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The Cadillac of Hot Glue Guns: On replicating objects for still life using the 3D pen and 3D printer

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Abstract

The act of reproduction results in two objects with similar visual qualities, but points to the method of fabrication for both objects: the original and the reproduction. Creating abstract shapes or representations of objects may show a similarity in the ideas of a linear visual record of movement, but reproduction innately pulls the fabrication method of the original into comparison with the fabrication method of the reproduction. To explore the dynamic between object and reproduction, I align my process to the genre of still life painting. Although my objects are three-dimensional, still life painting is my frame of reference for the reproduction of objects. In still life painting, objects are sometimes used symbolically, investing them with meaning, but at other times are used simply as a means to explore technical aspects of the medium. The use of a set of pears in a painting by Cézanne invests nothing in them beyond their shape; he uses them as vehicles to show technical renditions of light and composition. The same pears in a *vanitas* may point to death, decay, and the fleeting nature of time while simultaneously showing the technical exploration of the painter. My research explores both approaches to the genre of still life, keeping the foundation of each reproduction the timeline made by 3D pen and 3D printer.

The Cadillac of Hot Glue Guns:
On replicating objects for still life using the 3D pen and 3D printer

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The Cadillac of Hot Glue Guns

For this writing, I will be focusing exclusively on my body of work reproducing select tools and toiletries using the 3D pen and 3D printer. This body of work is one that sets up a comparison between the capabilities of machine and the human hand through reproducing machine-made objects. These tools, the 3D pen and 3D printer, track the movements of the machine and the hand by nature, as their creations are a recorded timeline of movement. This comparison in movement is a means to point to the body as a machine, an idea that is a foundation in the work that will follow using these tools. In the act of reproduction, I am using existing machine-made, commonplace forms to drape my ideas over like an armature. In doing so, the act of reproduction I employ points to technique much the way a painter might highlight ideas about painting in a still life. This writing will lead into my use of still life in the application of my technical research onto selected objects and then touch on how selected objects can be used to push beyond their use as an armature and mix techniques with content.

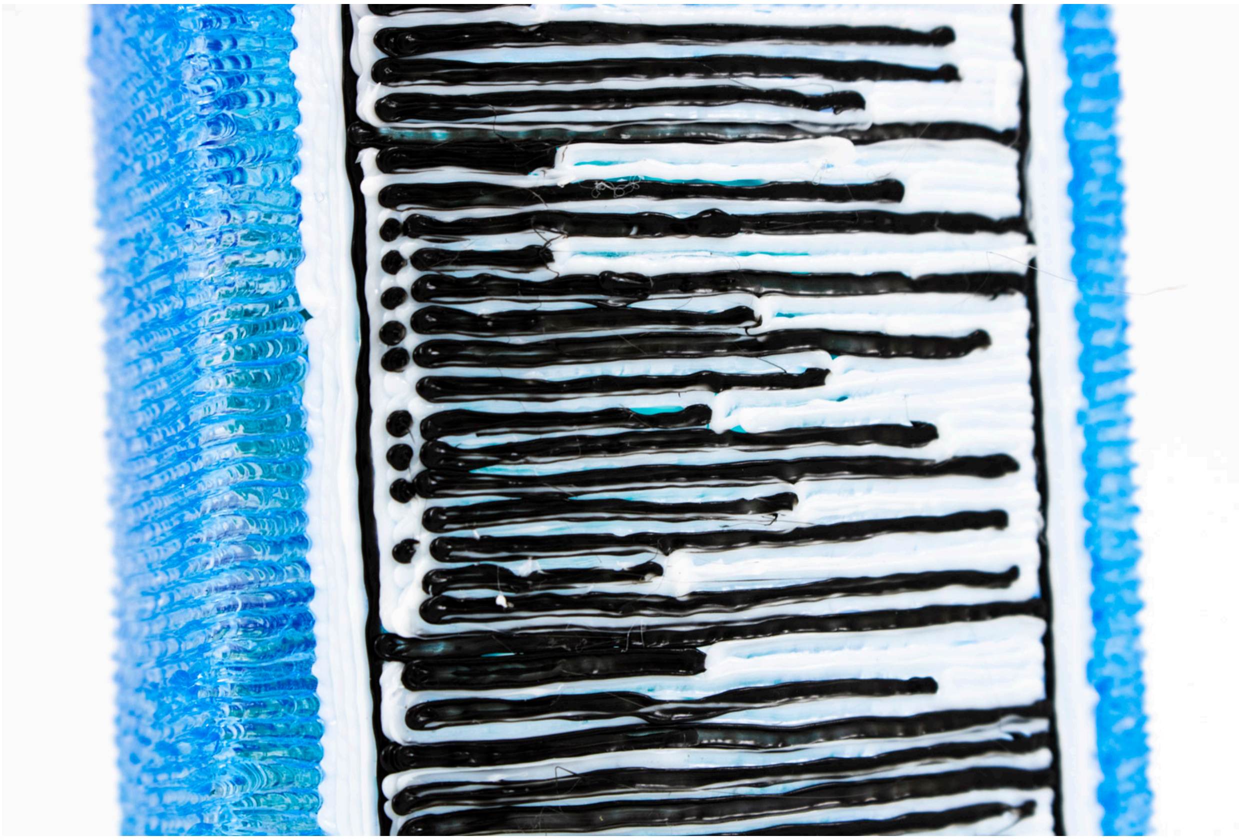
The 3D printer and 3D pen work as a comparison between the movement of machine and hand because the mechanism that both tools use to create objects in space is the same[1]. Each tool uses a small motor with a gear on the end to grip the plastic and push it through a heated nozzle (imagine a mechanized hot glue gun). The main difference between them is the mechanism that moves the nozzle. The 3D printer uses a set of stepper motors to move the platform the print is

