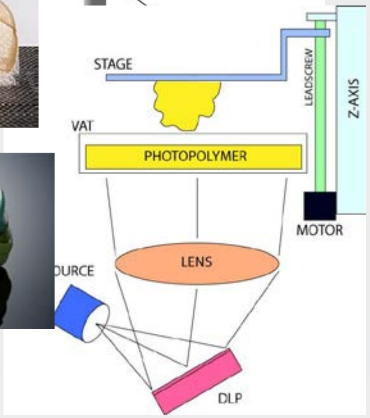
3D Printing Technologies

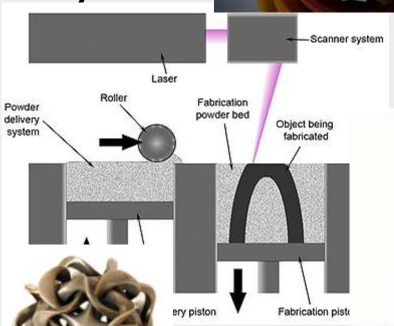
Fused deposition modeling (FDM)
Stereolithography (SLA)
DLP 3D printing
Photopolymer Phase Change Inkjets (PolyJet)
Selective laser sintering (SLS)
  Direct metal laser sintering (DMLS)
Plaster-based 3D printing (PP)
  Powder bed and inkjet head 3D print
Thermal Phase Change Inkjets
Laminated object manuf. (LOM)

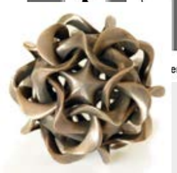


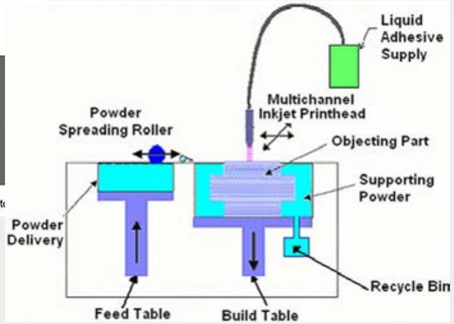


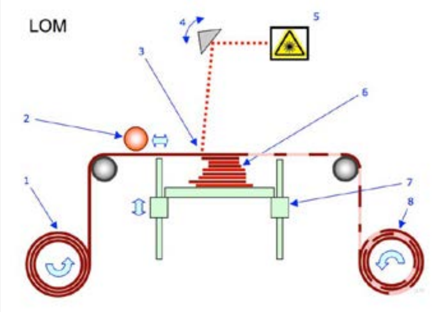


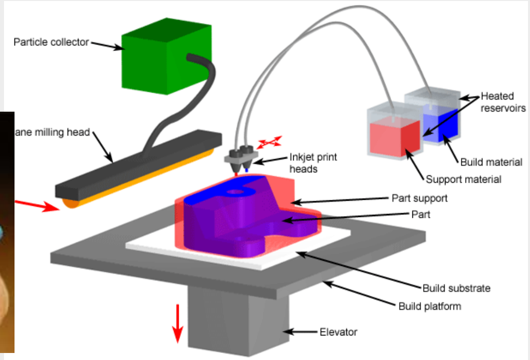






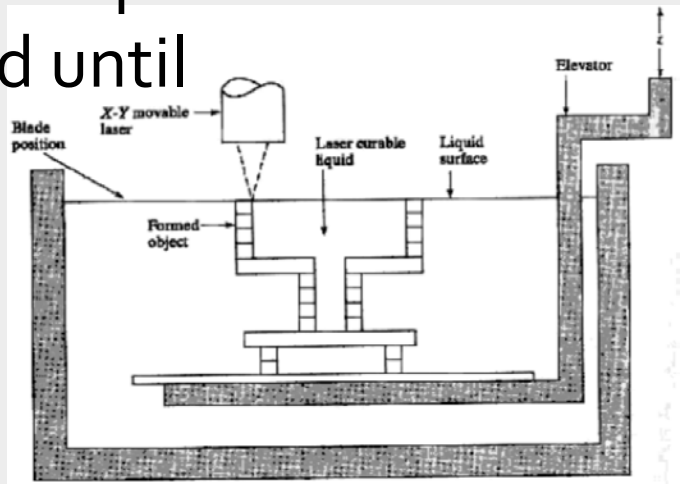






3D Printing, Rapid Prototyping

Solid Freeform Fabrication: Building a solid part from a CAD model, layer by layer, by material deposition.
Shape Deposition Manufacturing (SDM).
Solid Ground Curing (SGC).
Stereolithography (SLA) process operates by taking a thin layer of light-sensitive liquid plastic and passing the beam of an ultraviolet laser over the points where the part is to be solid. This is repeated until the entire part.



3D printing, stereolithography (STL, SLA)

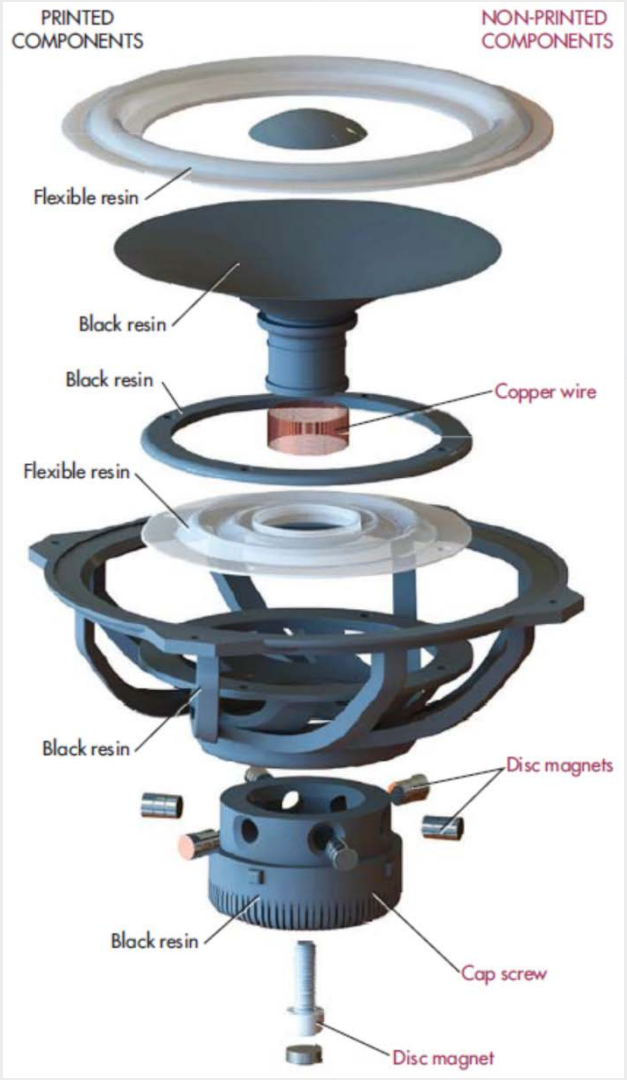
3d printed flute

a component produced
by direct metal laser sintering
(DMLS) is a steering stub axle.

