CS354 Computer Graphics
3D Printing

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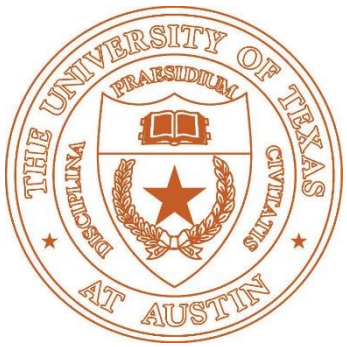
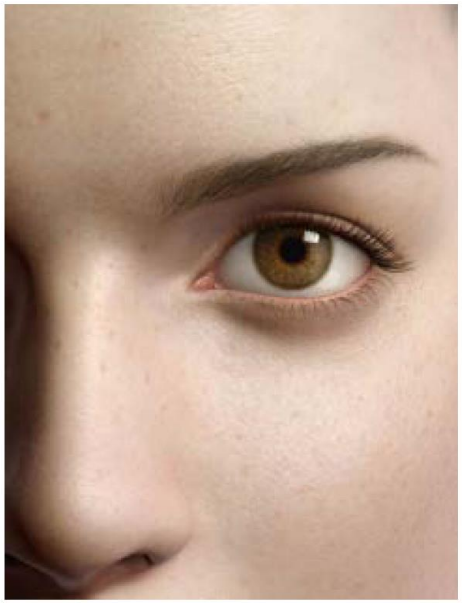


3D Graphics

- (from Wikipedia) 3D computer graphics are graphics that use a 3D representation of geometric data for the purposes of performing calculations and rendering 2D images

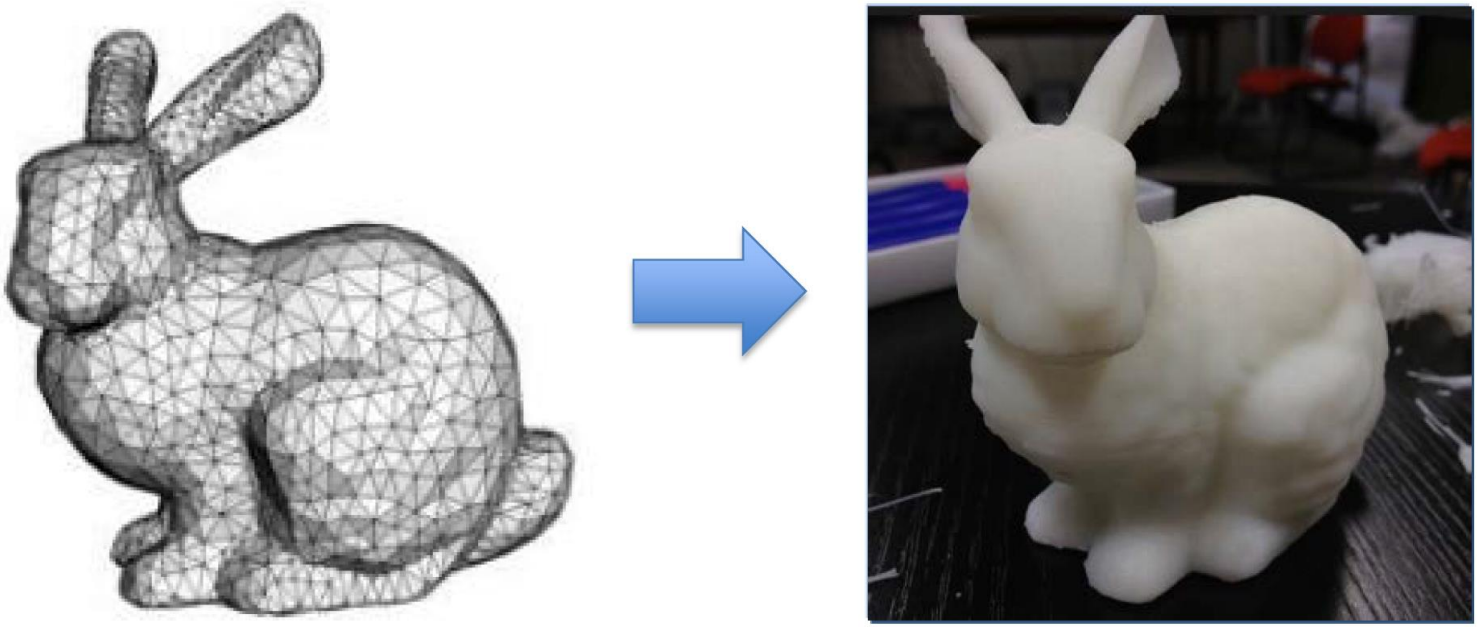


Printing

- (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



The basic idea

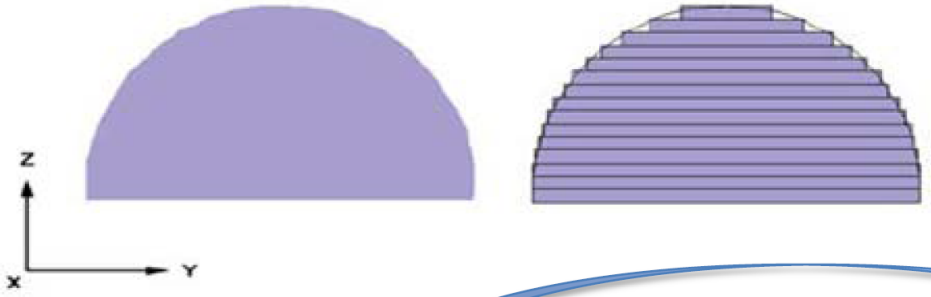
- Slice objects into layers
- Making the object layer by layer

Never see a 3D printer?

