Preliminary research Playaprinter 3D Nozzle

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Figure 1: playaprinter

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TO DO: bronnen plaatsen

Onderzoek naar Endstops als extra hoofdstuk???? onderzoek naar 8 bit vs 32 bit controllers

1 Introduction Playa Project//ISSUE/Probleemstelling

In our daily lives we use normal printers that can print the design on a flat surface, a 3D printer and a ordinary printer working principle is basically the same, just some different printing materials. Printing material for a ordinary printer is ink and paper. A 3D printer can be equipped with metal, ceramic, plastic, sand and other different print materials. The printer is connected to the computer through USB/Bluetooth through which it prints layers of material. The methods generally referred to as 3D printing is called fused deposition modeling(FDM).

In this research paper we shall examine the feasibility of creating a 4 by 4 meter 3D printer. This project is a collaboration between the Hogeschool Rotterdam and Havenlab RDM. It started at a Burning Man Festival with the idea to create a 3D printer that would "leave no Trace". The components of the Playaprinter needed to be crafted of parts that are available to the general public. Furthermore the design/code needs to be based off FOSS(free and open-source software). The "Leave no Trace" refers to the fact that the 3D printer could use natural resources like clay to create structures/sculptures.

Against this background, the central question that motivates this paper will be if it is possible to create a open source 'DIY' print nozzle. It is the most crucial part for creating precise 3D structures. In this paper we look at the different kind of 3D printer nozzles and how the work. In addition if it is possible to create a 3D printer nozzle and other needed materials that are available to the general public.

2 Different materials used in 3D printing

One of the most crucial factors in creating your own 3D printer is knowing the type of material being used. This determines the 3D head that is needed to transport/heat the substance. To answer this question, we begin by taking a closer look at the different kind of materials.

2.1 ABS - PLA - PTG

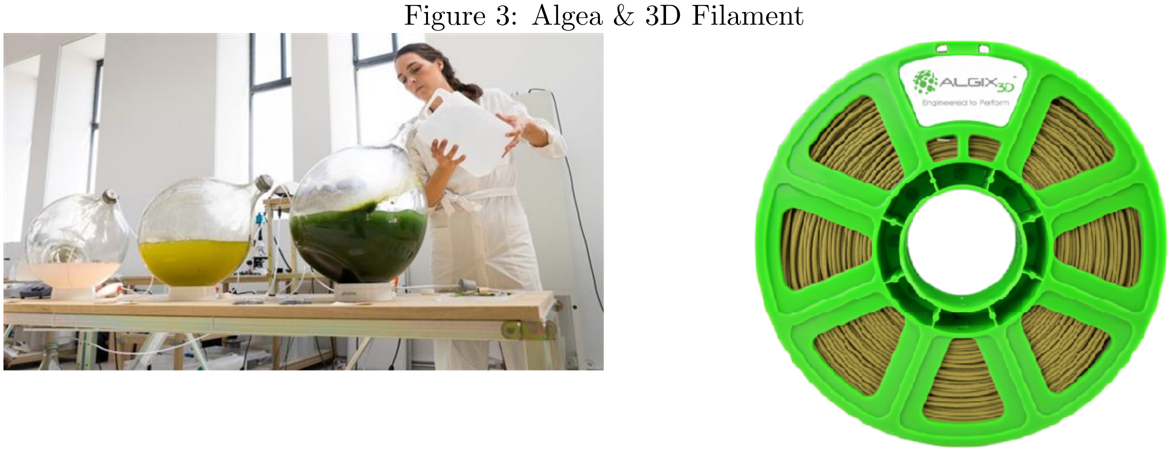
The most common type of 3D print material found in almost every consumer device. It is easily accessible and works well in different situations depending on the type 3D filament. Some filament can make a 3D structures flexible while others filaments excel at strength and pressure. ABS was one of the first plastic to be used with 3D printers. Many years later, ABS is still a very popular material thanks to its low cost and good mechanical properties. ABS is known for its toughness and impact resistance, allowing you to print durable parts that will hold up to extra usage and wear.

Figure 2: Common 3D printer material

2.2 Algae

Algae is a new 3D print material first proofed by researchers at the Wageningen University. Working with scientists, Klarenbeek developed a new way of 3D printing with living organisms. The created a 3D printed chair using living fungus, which then grows inside the structure to give it strength. A different version of this is growing algea and than process the algae into a special sustainable filament.

