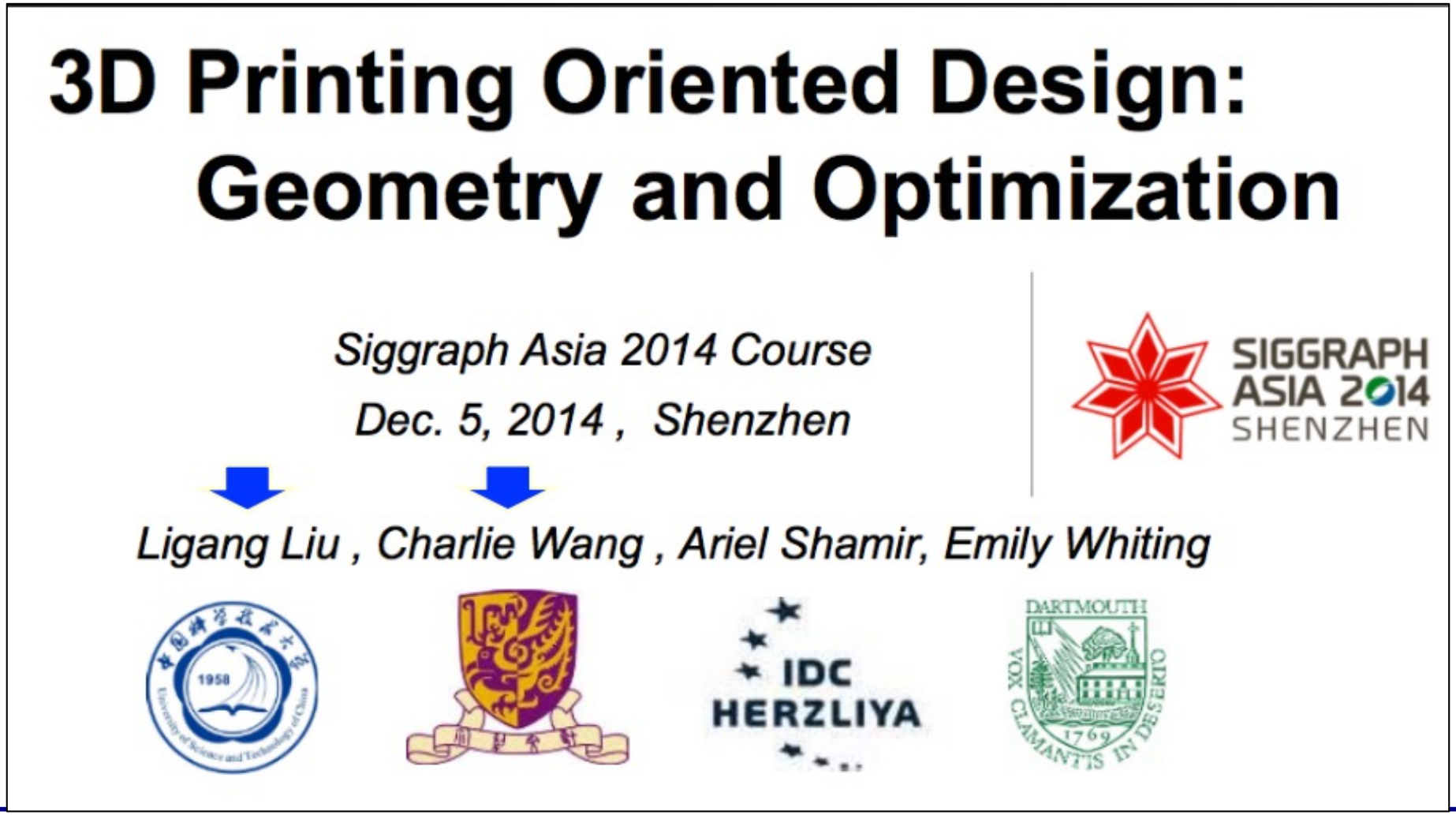
Introduction to 3D Printing

CMPT 464/764

Lecture 14

Source of slides



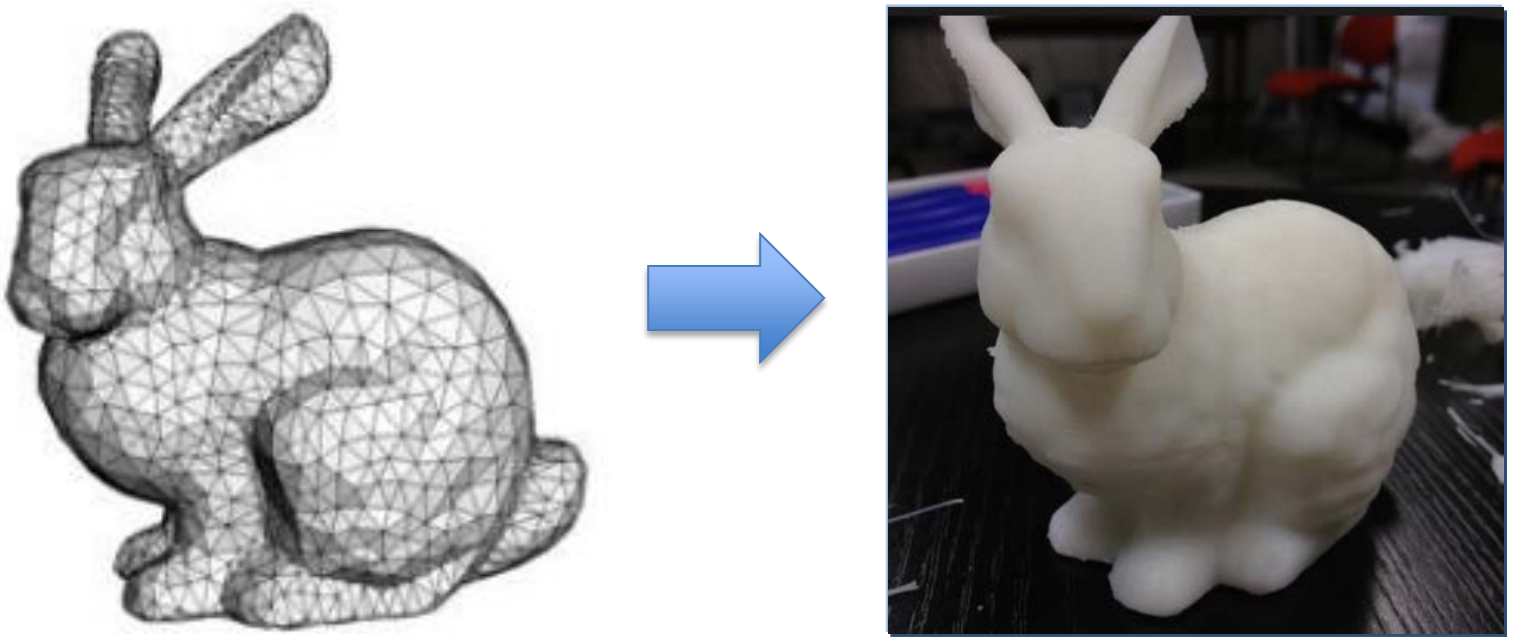
What is 3D printing?

Printing

- (*from Wikipedia*) Printing is a process for reproducing text and images, typically with ink on paper using a print press.