3D printing is just around us

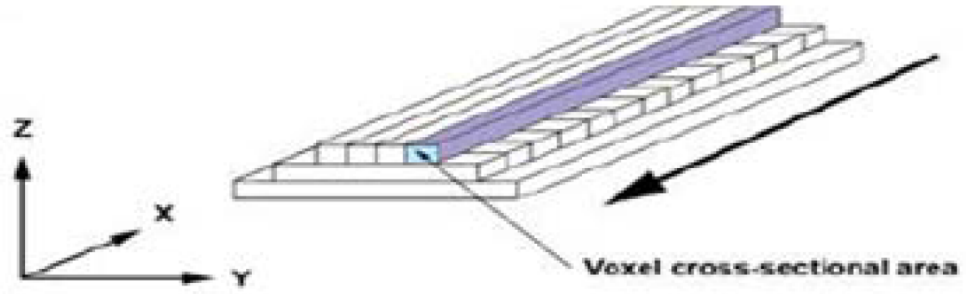
Process of 3D printing

- "Differential"
  - Slice an object into thin layers

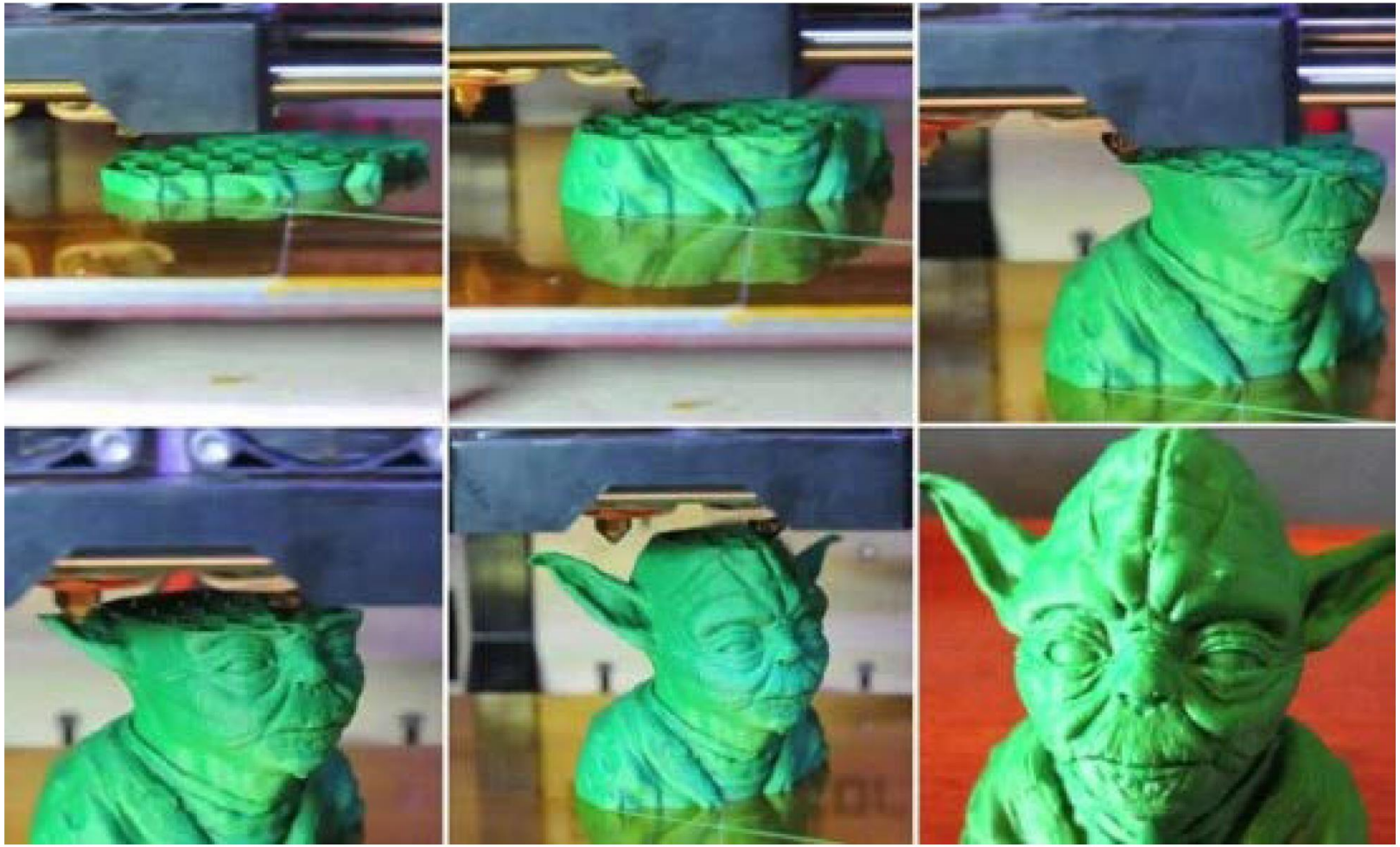


- "Integral"
  - Build layers with 'ink' and glue them together

Row material!



