NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

INTELLIGENT SYSTEMS DIVISION, ENGINEERING LAB

DEVELOPMENT OF A SOFT MATERIAL 3D PRINTER FOR ADVANCING CAPABILITIES IN SOFT
ROBOTICS AT NIST

SOP for Soft Material Printer

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Audience: Users who are required to print on the soft material printer.

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Disclaimer

Certain trade names and company products are mentioned in the text or identified in certain illustrations. In no case does such an identification imply recommendation or endorsement by the NIST, nor does it imply that the products are necessarily the best available for the purpose.

Change Log

Executive Summary

Problem Statement & Scope

The purpose of this documentation is to provide step-by-step instructions guiding users on how to use the soft material printer.

The scope shall be limited to describing the current methods for printing and should be updated if changes are made to the printer.

Goal

To provide a reference to users when printing elastomers or other soft materials with the soft material printer.

1. Requirements

Before using the soft material printer, the user should undergo appropriate safety training and prepare the Lulzbot Cura environment to simplify working with the printer.

1.1. Safety Training

To use the soft material printer, you must have undergone NIST's chemical safety training. If you have not completed this training, contact either your advisor or the division's current Safety Manager to get the proper training assigned.

After completing the safety training, you should also familiarize yourself with the Soft Robotics Material Manufacturing SOP.

1.2. Download the GitHub Repository

1. Contact Jennifer Case (jennifer.case@nist.gov) to get access to the GitHub repository.

2. [Optional] Download GitHub Desktop to manage repositories on the computer:

   https://desktop.github.com/

3. Pull the exploratory-soft-printer using GitHub Desktop or a preferred Git manager to desired location.

1.3. Lulzbot Cura Environment

1. If needed, download Lulzbot Cura from https://lulzbot.com/support/cura.

2. Add the Taz Pro printer to Cura:

   (a) Settings »Printer »Add Printer...

   (b) Select the TAZ Pro printer.

   (c) Select the SE | 0.5 mm | Nickel Plated Copper tool head.

   (d) Select Add Printer.

   (e) Another screen should appear that specifies various parameters including the Start Gcode and End Gcode. If you already have the Cura software installed and the TAZ Pro added, this window can be found via Settings »Printer »Manage Printers... »TAZ Pro »Machine Settings.

   (f) Edit Start Gcode (this Gcode can also be copied and pasted from `Start_and_End_Gcodes.txt` in the `exploratory-soft-printer\Documentation` folder):

   ```
   ;This G-Code has been generated specifically for LulzBot TAZ Pro
       with SE Tool Head - edited by J. Case 8/22/2023 for printing
       soft materials
   ;
   ;The following lines can be uncommented for printer specific fine
       tuning
   ;More information can be found at https://marlinfw.org/meta/gcode/
   ;
   ;M92 E420                 ;Set Axis Steps-per-unit
   ;M301 P21.0 I1.78 D61.93  ;Set Hotend PID
   ;M906 E960                ;TMC Motor Current
   ;
   M73 P0                   ; clear LCD progress bar
   M75             ; Start LCD Print Timer
   ```

```
G26             ; clear potential 'probe fail' condition
M107            ; disable fans
M420 S0                   ; disable leveling matrix
G90             ; absolute positioning
M82             ; set extruder to absolute mode
G92 E0           ; set extruder position to 0
M140 S{material_bed_temperature_layer_0} ; start bed heating up
G28             ; home all axes
G0 X145 Y187 Z156 F3000       ; move away from endstops
M117 Q - SE Heating Up...     ; progress indicator message on LCD
;M109 R{material_soften_temperature}  ; soften filament before
    retraction
;M117 Q - SE Retracting Filament...     ; progress indicator message
     on LCD
;G1 E-15 F75          ; retract filament
;M109 R{material_wipe_temperature}               ; wait for
    extruder to reach wiping temp
;M206 X0 Y0 Z0           ; uncomment to adjust wipe position (+X
    ~ nozzle moves left)(+Y ~ nozzle moves forward)(+Z ~ nozzle
    moves down)
;G12                     ; wiping sequence
M206 X0 Y0 Z0           ; reseting stock nozzle position ###
    CAUTION: changing this line can affect print quality ###
;G1 X0 Y0 F3000        ; move toward first probe point
;M109 R{material_probe_temperature} ; wait for extruder to reach
    probe temp
;M204 S300          ; set probing acceleration
;G29            ; start auto-leveling sequence
;M420 S1                   ; enable leveling matrix
;M425 Z           ; use measured Z backlash for compensation
;M425 Z F0          ; turn off measured Z backlash compensation. (
    if activated in the quality settings, this command will
    automatically be ignored)
;M204 S2000         ; restore standard acceleration
;G1 X5 Y15 Z10 F5000       ; move up off last probe point
;G4 S1            ; pause
M400             ; wait for moves to finish
M117 Heating...         ; progress indicator message on LCD
M109 R{material_print_temperature_layer_0} ; wait for extruder to
    reach initial printing temp
M190 R{material_bed_temperature_layer_0} ; wait for bed to reach
    printing temp
G1 Z2 E0 F75          ; prime tiny bit of filament into the nozzle
M117 Q - SE Printing...   ; progress indicator message on LCD
```