Figure 3: Algea & 3D Filament



2.3 Clay and other sand combinations

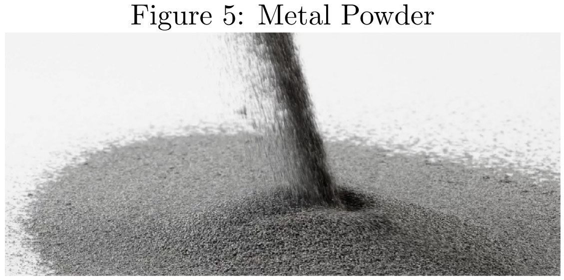
Clay is a common resource that can be found almost anywhere, it is a finely-grained natural rock or soil material that combines one or more clay minerals. Clay are plastic due to particle size and geometry as well as water content. A property of clay is that it become hard, brittle and non–plastic upon drying or heating. In the natural environment a lot of different combinations of sand, silt and other materials can be found. Clay is distinguished from other fine-grained soils by differences in size and mineralogy.

Figure 4: Building Clay & Natural Clay

2.4 Metal powders

Metal 3D printing is carried out by fusing powdered metal particles together to create a object in a successive layer by layer printing process. Metal is heated up and requires specialized equipment to create special 3d metal powder. A powder bed fusion 3D printer uses a laser to sinter powdered material. A powerful laser beam selectively melts and fuses tiny powder particles together. Once a layer is finished, more powder is rolled and spread onto the print bed. The particle properties of the metals is very important for successful 3D printing.

Figure 5: Metal Powder



All these different types of materials require a specific type of 3D nozzle + extruder combination to work. ABS & Alga and other common filament uses a more traditional hotend to create 3D objects. For clay and other natural resources this usually requires a auger design with a fluid pump to work correctly. This is due to the fact that it needs a container and controlled pressure.

Industrial installation uses metal powder to use as a base material for printing. In the next chapter the paper will look at the different kind of systems in greater detail.

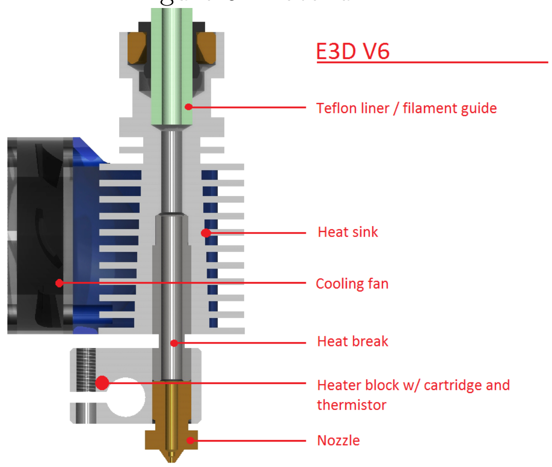
3 Printhead

In this section we will look at the different 3D nozzle & extruders combinations and the working principles behind them. Our focus is on the possibly to replicate it with normal means and being applicable for the (PlayaPrinter) 4m by 4m printer.

3.1 Hotend Design

The hotend the is most common used in a 3D printer. The hotend is where the heated filament comes out and moves through the nozzle to the print bed to create a 3D object. The heaterblock is the part that is responsible for heating up the filament. ABS needs to be around 230 degrees to start to liquefy. During the liquefaction stage the filament is compressed in smaller space to increase heat friction. Temperature control is a big factor for creating good 3D print results.

Figure 6: Hotend

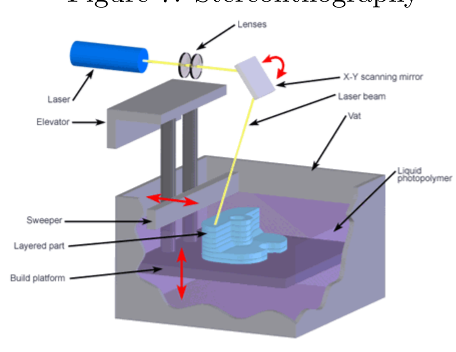


3.2 Stereolithography

The stereolithography process first appeared in the early 1980s, when Japanese researcher Dr. Hideo Kodama invented the modern layered approach to stereolithography by using thin layers of a material curable by ultraviolet light. A process by which light causes chains of molecules to link, forming polymers.

Today it is still one of the most popular method for designers. The finished parts have a very high resolution and accuracy, clear details and the smoothest surface finish of all plastic 3D printing technologies. Futhermore the advantages of stereolithography is its speed, functional parts can be manufactured within a day.