Process of 3D printing: an example



Types of 3D printers

Types of 3D printers

Material of 3D printing

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

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
- History: over thousands of years

Forging: equaled manufacturing

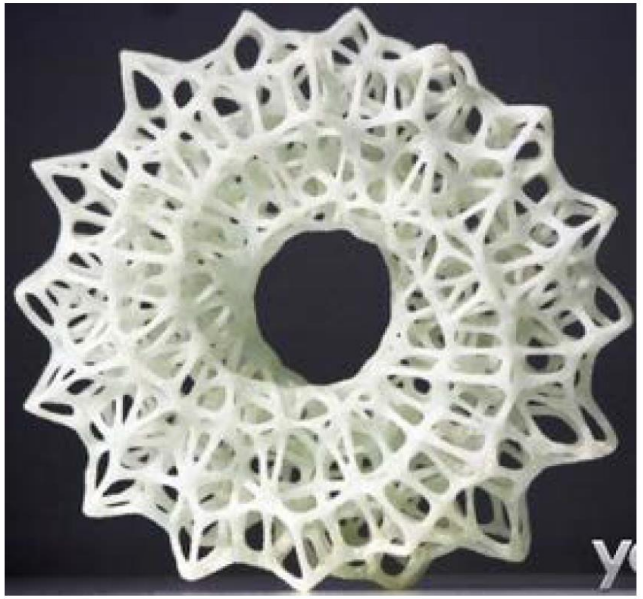
- Shaping metal using localized compressive forces by a smith using a hammer
- History: over thousands of years

Modern CNC: subtractive manufacturing

- Cutting out material from a solid
- History: about 100 years

3D printing: additive manufacturing

- Can produce arbitrary complex (either in geometry or in topology) objects
- History: less than 30 years



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

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

Disadvantages

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

3D printing: a new manufacturing tech.

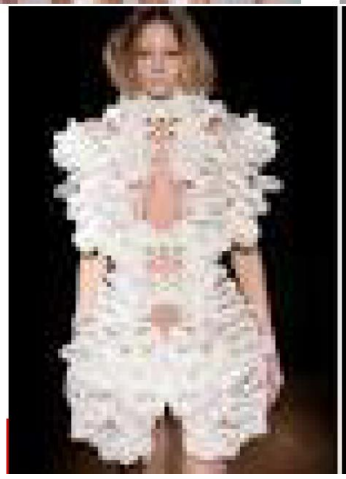
- Do not replace other manufacturing technologies
- A supplement to modern manufacturing

