A Computational Design Pipeline to Fabricate Sensing Network Physicalizations

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A SUMMARY OF NOTATION

Table A.1 summarizes notation for frequently referred mathematical symbols across multiple subsections.

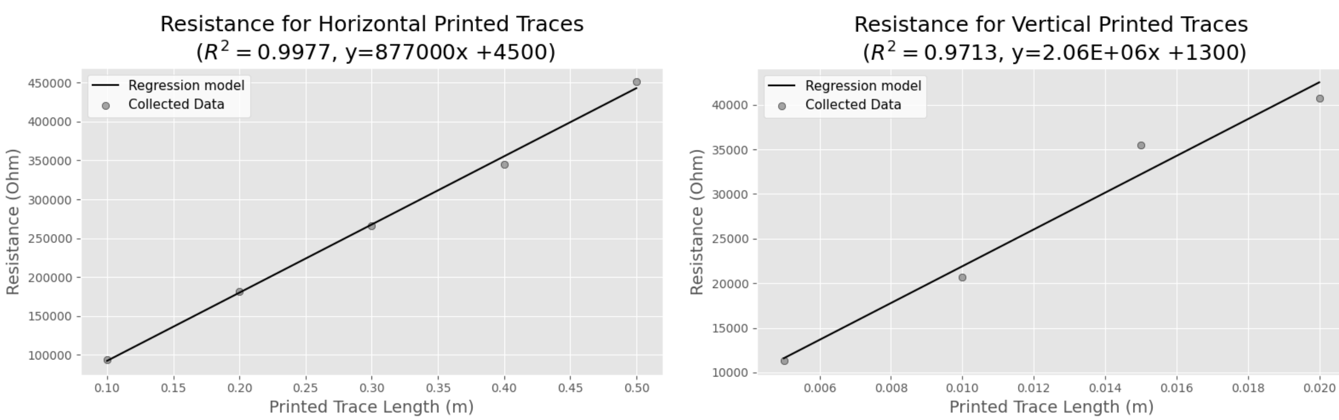
Table A.1: Summary of notation.

N	# of nodes
L	# of links
B	# of path branches of resistor links
S	# of mathematical symbols
$J_{\text{int}}^{\text{res}}$	intersection loss for resistor links
$J_{\text{int}}^{\text{non\_res}}$	intersection loss for non-resistor links
$J_{\text{int}}^{\text{node}}$	intersection loss for nodes
J_{pos}	layout change loss
J_{len}	non-uniform link loss

B SUPPLEMENTARY EXPERIMENTS (RESISTANCE MEASURE) FOR SEC. 4

B.1 Linear Regression

Fig. B.1 shows the results of our empirical investigation when we measured the resistance of the conductive filament (Protopasta's conductive PLA (1.75 mm)[1]). We measured the printed traces horizontally and vertically as our conductive traces move in a serpentine trace pattern for each horizontal layer connected with a straight vertical trace.



(a) Resistance measure for horizontal traces.

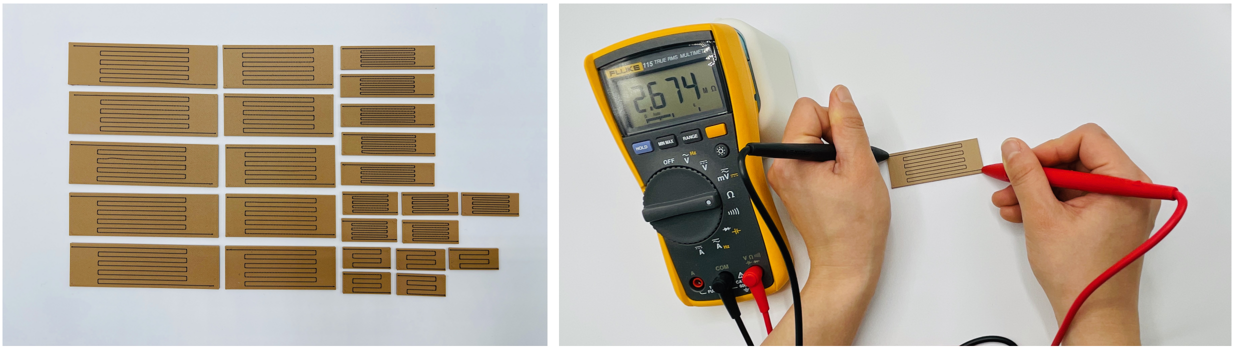
(b) Resistance measure for vertical traces

Figure B.1: The two linear regression models informed how to generate (i.e., draw) the conductive traces for fabrication (Sect 3.5) such that it achieves the resistance optimization (Sect 3.3.2).

