2020

Economical Custom-Made 3D BioPrinter

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V I R G I N I A   C O M M O N W E A L T H   U N I V E R S I T Y

Economical Custom-made 3D Bio-Printer

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Motivation

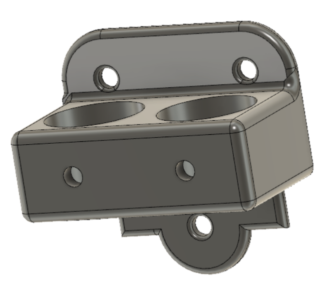
Bioprinters are used to extrude biomaterials that contain living cells to develop synthetic organ and tissue models. Being able to 3D bio-print these models allows us to build the small intricate structures that mimic complicated living organs. As of now, the technology is expensive, with the average bioprinter exceeding ten thousand dollars. The high price often makes this tool a high-risk investment for many biomedical companies and researchers who may want to use utilize this technology. Fortunately, the components that make a bio-printer could be inexpensive, especially with the open-source environment 3D printers have become. Altering the firmware and mechanics of a 3D printer can be relatively simple.

Methodology

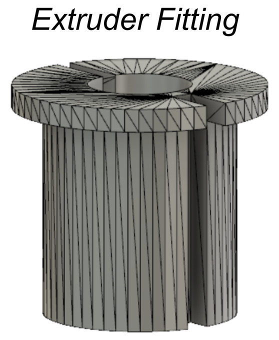
❑ Modified Pneumatic Extruder Holder

Structure: When making a new extruder, the one that came with the machine had to be replaced by a holder that was designed using CAD software and then printed. The holder was made to accommodate up to two extruders.

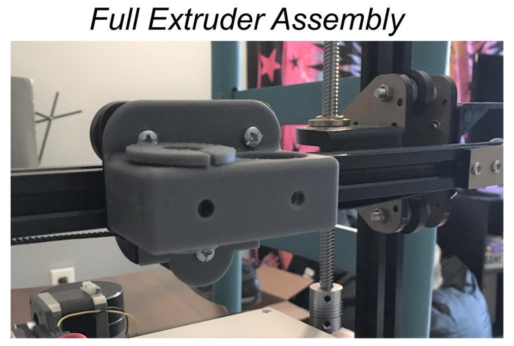
Extruder Holder



Extruder Fitting

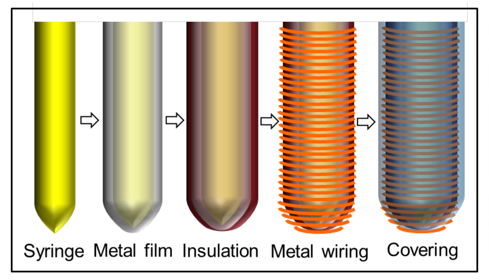


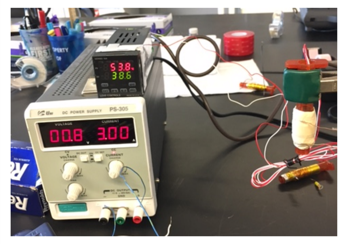
Full Extruder Assembly



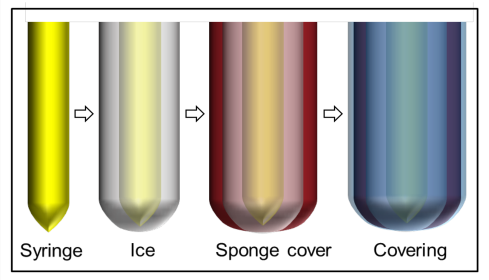
Temperature Sleeves: When using bio gels, certain temperatures need to be maintained to either preserve the life of the cells that may be in it or to change the viscosity of the gel so that it can be printed without too much ooze to the point the structure is lost. That is why this printer is accommodating to the different temperatures that different bio gels need for successful printing.

