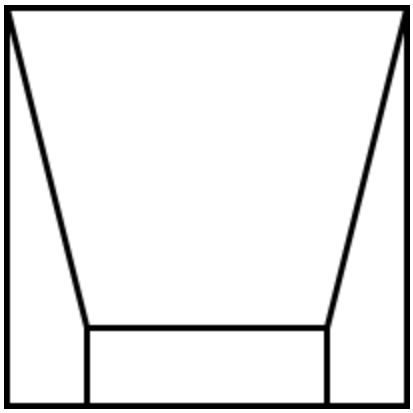

Instructions for converting a RepRap into a cost-effective bioprinter

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February 2016

MATERIALS REQUIRED

- 1 x T5 10 teeth metal drive gear
- 1 x 5-6mm wide T5 belt (~40cm in length)
- 4 x 624 bearings
- 1 x 608 bearing
- 1 x 20mm M8 smooth rod
- 1 x 75mm M4 bar or bolt
- 1 x 55mm M4 bolt
- 4 x 20mm M4 bolts
- 2 x 45mm M3 bolts for idler
- 5 x 10mm M3 bolts
- 4 x M4 plain nuts
- 4 x M4 Nylock nuts
- 3 x M3 plain nuts
- 14 x M4 washers
- 4 x M3 washers
- 1 x M4 hex spacer (or M4 wingnut)
- 1 x spring or Silicon pressure spacer for idler
- 1 x small zip tie
- 1 x plastic sheet
- 1 x 10ml Luer Lock Syringe with replaceable needles
- 1 x 4mm thick acrylic sheet - 100mm x 100mm. - bent into an angular U shape. (Used to mount the extruder onto the RepRap - any material that can be bolted will do).

METHOD

Extruder

The methodology used to convert the RepRap to a bioprinter is largely based on Richard Horne's open source Universal Paste Extruder design[1], with some modifications. This design uses the NEMA17 stepper motor usually used for extruding solid material in the RepRap to compress a syringe filled with biomaterial. The steps are illustrated in Horne's video instructions[2], but for more clarity has been outlined below:

1. Use the RepRap to print the extruder body and gear sets for the Universal Paste Extruder. The part files can be downloaded freely from Thingiverse[3].

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[1] "Universal Paste extruder - Ceramic, Food and Real ..." 2012. 1 Feb. 2016 <http://richrap.blogspot.com/2012/04/universal-paste-extruder-ceramic-food.html>

[2] "Universal Paste Extruder Assembly Instructions - YouTube." 2012. 1 Feb. 2016 <https://www.youtube.com/watch?v=iiyEOKpz_b8>

[3] "Universal Paste Extruder for 3D printers - Thingiverse." 2012. 1 Feb. 2016 <http://www.thingiverse.com/thing:20733>

2. Insert M3 nut into slot in the printed small motor gear, and screw in an M3 x 10mm bolt.
3. Insert 2 x M3 nuts into the small slots at the top of the printed extruder body and an M4 nut into the third slot.
4. Insert the M8 x 20mm smooth rod into the 608 bearing and snap it into the printed idler bearing holder.
5. Insert an M4 plain nut into the big slot and the M4 hex spacer in the hexagonal cavity in the printed large gear.
6. Remove the NEMA17 stepper motor used for extruding on the RepRap and fix the small motor gear to it's shaft.
7. Remove the M3 x 10mm bolt from the small motor gear, fit the motor to the printed body using 4 x M3 x 10mm bolts and 4 x M3 washers, and screw in the M3 x 10mm bolt into the small motor gear again.
8. Insert an M4 plain nut into the printed idler and fit the printed idler to the printed body using the M3 x 45mm bolts.
9. Fit the M4 x 75mm bar through the M4 hex spacer in the printed large gear and use an M4 Nyloc nut to fix it. Bolt an M4 x 20mm bolt into the previously inserted M4 nut to tighten it.
10. Insert the T5 gear and belt into the printed extruder body, press fit 2 x 624 bearings into the bearing cavities of the printed extruder body (one on each side). Put on 4 x M4 washers onto the M4 x 75mm bar attached to the printed large gear, and slide the bar through the 2 x 624 bearings and the T5 gear. Put a washer on the other side and fix it with an M4 Nyloc nut. Tighten the T5 gear to M4 x 75mm bar.
11. Insert a 624 bearing and M4 washer into the printed pressure cap, and fix it in place using an M4 x 20mm bolt and an M4 plain nut and M4 washer.
12. Press fit the last 624 bearing into the side of the printed extruder body (between the printed small and large gears). Insert the M4 x 55mm bolt through the printed middle gear (with a washer in between), add 3 M4 washers to the bolt and fix it to the printed extruder body through the middle 624 bearing using an M4 Nyloc nut and M4 washer.
13. Insert the T5 belt into the bottom of the printed pressure cap and then between the printed middle gear's shaft and printed extruder body.
14. Use the cable tie and the slots in the printed idler to tie the end of the T5 belt; this is done to prevent belt jams.
15. Use a bolt and a spring or a silicone pressure spacer on the printed idler.
16. Roll up the plastic sheet and insert into the cavity in the printed extruder body next to the T5 gear. Insert the 10ml syringe into this and fix it in place using an M4 x 20mm bolt. Attach the printed pressure cap to the top of the syringe plunger.
17. Bolt the bottom of the paste extruder body to the acrylic platform (or any other platform design) using 2 x M4 x 20mm bolts and 2 x M4 nuts and attach it to the RepRap axes.