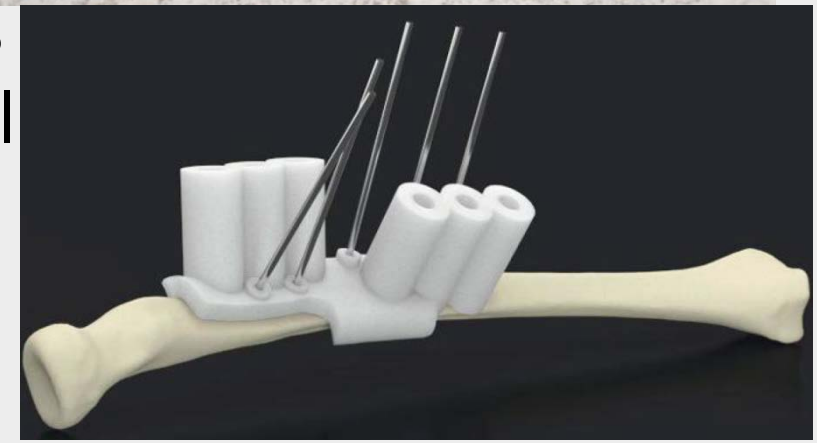
3D printing, stereolithography (STL, SLA)

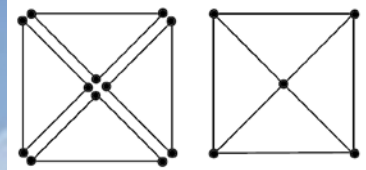
propellers

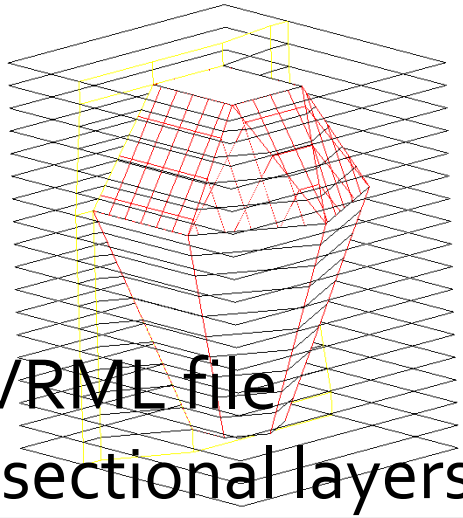
speaker

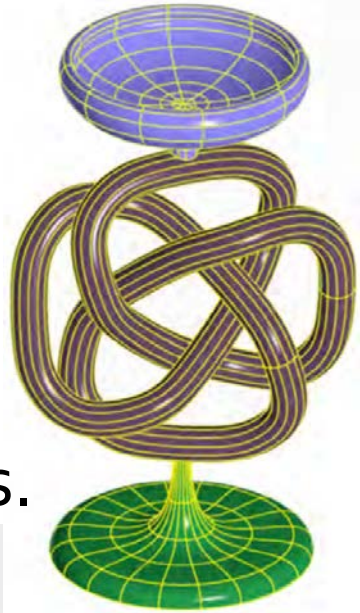


drill guides for medical operation



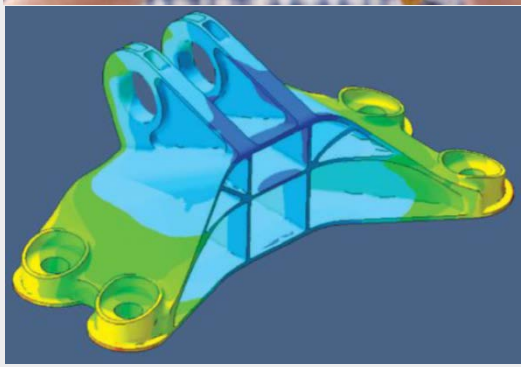




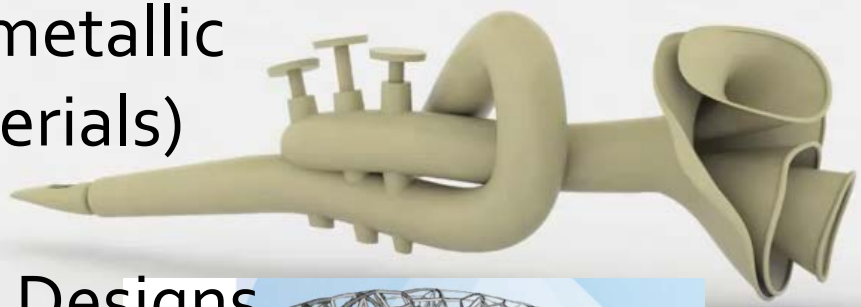


3D printing

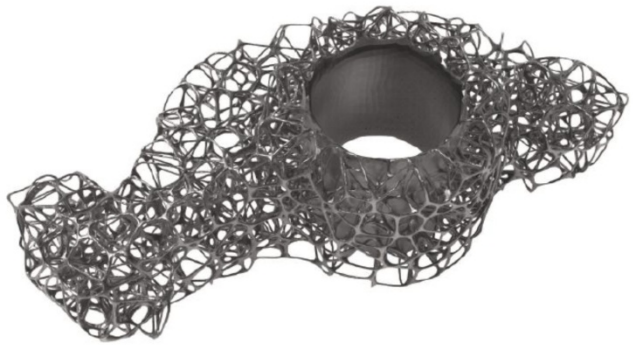
Slice the STL, VRML file
into thin cross-sectional layers.