3D + Printing = 3D Printing

- 3D printing is the process of making a real physical 3D object from digital file using some material, in a manner similar to printing images on paper. (material = ink = powder/polymer/plastic)



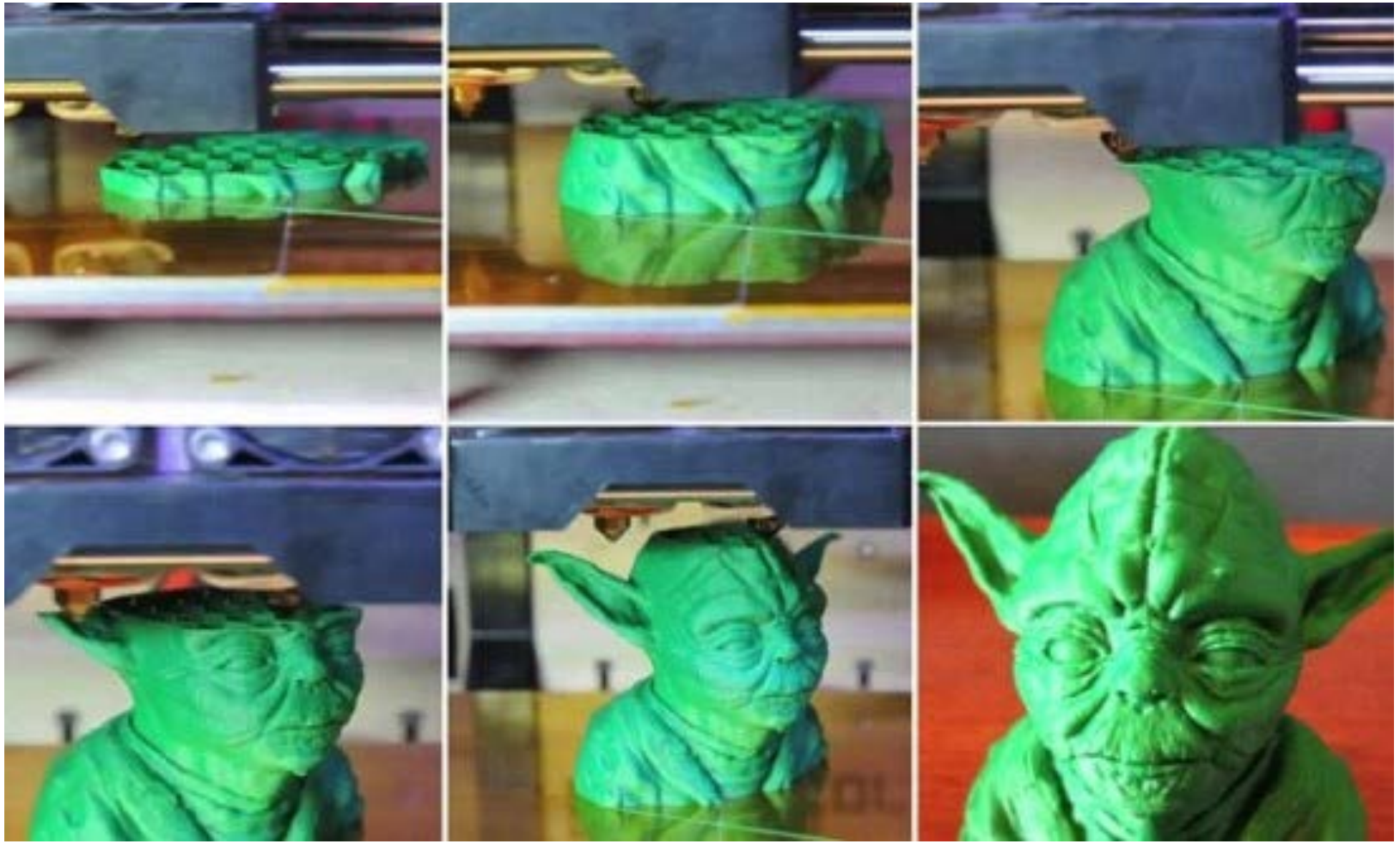
The basic idea

- Slicing objects into layers
- Making the object layer by layer

Never see a 3D printer?

3D printing is just around us…

Process of 3D printing: an example



Types of 3D printers (covered later)

Material of 3D printing

- Plastics
  - PLA
  - ABS
- Metals
  - Stainless steel
  - Sterling silver
- Glass
- Ceramics
- Resin
- Sandstone
- Rubber

Food!

However, 3D printing is not new…

- A type of manufacturing (fabrication) technologies
  - Has existed for over 20 years
- Also known as
  - Rapid prototyping
  - Additive manufacturing (AM)

Existing Manufacturing Technologies

Casting: equaled manufacturing

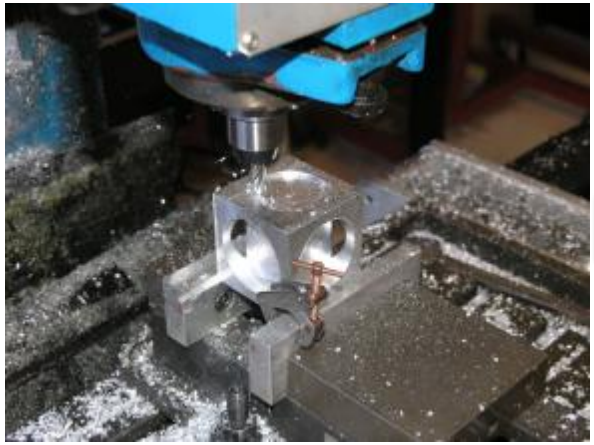
- Pour a liquid material into a mold and then solidify (3D printing employed to produce molds)
- History: over thousands of years

Forging: equaled manufacturing

- Shaping metal using localized compressive forces by a smith using a hammer
- History: over thousands of years

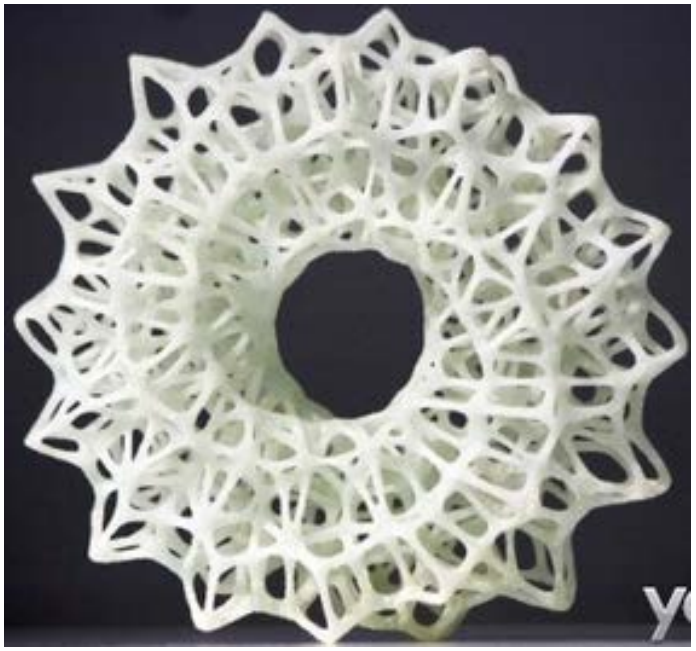
Modern CNC: subtractive manufacturing

- Cutting out material from a solid
- History: about 100 years (cannot produce hollows)



3D printing: additive manufacturing

- Can produce arbitrarily complex (either in geometry or in topology) objects
- History: less than 30 years (hollows: no problem)



Manufacturing technologies: comparison

Casting or forging

1000+ years

- Mold is expensive
- Cannot be complex

CNC

100 years

- Waste of material
- Cannot be complex

3D printing

20+ years

- No waste of material
- Can be arbitrarily complex

Advantages and Disadvantages of 3D Printing Technology

Advantages

(relative)

- Quick production of prototypes
- Less waste
- New shapes and structures
- New combinations of materials

Disadvantages

- Slow printing speed
  - Over hours
- Not available for batch manufacturing
  - Better for customized manufacturing — like printing of molds
- Size limitations
  - Need larger printers in the future
- Raw material limitations
  - Mixed material will be developed

3D printing: a new manufacturing tech.