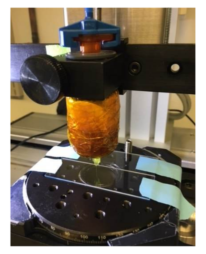
Heating Sleeve for Pipette



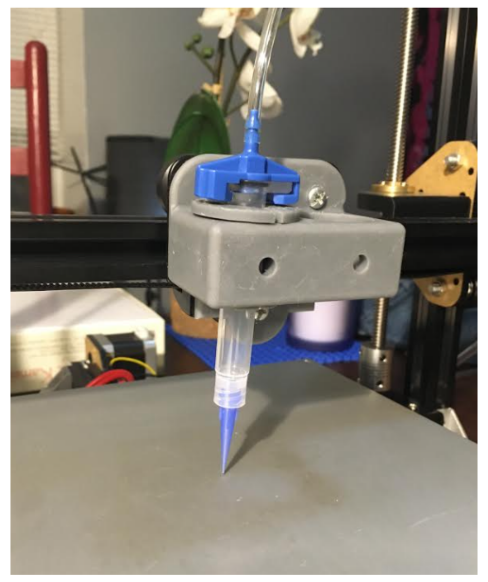


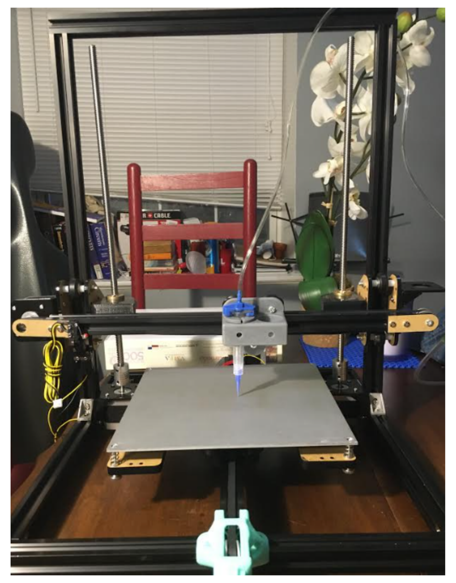
Cooling Sleeve for Pipette

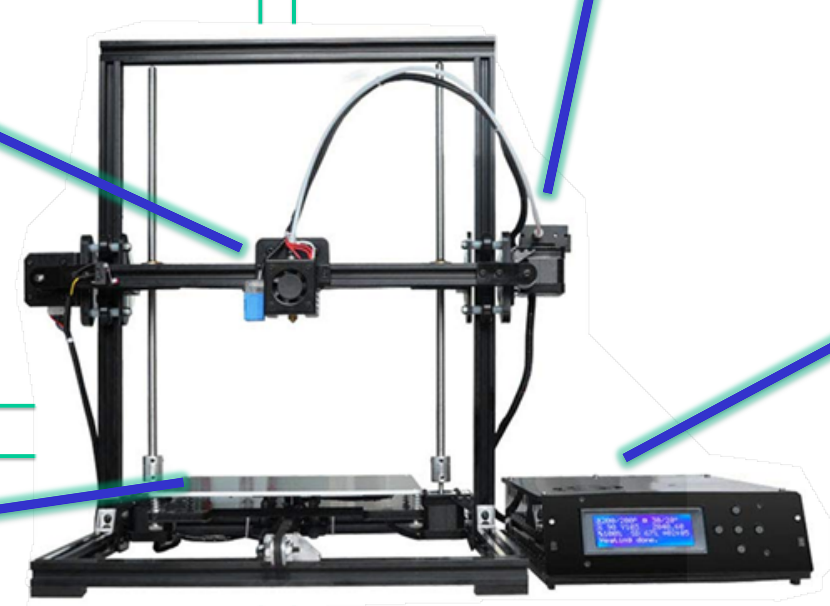




The coil of wire for the heating sleeve for this system is powered by the on-board voltage pins. While the cooling sleeve will use the ice method seen in the diagram as an effective but less permanent solution. The good thing about this system is that it was made by interchanging parts from a conventional 3D printer which makes the bio-printer overall a more versatile machine, so interchanging parts like for heating/cooling doesn't become a timely task.