- Quick prototyping
- Customized manufacturing
- Complex shapes

Applications of 3D Printing

Application: Industrial design

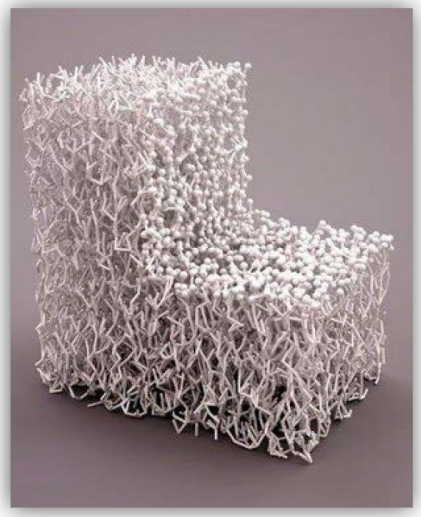
Application: Fashion design



Application: Education

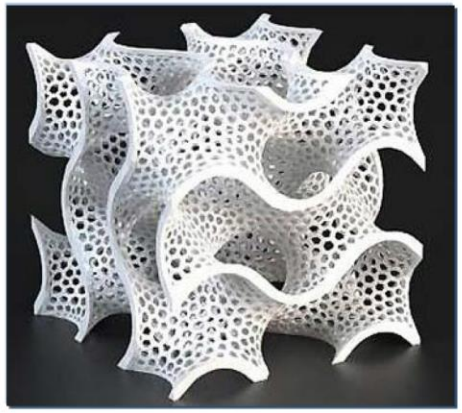
Application: Toys

Applications: Decorations



Application: Food

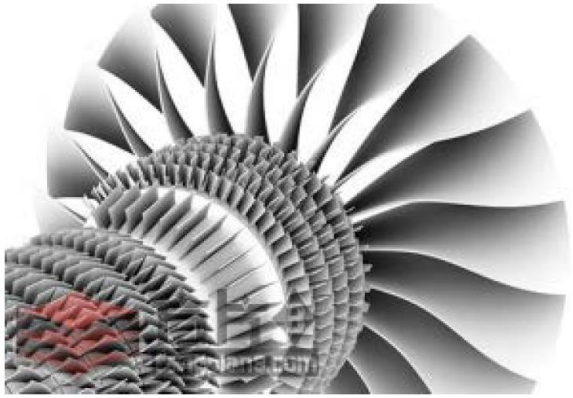
Application: Art



Application: Medical treatment

Application: Heritage