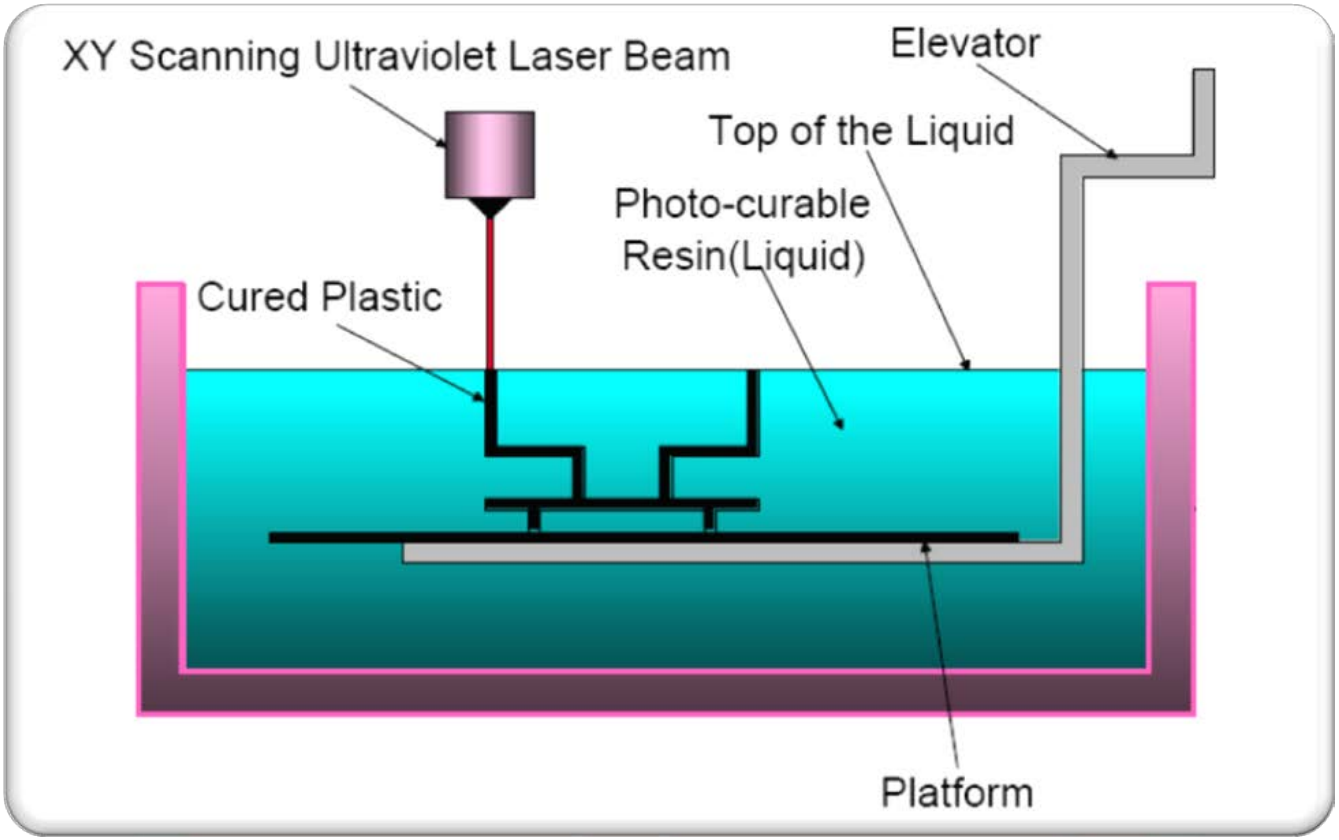
- Do not replace other manufacturing technologies
- A complement to modern manufacturing

- Quick prototyping
- Customized manufacturing
- Complex shapes

Four Types of AM – Different Principles

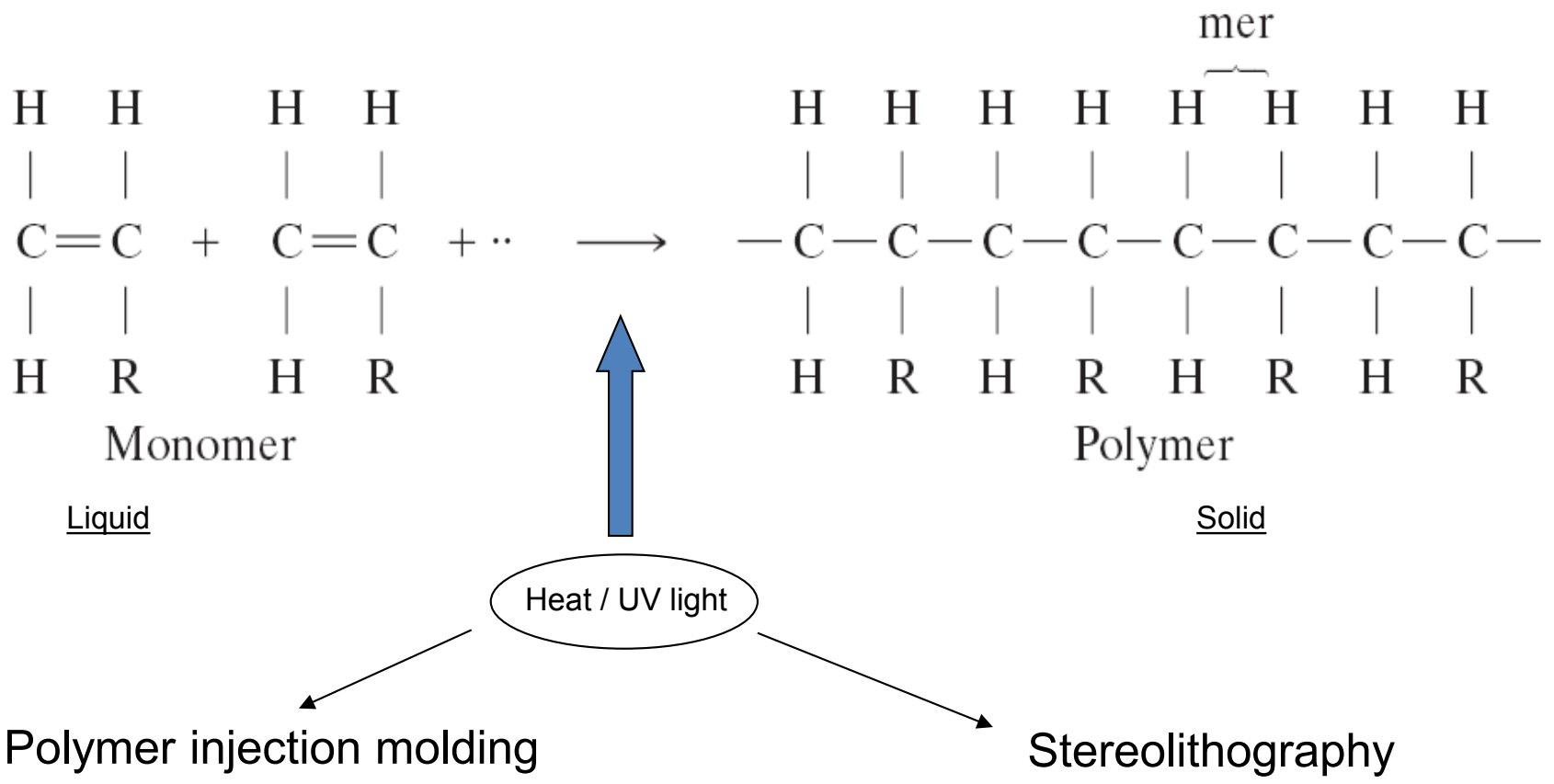
- Lasers:
  - Stereolithography Apparatus (SLA)
  - Selective Laser Sintering (SLS)
- Nozzles:
  - Fused Deposition Modeling (FDM)
- Printheads:
  - Multi-jet Modeling (MJM)
  - Binder-jet Printing (3DP)
- Cutters:
  - Laminated Object Modeling (LOM)

