

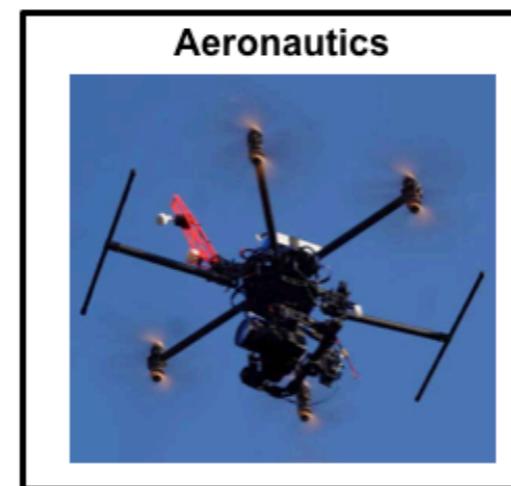
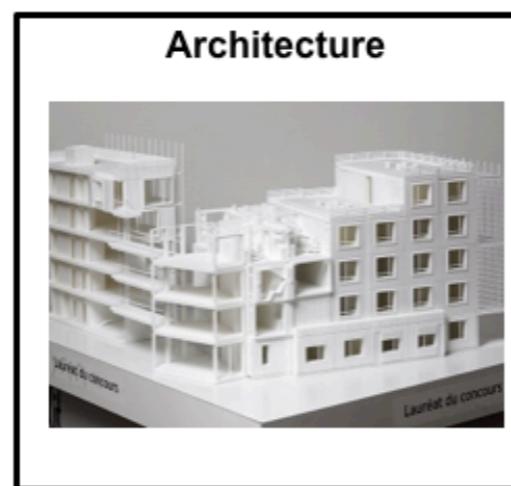
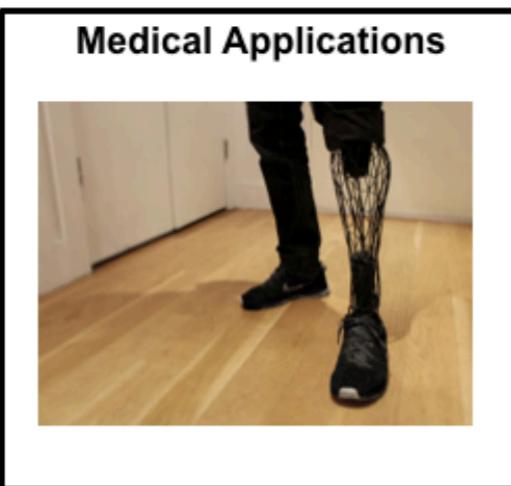
3D PRINTING

Eunsun Lee
eunsunlee@g.ucla.edu



3D Printing

- Fabrication methods used to print 3D objects, by depositing material layer by layer



