Discussing Cura, STL files, and debugging for printing

When generating STL files can choose between
fine medium coarse
- more pixelation
- more triangles

→ filament will smooth itself out as layers due to chemical properties of the filaments
- fdm will smooth out the tiny facets w/in the STL

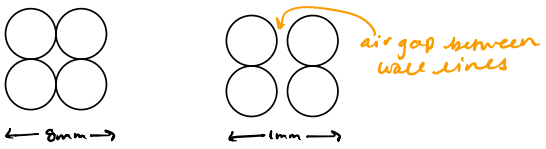
Cura:
- recommend opening as a project, rather than a file, to see previous print settings
- change color scheme to line type to see line by line
  - including printing of the brim
- run outside line, then inside line to get geometry down, then infills
  - use infill in FDM to reduce material and warping of the part
- controlling of the parameters: custom
  → expand menu
  → also settings >> configure setting visibility >> add other parameters to the material selection
  ⊛ don't adjust/add/subtract these parameters unless you know what to do

- when see the red, means need supports (but we may be able to push the printer)
  → can adjust support overhang angle
  → even when ↑ angle of example lattice, see red still since the lattice has a rounded shape

- enabling retraction: when nozzle travels in between layers, pulls filament up temporarily to prevent spider webs

- z-hop if printing very fine items ... moves nozzle out of way
  - each retraction at z-axis, messes w/steppers
  - ↑ error potential, adds to print time
  * takeaway is each parameter has an optimal pt and have to play with it

- almost everything in increments of .4 because it's the stock nozzle size
  - width of nozzle going to drive width of road and thickness of wall
    - if make wall .5mm — might be .4 or .8
    - if " " 1mm will be 1mm but will be gap

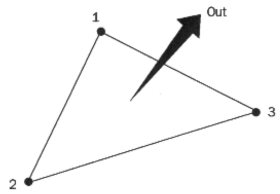


*watch the multiples of 0.4 for wall lines and wall thickness

STL File Format
- describes only the surface geometry of a 3D object, allows computer to communicate with 3D printer hardware when used in conjunction with a 3D slicer
- **ST**ereo**L**ithography … Standard Triangle Language … Standard Tessellation Language
- main purpose of the STL file format is to encode the surface geometry of a 3D object—> encodes this information using a concept called **Tessellation**
- invented by Chuck Hull in 1987, for The Albert Consulting Group for 3D Systems —> they realized that if they could store the information about these tiny triangles in a file, then this file could completely describe the surface of an arbitrary 3D model

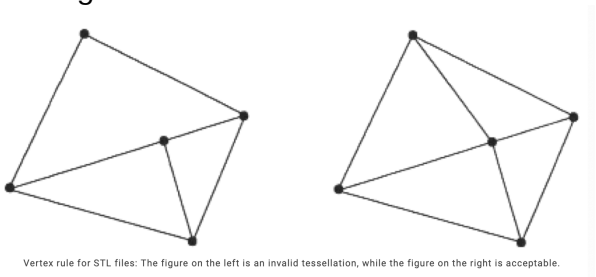
Tessellation — process of tiling a surface with one or more geometric shapes such that there are no overlaps or gaps

How STL file stores information about Facets
There are two different ways: ASCII encoding and binary encoding. In both formats, the following information of each triangle is stored
1. the coordinates of the vertices
2. the components of the unit normal vector to the triangle; the normal vector should point outwards with respect to the 3D model



Binary STL file format — if the tessellation involves many small triangles, the ASCII STL file can become huge, and the binary version is more compact

Rules for the STL format
1. The vertex rule states that each triangle must share two vertices with its neighboring triangles

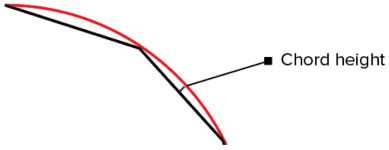

Vertex rule for STL files: The figure on the left is an invalid tessellation, while the figure on the right is acceptable.

2. The orientation rule says that the orientation of the facet (i.e. which was is “in” the 3D object and which way is “out”) must be specified in two ways
    a. direction of the normal should point outwards
    b. vertices are listed counterclockwise order when looking at the object from the outside (right-hand rule)
3. The all positive octant rule says that the coordinates of the triangle vertices must all be positive
4. The triangle sorting rule recommends that the triangles appear in ascending z-value order (helps slicer slice 3D models faster)

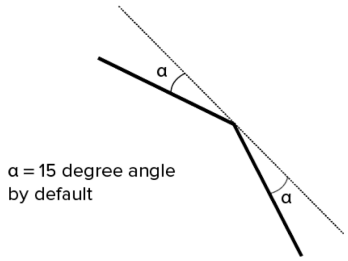
3D Printing an STL File
- slicer is a piece of 3D printing software that converts digital 3D models into printing instructions for your 3D printer to create an object
- slicer chops up the file into hundreds of flat horizontal layers based on the setting you choose and calculates how much material printer will need to extrude and how long it will take to do it
- this information is bundled into a GCode file, which is the native language of the 3D printer

- 3D models suitable for 3D printing need to have a minimum wall thickness and a “watertight” surface geometry to be 3D printable

Optimizing an STL File
- the STL file format approximates the surface CAD model with triangles; approximation is never perfect and the facets introduce coarseness to the model
- by making triangles smaller and smaller, approximation can be made better and better, resulting in good quality prints
- however, as decrease sizeof the triangle, number of triangles needed to cover the surface also increases, which can lead to a large STL file that 3D printers can’t handle
- must find right balance between file size and print quality
- *Chord Height or Tolerance* — chosen in CAD software, maximum distance from the surface of the original design and the STL mesh; if choose the right tolerance prints will look smooth and not pixelated —> smaller chord height, more accurately the facets represent the actual surface of the model (recommended to set tolerance between 0.01 mm - 0.001 mm)



- *Angular Deviation or Angular Tolerance* — limits the angle between the normals of adjacent triangles; default angle usually set to 15 degrees —> decreasing tolerance improves print resolution (recommended setting for this parameter is 0)
- binary format is always recommended for 3D printing since it results in smaller file sizes, but if want to manually inspect STL file for debugging then ASCII is easiest to read



Alternatives to the STL file
- OBJ can store color and texture profiles
- PLY was originally used for storing 3D objects
- 3MF is new one up and coming by 3MF Consortium to streamline & improve printing process

When ***not to*** use an STL — want multiple colors or multiple materials, OBJ best
When ***to*** use an STL — print single color or material, simpler and smaller file sizes, faster processing

STL advantages:
- universal, supported by nearly all 3D printers (can’t be said for OBJ)
- mature ecosystem: plenty of third party software

STL disadvantages:
- smooth curved surfaces can result in massive file sizes
- impossible to include metadata such as authorship and copyright info

It’s entirely possible to edit an STL file and convert to another file format
Repairing an STL file:
- adjacent triangles must share two vertices and the RHR applied on the vertices should result int he same orientation as the normal vector (otherwise if violated, then file is corrupt)
- several programs to repair a broken STL file