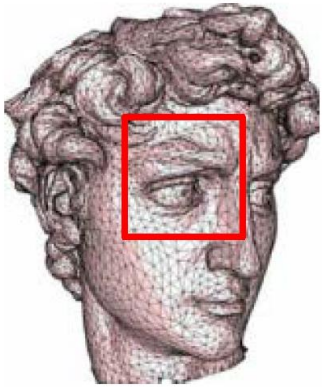
Application: Aerospace



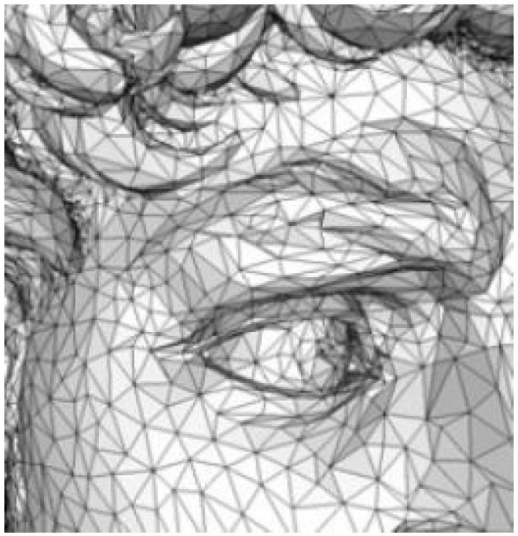
Application: Architecture

Input models for 3D printing

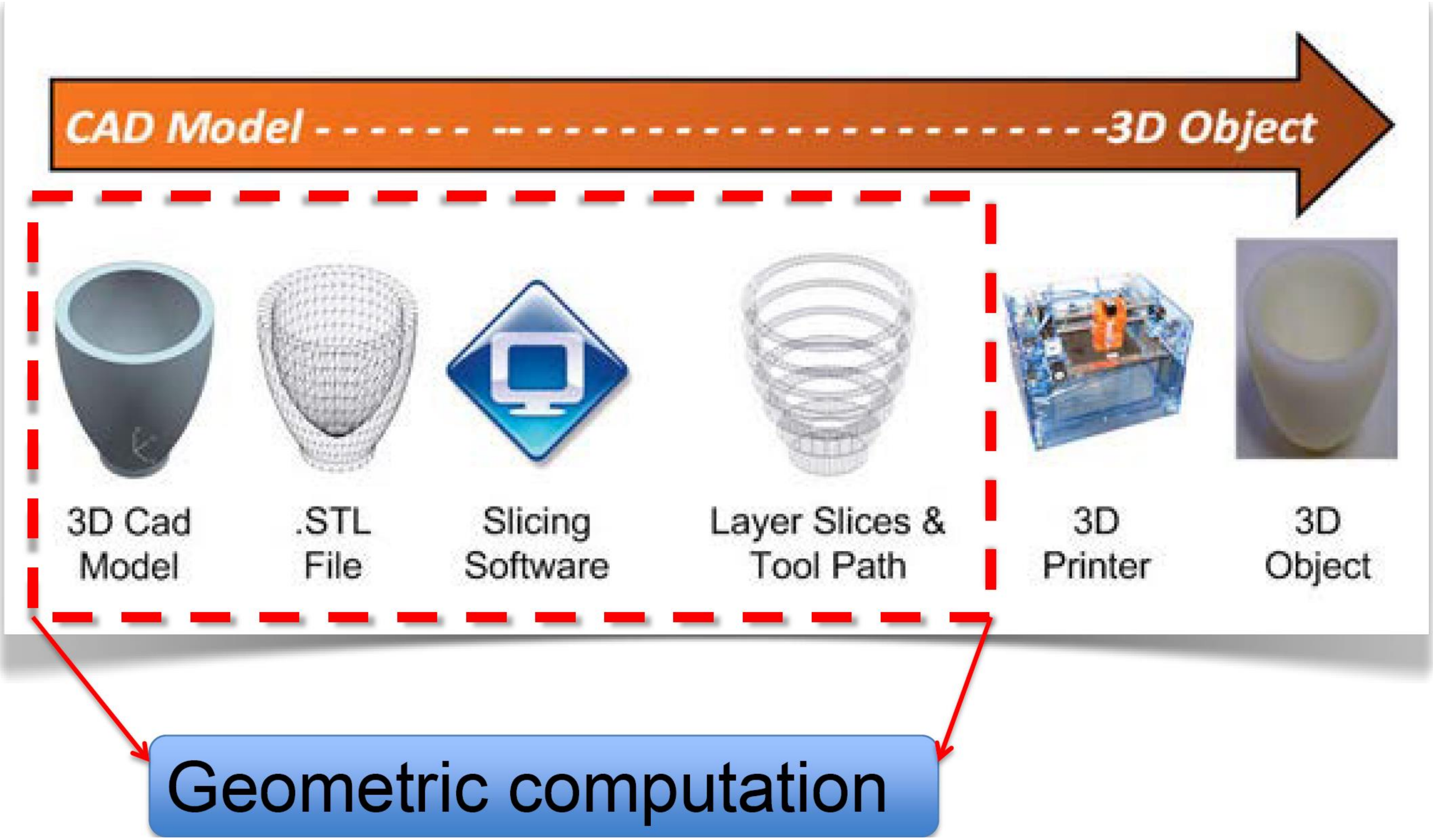
- *.STL: Standard Tessellation Language
- Mesh file format created by 3D Systems
  - Either in ASCII or in binary
- Unstructured triangular surface



```
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



Research Fields in 3D Printing