RepRap Design Changes and Wiring

The wiring for the normal RepRap stays almost identical to the paste extruder; the only difference is that the extruder motor wires are interchanged on the RepRap circuit board to swap the direction of extrusion so that the stepper motor presses down on the syringe plunger without having to change any of the default settings on the software.

The fan and thermistor were no longer needed as the heat bed and thermistor temperatures were set to 0 (off), but as the fan is still required to work, this was attached to the top of the frame to ensure it was out of the way.

EXAMPLE PRONTERFACE SETTINGS

The extrusion settings on the Pronterface software had to be experimented with depending on the material that was extruded from the syringes, the environmental conditions, and the desired nozzle diameters (which were changed by using different attachable needles for the Luer Lock syringe). As such, it is difficult to state the 'correct' settings, but as a guide, the following settings were used for a highly-viscuous conductive paint[4], at a temperature of 21°C, with a nozzle diameter of 2.1mm:

Layers and perimeters

Layer height: 0.4 mm
First Layer Height: 0.35 mm
Perimeters (Minimum): 1 (Generate extra perimeters when needed)
Solid layers: Top: 1, Bottom:

Infill

Fill Density: 0.45
Fill pattern: Rectilinear
Fill angle: 45 degrees
Solid infill threshold area: 70 mm^2
Infill every 1 layer & only retract when crossing perimeters

Speed for print Moves

Perimeters: 200 mm/s
Small perimeters: 200 mm/s
External perimeters: 70%
Infill: 400 mm/s
Solid infill: 400 mm/s
Top solid infill: 300 mm/s
Support material: 400 mm/s
Bridges: 400 mm/s
Gap Fill: 150 mm/s

[4] "Electric Paint Application Notes - Bare Conductive." 2015. 1 Feb. 2016 <http://www.bareconductive.com/wp-content/uploads/2015/01/ElectricPaint_ApplicationNotes.pdf>

Speed for non-print moves
Travel: 130 mm/s

Modifiers
First Layer speed: 30 mm/s
(No acceleration control)

Skirt
Loops: 1
Distance from object: 6mm (arbitrary)
Skirt Height: 1 layer
Minimum extrusion length: 0 mm
(No brim)

Extruders
Perimeter extruder: 1
Infill extruder: 1
Support material extruder: 1

Extrusion width
First layer: 100%
(All other setting under this category are 0)

Filament Settings
Filament
Diameter: 2 mm
Extrusion multiplier: 1
(Cooling setting are set to default)

Printer Settings
Extruder 1
Nozzle diameter: 3 mm

Retraction
Length: 2 mm
Lift Z: 10 mm
Speed: 500 mm/s
Minimum travel after retraction: 1.8 mm

Retraction when tool is disabled (advanced settings for multi-extruder setups)
Length: 3 mm