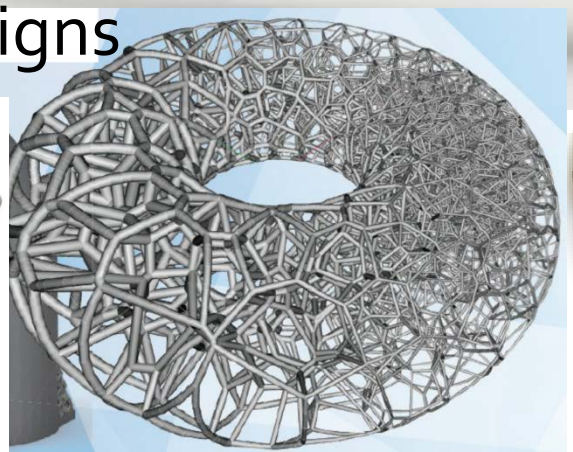


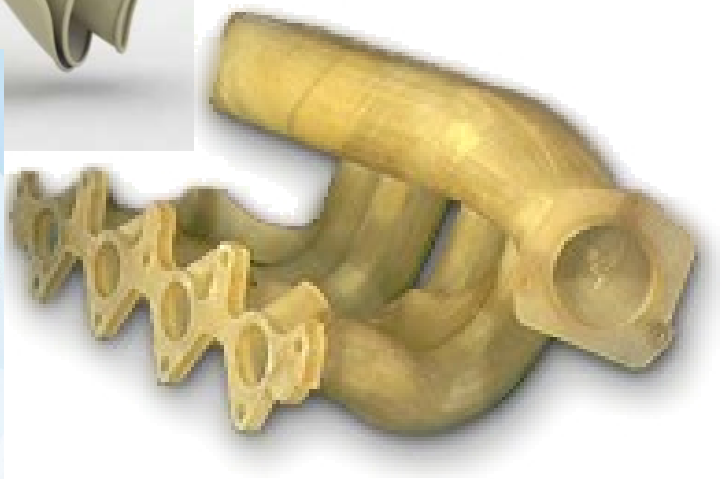
Complex designs for 3D printing
(ABS, PLA, metallic
filaman materials)



Lightweight Designs







3D printing, Additive Manufacturing

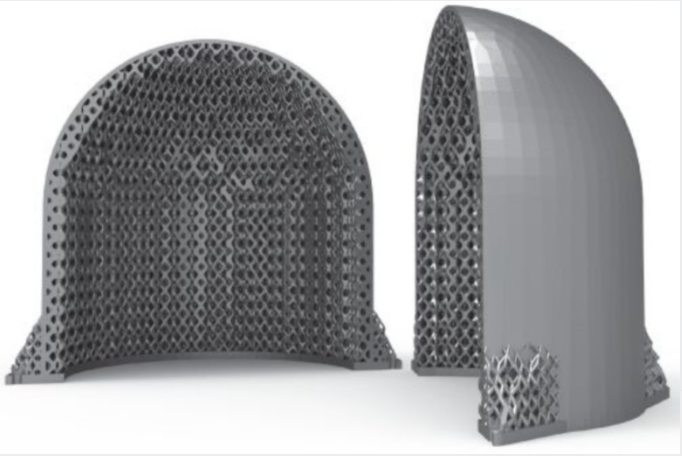
A Car Printed in 40 hours

Popular Mechanics SA 2015.10

Evaluation Engineering EE 2017.01

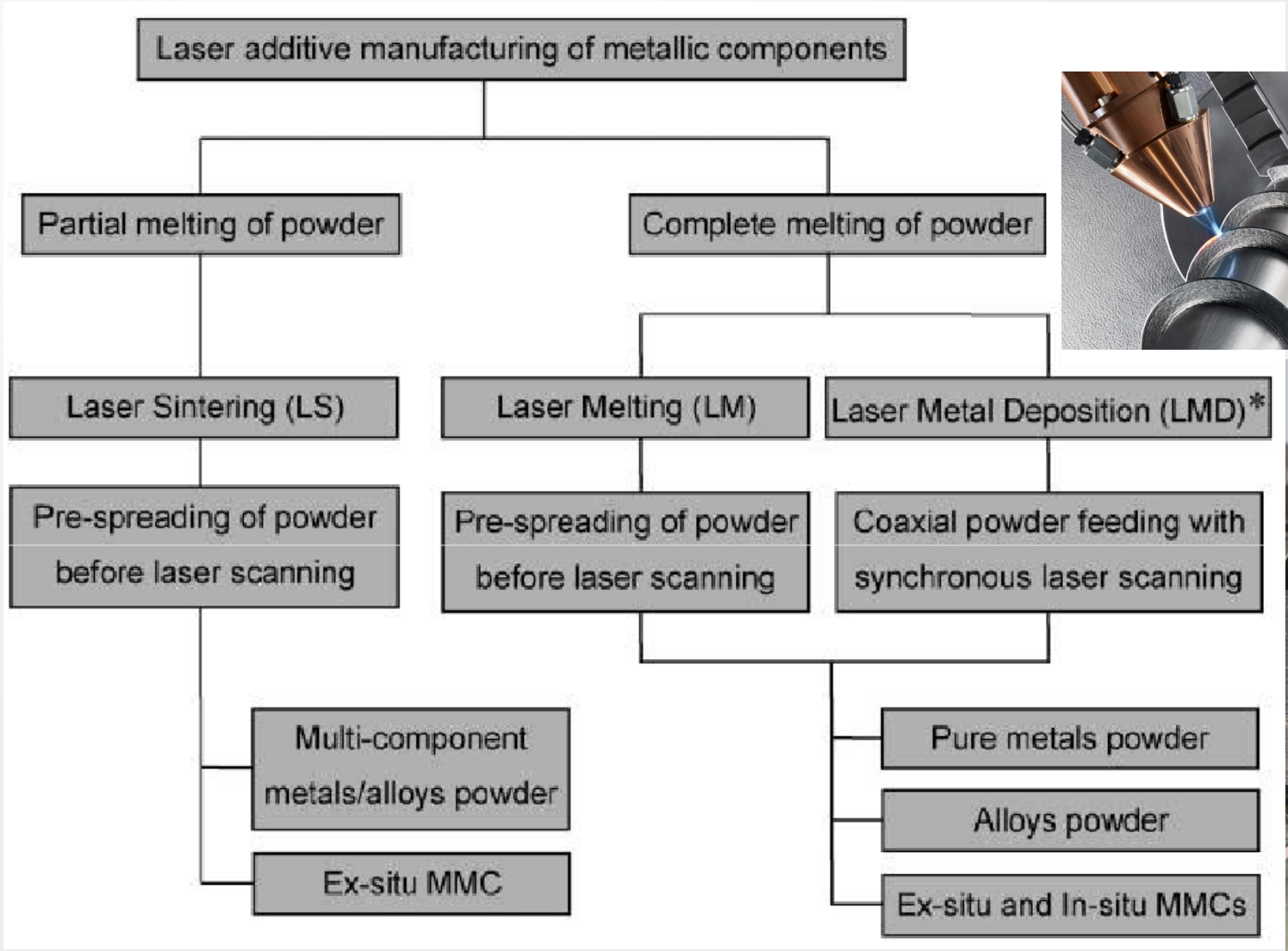
Additively Manufactured (AM) Metal Parts