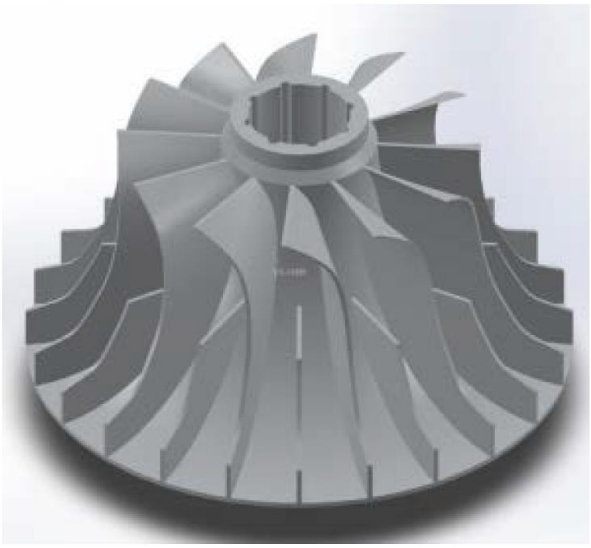
Machine

- SLS
- SLA
- FDM
- 3DP

Material

- Plastics
- Resin
- Ceramics
- Metals

Modeling



- Modeling
- Processing
- Computation
- Optimization

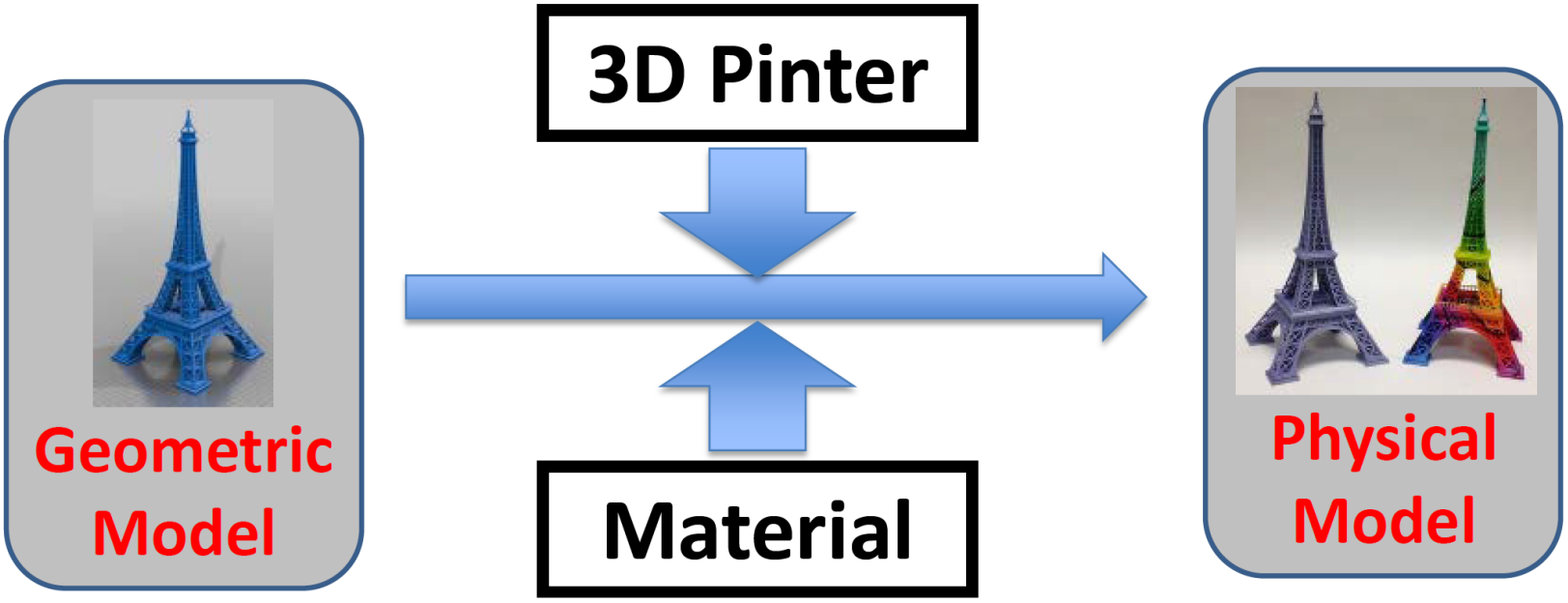
3D Modeling for Fabrication

- Traditional modeling
  - For rendering
  - Smooth surfaces
  - Virtual objects
  - Non-physical
- Modeling for fabrication
  - For fabrication
  - Complex volumes
  - Real objects
  - Physical properties