Sagrada Família

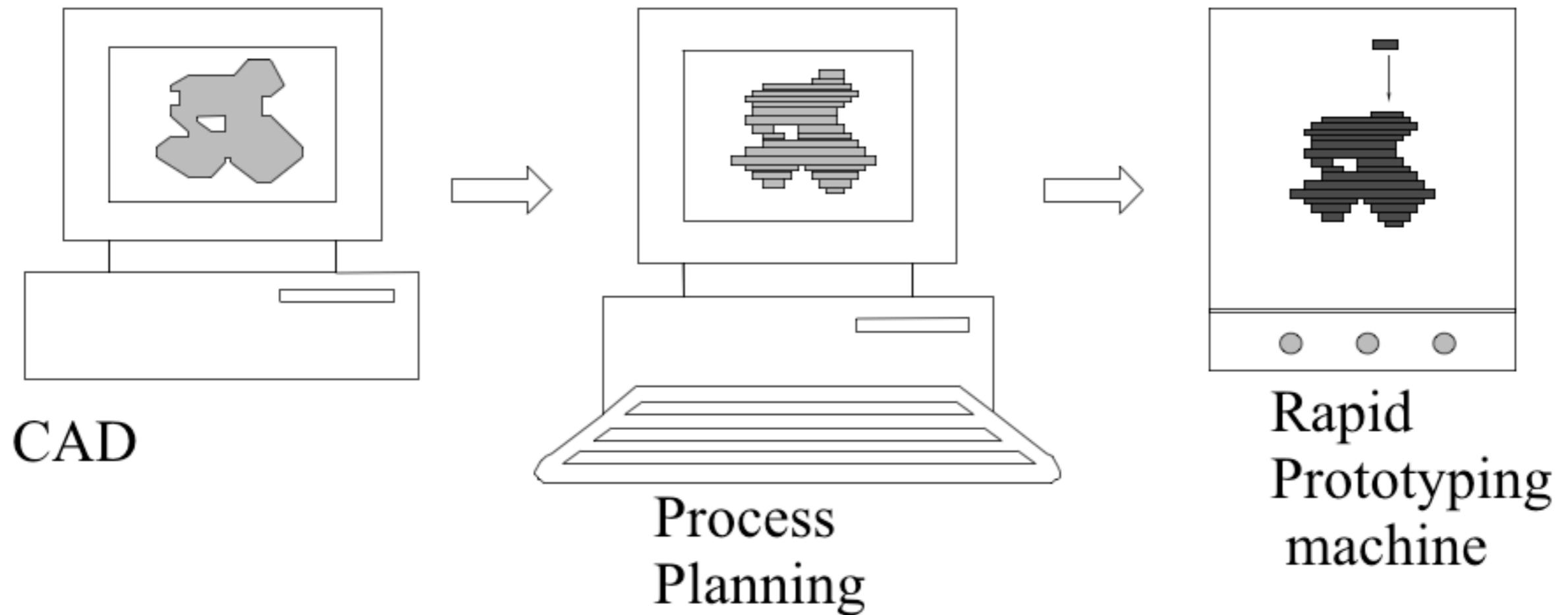


Why 3D Printing?

- Fast turn-around
- Cost-effective!

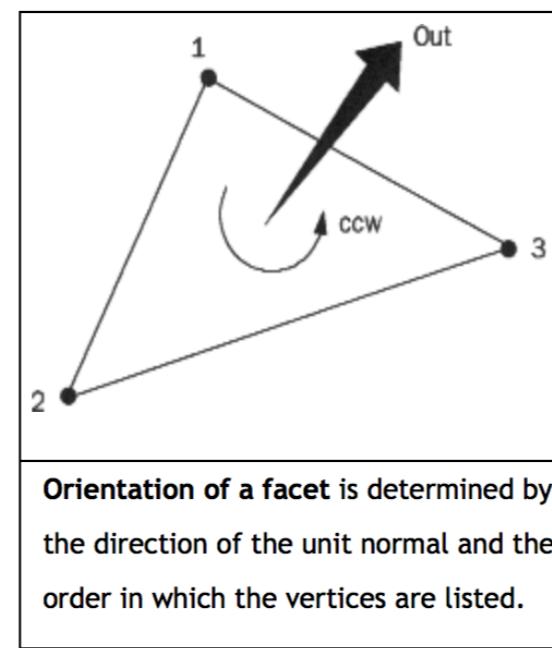
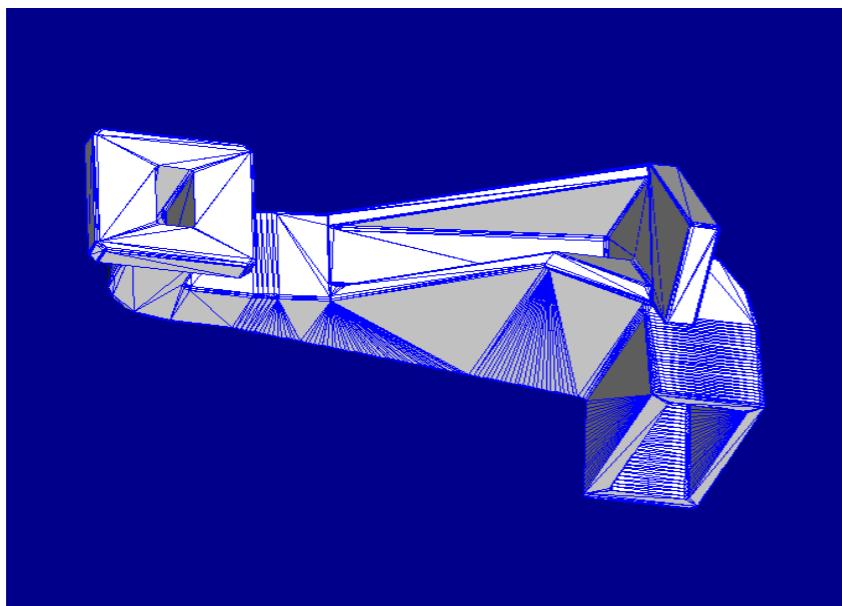
What is 3D printing flow like?