Stereo Lithography Apparatus (SLA)

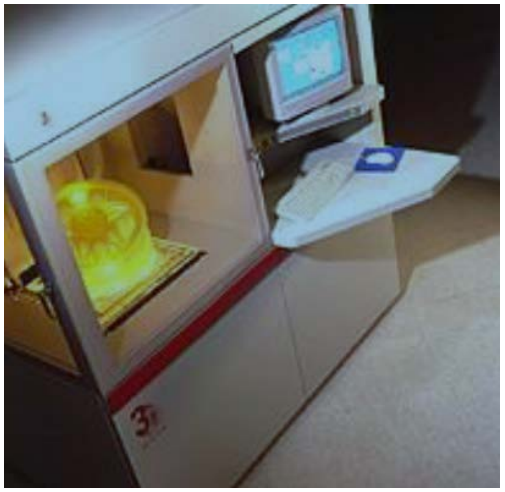


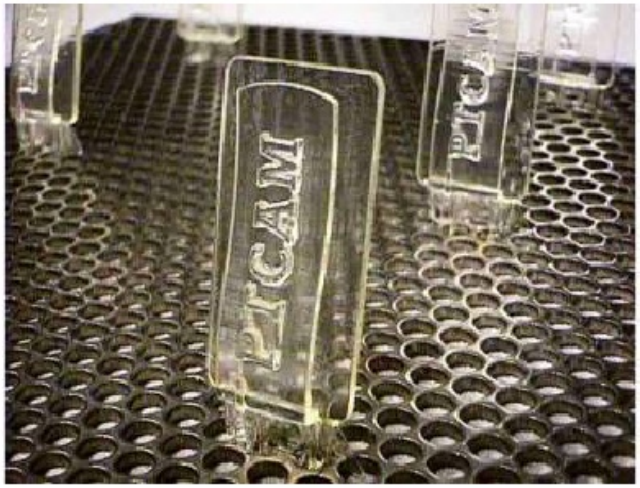
- Introduced in 1984 by *Charles Hull* who founded 3D Systems Inc.
- The first commercial Solid Freeform Manufacturing process;
- Based upon the use of an ultraviolet laser which is used to solidify a photocurable liquid polymer.