Fabrication-oriented Design

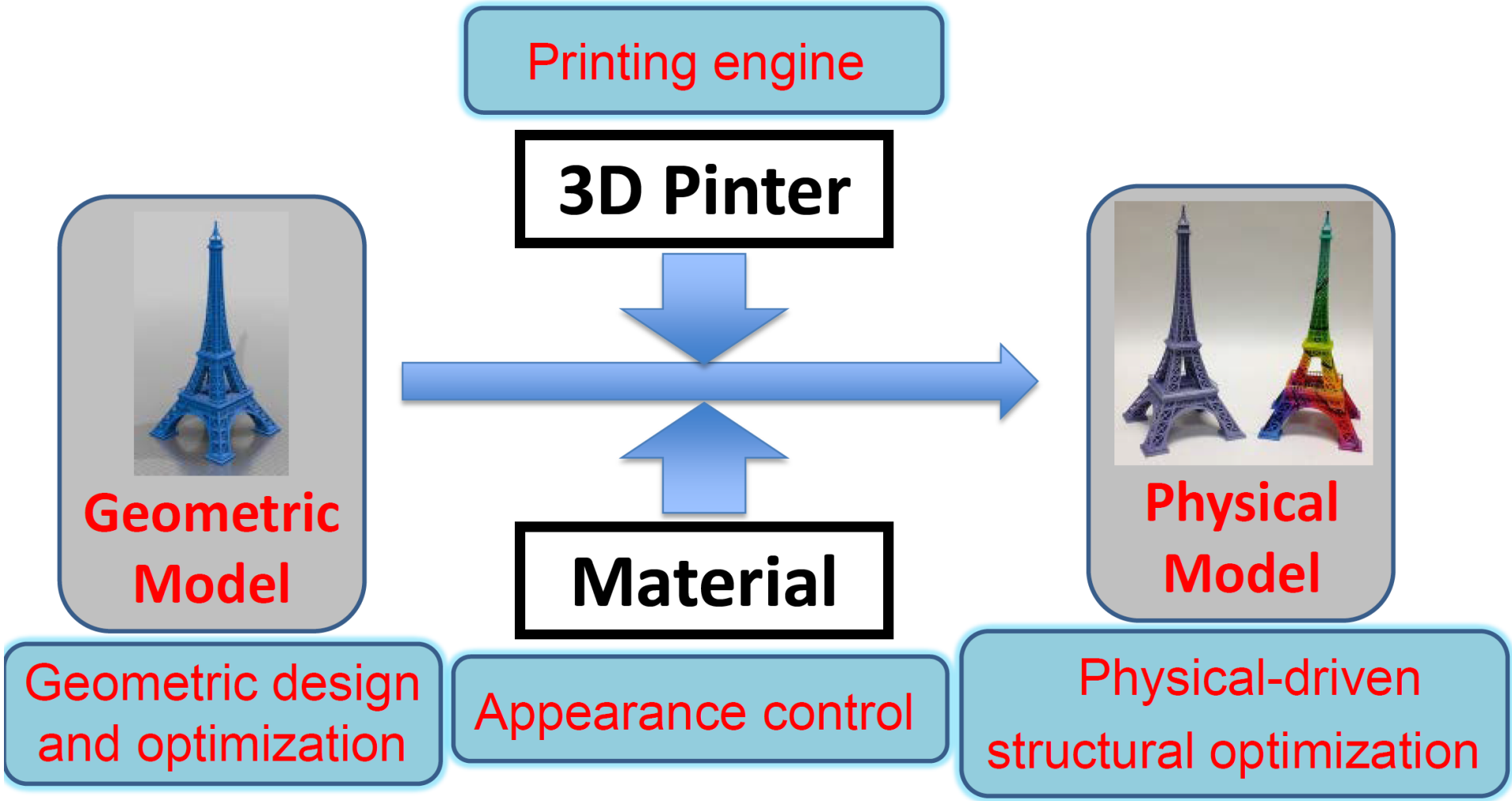
- Given printing machine and material, how to optimize geometries and computational cost

Computational Issues



What are the computational issues?

Computational Issues

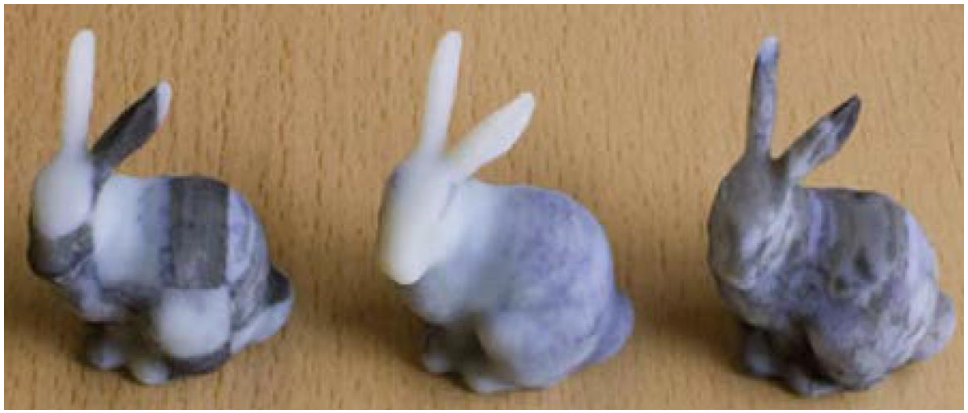


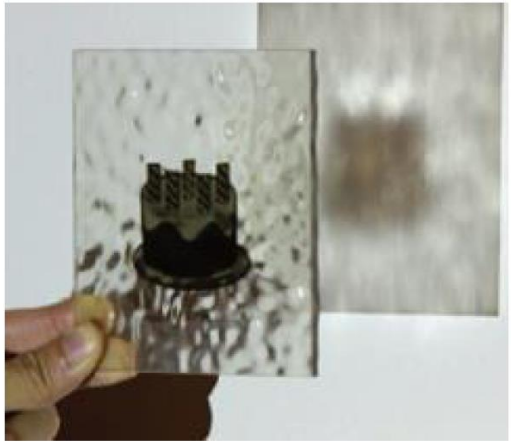
Printing engine

- Slicing
- Support structure
- Numerical robustness

Appearance control (Arik)