[1] For the purposes of easy comparison to the 3D pen, all references to the 3D printer made in this paper are to fused filament fabrication (FFF) also trademarked as fused deposition modeling (FDM). FFF printing uses a small motor to push a spool of plastic filament through a heated nozzle, creating objects layer by later. This type of printing is the most commonly known form of 3D printing and the most widespread type of printer. Multiple types of printers exist even within the category of FFF. My experience only extends to three axis printers so they will be the only reference point for the discussion of FFF 3D printing in this paper.

made on – the print bed – and the nozzle, part of the larger print head[2]. With the 3D pen, the mechanism that moves the nozzle is the human hand. The method used for these tools to create objects in space is additive manufacturing, a process that results from the successive building, layer by layer, of material.

My uses for additive manufacturing and the way it can be altered and showcased through these tools is that it is – and must be – a timeline. When the nozzle on the 3D printer starts to flow, the head moves creating a line of plastic. To create form, the print head rises and the line builds on top of itself rising higher and higher after each pass. Thus, it creates objects out of a single linear path, from which you can look back in time and see every movement from start to finish laid out like sediment. The 3D pen has more wiggle room to create form because it can be rotated in the user's hand and its flow can stick to some surfaces. My method of using the pen relies heavily on the ideas of additive manufacturing to maintain the visual of a timeline. I create form with the 3D pen line by line, stacking each line next to the previous to create a thin shell as a reproduction of what lies underneath. This use of the pen reveals the motion of the hand through its tension with the object's surface.

[2] In the print head the nozzle is considered the hot end and the extruder is the cold end. The cold end feeds the filament into the hot end to melt it so there are many settings in the relationship between these two parts that control how the melted PLA comes out, things like speed, temperature, and retraction all happen here. Some printers have the extruder separate from the print head itself but the relationship remains the same, it is just easier to break filament when the hot end and cold ends are farther apart.