Monomer and Polymer

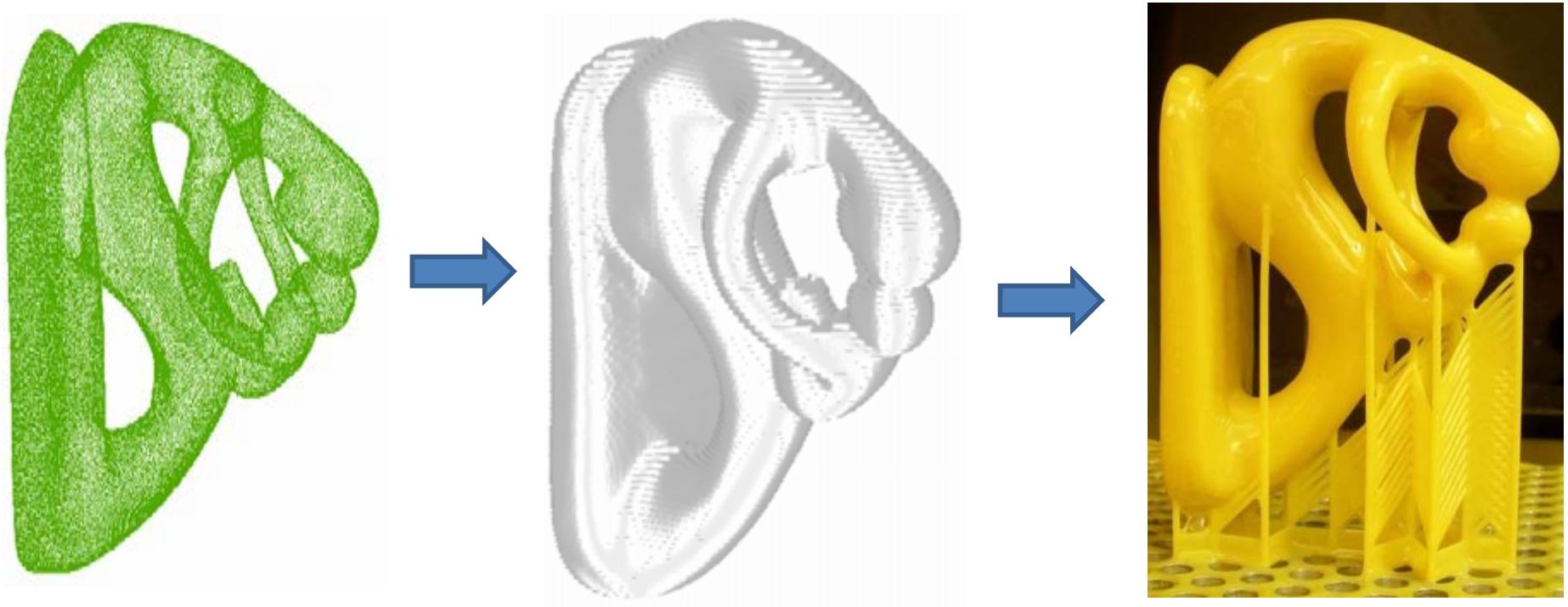


Example Parts





Support Generation Example



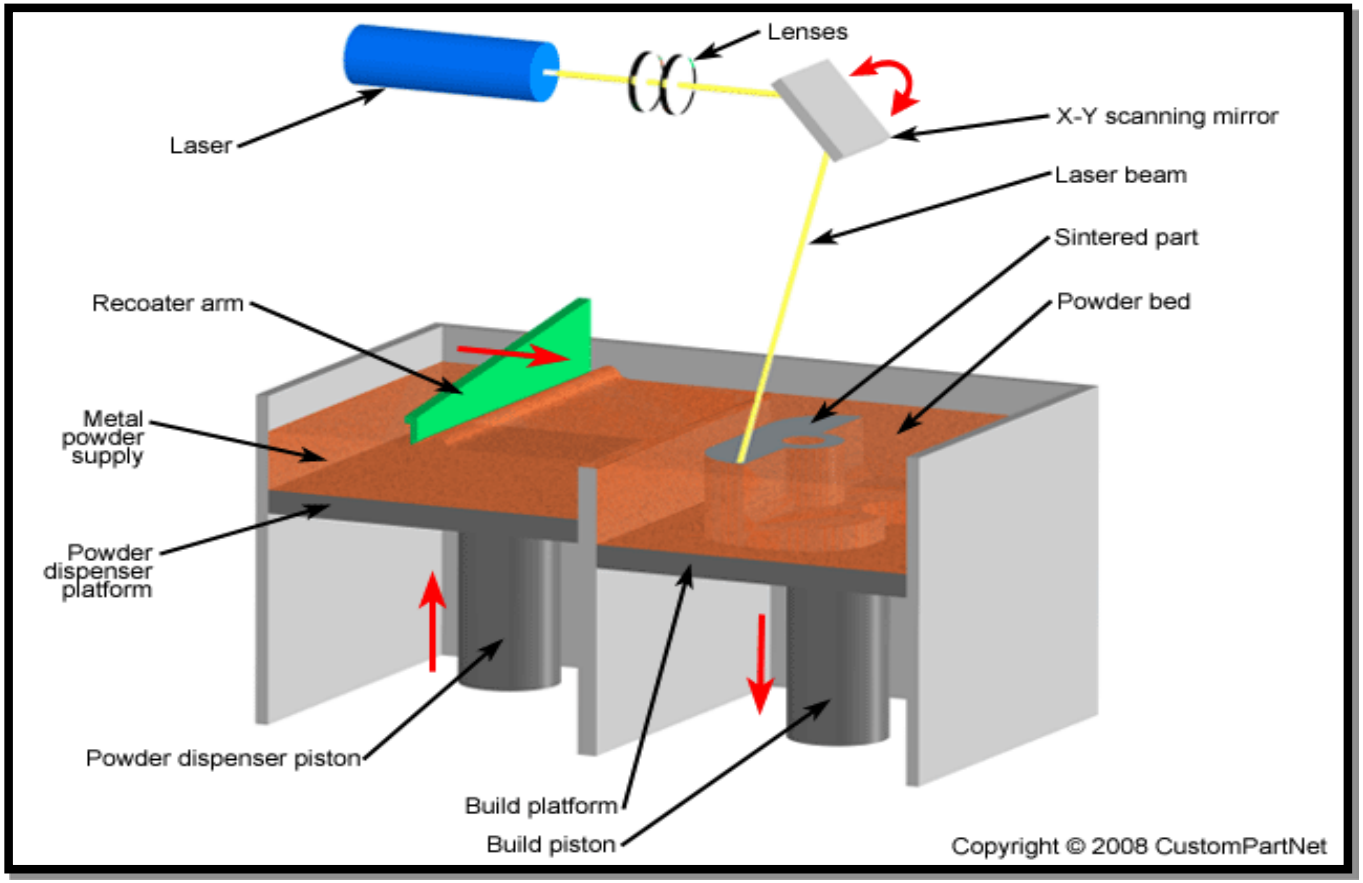
Point cloud

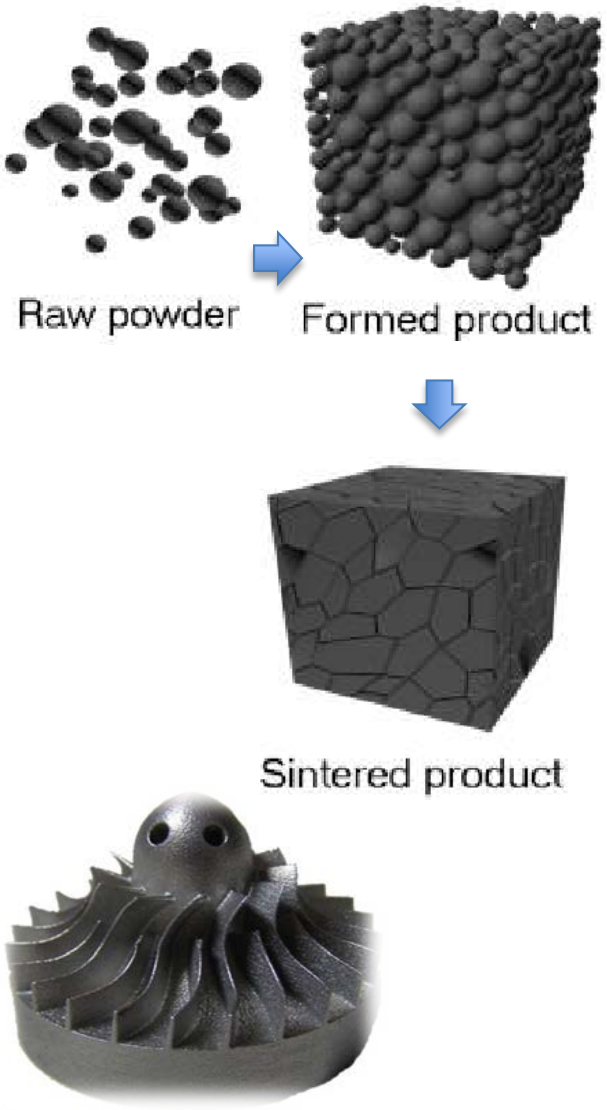
Sliced model

Fabricated Object

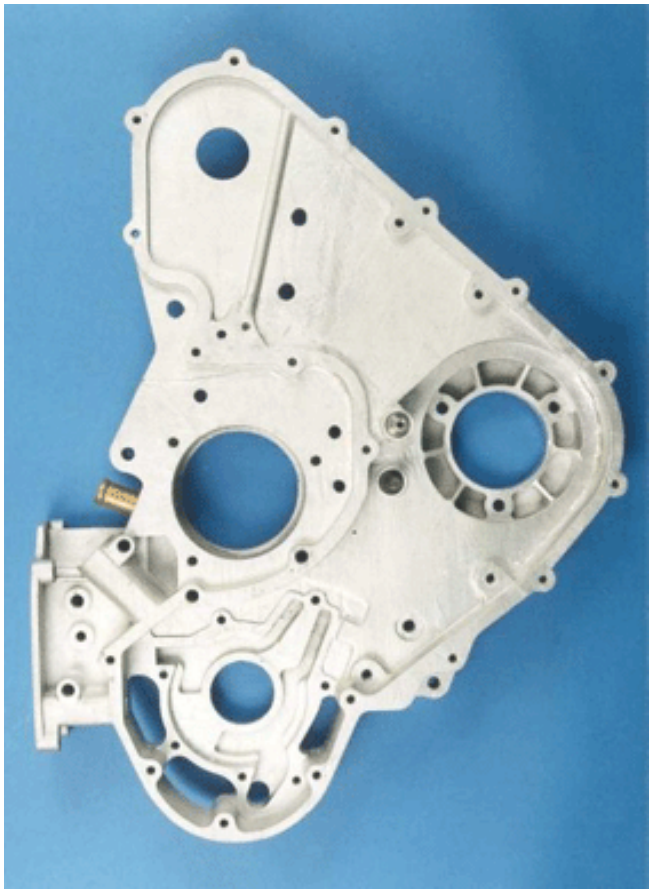
By Yong Chen (University of Southern California)