- a.k.a Rapid prototyping (RP), Layered Manufacturing (LM)



Object representation: .STL file

- STL: STereoLithography
- Representation of the surface geometry of a 3D object
- Triangles
 - For each triangle: X, Y, Z coordinates of the three vertices, and the surface normal



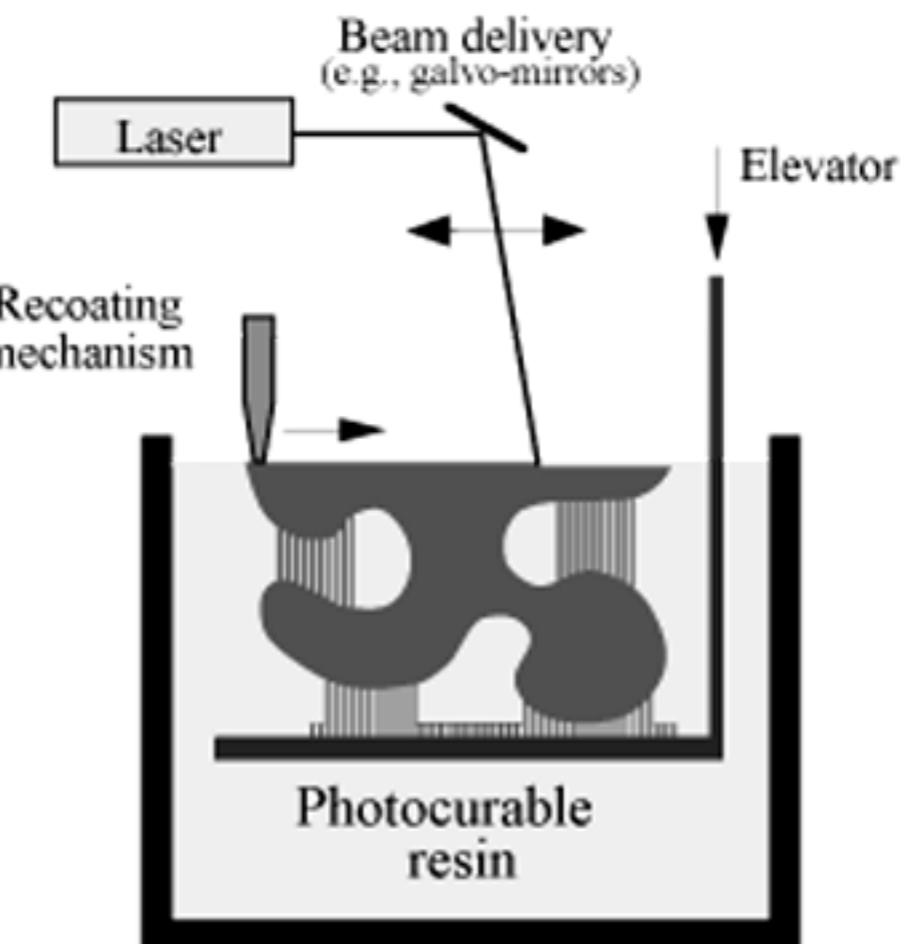
```
solid name
  facet normal ni nj nk
  outer loop
    vertex v1x v1y v1z
    vertex v2x v2y v2z
    vertex v3x v3y v3z
  endloop
endfacet
endsolid name
```

Different types of 3D printing

- Stereolithography (SLA)
- Fused Deposition Modeling (FDM)
- Digital Light Processing (DLP)
- Selective Laser Sintering (SLS)
- Binder Jetting (BJ)