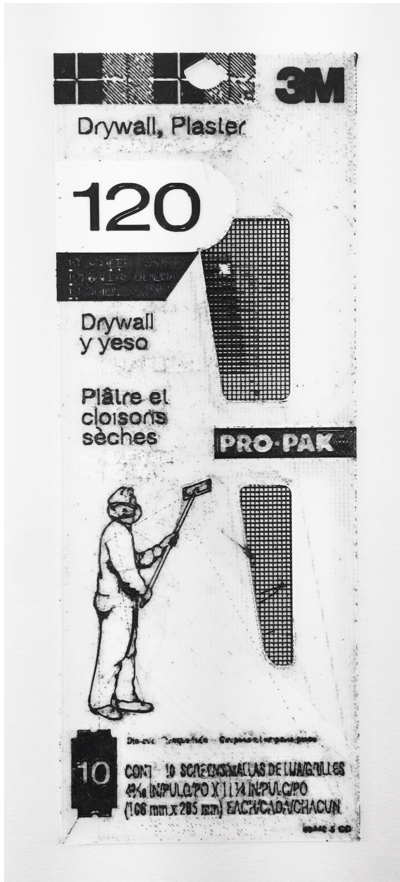


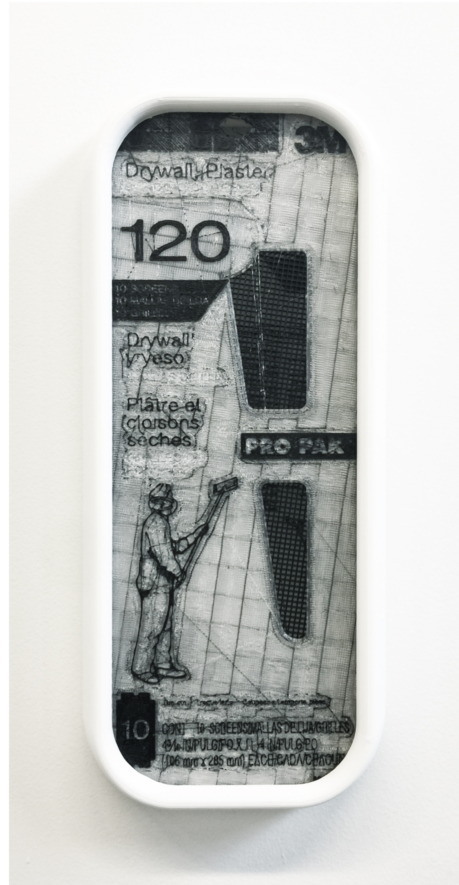
[Figure 1. *Act Mouthwash* (Detail), PLA from 3D pen, 2019]

The comparison between the capabilities of the machine and the human hand in reproducing objects at first showcases a lack of precision in the hand given the same tool. The machine can execute .1mm lines layer after layer with sloping complex geometry while my hand with the 3D pen shakes and wobbles, seeming to struggle with the task of repeating the same motion with consistency. On a second glance, the lines are a record of other movements, tracking my body's action throughout the task of reproducing. The lines capture the movements of my body as I breath and overextend the reach of my fingers. Even as I try and hold my breath to steady myself, the line records the increased pulsing of my heart. This record of movement shows my body as a whole, trying to become a machine in action, but undermined by the mechanisms at play keeping my body alive.

To bring this technical comparison to the forefront, and bring attention to the quality of the lines, I have chosen to reproduce objects. The act of reproduction results in two objects with similar visual qualities, but points to the method of fabrication for both objects: the original and the reproduction. Creating abstract shapes or representations of objects may show a similarity in the ideas of a linear visual record of movement, but reproduction innately pulls the fabrication method of the original into comparison with the fabrication method of the reproduction. To explore the dynamic between object and reproduction, I align my process to the genre of still life painting. Although my objects are three-dimensional, still life painting is my frame of reference for the reproduction of objects. In still life painting, objects are sometimes used symbolically, investing them with meaning, but at other times are used simply as a means to explore technical aspects of the medium[3]. The use of a set of pears in a painting by Cézanne invests nothing in them beyond their shape; he uses them as vehicles to show technical renditions of light and composition. The same pears in a *vanitas* may point to death, decay, and the fleeting nature of time while simultaneously showing the technical exploration of the painter. My research explores both approaches to the genre of still life, keeping the foundation of each reproduction the timeline made by 3D pen and 3D printer.

[3] Photography uses the still life in such a way that bounces between loaded object and technical study but in painting the connection of the brushstroke as a record of the buildup of lines over time is more prevalent. I am not exploring light or color, only the recording of time.