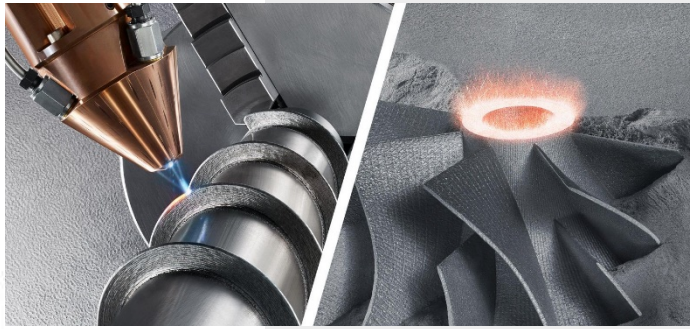
internal lattice
lightweight
structure
caliper-hanger
(metal powders)



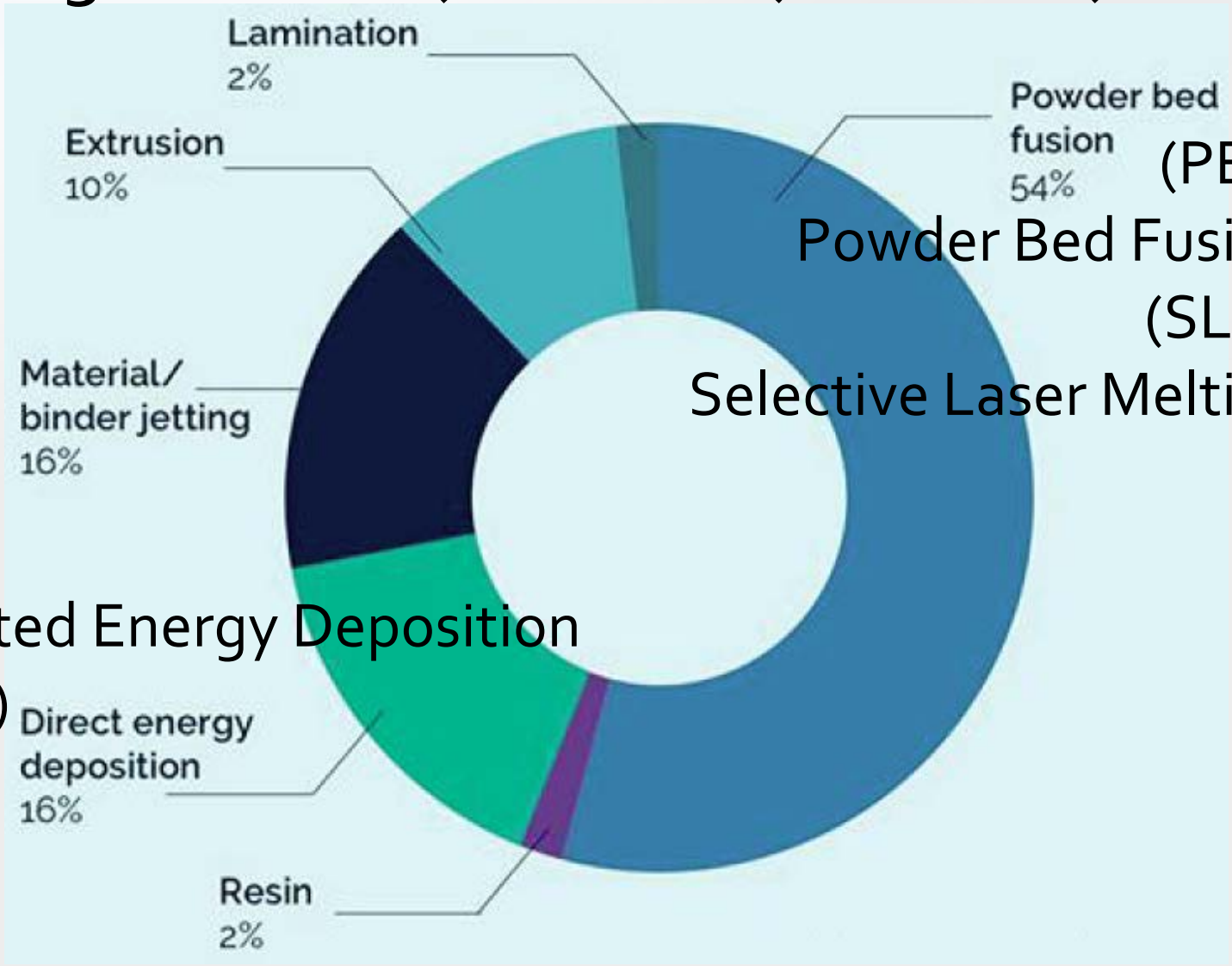
Two additively manufactured Ti64 parts built in two orientations with supports auto-generated by exaSIM

Additive Manuf. Laser Metal Deposition





Metal 3D Printer (Add.Mnf.) Market (2018)



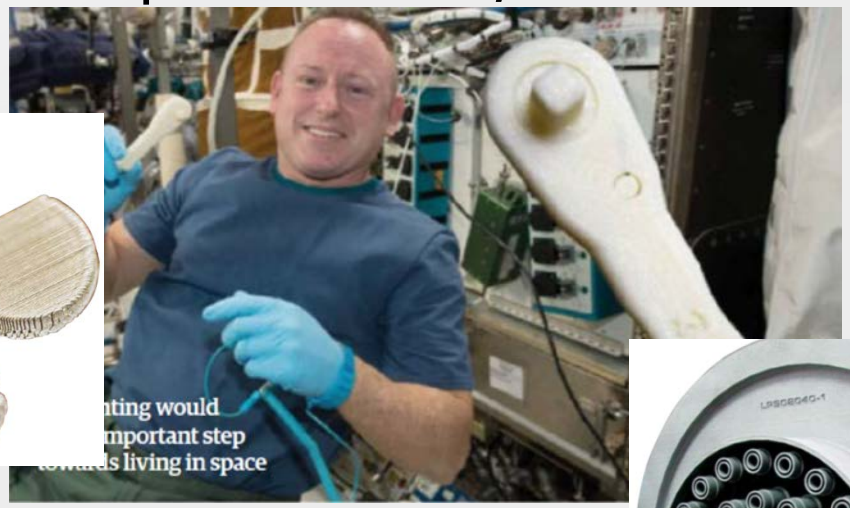
(PBF)
Powder Bed Fusion
(SLM)
Selective Laser Melting