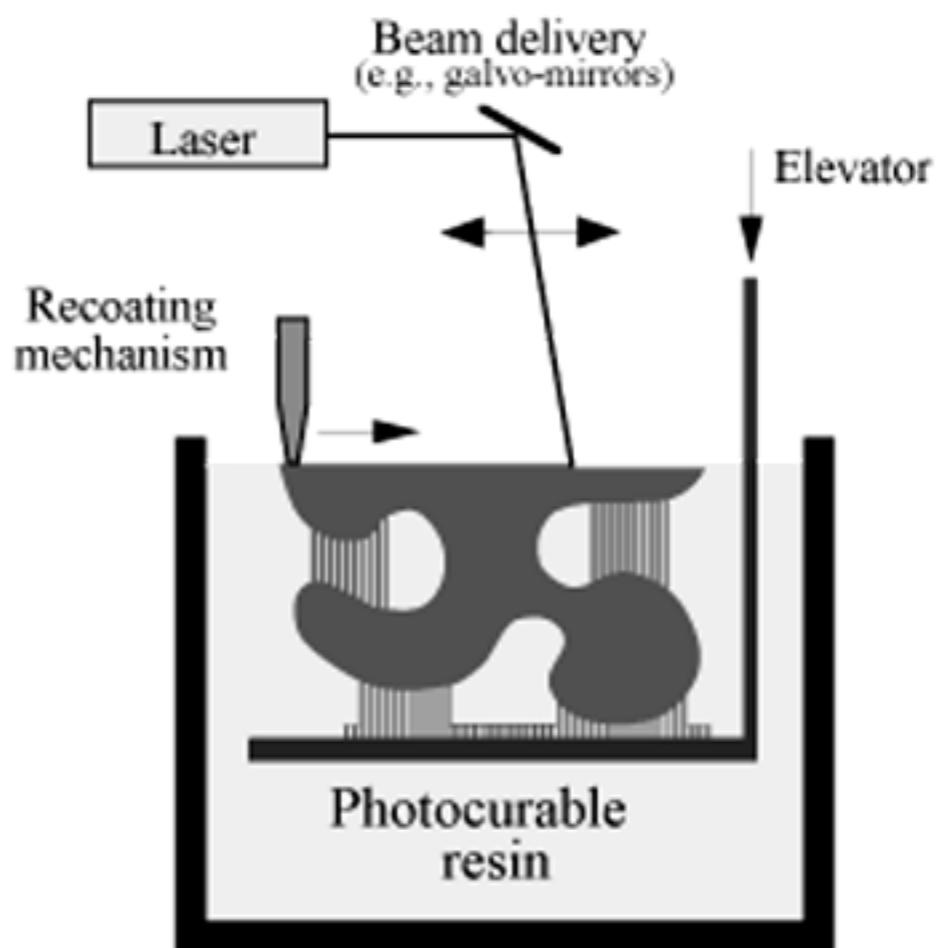
Stereolithography

- First Commercial Rapid Prototyping
- UV Laser traces a cross-section of the part on the surface of the liquid resin
- Exposed resin solidifies and joins layer below



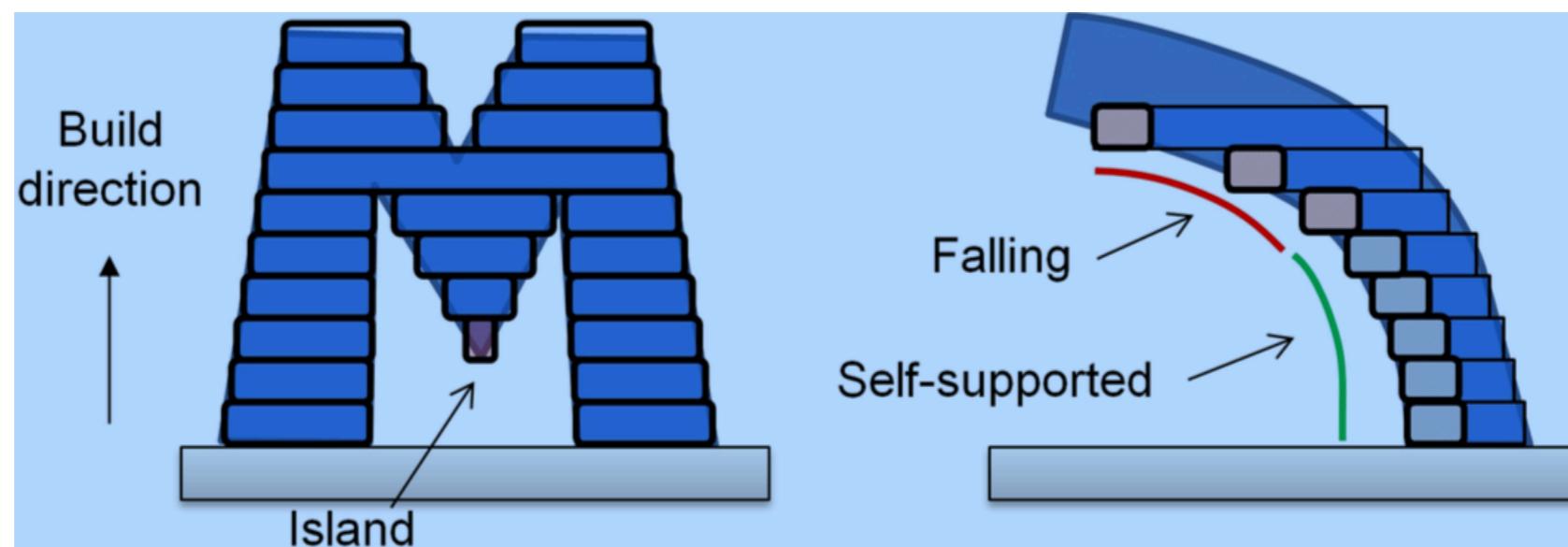
Stereolithography

- To build next layer:
 - SLA's elevator platform descends by a distance equal to thickness of a single layer
 - A resin-filled blade re-coats it with fresh material