[Figure 2. (left) *120 Grit Pro-Pak Sanding Screens Box Sample No.1*, PLA from 3D printer, 2019]
[Figure 3. (right) *Biting the Hand That Feeds No. 5*, PLA from 3D printer, acrylic, 2020]

In making a series of Pro-Pak Sanding Screens boxes I use the object purely as a substrate on which to explore the connection of hand to machine using the 3D printer. I selected the Pro-Pak Sanding Screens box for its high contrast exterior and the structure of its contents. The sanding screen's exterior is almost entirely made of black and white. Using a dual extrusion printer, I was able to model almost the entire contents of the box true to their color and then manipulate the information going to the printer to change the drawing method while keeping the reference to reproduction[4]. The screens within the box are a tight rectilinear grid that is coated in

[4] A dual extrusion 3D printer is able to print two types of filament within the same print. The printer I use has two separate nozzles that sit on the same print head. When one nozzle is printing, the other rides alongside and sits idle. Other dual extruders have a

an abrasive used to smooth out drywall. From a visual standpoint, this grid that makes up the entire interior of the box is the same formation as infill, the auto generated interior that is used to fill the space inside a 3D print[5]. By changing the color and layer thickness, I am able to expose the infill showing the boxes' interior as both reproduction and as a necessary element in the object's fabrication. The words and imagery on the exterior serve only as visual reference back to the original box. Using black, white, and clear filament I use the box to show through the entire process that led to the creation of the reproduction. By changing the code that enters the printer I am also able to manipulate the actions of the printer to push it to a limit, exposing the actions it is taking to build the reproduction. The sanding screens box acts as armature for this series of explorations in the capability of machine and hand, existing as visual and structural reference for my reproductions.

separate print head for each nozzle and some use just one nozzle for both types of filament.

[5] There are many patterns of infill but my preferred method is rectilinear for its visual association with construction and clear representation of movement through repeated line. Rectilinear pattern is a series of straight lines. Two rectilinear angles interesting perpendicular created a grid pattern.

[Figures 4 - 5. *Act Mouthwash*, PLA from 3D pen, 2019]

In reproducing a selection of my toiletries, the reference to still life entails both the use of object as armature but also a musing on the original object's function. This usage of the genre allows me to present the technical ideation of hand and machine with associations of the reproduced objects to the viewer. In this selection of work, I have chosen toiletries that serve as a contemplation on the body's function in their efforts of fighting off decay. Each day, I partake in a ritual of repetitive motion in the morning and at night, brushing my teeth and using mouth wash to protect the thin enamel wearing away from food I ingest to give me energy. This repetitive maintenance of the body in combination with my usage of the 3D pen works together with the imagery of my mouthwash and toothbrush to compare the body to machine. The Act Mouthwash as a reproduction is a record of my body's motion, capturing line by line the attempt I make to turn my body into a machine. Each line showing a discrepancy in my ability to repeat with exacting consistency. But in the bottle's own reference to my rotting teeth and my need for maintenance, the technicality of the lines mixes with the content of the bottle. The wavering of the lines are created by my breathing and pulse; both constant indicators of my body as a machine.

In using the reference of still life, there is always an underlying notion of time. The still life's name is an indication of a frozen moment in time and the genre has been widely used for reflection, pausing the flow of life and our linear experience of time. In my work, the passage of time through the movement of the 3D pen and 3D printer creates objects. Those objects become a literal linear timeline; time frozen in which you can see every motion that led to their being. It is this combination of individual moment and solid recording of time that my work highlights and explores though my methods of reproduction. The comparisons between the capabilities of machine and the human hand that I have set up through this research are a foundation on which I can explore a wide range of ideas by varying the objects I select to reproduce. Through the lens of the still life, I am able to explore the shifting focus where technique and content mix. It is through this lens that I will continue my research exploring the use of objects as armature in new methods of making with the 3D pen and 3D printer.

[Figure 6. *Still Life With Pear and Cat Skull,* PLA from 3D printer and 3D pen, glass, bosc pear, 2020]

Shop Talk

1. To further expand upon the relationship between 3D printing and the 3D pen I will provide a brief description of the process in both categories. As previously stated, the mechanism in the 3D pen and the 3D printer that melts plastic through a nozzle is primarily the same. A small motor turns a gear that pushes plastic filament through a hot nozzle[6]. The filament I use is a spool of PLA, typically 1 lb. that must be the same size as the mechanism pushing the filament into the heated nozzle on the printer[7]. My printer and pen both require the same size filament, 1.75 mm so the same filament can be used for each tool. The nozzle is heated to the melting point of PLA, then as the PLA is pushed out in melted form it begins to cool, hardening again in a few seconds. In 3D printers, the nozzle is fixed to a xyz axis the entire object is printed layer by layer [8]. When PLA is heated, it will stick to itself immediately and with no pressure, even if one of the connecting parts is cold. This allows the 3D printer to fuse the PLA to itself with the addition of each layer[9]. The object builds one shape at a time in a vertical direction. With

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[6] When I reference gears here I am meaning the sharper gear directly touching the filament, not a gear box to slow the motor movement output.