Selective Laser Sintering/Melting





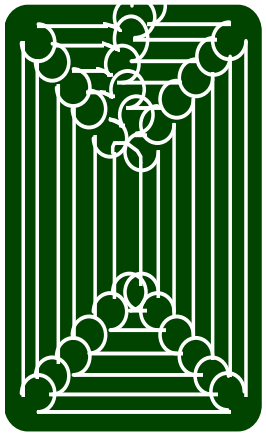
Models Fabricated by SLS

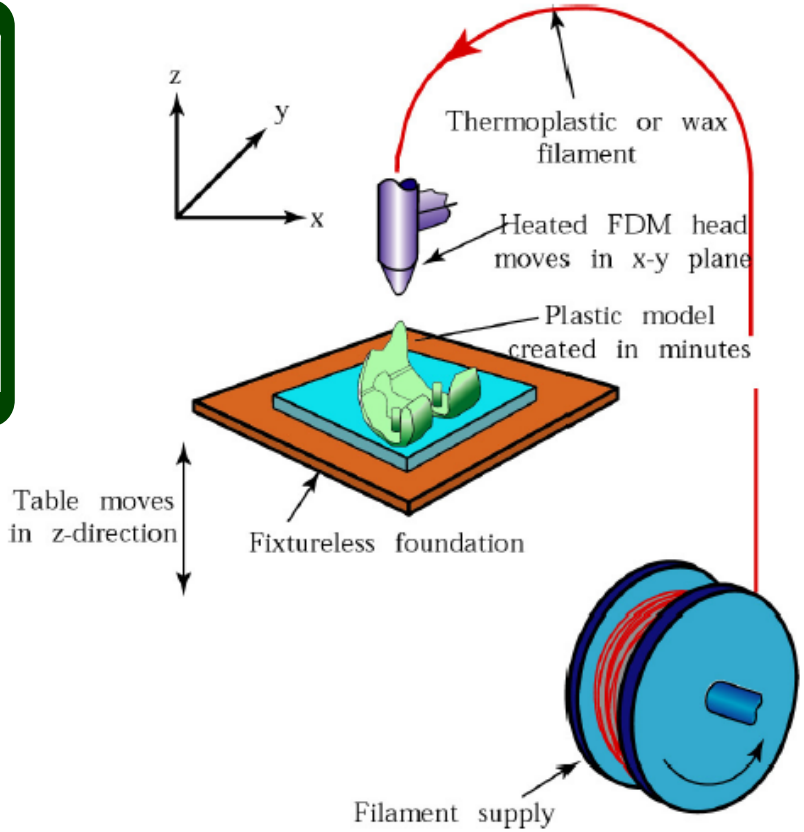


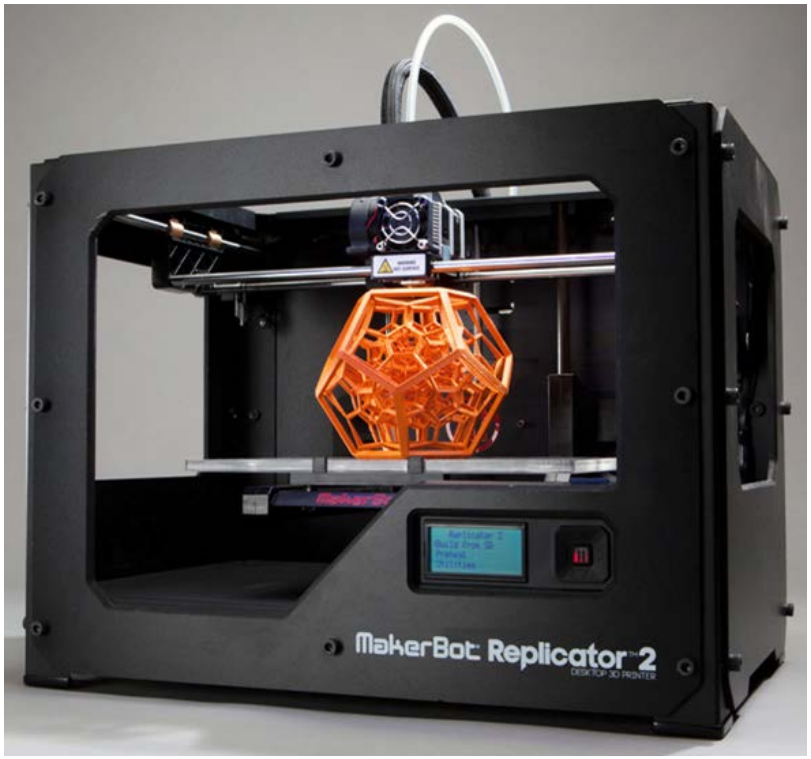
Metal Part by SLS

Polymer Part by SLS

Fused Deposition Modeling





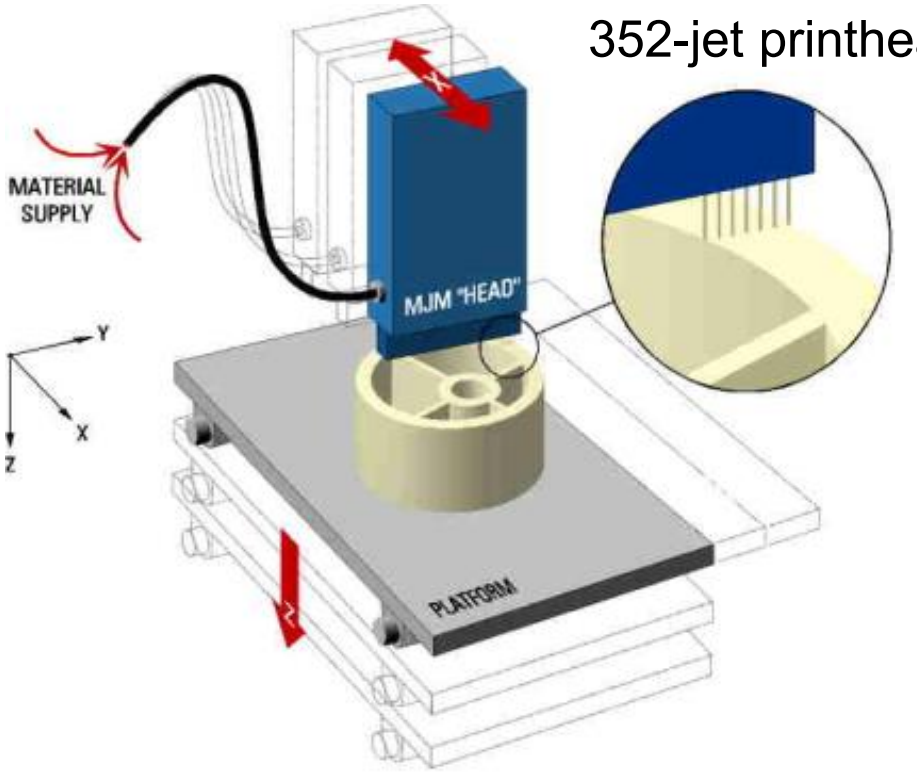


- Introduced in 1988 by *Scott Crump* who founded *Stratasys*
- The best-selling Rapid Prototyping technology in terms of installation number

Multi-Jet Modeling

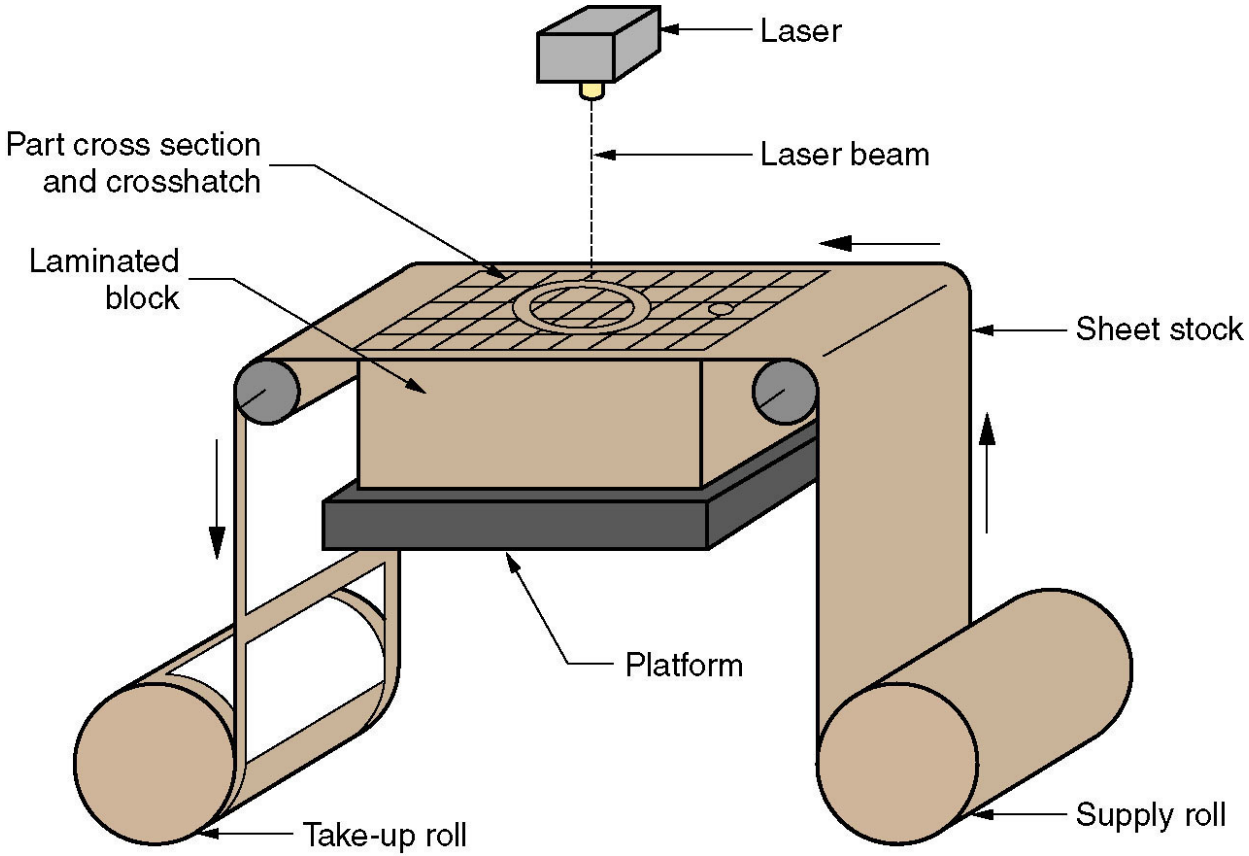
Jetting of photopolymer in desired space, which is then cured by a flash of UV light