Support Structures for SLA

- SLA sometimes requires supporting structures to attach part to elevator platform
- Removed in post-processing

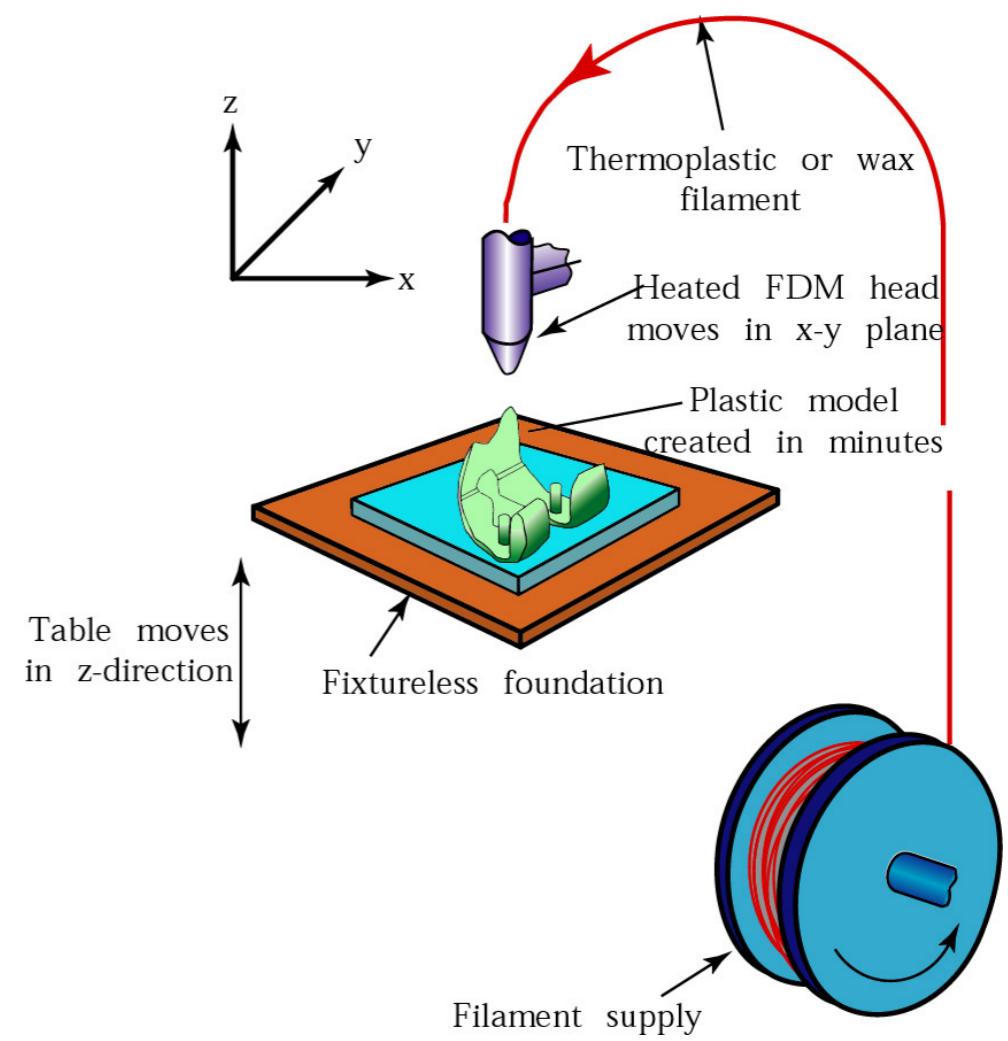


Stereolithography Link

- [https://www.youtube.com/watch?
time_continue=91&v=8a2xNaAkvLo](https://www.youtube.com/watch?time_continue=91&v=8a2xNaAkvLo)

Fused Deposition Modeling (FDM)

- FDM is the most common desktop 3D printing method.
- **Thermoplastic filament** is heated and extruded through a head that deposits the molten plastic in X and Y coordinates
- The build platform lowers the object layer by layer in the Z direction