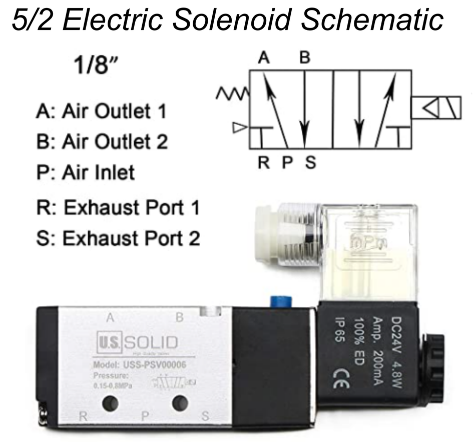
❑ Heated Build Plate

The heated build plate is important to this process because it will help maintain the heat of the bio gel post extrusion if needed. Luckily, the Tronxy 3D printer came with a built-in heated build plate. When using the build plate it is important that it maintains a lower temperature than typical 3D printers use to preserve the living cells within the bio gel.

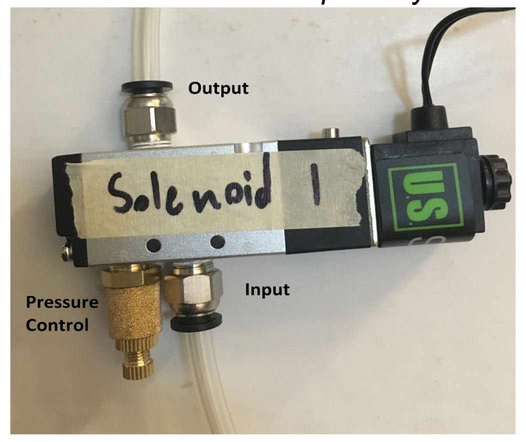
❑ Pneumatic Extrusion System

Solenoids: Two solenoids are used to control the air pressure that pushes the bio gels out of the pipettes. For dual extrusion, there are two solenoids that use the same air compression source. The way these solenoids work is by having them connected to the motherboard to be controlled by the firmware. Whenever gel is to be extruded, the air pressure valve is open otherwise it will be closed.

5/2 Electric Solenoid Schematic

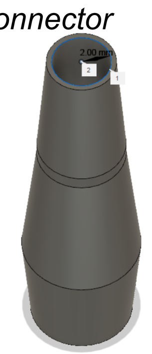


Actual Solenoid Setup for System

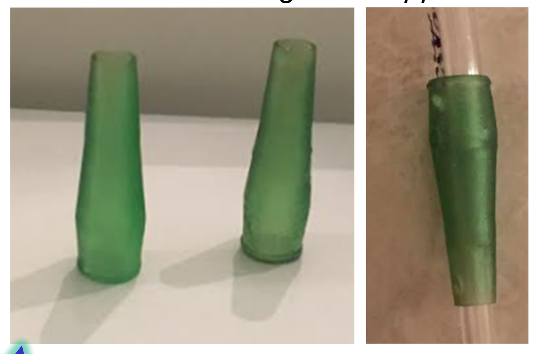


Connectors: The system to the right encompasses all the components needed for a dual extrusion setup for the Bio 3D-Printer. The custom connectors seen below are important because it provides a flow connection between tubes of different diameters so that there is consistent and predictable air force going to the gel in the extruders.