[7] The type of plastic most common in 3D printing is Polylactic Acid (PLA). The second most common plastic is Acrylonitrile Butadiene Styrene (ABS). Most 3D printing pens have the option for either PLA temperatures or ABS temperatures. For many reasons, I exclusively use PLA. It has a lower print temperature which makes it easier to handle but more importantly ABS is extremely toxic and must be printed in complete ventilation.

[8] Operating on a xyz axis means the print head can move in six directions: up, down, forward, backward, left, and right. Both the up and down are the z axis, the left and right are the x axis and the forward and backward motion is the y axis. These dimensions are called a Cartesian coordinate system. The x and y axes in combination with each other allow the printer to create organic or geometric shapes. The z axis allows the printer to build these shapes on top of one another to create objects.

[9] If the pen is perpendicular to the surface and too far away, it will not stick at all to the surface. If the pen is slightly closer, the line will stick and the space the plastic occupies will have a mostly flat shape since the nozzle is dragging over the top as it lays a bead. With an even closer distance the plastic will be forced to either side of the nozzle and

the 3D pen, there is no set axis for printing. This allows for the application of PLA in any direction as long as it can stick to itself. In my use of the tool, I apply rows of PLA next to one another, which allows the PLA to stick to itself on the edges of the rows to build volume. Depending on the angle of the nozzle, the size and shape of the row changes and resembles the shape of a string or bead[10]. As my understanding of the angle and flow of the pen changes I am able to make these beads more and more uniform and mechanical[11].

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appear in a thick flat line. Pushing the pen almost directly against the object makes the nozzle drag through the plastic even as it lays it down. This causes there to be almost no material in the middle of the line but material in a slope on either side. In this last scenario, the PLA is almost see through in the middle and has a stripped appearance with the thicker slopes on the outside of the lines. By angling the pen at an acute angle to the surface and pushing it in a scrapping direction the same rut will occur as with the last perpendicular example, but the line can be made thicker. The rut here is created but the back end of the nozzle dragging through the plastic and can be made more dramatic by moving the pen closer to the material. By angling the pen at an obtuse angle to the surface and pulling the pen in a dragging motion, the bead will appear very round as it is able to flow freely with no interruption. This line quality is most affected by the speed of the dragging to determine line size. By putting the pen at an acute angle, perpendicular to the direction of the line being drawn the plastic comes out in a dropping bead. The shape here is similar to a teardrop extended into a line. As the plastic gets pushed out it forms the rounded bottom but as it is dragged the top remains thin. All these affects are made more dramatic with a decreased speed of the pen and more streamlined with increased speed. The more pressure caused by the nozzle and surface area the better the PLA will stick.

[10] The word bead here is not to reference the more common usage of the term, indicating a solid singular rounded shape. I am using the word bead the way one might think of the path traveled by such a shape, resembling the line from a caulk gun or a ceramic coil. You can think of it like frosting on a cake. In fact, the newer versions of 3D pens often have tip accessories like frosting tips that change the shape of the extruded plastic. This is the purpose of rule 7 in the 3D Pen Rulebook. I am against the use of these as it muddles the comparison between the mechanism used in controlling a basic nozzle in 3D pen and 3D printer.

[11] I have been getting better at losing these bumps by using the heat of the nozzle to go over the start of the bead. I know generally the timing of the delay and can begin to move my hand as the bead starts to come out of the pen. When I travel around and come back to where the line started I can anticipate the delay of the pen, click the "forward" button to stop the flow, and then run the nozzle right over the start of the bead to blend the line together. This does not completely flatten the bump but it makes it far less noticeable and strengthens the appearance of each line.

2. 3D printing is often treated with post processing techniques like sanding and painting in order to hide the layer lines. Since the layer lines are the timeline that fascinates me most about 3D printing I do zero post processing on my 3D prints and pen drawings. In my 3D pen drawings I use colored filament to get a wide variety of color, making the reproduction as close as possible to the original given the constraints of the tool.