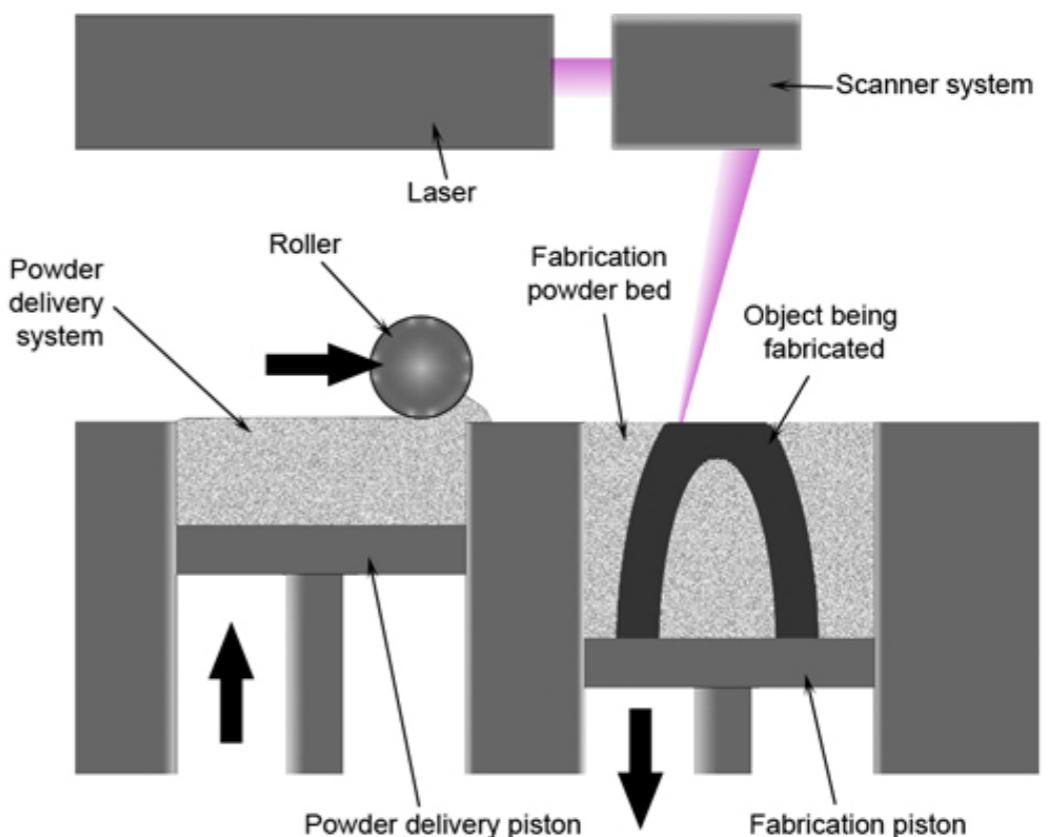


FDM video

- <https://www.youtube.com/watch?v=WHO6G67GJbM>

Selective Laser Sintering (SLS)

- SLS is similar to SLA, but uses powdered material instead of liquid resin.
- Laser is used to selectively sinter a layer of granules, which binds the material together to create a solid structure
- Similar process used for metals



SLS video

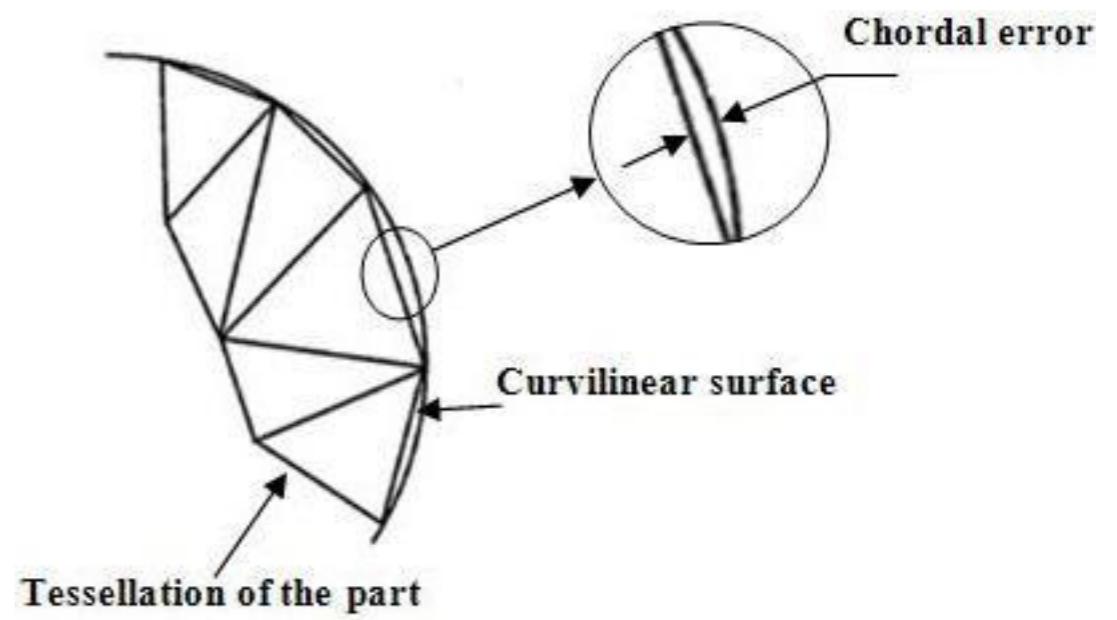
- https://www.youtube.com/watch?v=9E5MfBAV_tA

What is difficult about 3D printer?