(BDJ)

Directed Energy Deposition
(DED)

3D printing without gravity

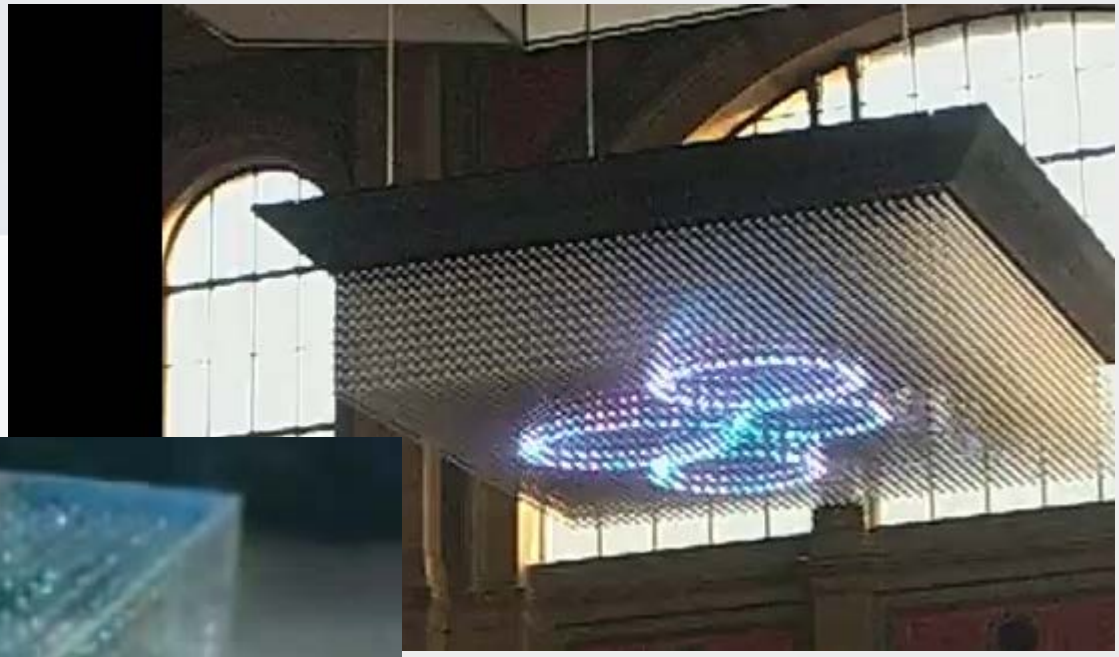
- In November 2014, NASA astronaut Barry became the first person to use a 3D printer in space. Four hours and 104 layers of plastic later, the wrench was finished.



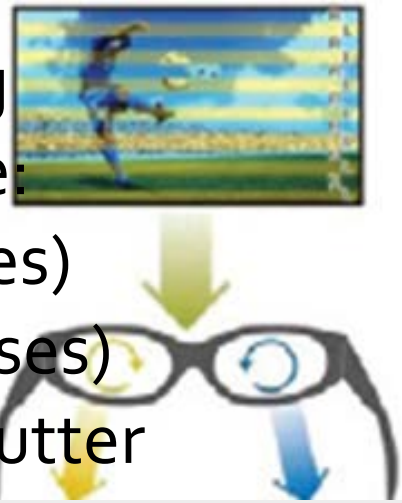
An injector fuel nozzle of rocket by DMLS

3D Display

- 3D LED Cube



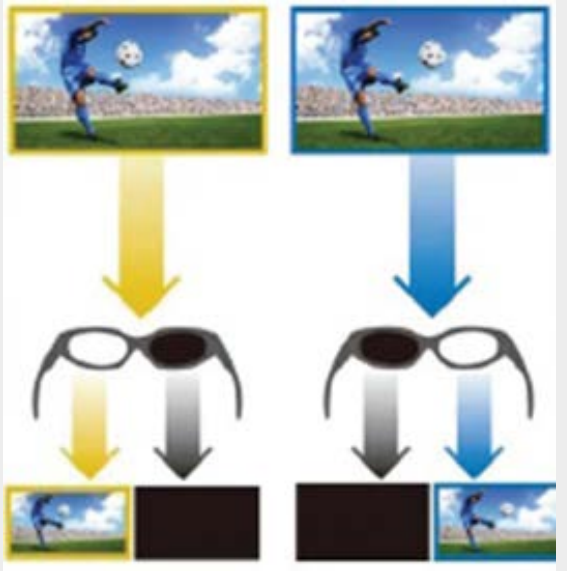
Stereoscopic Technology (3D Display)



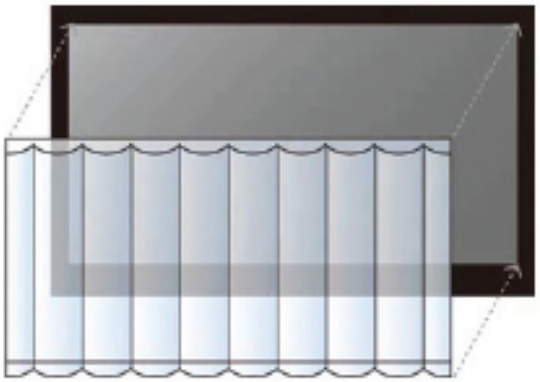
Common 3D display technology for projecting stereoscopic image pairs to the viewer include:

- Anaglyphic 3D (with passive red-cyan glasses)
- Polarization 3D (with passive polarized glasses)
- Alternate-frame sequencing (with active shutter glasses/headgear)
- Autostereoscopic displays (without glasses/headgear)

glass free 3d displays



3D TV technology, lenticular system

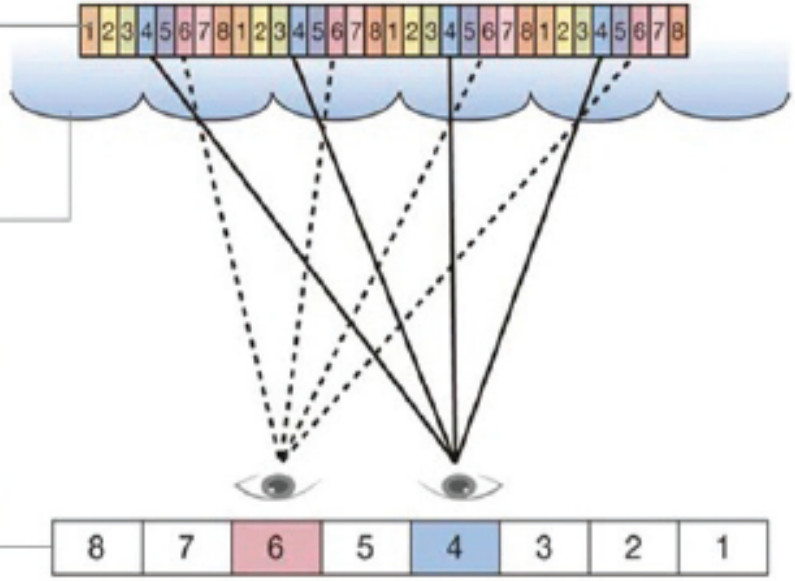


lenticular sistem

Şu an televizyona uyarlamak için uygun değil

Merceksel lens sistemi nasıl çalışıyor (konsept)