[Figures 7 - 8. *220 Grit Pro-Pak Sanding Screens Box,* PLA from 3D pen, 220 Grit Pro-Pak Sanding Screens Box, 2020 (left) with 100 Grit Pro-Pak Sanding Screens Box (right)]

3. The piece in which a transition of hand into machine came to my attention was the 3M Pro-Pak 220 Grit Sanding Screens box[12]. The lines I make with the pen are so controlled and even that its appearance ventures closer to machine made than any previous work. The reasoning for this surely is both an increase in experience as I learn to control the pen, and the rectilinear shape of the object. The sanding screens box is thick in width and thin in depth. All sides are flat and the only discrepancies in this flatness are two holes at the front, the folds of each section of cardboard[13]. It helps too that the sanding screens

[12] This reference is to the 3D pen version of the Pro-Pak Sanding Screens box, not the 3D printer drawings.
[13] Around the edges of the box there are tiny cuts along the fold edges from scoring during production. The little cuts are at a size where I am not sure if they can or should

box is white with black text, which boosts the visibility of inconsistencies through shadows and contrast. The flatness of the sides and the width of the front face work to let my hand lay even bead after even bead. Long objects require either the bead I am working on to stop and be made in several sections or I must lift my arm off any support and leave it shaking in air trying to keep straight as possible. The width of the sanding screens box is very close to the perfect distance my hand can travel without having to change angle or lift. Since it is a flat object, I can maintain consistency that is rare to achieve with rounded or curved objects.

The reasons this object translates so well into clean lines with the pen also make it a prime candidate for 3D printing. I can print the whole of the object with no support structures and the layer lines will be true with the object[14]. The color is also a huge factor in its limited palette. Apart from a small amount of grey and yellow, the sanding screens are almost entirely black and white. This means that most of the box can be printed with a dual extrusion print head, which can print with two different types of filament at the same time[15]. This will allow me to create most of the model in the refined lines of the printer

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be reproduced. They are a minimal detail, but yet they exist. To make them individually with the pen it would blow them far out of proportion due to the nozzle size being twice the diameter of the lines, and producing an even larger sized bead of filament each click. And yet, they are there.

[14] The layer lines are an important indication of the objects history and they carry the idea of motion with them. To make a box, the printer can make it any direction and put the lines at any angle but the simple adjustment to make the lines parallel or perpendicular to the box's lines goes a long way in showing the awareness and capability of the maker. The set-up of the object then is just an important as the designs made using the 3D pen. Once the design is made and I have seen it print, I do not need to be the one to print it. I would say the same for the 3D pen objects. I need to make it once and then it does not matter to me that it is the artists hand.

[15] There are two main types of dual extrusion print heads but their function is to print two different types of filament in the same print. This is the go to tool for using experimental filaments like dissolvable filament. Dual extrusion printers can print all the support

and then fill in the grey and yellow with the 3D pen directly onto the print. This is the fostered relationship between the 3D printer and 3D pen from the rulebooks. They allow for the machine to reproduce with its full potential but the extruder is limited in color[16]. The 3D pen is the tool to come and fill in the blanks of what the printer could not do on its own.

4. The creation of a 3D print relies on the computer's ability to determine a clear interior and exterior in a data set. The information that matters to the computer is surface and the rest is just filled in with a support grid. My process in a similar way is only concerned with the exterior boundary of the objects being reproduced. My work creates a shell made from a thin skin and references the algorithmic treatment of computer models instead of some of the more common practices of 3D printing through rapid protoyping, like testing the interior gears and parts of objects in engineering.

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structures in dissolvable filament and the desired print in PLA and then the print just needs to be placed in water to be cleaned. For my purposes, I use dual extrusion to reproduce the two most predominant colors on the object to be printed. This is convenient as contrast sells in the construction world so almost all my studio tools are predominantly two colors.

[16] There are two major types of color 3D printers. There is direct color 3D printing and indirect color 3D printing. Direct color is using the actual filament color as the resulting multicolor print. In indirect color 3D printing, color is applied from an external source. I use dual color printing here to maintain the relationship to the 3D pen and to keep the history of the material plainly visible.