- Different types of 3D printer
- Depends on the model, material, requirements, and etc

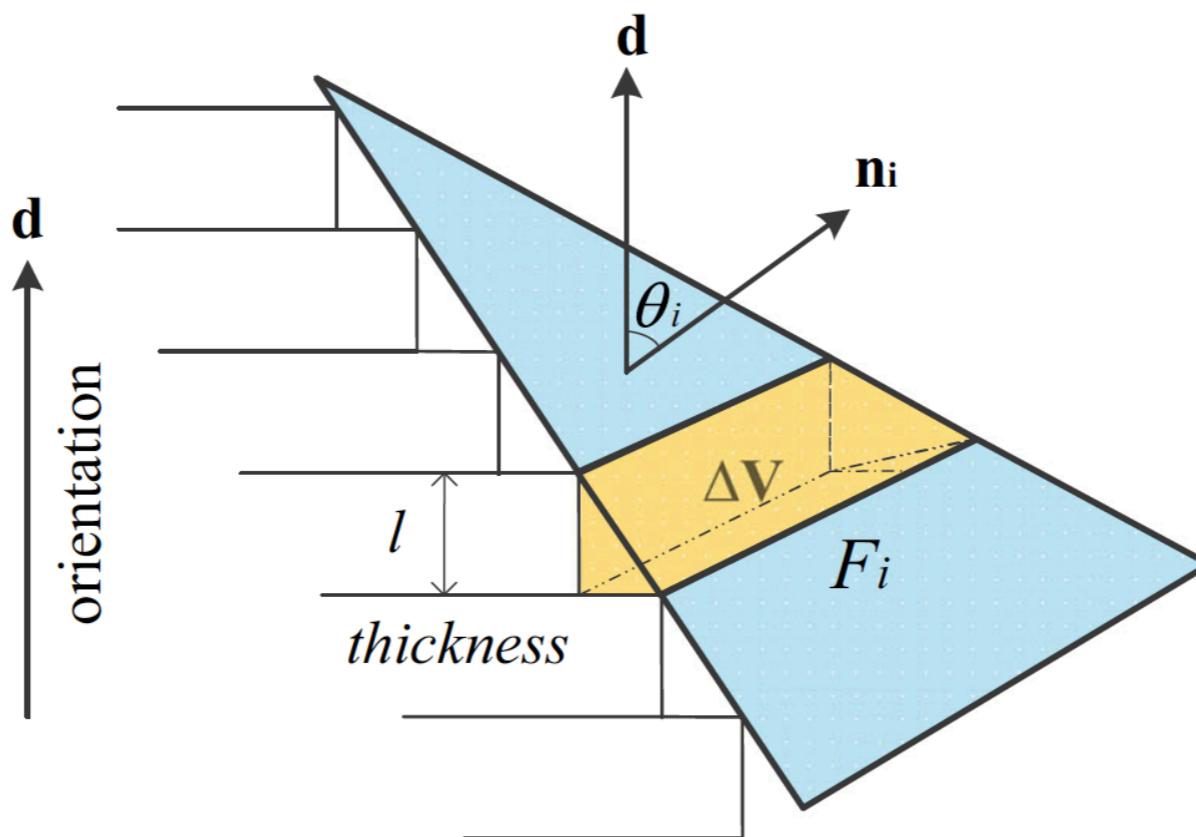
Chordal Error

- Tessellation of object: tiling a surface with geometric shapes such that there are no overlaps or gaps.
- Chordal error: defect due to tessellation
- To reduce chordal error:
Increasing number of triangles
-> increase computational complexity