352-jet printhead



Material Deposition

Laminated Object Manufacturing



Stacking layers of sheet stock, each an outline of the cross-sectional shape of a CAD model.

Starting material is sheet stock, such as paper, plastic, cellulose, metals, or fiber-reinforced materials.

Applications of 3D Printing

Why 3D Printers Become Popular?

- Many patents are expired
  - Protected → Open sources
- Prices are decreasing
  - Thousands of dollars → Hundreds of dollars
- Sizes are reducing
  - Industry oriented → Home oriented (desktop)
- More and more applications
  - …

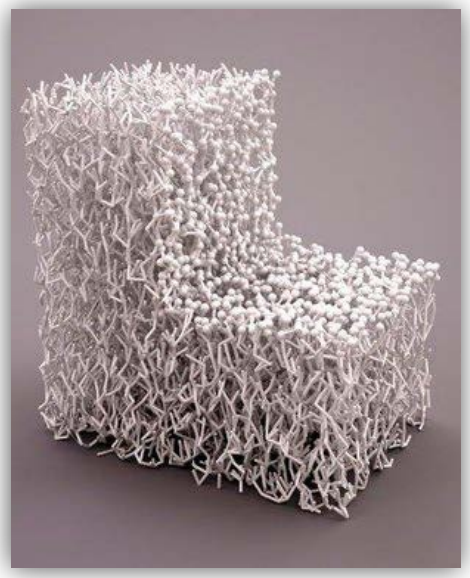
Application: Industrial design

Application: Fashion design

Application: Education

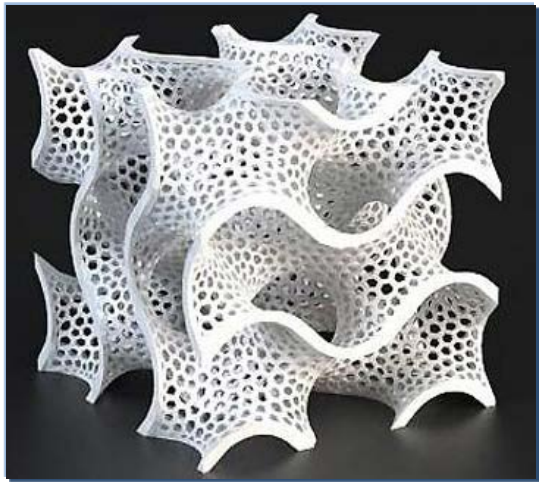
Application: Toys

Applications: Decorations



Application: Food

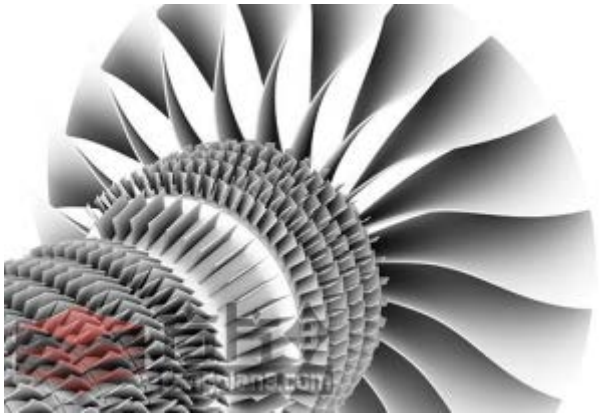
Application: Art



Application: Medical treatment

Application: Heritage

Application: Aerospace

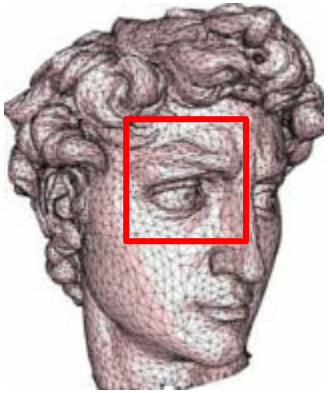


Application: Architecture

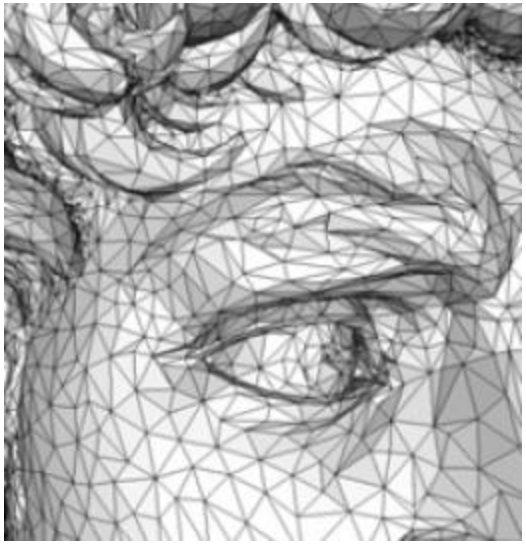
Researches in 3D Printing

Input models for 3D printing

- *.STL: Standard Tessellation Language
- Mesh file format created by 3D Systems
  - Either in ASCII or in binary
- Unstructured triangular surface



```
facet normal n_i n_j n_k
    outer loop
        vertex v1_x v1_y v1_z
        vertex v2_x v2_y v2_z
        vertex v3_x v3_y v3_z
    endloop
endfacet
```