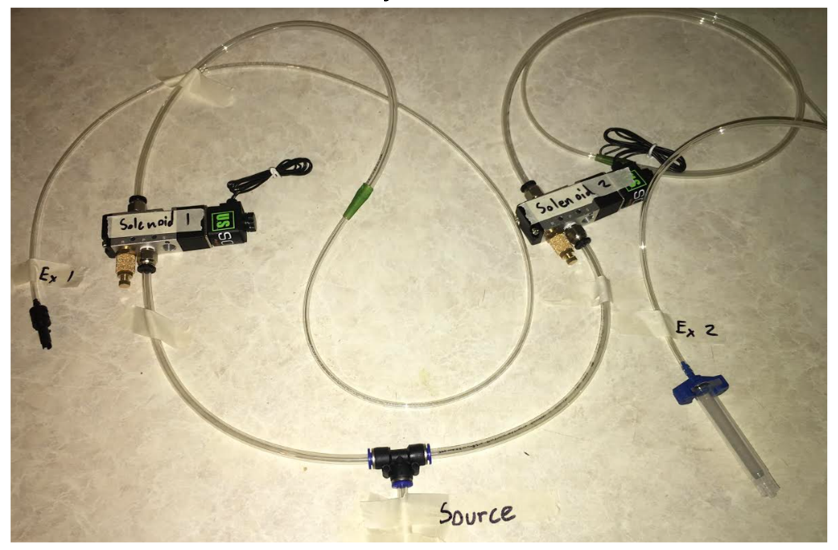
CAD Model of Connector



3D Prints of Design with Application



Full Pneumatic System for Dual Extrusion

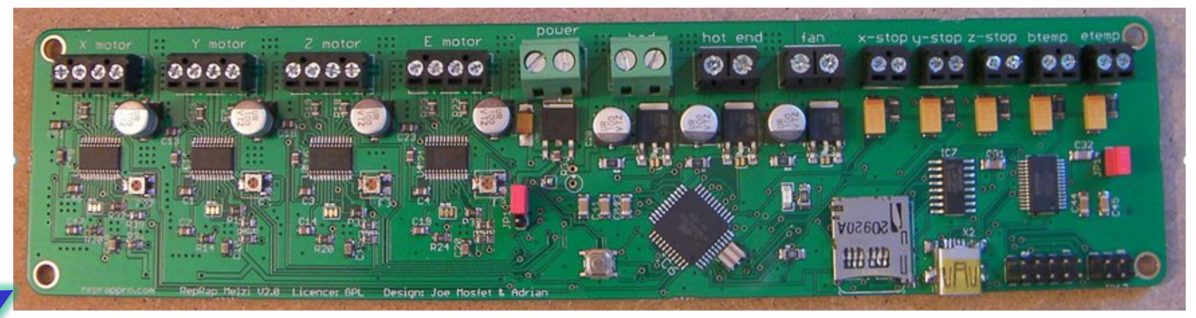


- **Custom tubes made in Fusion 360 to alter the Flow Diameter to work with the pipette**

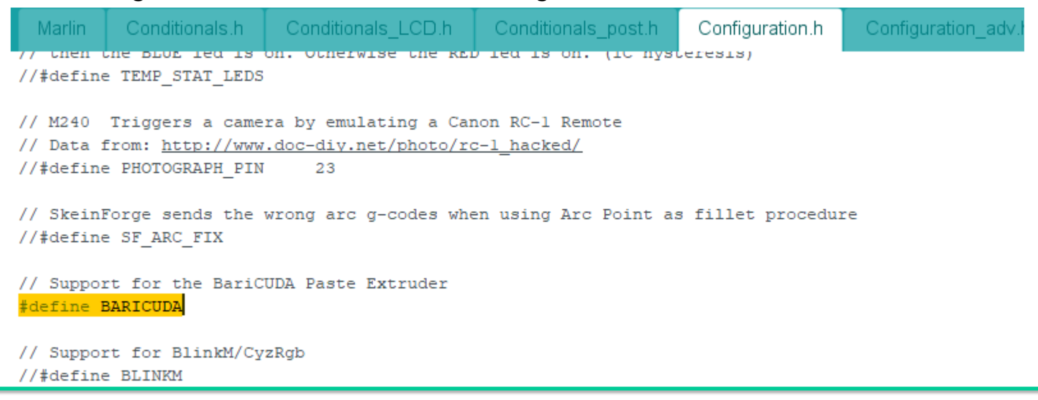
❑ Updating Firmware

The motherboard that came with the Tronxy 3D printer is a Melzi 2.0 and the updated firmware includes a header file by the title of Baricuda that controls the electric solenoids. After this update, the printer will no longer use a stepper motor and heated nozzle for extrusion and instead use the electric solenoids and the temperature sleeves.