The Origins of 3D Pens and Printers

Imagine a man in his basement holding a hot glue gun. A furrowed brow, a few beads of sweat, pushing out bead after bead of glue trying to build a toy frog for his daughter. This image is in fact, or at least in lore, the actual origin of fused filament fabrication (FFF), the most commonly known form of 3D printing. A father, an inventor, and a future co-founder of Stratasys, one of the early leading 3D printing companies, making a toy frog layer by layer. A frog that led to the patent that would go on to make 3D printing widely accessible and common place. Clearly, there is no coincidence here that 3D printers are in essence big fancy hot glue guns. S. Scott Crump is the father in this story, and as he and Stratasys co-founder Lisa Crump patented ideas and advanced a technology, the maneuverability of the mechanism to moving the nozzle of these fancier hot glue guns was being measured in fractions off a mm. This process was advanced to account for speed and consistency, and can now print ten identical toy frogs with a .2 mm layer height in a matter of hours.

In this evolution of printing technology, it would be logical to presume that the 3D pen played a part in this development. Strangely, that is not the case. Crump made his glue gun frog attempts in 1988, sold his first 3D printer in 1992, and the first 3D pen was not released until 2013[17]. The pen itself was invented due to a 14 hour 3D print resulting in a single missing line. This evolutionary back step and shuffle was the hand fixing the machine that fixed the hand.

[17] The 3D Doodler was invented by Maxwell Bogue and Peter Dilworth when they had one line fail to print on a 14 hour 3D print. The pen was made to fix a section of the machine's job and that task remains as one of the major uses of the 3D pen. My first exposure to the pen was in Syracuse University's digital fabrication lab, which had one for the sole purpose of "welding" broken 3D prints back together. The 3D printer was made to better the hand and the 3D pen was made to better the machine.

Notes On Display

In the display of the objects, to further contrast the line quality in the 3D pen with the precision of the 3D printer, I make my own shelves. The shelves are all white, 3D printed on a Lulzbot TAZ 6 layer by layer. The first one I made was almost perfect aside from the fact that the filament caught halfway through the print. The filament had a tangle in it when it was loaded onto the printer, which can affect a print immediately or wait for hours. I watched my shelf start to print, and sat with it for seven hours, making sure nothing went wrong, and then I left it overnight to print the remaining six hours and fifty minutes. The tangled filament seized up and locked the print within an hour of my leaving so the printer continued to go through the motions of the print, layer by layer, with no filament coming out of the nozzle. What this means I am left with is a block of PLA with a smooth top and absolutely no bottom.

The shelf I designed was made for boxes of nails that I have been using as a base for other objects. They are black with light detailing so they serve as a good foundation for the arrangements. The shelf is white so that every shadow and detail is read loud and clear, and it is meant to blend well with the wall, showcasing the objects on top. The shelf leaves an inch of space around the nail boxes on every side, and then has a filleted edge on the corners. The shelf is made to be printed with this side facedown. The section of the print that touched the heated bed of the printer is the most pristine and flat for two reasons. The first is that the extruder nozzle moves much slower during the first layer of printing to ensure that the print sticks well to the bed. The second is that that bed is heated, to again ensure the best possible adhesion so this combo means that the lines on the first layer become wide and flat and seem to melt together to form a very flat surface bonded to the bed.

The shelf is made from a basic shape consisting of five surfaces: The top, the back, the two sides, and the front. The front of the shelf is a large curved plane that connects the front edge of the shelf to the bottom where it meets the wall. Looking at the shelf from the side profile, the top comes to a right angle with the wall. The front face of the shelf, is an arc that evenly comes down from the front edge to wall. The sides are similar to quarter circles that fill in the area left by front, back, and top. The overall shape is not dissimilar to the digging bucket on a backhoe but with a flat top and cleaner curve. From this shape, there is a compound radius curve along the edges where the sides and front meet. I added this radius as it is simple and quick for the modeling software to do and then just as simple for the 3D printer to execute the curve with precision. This curve is meant to make the machines show off and contrast their ability to create this complex task with the goopy flat planes of the 3D pen objects.

I am for the showcasing of the history of how each piece is made, what is happening to support the inside, how precise the lines were made, and putting failed prints on display so the completed print can be better understood. I am for showing the material as it is for what it is. To this end, I only use PLA in the creation or arrangement of all object reproductions. This extends to the shelves as well, which are made entirely from PLA and have the hanging mechanism built into the part itself. Each element in these arrangements pushes the skill of the hand and the ability of the machine and serves to showcase the capabilities of both categories of making.

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