Figure 7: Stereolithography



3.3 Powder Bed Fusion

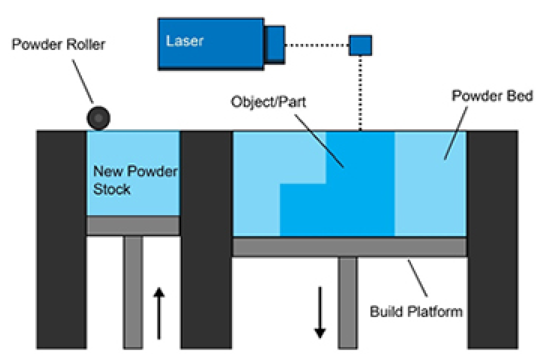
Selective laser sintering (SLS) was one of the first additive manufacturing techniques, developed in the mid-1980s by Dr. Carl Deckard and Dr. Joe Beaman at the University of Texas at Austin. Their method has since been changed to work with a larger range of materials. This include plastics, metals, glass and other composite material powder. Today this is called Powder Bed Fusion.

Power bed fusion is the most common additive manufacturing technology for industrial applications. It starts by using a atomizer. Atomisation is the process of transforming a solid solution form into fine particles in a surrounding gas. The end result is a powder which than can be used for 3D printing.

Industrial power bed fusion systems use a single or multiple high-power carbon dioxide lasers. Powder is dispersed in a thin layer on top of a platform inside the build chamber. The printer preheats the powder to a temperature just below the melting point. This makes it easier for the laser to raise the temperature of specific regions of the powder bed as it traces the model to solidify a part. This fuses the particles together mechanically to create one solid part.

It is most used in very specialized facilities and has very specific requirements to work properly though it is superior in its strength and for creating very large objects.

Figure 8: Powder Bed Fusion

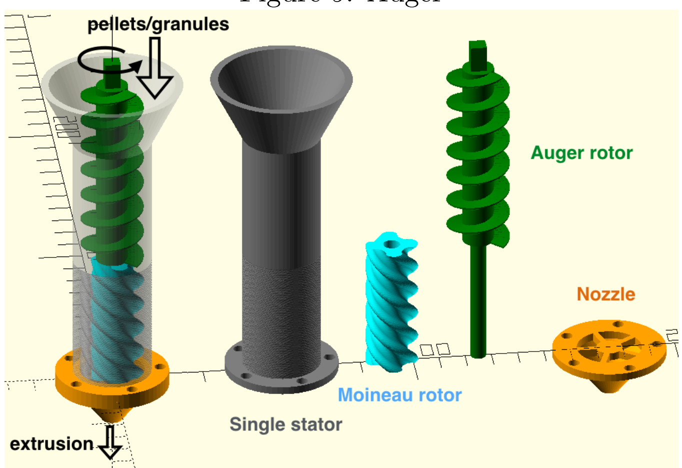


3.4 Auger Design

A auger design is based on the principles of the Archimedes screw. It is a machine used for transferring water from a low-lying body of water into irrigation ditches. Water is pumped by turning a screw-shaped surface inside a pipe. This technology has been around since Egyptian times, when it was used to remove water from the Nile river.

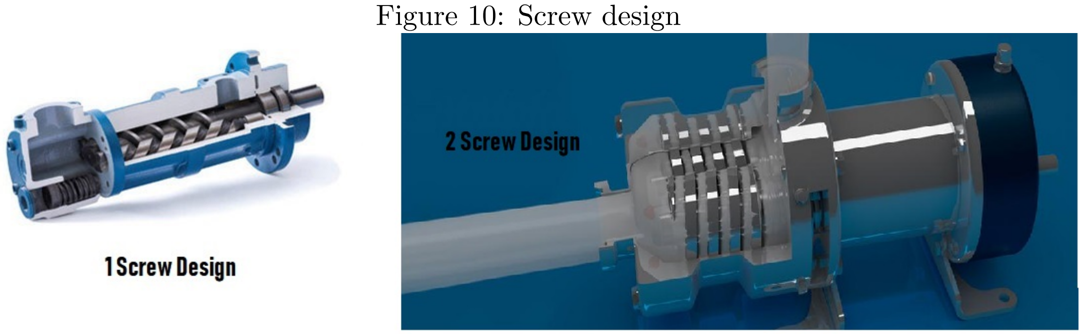
An auger design uses a screw (auger) to move material down a cylinder. The rotation of the screw creates a shearing force on the material which drives it down the threads of the screw. A example of a 3d print auger design is shown below.