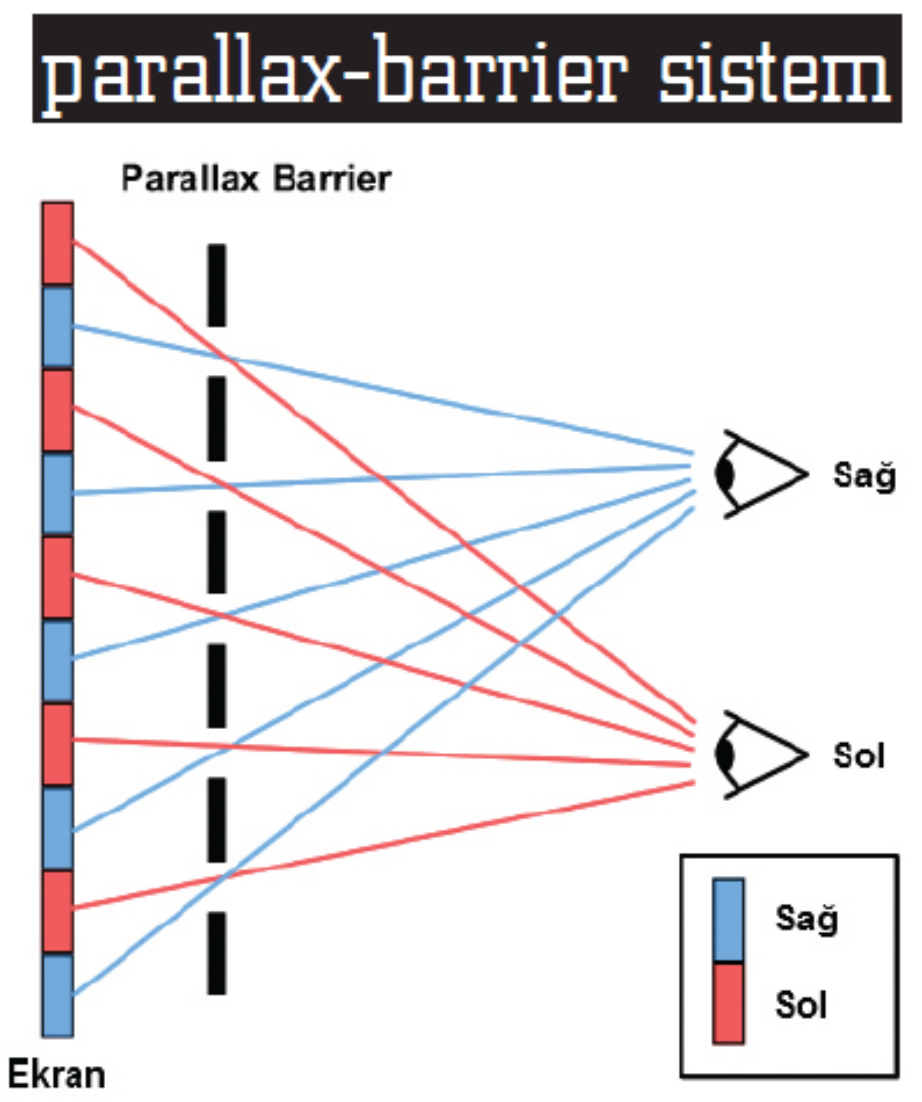
Görüntü



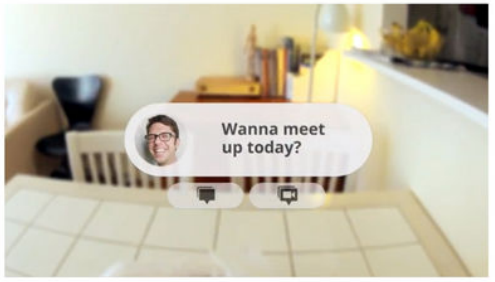
Bir merceksel lens sistemi ışığı kırıyor. Böylece sol ve sağ göz farklı imajlar görüyor.

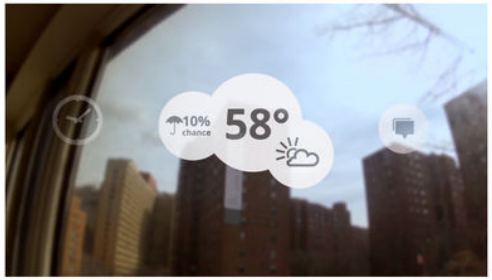
İzleyenin gördüğü görüntü izleme konumuna göre farklılaşıyor.

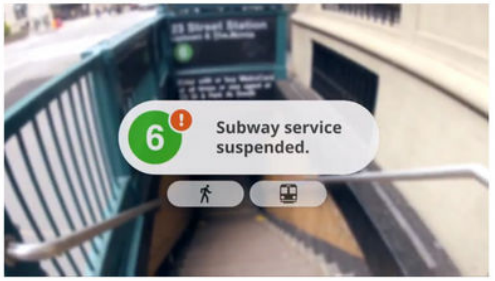
3D TV technology, parallax-barrier system