Staircase Error

- Volumetric error
 - Between the model and printer object



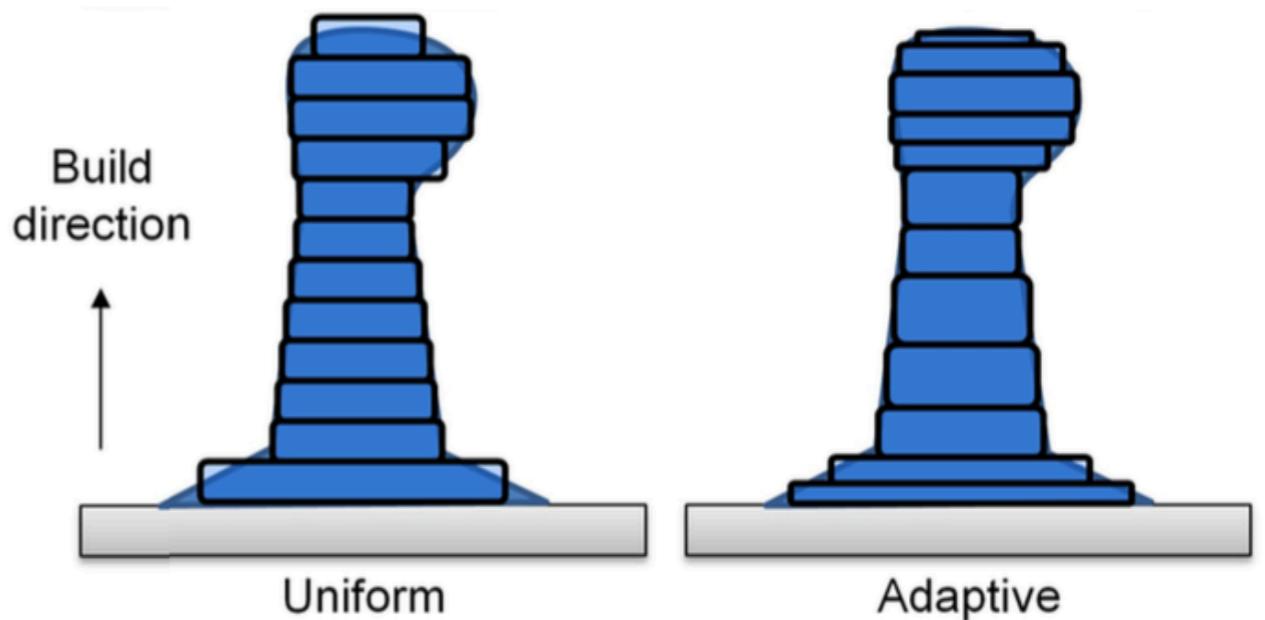
(a) Slicing of facet

Selecting orientation

- Orientation affects:
 - Surface Quality
 - If build direction is parallel to objects edges -> no staircase error
 - Time needed to print object
 - Fewer layers -> shorter print time
 - Amount of support structures needed
 - Orientation determines the overhang in the objects and the islands

Slicing

- Uniform Slicing
 - One slice thickness used throughout the whole object
 - Tradeoff between accuracy and printing time
- Adaptive Slicing
 - Small thickness where high accuracy is needed
 - Thicker slice -> Faster



3D Scanning for 3D printer

- Many smartphone apps are available for 3D scanning
- Demo

Make an interesting object to print

- Go to the link below:
- <https://www.sketchup.com/>
- To save model:
 - save -> 3D Warehouse
 - Privacy : public
 - Title : LACC_3D_yourname
 - Description
 - No URL
 - Upload
- Go to : <https://3dwarehouse.sketchup.com/>
- Search your model!

Requirements for Project

- Download software for the Formlabs 3D printer: preform
- <https://formlabs.com/tools/preform/>
- Download numpy-stl and tqdm
 - OSX:
*sudo easy_install pip
pip install numpy-stl
conda install tqdm*
 - Windows:
*pip install numpy-stl
conda install tqdm*

Assignment: Rotate the lion

- Open Preform
- Load SimpleLion.stl -> repair
- In the python code,
 - Rotate the object by 90 degrees around x-axis
 - Save the rotated lion as rotatedLion.stl
- Load rotatedLion.stl in Preform -> repair

Project

- Required:
 - Find the “best” orientation to print the object
 - Best tradeoff between printing accuracy and printing time
 - Metric: $\sqrt{\text{number of layers}} * \text{ERROR}$
 - Find angles (x,y,z) to achieve minimum possible metric value
- We will ignore support structures
- Degrees of freedom:
 - 360 degrees rotation around X-axis
 - 360 degrees rotation around Y-axis
 - 360 degrees rotation around Z-axis

Project

- Error Calculation for one orientation only takes more than 2 minutes
 - No way to sample all possible orientations for error
 - Figure out a smart way to sample “enough orientations”
- To calculate error
 - `calculateError(stlObj, 0.2, 5)`

Research/Presentation Topics

- Adaptive Slicing Algorithms(s)
- Orientation Selection Algorithm(s)
- Algorithm(s) to generate support structures
- Comparison between commercial printers (personal use and large scale printers)
- A type of 3D printing
 - Examples: Digital Light Processing (DLP), Binder Jetting (BJ), Continuous Liquid Interface Production (CLIP)