Figure 9: Auger



Types of screw There are many variations in the design of the screw which are fundamental in moving the fluid through. The primary differences consist of the number of intermeshing screws involved, the pitch of the screws, and the general direction of fluid flow. A single screw pump contains a single screw that rotates within a closed tube. The individual screw pushes a set volume of fluid forwards with every rotating. Two screws or more can benefit a precise flow rate but come at the expense of high cost and additional maintenance.

Figure 10: Screw design



3.5 Auger Design + Fluid Pump Extruder

The characteristics of a fluid pump is that by adjusting the motor speed you can control the flow rate. It works by having a closed tube with at the end a cover which creates a airtight seal. This cover is connected to the motor which pushes it down through the tube.

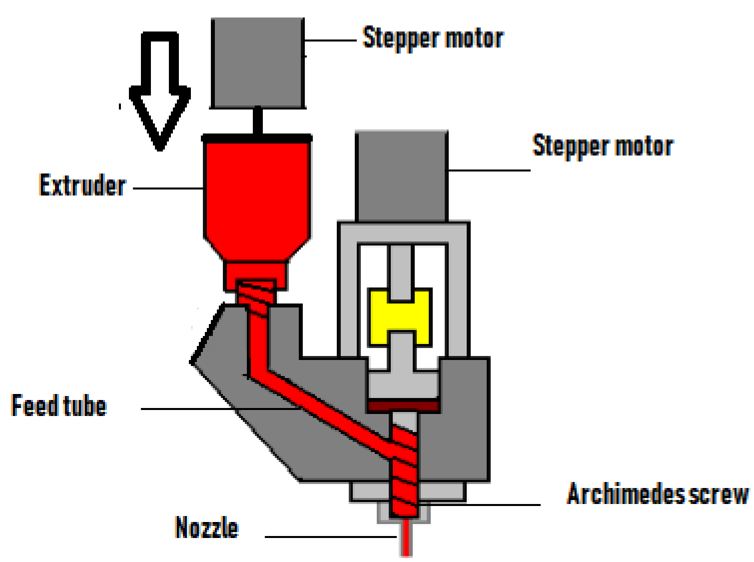
As the material is pushed down it comes in contact with the screw, which turns for a set length of time or rotates at a specified speed. The screw is causing the material to move down the threads. As the material reaches the end of the nozzle the pressure increases. This is due to the fact that the flow encounters resistance due to the restriction in area at the nozzle.

Any area restriction such as at the output of the auger creates backflow. The amount of backflow is proportional to the pressure drop from the nozzle to the extruder. As long as the the pressure inside the system is stable, the flow out of the needle is equal to the rotorspeed flow minus the backflow.

With this design it is very import to control the pressure inside the system.

- Low Air pressure
  - screw will cavitate
  - create missed dots
  - inconsistent 3D objects
- High Air pressure
  - Material will be forced through
  - drool(excess of fluid)
  - inconsistent 3D objects

Figure 11: Auger & Extruder



4 Motors

In this part of preliminary research we will look at the different kind of motors available. Every printer needs motors for the x & y & z axis, futhermore the 3D printhead/extruder needs depending on the type also 1 or more motors.

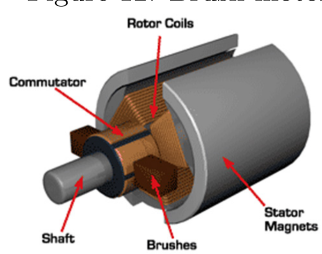
4.1 Brush motor

The DC brush motor is one of the simplest motors in use today. You can find these motors just about anywhere. They are in household appliances, toys, and automobiles. Being simple to construct and control, these motors are the go-to solution for professionals and hobbyists.

If energy flows the windings are energized, they attract to the magnets located around the motor. This rotates the motor until the brushes make contact with a new set of contacts. This new contact energizes a new set of windings and starts the process again.