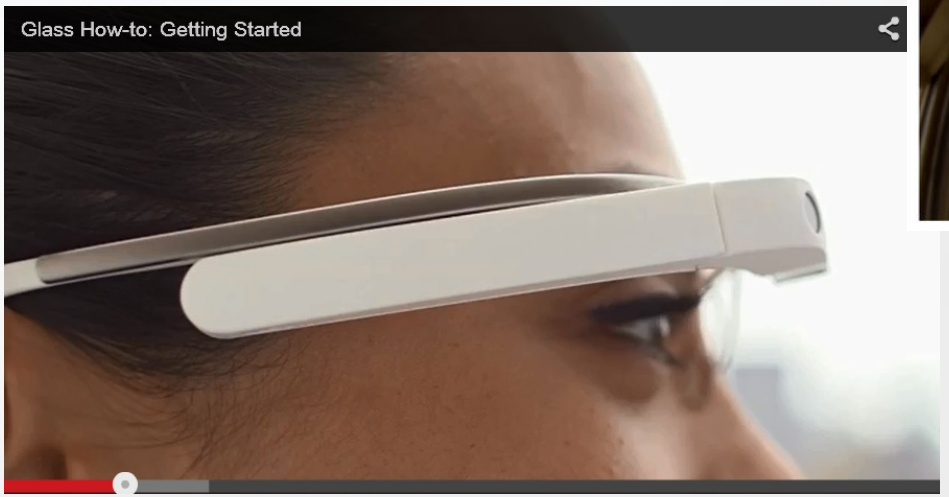


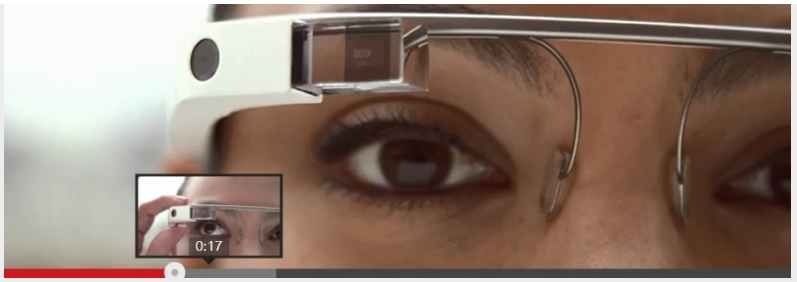
Google glass (2013)