(g) Edit End Gcode (this Gcode can also be copied and pasted from `Start_and_End_Gcodes.txt` in the `exploratory-soft-printer\Documentation` folder):

```
M400                                      ; wait for moves to finish
M140 S{material_part_removal_temperature} ; start bed cooling
M104 S0                                    ; disable hotend
M107                                       ; disable fans
;G92 E5                                    ; set extruder to 5mm for
    retract on print end
```

```
M117 Cooling please wait                 ; progress indicator
    message on LCD
G1 X5 Y5 Z290 E0 F3000                    ; move to cooling position
;G1 E5                                    ; re-prime extruder
M190 R{material_part_removal_temperature} ; wait for bed to cool
    down to removal temp
G1 X145 F1000                            ; move extruder out of the
     way
G1 Y260 F1000                            ; present finished print
M140 S{material_keep_part_removal_temperature_t}; keep temperature
    or cool down
M77          ; End LCD Print Timer
G90                                      ; absolute positioning
M18 X Y E          ; turn off x y and e axis
M117 Print Complete.                     ; print complete message
```

3. Add "Elastomer" as a material to Cura:

   (a) Settings »Material »Manage Materials...

   (b) Select Import.

   (c) Navigate to the `exploratory-soft-printer\Documentation` folder and open
       `elastomer.xml.fdm_material`.

   (d) Select close.

   (e) On the right side of the screen, change the material to Elastomer.

   (f) On the right side of the screen, under Print Setup, select Custom.

   (g) Open up the Material submenu that should have appeared and change Printing Temperature Initial
       Layer to 0, as shown in Figure 1.

   (h) Additional tuning will need to be specified in the future with regards to material diameter and
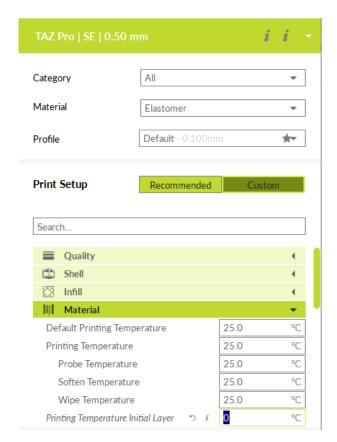   nozzle size since these will likely influence the print speed.

Fig. 1. Screen capture showing Printing Temperature Initial Layer.

2. Loading Material

3. Running a Print

1. Generate G-code either manually or using a slicer like Lulzbot Cura. If you are using Lulzbot Cura it is recommended to follow the set-up instructions given in Section 1.

2. Save the G-code onto a USB.

3. Load the USB into the Lulzbot printer.

4. Turn the printer on.

5. Use the menu to run the print.

6. Since this is an experimental printer, the user should stay close by and alert during the print to prepare to kill the print should something go wrong.

4. Cleaning the Print Head

5. Using the Heated Chamber

6. Maintenance

6.1. General

6.2. Syringe Pump

6.3. Print Head

6.4. Heated Chamber