- Pros
  - Simple to control
  - Excellent torque at low RPM
  - Inexpensive and mass produced
  - Simple to control
- Cons
  - Brushes can wear out over time
  - Brush arcing can generate electromagnetic noise
  - Usually limited in speed due to brush heating

Figure 12: Brush motor



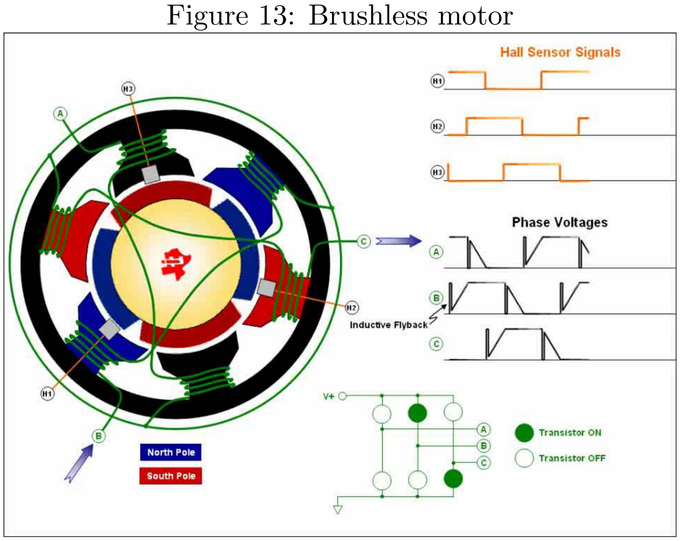
4.2 Brushless motor

Brushless motors have begun to dominate the hobby markets between aircraft and ground vehicles. Controlling these motors was until a few years difficult due to the fact that controllers were buggy and expensive. Nowadays micro controllers are cheaper and powerful enough to handle the task. Without brushes to fail, these motors deliver more power and can do so more silently.

The mechanics of a brushless motor are simple. The only moving part is the the rotor, which contains the magnets. Where things become complicated is orchestrating the sequence of energizing windings. The polarity of each winding is controlled by the direction of current flow.

- Pros
  - Reliable
  - High speed
  - Efficient
  - Mass produced and easy to find
- Cons
  - Difficult to control without specialized controller
  - Requires low starting loads
  - Typically require specialized gearboxes in drive applications

Figure 13: Brushless motor



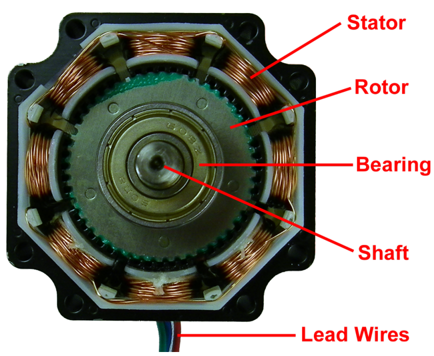
4.3 Stepper motor

Stepper motors are motors for position control. They can be found in desktop printers, plotters, CNC milling machines and anything else requiring precise position control. Steppers are a special segment of brushless motors. They are purposely built for high-holding torque. This high-holding torque gives the user the ability to incrementally ”step” to the next position.

Stepper motors behave exactly the same as a brushless motor, only the step size is much smaller. The only moving part is the rotor, which contains the magnets. As with brushless motors the complicated aspect is orchestrating the sequence of the windings.

- Pros
  - Excellent position accuracy
  - High holding torque
  - High reliability
  - Most steppers come in standard sizes
- Cons
  - Small step distance limits top speed
  - It’s possible to ”skip” steps with high loads
  - Draws maximum current constantly

Figure 14: Steppermotor



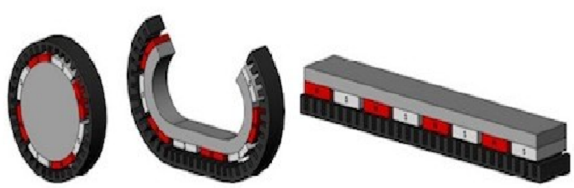
4.4 Linear motors

A linear motor is often described as a rotary motor, just cut up and rolled out. Linear motors use magnetic levitation to move an object. This way it is not slowed down by friction and can actually achieve more precise control than mechanical options.

In a traditional electric motor, the rotor spins inside the stator. In a linear motor the stator is unwrapped and laid out flat and the ”rotor” moves past it in a straight line. Linear motors have a number of advantages over ordinary motors. There are no moving parts to go wrong. As the platform rides above the track on a cushion of air, there is no loss of energy to friction or vibration. The same technique drives the Maglev trains.