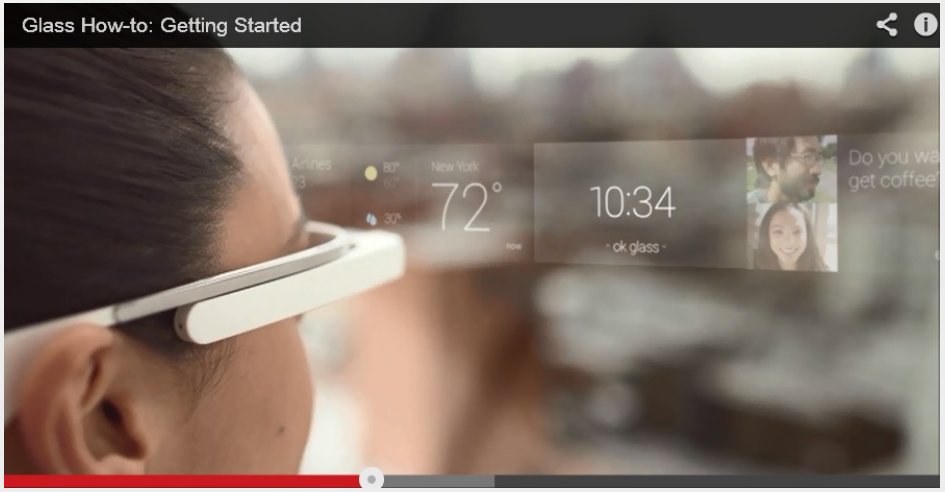


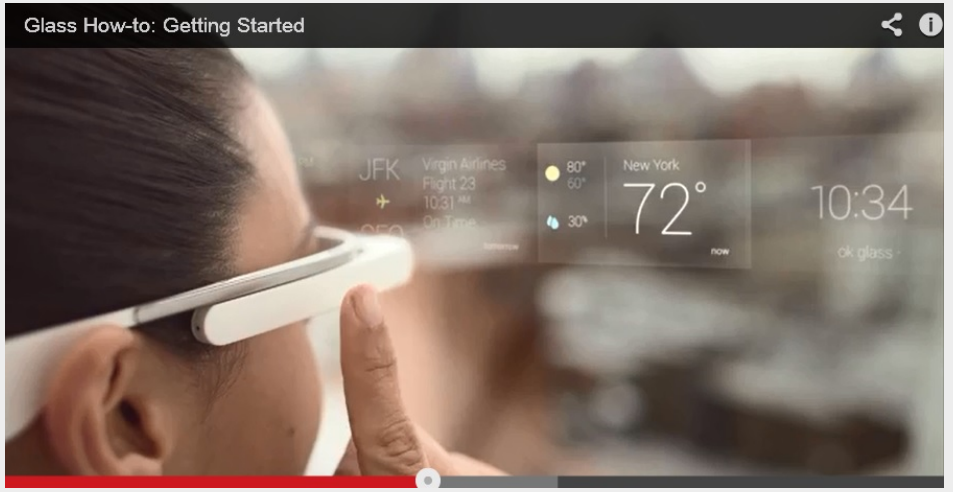




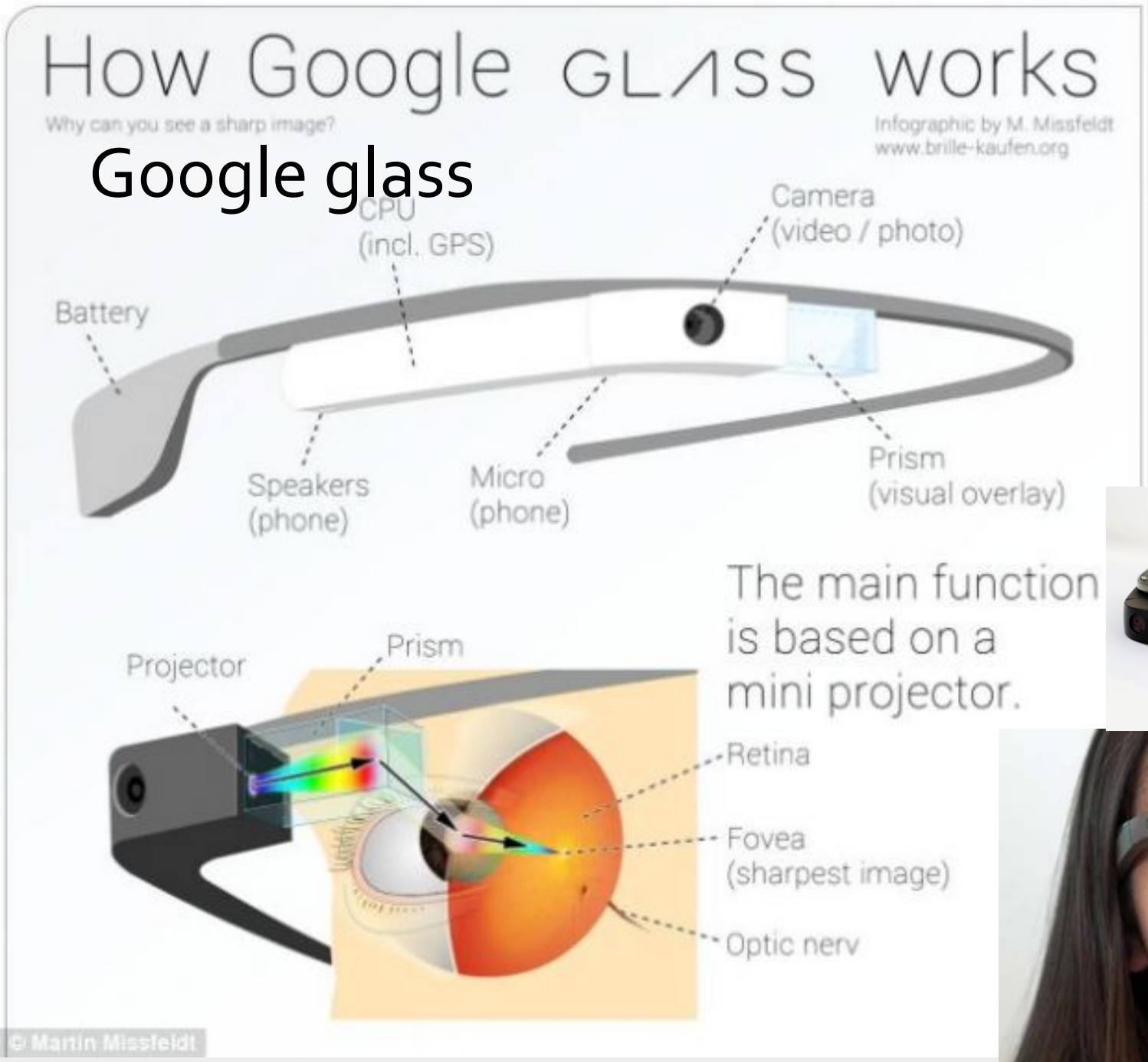








Google glass

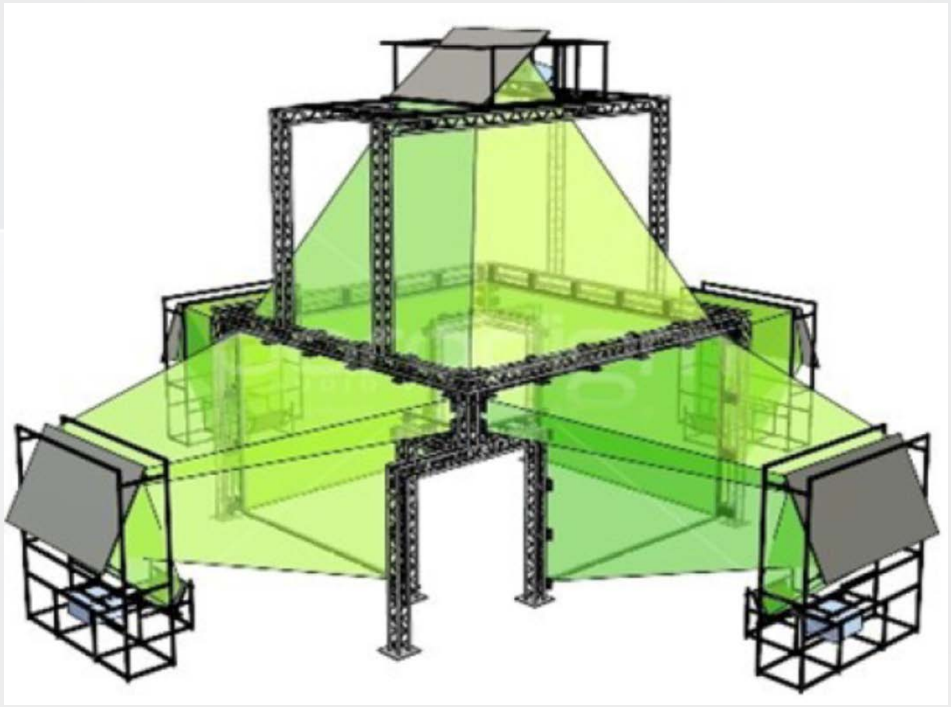


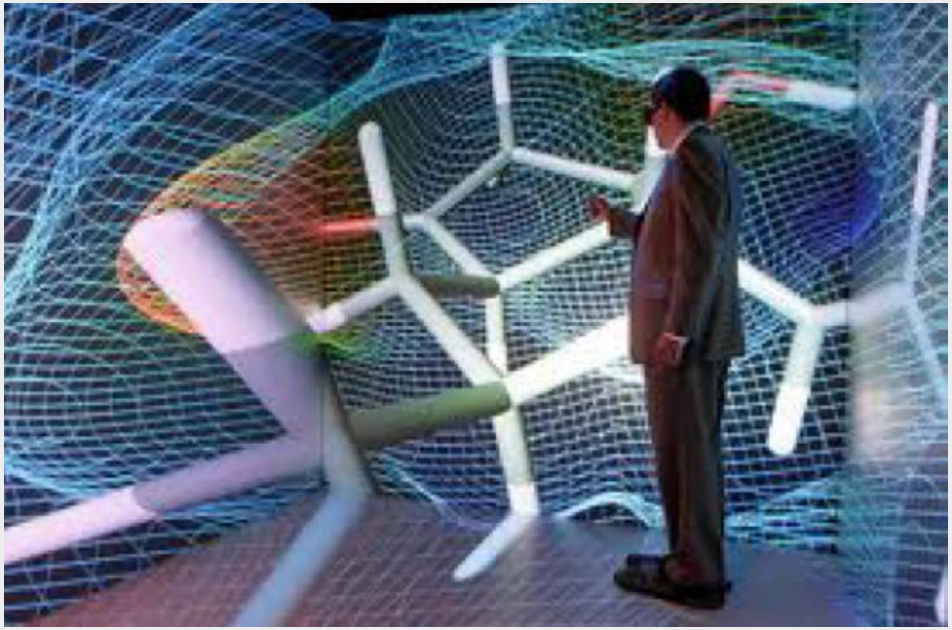
MS Windows 10 holographic HoloLens

AR Augmented Reality

Virtual Reality

3D CAVE





The end of Advanced CAD Technologies

1 Advanced CAD Technologies, Hardwares, Softwares

2 **Geometric Modeling**

3 Transformations

4 Parametric Curves

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