**3D Printing in a Nutshell**

“3D printing” in this case refers to a rapid-prototyping technique known as Fused-Deposition Modeling or FDM (sometimes FFF) printing. Most desktop 3D printers that have become so popular these days are FDM printers, namely Makerbot and Ultimaker. In essence, an FDM printer is a cross between a hot glue gun and an arcade claw machine. A “toolhead” (the glue gun part) can be moved along three perpendicular axes (the claw machine part (x,y,z)) and as the computer moves the toolhead along the correct path, it lays down melted plastic onto the build plate. In this way the model is literally drawn in place, layer by layer.

The process begins with loading a 3D model into the printing software known as a “slicer.” The slicer interprets the 3D model based on certain contraints selected by the user, and slices it into separate layers. These layers correspond to the height, or the “z” dimension. For each layer, the cross-section is a 2D shape existing in the x-y plane. This cross section is converted into a set of instructions for the printer to follow in order to draw each slice. In this way, 3D objects can be grown by correctly stacking the layers and laying down plastic one slice at a time.

**Considerations for Designing with FDM Printing in Mind**

Materials - Poly-Lactic Acid (PLA) 3D Printer Filament

The first thing to remember is that the material we use for the majority of our 3D prints is a bio-plastic known as PLA. Derived from corn or sugarcane, PLA can be easily and safely melted down in order to be placed on the buildplate. It is important to be aware that PLA pieces are prone to warping and deformation if it gets too warm. The melting temperature is around 180 degrees celcius, but the material becomes very soft and malleable at temperatures even lower than that. Additionally, PLA has less tensile strength than some of the other 3D printing filaments such as ABS. PLA is said to be food-safe, but contact with components of the printer such as brazz nozzles may be cause for concern. Be aware that PLA should probably not be used for eating utensils or for anything in contact with water or prolonged high temperatures (no mugs or cookware!).

Our current operation has made use of a few specialty filaments. One filament, known as Ninjaflex, is very flexible. It has a rubbery texture to it so it can be great for creating a tight seal between two pieces. It can also be used for hinges or spring-like assemblies. Other filaments have various properties like the ability to conduct electricity. A lot of exciting developments are going on in the realm of 3D printing materials, and more options are becoming available all the time.

Detail Resolution - Layer Height

The height of each layer in a given model determines the amount of detail that can be effectively resolved. Shorter layer heights for a given object means more layers will be needed to complete the shape at the specified size. This means more time is needed to complete the object, but it also means the curved features which need the most detail will look smoother and cleaner. For simple geometric shapes, the resolution may not matter much, but it certainly is worth considering for more complicated models that require a certain level of detail.

Structural Integrity - Infill Density, Wall Thickness

In general, one needs to consider how strong an object would need to be and to account for this during the design process. Part of the print process is setting the internal material density for the print. The print software is able to add internal support structure, typicaly in a honeycomb pattern. Stronger prints are made by using more material in a smaller, more resilient honeycomb structure. One can set the model to be completely hollow, or completely solid or anywhere in between. In addition to infill, one also has control over the thickness of walls for a given model as well as dozens of other variables for the size and placement of different parts of a model.

For objects which do not have to bear a large load or redirect a lot of weight, this internal density and wall thickness matters less. In such cases, one would likely minimize the infill and therefore the internal strength, in order to save on time and material use.

Scale - Size of Prints, Number of Components

The printing software will allow one to set the overall size of an object. This size determines how long and costly a print will be. One is limited by the dimensions of a given 3D printer, so if a project would have to be bigger than a single printer could handle, one would have to print the project in multiple pieces which could then be assembled later. For complicated models, this is often the most reasonable course of action. Projects incorporating separate pieces can be made to have moving parts such as gear trains and hinges, etc. The trick here is in designing things to fit together. If two pieces are connected by a slot and a pin, the slot has to be slightly bigger than size of the pin for the two to fit well together.

Orientation - Placement and Overhang

The slicer displays any uploaded 3D models on a virtual build plate. This allows one to determine where the model will be printed on the actual plate. Size and orientation can also be adjusted meaning one can determine which side of the model should be on the bottom. There can be a great deal of strategy in making this decision. Certain orientations are more reliable than others and can influence one’s success with a given print. One of the biggest factors in a print’s stability is whether or not a model has any overhang. Because objects are printed up from the buildplate, if higher layers extend past the layers beneath them, this can lead to sagging where the higher layer was not supported. Models which have some small amount of overhang can still be printed, but if the angle in question is too large, then the object would not be able to be printed out successfully. There are a few ways around this. One way is to reorient a print such that the overhang goes away. Another way is to add external support structure underneath the overhang such that the model is held up where necessary. This support can be built into one’s design on an ad hoc basis, but slicers also have the ability to interpret a model at a given orientation and decide where support would be needed. This generated support structure is very effective and is made to be easily removed leaving just the original model.

Clever placement of objects and clever designs can go a long way towards saving time, and material as well as ensuring higher rates of successful printing.

Watertight

Models must be watertight. This means that they need to be entirely closed up. In Mathematical terms, an object must have a closed surface such that it actually encloses some volume. In visual terms, one should not be able to see the interior faces in the CAD software.

Inside and outside faces are used by the slicer in determining where to add internal support and where to set the boundary of the model. These faces must be logically consistent in one’s design in order for the model to be interpreted correctly. Inside faces should only go with other inside faces, and outside faces should only go with other outside faces.

Sometimes, models are drawn with extra faces in the interior space. This tends to lead towards confusing the slicer. Leaving the extra faces in the wrong place can tell the slicer that the model’s boundary is at the interior face rather than where you want it to be. Any situation that lets the computer decide what was “real” and what can be ignored is likely to cause the model to be interpreted incorrectly. Minimizing extra information is the only way to ensure that what you tell the computer is what you really want it to make.

**Project Ideas**

For someone just starting out I would suggest trying to design a simple object that would serve some useful function for you

Ideas:

Headphone Stand

USB Organizer

Pencil Cup

Business Card Holder

Soap Dish

Keychain

Refrigerator Magnet

For these ideas and anything you come up with, think about the different design requirements that each would have. For some projects like the headphone stand, internal strength might be the most important factor to consider. What good is a stand that does not actually hold together under strain? For other projects such as the USB organizer a more important consideration is the exact size of the slots. In this case, the object would not have to support much weight, but the precision of the fit suddenly determines if the object is functional or not.

Whatever you decide to create, first think through the function of the model and what considerations are most relevant given that function. Then think about how a design could be altered to account for certain constraints. Pick something you will be proud to have made and get to designing!

**Resources:**

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