- Pros
  - Reliable
  - High speed
  - Efficient
  - No rotary to linear conversion required
- Cons
  - Expensive
  - Require custom controllers
  - Purpose built for each system

Figure 15: Linear motor



5 Morphological Chart

Table 1. Morphological chart

Sub Functions	*Solutions*	*Solutions*	*Solutions*	*Solutions*
3D head Type	Stereolithography	Power Bed Fusion	Auger + Extruder	Hotend
Motor	Brush motor	Stepper motor	Linear motor	Brushless motor
Screw type	1 Screw	2 screw	x	x
3D printhead material	ABS/PLA	Metal casting	Aluminum	Wood
Nozzle size	0.6	0.8	1.2	1.5
Controller	Mega + RAMPS	Smoothieboard	Azteeg X5 GT	RADDS

6 Are there already existing (partial) solutions to this problem?

For the Playaprinter the objectives are to create a massive 3D printer that can print with natural resources. The choice for this project is based on clay or other materials with a similar liquid properties. It needs to be fabricated with normal purchasable parts without resorting to expensive solutions. Furthermore it needs to print large 3D objects with a high level of detail.

Currently the are no (affordable) clay printer purchasable. The are a few clay nozzle sets and extruders but for a very steep price and with questionable performance. The also come bundled with closed software and are meant for small printing.

So it will be required to make a custom solution that satisfies the needs for this project. This will include the 3D print head which receives the clay and hold the auger and motor. The nozzle will be attach to the bottom of the 3D head which will feed the clay.

With regards to the other parts:

- Nozzle size
- Controller

In these categories the are several parts available to purchase. It will be a combination of desk research and field research to determine the best combination of components. After this process the need to be combined through soldering and creating code for all the individual component necessary.

7 Conclusion

Playaprinter needs to be a printer that is able to print material over a large x & y & z axis, with a 3D head + nozzle that is capable to print clay with a high level of detail.

The playaprinter will need a auger + extruder design to function correctly. This is because of the sheer pressure required to push the clay through.

The extruder can push the clay in which the extruder is essential. In combination with a auger design it should be possible to print clay. The combination of a auger and extruder should ensure a system in which a double system of delivery works together. The auger creates a high pressure zone in which the clay is pressed through the nozzle whilst the extruder controls the overall system pressure.

With the combination of a auger and a extruder the accuracy of the 3D print should increase. It can solve outflow problems due to the fact that pressure inside is controlled and should result in a smooth and accurate 3D printed object.

It will require creating several custom 3D printed objects to craft all the necessary parts. Also needed is a workshop to create and lay out all the parts.

Beside the fact that a 3D printer is needed for the project, a laser cutter is very useful for easy and fast prototyping. The material for the frame while be aluminum. The is because of the lightweight and sturdy properties.

The frame that will support the 3D head also needs to be created. It needs to be flexible in design so that in the future it can be easily replaced or swap with a more traditional hotend or other designs. Futhermore it needs to able to withstand all the stresses and weight from the clay extruder.

Lastly the motors that will be used are steppermotors. The reason for this is that we need a high level of accuracy. One of the most important aspect will be to generate enough torque. A normal steppermotor can't deliver enough torque to push clay through. A additional gearbox or gear conversion is needed to maintain the best combination of torque and speed.

Table 2. Morphological chart with part selection

Sub Functions	*Solutions*	*Solutions*	*Solutions*	*Solutions*
3D head Type	Stereolithography	Power Bed Fusion	Auger + Extruder	Hotend
Motor	Brush motor	Stepper motor	Linear motor	Brushless motor
Screw type	1 Screw	2 screw	x	x
3D printhead material	ABS/PLA	Metal casting	Aluminum	Wood
Nozzle size	0.6	0.8	1.2	1.5
Controller	Mega + RAMPS	Smoothieboard	Azteeg X5 GT	RADDS

8 Bills of Materials

These items are necessary to create the 3D head and create a 3D design that works with clay extruder.

- 3D Printhead
  - Printed 3D Head(needs to be printed)
  - Printed Base (needs to be printed)
  - Nema 17 stepper motor
  - Stepper driver A4988
  - Mega 2560 + RAMPS 1.4
  - 1/2" Flat faucet washer
  - 3/8" x 3/8" push fit male adapter
  - Aluminum coupler 5mm
  - Deck Screw
  - Cake decorating tips (nozzle)
  - Acces to wood/metal for creating frames and support structures.
- Extruder
  - 3D parts (needs to be printed)
  - Nema 23 stepper motor
  - Stepper driver A4988
  - Nema 23 gearbox: either 20:1 or 30:1
  - Leadscrew
  - Acces to wood/metal for creating frames and support structures.

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