3D printing **engine**

Geometric computation

Research Fields in 3D Printing: 3M

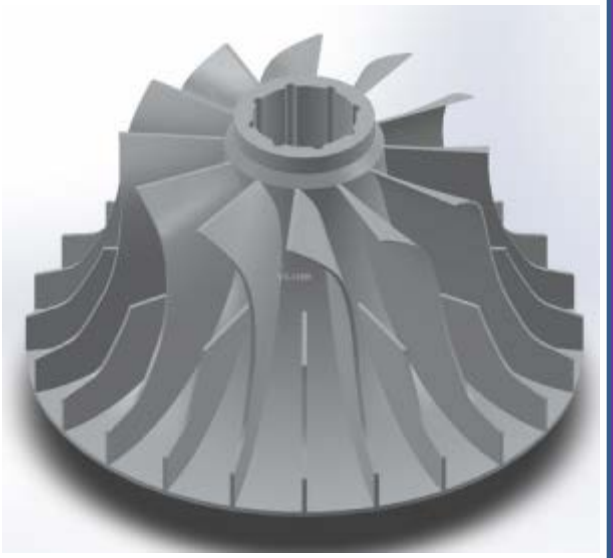
Machine

- SLS
- SLA
- FDM
- 3DP

Material

- Plastics
- Resin
- Ceramics
- Metals

Modeling



- Modeling
- Processing
- Computation
- Optimization

Mechanical control

Material science

Computer graphics

Traditional modeling **VS** Modeling for fabrication

- For rendering or animation
- Smooth surfaces
- Virtual objects
- Non-physical

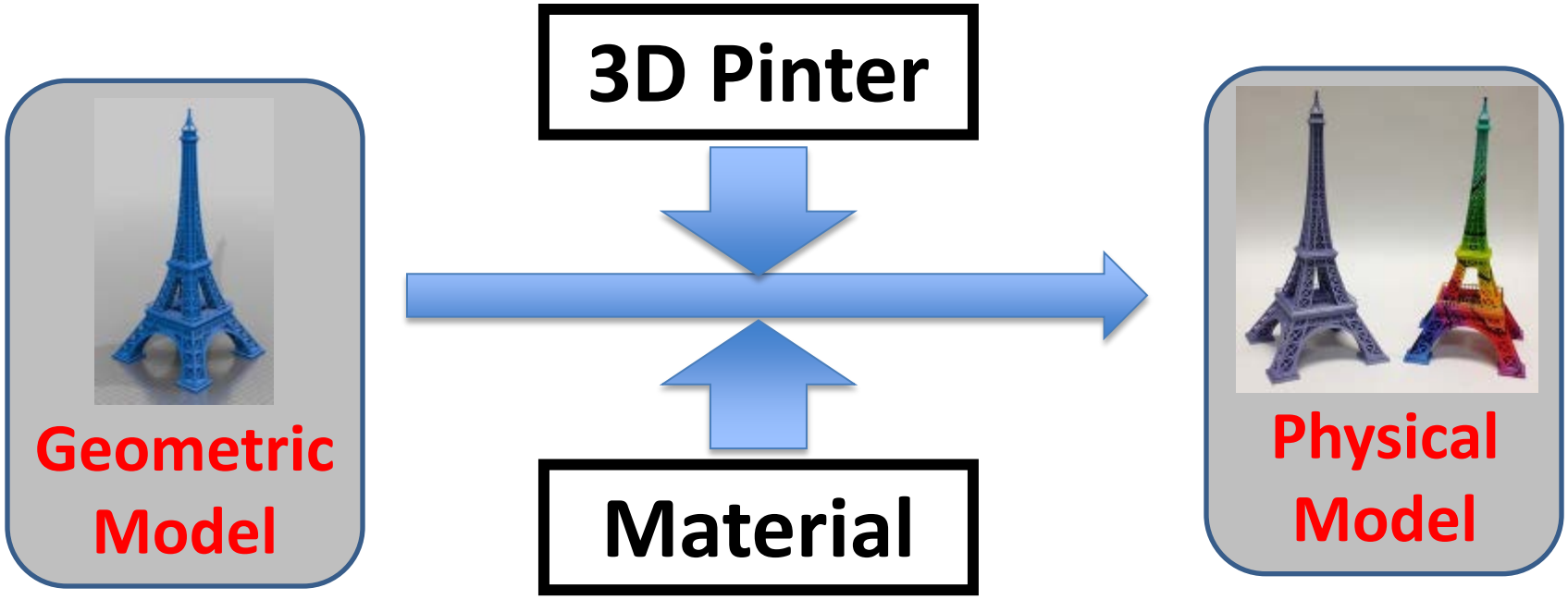
- For fabrication
- Complex volumes
- Real objects
- Physical properties

Fabrication-oriented Design
(Design for Additive Manufacturing)

Given printing machine and material,

how to optimizing geometries and its computing to gain highest performance?

Computational Issues



What are the computational issues?

Computational Issues

Printing engine

3D Pinter

Geometric Model

Physical Model

Material

Geometric design and optimization

Appearance control

Physical-driven structural optimization

Computational Issues

Printing engine

3D Pinter

Geometric Model

Physical Model

Material

Geometric design and optimization

Appearance control

Physical-driven structural optimization

Printing engine

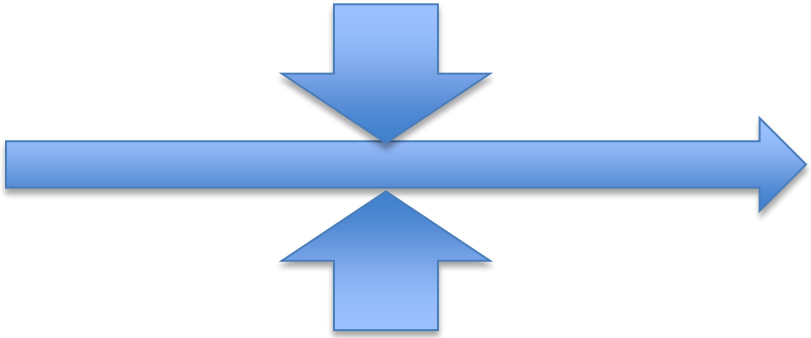
- Slicing
- Support structure
- Numerical robustness

Computational Issues

Printing engine

3D Pinter

Geometric Model



Material

Physical Model

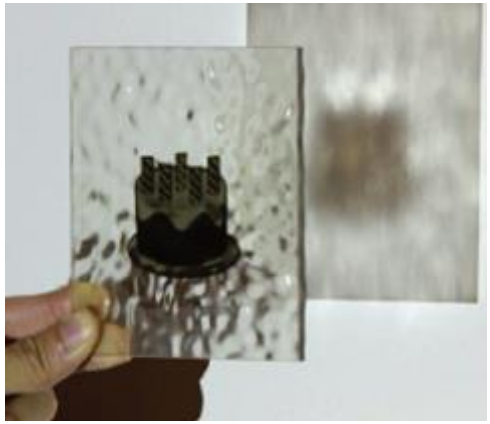
Geometric design and optimization

Appearance control

Physical-driven structural optimization

Appearance control

- Texture and BRDF
- Subsurface scattering
- Caustics



Computational Issues

Printing engine

3D Pinter

Geometric Model

Physical Model

Material

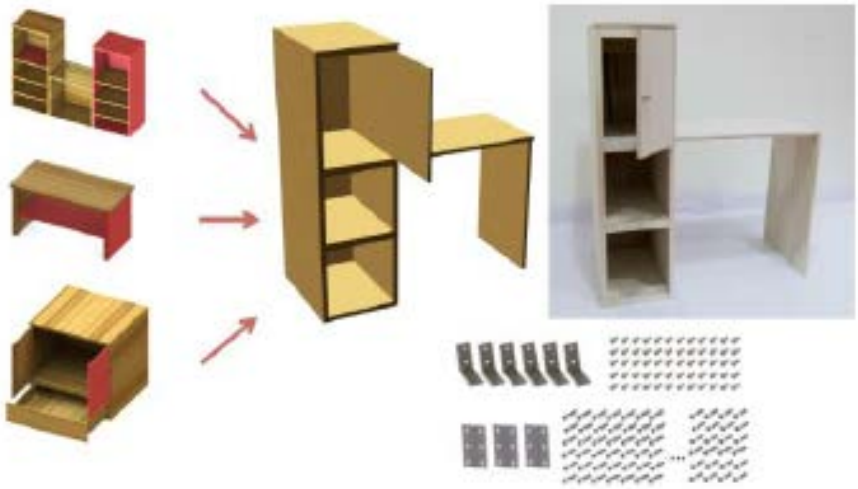
Geometric design and optimization

Appearance control

Physical-driven structural optimization

Geometric design and opt.

- Simple tools for designing
- Motion modeling
- Fabrication by example



Computational Issues

Printing engine

3D Pinter

Geometric Model

Material

Physical Model

Geometric design and optimization

Appearance control

Physical-driven structural optimization

Structural optimization

- Physical loads
- Analyze structure
- Apply corrections