[1]ProtoPasta Purchase Link

B.2 Equipment and Procedure

To obtain the results for Fig. D.1, we produced four sets of each measurement. Fig. D.1 shows the sets for the horizontal traces. We used a Fluke 115 Digital Multimeter to measure the resistance by touching the endpoints of each trace for 10 seconds. We waited for 10 seconds to account for fluctuations and noise.



(a) Resistance measure for horizontal traces. (b) Resistance measure with multimeter

Figure B.2: Serpentine trace patterns printed to measure the horizontal traces' resistance.

C Design Guidelines: Printing with the Prusa i3 MK3S and Mosaic Palette

C.1 Materials and Equipment

As discussed in Section 3.7, we used a Prusa i3 MK3S+ 3D printer[2] coupled with a Mosaic Palette Pro 2[3] to enable multi-material printing. There are other ways to achieve multi-material printing (e.g., dual-nozzle printers). However, we outline design guidelines specific to the Prusa i3 MK3S+ and Mosaic Palette Pro 2. We will update this document as we continue to test the computational pipeline with other printers.

C.2 Software

For our slicer, we used a p2pp processing tool (v.8.00.49)[4] that enabled us to use PrusaSlicer (v.2.5.2)[5]. We did not use the Chroma slicer that came with the Mosaic Palette Pro 2.

C.3 Print Settings

Infill: We used 80% rectillinear infill for the links and used 15% gyroid infill for the nodes.

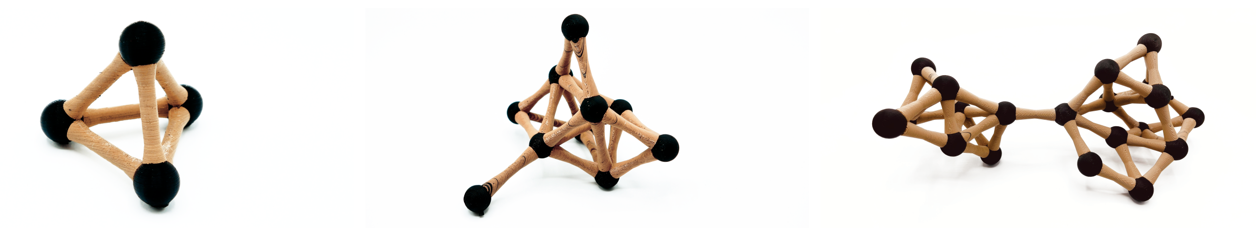
Purge Volume: We set the purge volume to $2500mm^3$ when switching from the non-conductive filament (i.e., iSANMATE Wood Filament PLA+) to the ProtoPasta. All other transition values were set to $300mm^3$. This purge is necessary to have a clean transition from filament A to filament B. For more information, please refer to this article[6]. This is one limitation for a single-extruder setup.

C.4 Printing Networks (N, L)

Depending on the print, we found that the purge block can take up to 40% of the print bed (250 x 210 x 210 mm). This limits how "big" of a network one can print. With the purge block, we found that the network presented in Sec 3 ($N = 20, L = 40$) is the largest we can currently print with this setup. Note: for this network, the number of nodes ($N = 20$) is close to the upper limit we derived from our computational evaluation (Section 4.1.2 "Fabrication Scalability").

[2] Prusa i3 MK3S+
[3] Mosaic Palette 2
[4] https://github.com/tomvandeneede/p2pp
[5] https://www.prusa3d.com/page/prusaslicer_424/
[6] https://help.prusa3d.com/article/purging-volumes_125097

D NETWORKS OF DIFFERENT DENSITIES AND SIZES



(a) $N = 4, L = 6$ (b) $N = 10, L = 18$ (c) $N = 20, L = 40$

Figure D.1: Printed network physicalizations of different sizes and densities.

E EXPERT DISCUSSION MATERIALS

E.1 Demographics

Participant	Interview Condition	Expertise
E1	In-person	High-dimensional data (national lab)
E2	In-person	Material scientist (national lab)
E3	Remote	Computational biologist (academia)
E4	In-person	AR/VR (national lab)
E5	Remote	AR/VR (Ph.D. student)
E6	In-person	AR/VR (Ph.D. student)

Table E.1: Summary of participants' backgrounds in the expert feedback.

E.2 Interview Questions

Questions asked after the demonstration of the sensing network.
Q1: Can you explain your experience with and/or analytical practice with network datasets?

Q2: What was your impression of the sensing network? Can you describe the strength and weaknesses of the proposed method?

Q1: With its current ability, do you envision integrating the network to your current practice? Why or why not?

Q1: Can you describe scenarios where you felt limited by the traditional mouse/desktop setup or AR/VR headsets?

Q1: What future improvements do you think can strengthen this work?