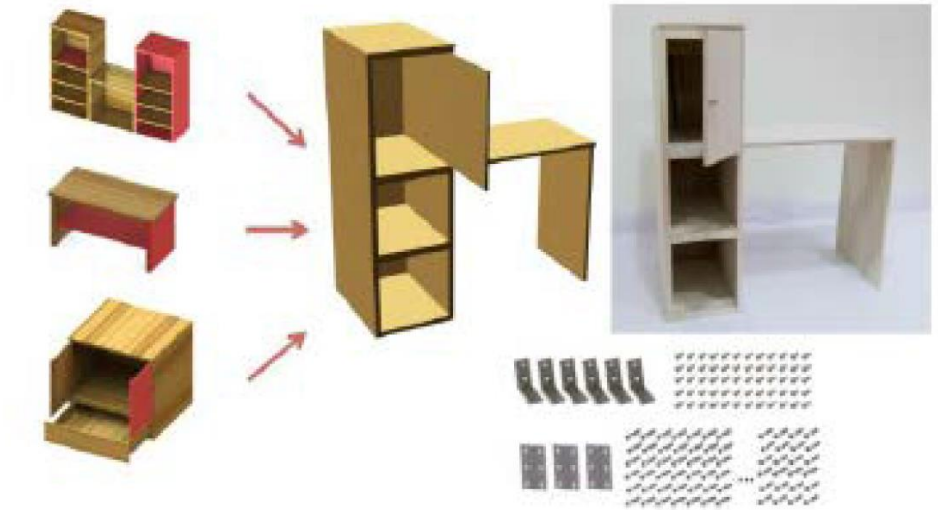
- Texture and BRDF
- Subsurface scattering
- Caustics





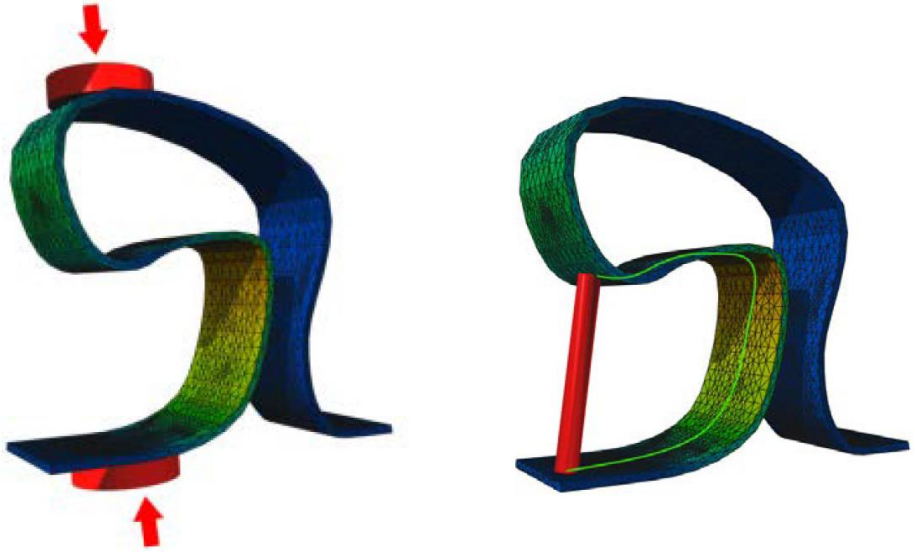
Geometric design and opt.

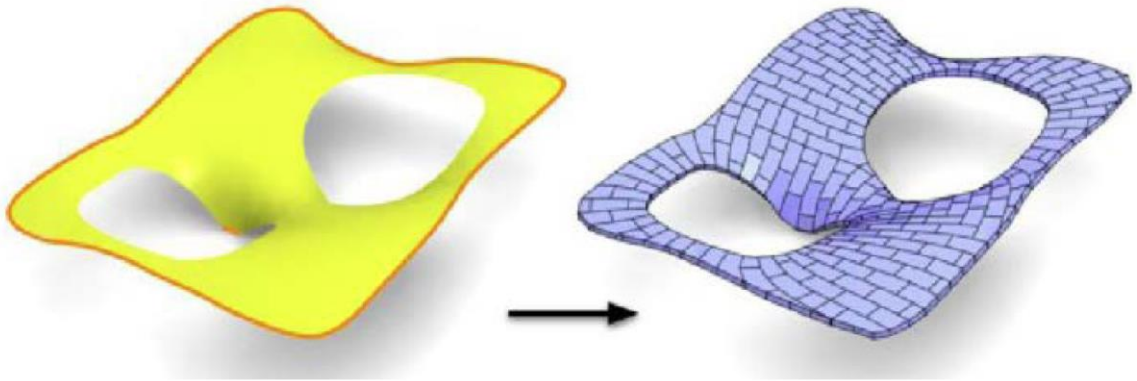
- Simple tools for designing
- Motion modeling
- Fabrication by example



Structural optimization

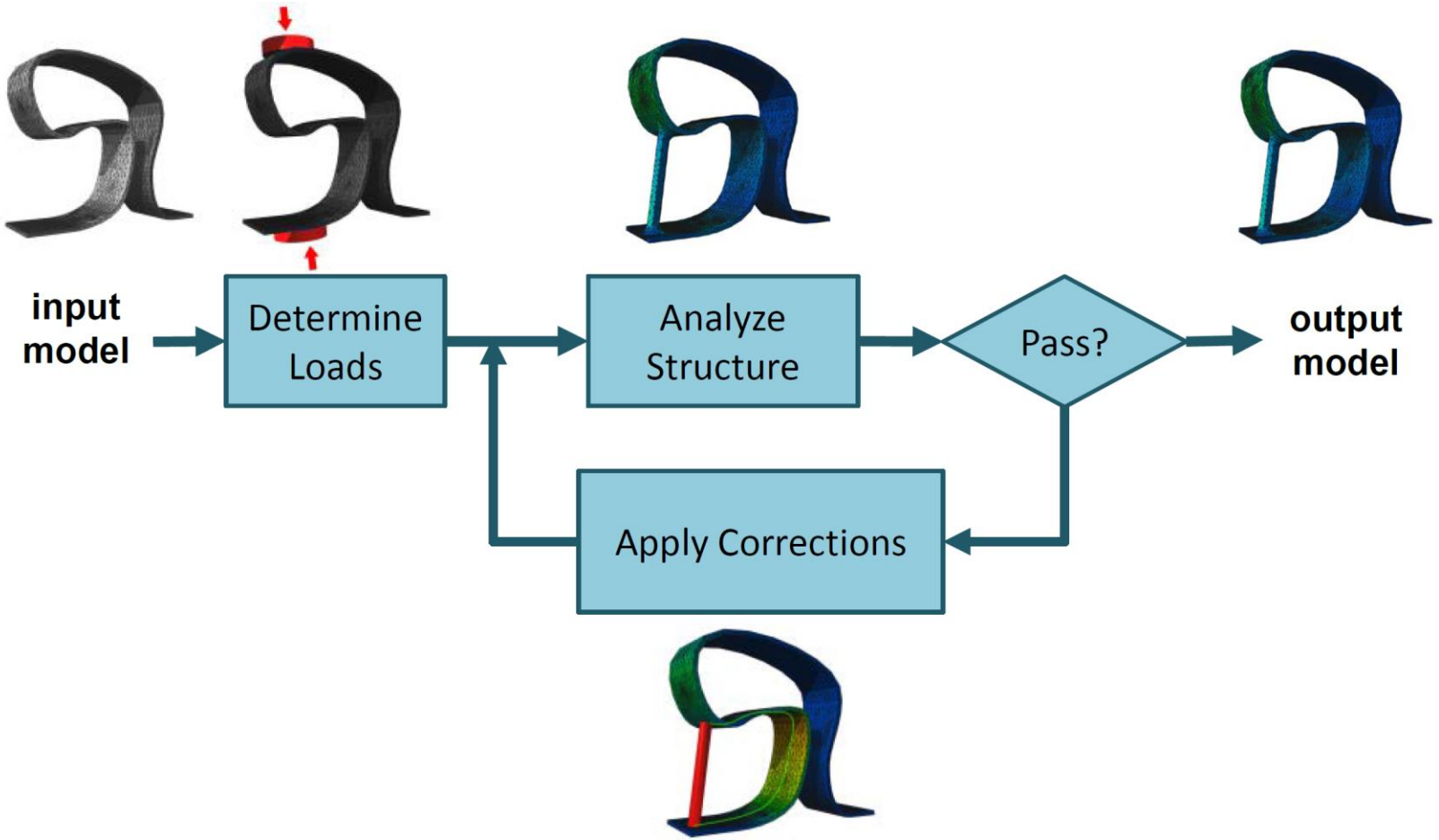
- Physical loads
- Analyze structure
- Apply corrections





Structural optimization

[Stava et al. 12]



Discussion