Melzi 2.0 Motherboard



Enabling Baricuda in the Marlin Configuration Header File




```
//#define TEMP_STAT_LEDS

// M240  Triggers a camera by emulating a Canon RC-1 Remote
// Data from: http://www.doc-diy.net/photo/rc-1_hacked/
//#define PHOTOGRAPH_PIN     23

// SkeinForge sends the wrong arc g-codes when using Arc Point as fillet procedure
//#define SF_ARC_FIX

// Support for the BariCUDA Paste Extruder
#define BARICUDA

// Support for BlinkM/CyzRgb
//#define BLINKM
```

Results/Discussion

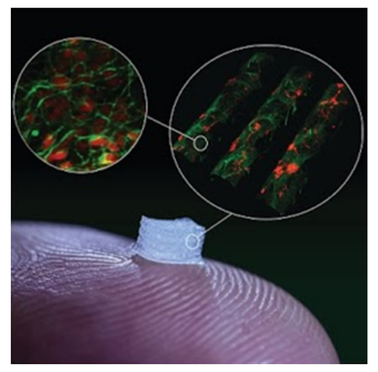
For this proof of concept project, converting a traditional Cartesian 3D printer to a bio-printer is shown to be possible on the hardware and software level. On the hardware level, a new extruder was developed using pipettes and designing a new extruder holder for them. The more complicated part of the project was editing the firmware to support the change in hardware. Finding the right firmware to edit, making the correct changes to the code, and flashing the motherboard to install the new firmware took a lot of time to figure out, but it proved incorporating bio-printer hardware with a traditional 3D printer is possible.

Conclusion

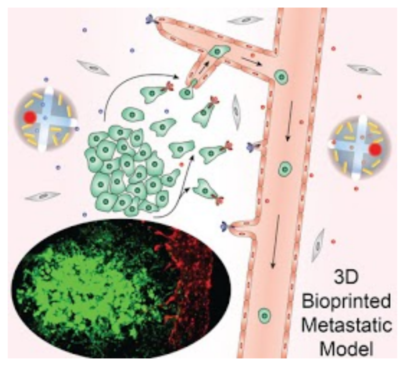
Using the skeleton of a plastic extrusion 3D printer allows for the precision of the device's expected use to be applied to a whole different material. We believe the rapid innovation and availability of 3D printers will open doors for many new manufacturing techniques and uses. The proof of being able to apply this technology to the printing of biomaterials confirms how others can make steps to innovate in most areas using 3D printing as a vessel.

Future Implications

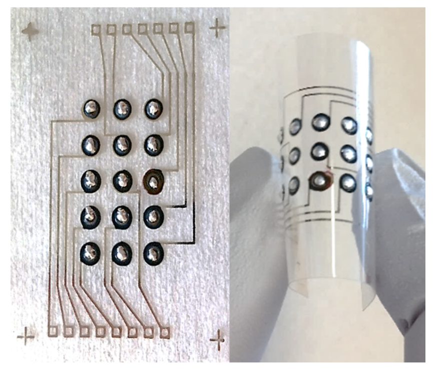
With this economical custom-made 3D bio-printer, we can develop platforms of 3D functional devices for diverse applications in regeneration devices, In Vitro cancer models, and biomedical sensors, opening new opportunities to test therapeutic options.



Adv. Funct. Mater. 28, 1801850 (2018)



Adv. Mater. 31, 1806899 (2019)



Adv. Mater. 30, 1803980 (2018)

Works Cited

- Resources for firmware editing
https://all3dp.com/2/marlin-firmware-how-to-get-started/
- Installing Firmware
https://letsprint3d.net/guide-how-to-flash-a-bootloader-on-melzi-boards/

Acknowledgements

I would like to thank Dr. Daeha Joung for guiding me through this prosses and suggesting this project for me as well. Without his back-ground in 3D bio-printing, I would not have the insight to go about this task correctly.