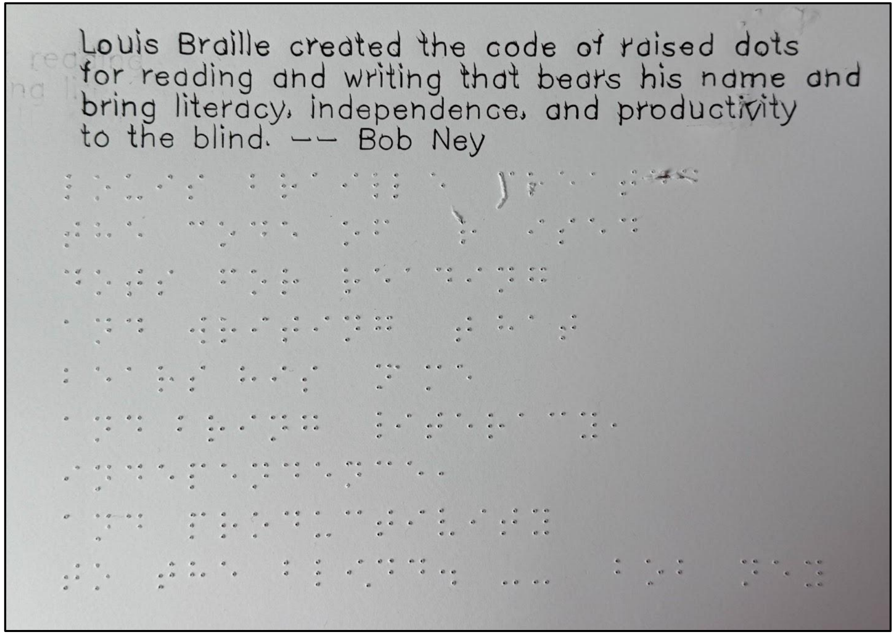
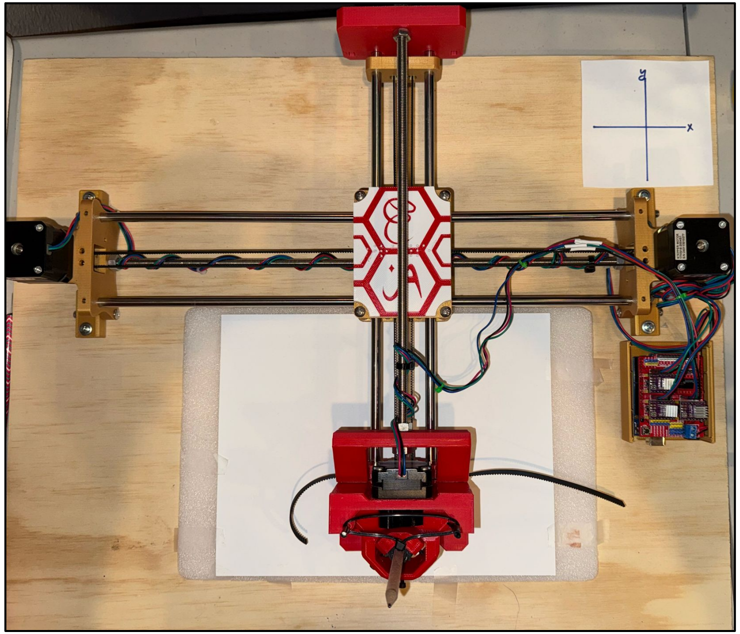
Low-cost Portable Braille Embosser for Education

JR - Engineering: Electrical, Mechanical, and Robotics

Ethan Hu, Grade 8

Andrew Xu, Grade 7





ABSTRACT

- Adequate access to Braille resources is one of the largest challenges that can improve blind people's education level and social connectedness. Only 10% of blind people can read Braille[2], and the current embossers on the market are extremely expensive and hard to maintain. We thought that by redesigning a CNC plotter, we could develop an inexpensive, high quality, scalable Braille embosser to assist more blind people learn Braille.
- Our Braille embosser was designed, built and implemented from a CNC plotter, which works inline with our Javascript web interface SVG converter that is compatible with GRBL open source. This plotter used linear rods and bearings, making it extremely low maintenance. After a few iterations of our innovative and robust toolhead, we tested multiple common types of paper to confirm how compatible each paper was with the machine. We wore down the Braille texts around 100 times and compared it with freshly printed Braille to get our answer. We also experimented with different stylus/needle types, and found that a sewing needle would be best.
- We noticed that the thicker paper holds up better to reading. We also found that sewing needles didn’t need much force to punch the paper with and they had less friction when moving up and down in the paper.
- We were successful in designing and building a Braille embosser based on a CNC plotter. This embosser could benefit many blind people with easy and fast access to Braille, as it is affordable, easily accessible and scalable.

INTRODUCTION

- Blind and low vision communities around the world suffer from limited information they can obtain daily. Louis Braille, a French Educator, invented a tactile system of reading and writing for the blind and visually impaired [4] in 1824. Ever since then, Braille has been introduced to the rest of the visually-challenged communities around the world as a method for being able to read. The AFB (American Foundation for the Blind) reports that only 10% of them use Braille day-to-day, while 90% of braille-literacy blind adults in the US were employed, compared to 33% of those who didn't know braille[1]. The lack of access to Braille material not only impacts their quality of life but also limits their ability to join the workforce.

- At the beginning, a wood writing board with paper and a stylus was used for writing Braille. In the 1960s, the Braille embosser was invented [6]. It was a great milestone allowing Braille publications to reach a larger group of readers. However, the machine advanced very slowly. It was a challenge mechanically to punch holes accurately and consistently. The consumer base is relatively limited. A special kind of thicker and smoother paper, Braille paper, must be used with traditional Braille embossers. All these contribute to the high cost of commercially available Braille embossers. A Braille embosser is easily over $1500, compared to inkjet printers that are often below $100 [15].

- **Problem**: Can we solve the problem by designing and implementing a low cost, portable, and scalable Braille embosser on an open source platform?

- **Hypothesis**: We believe that we can make an open source braille embosser that is easy to set up with inexpensive materials and is reliable for helping blind people learn how to read braille by printing braille reading resources.

MATERIALS

Electronics Off The Shelf Bill of Materials

#	Description	Specification	Vendor	Count
1	Nema 17 Stepper Motor	3-17HS08-1004S	Stepperonline	1
2	Nema 17 Stepper Motor	17HS16-2004S	Stepperonline	2
3	Arduino UNO R3	ATmega328P	Arduino	1
4	USB 2.0 cable	USB-A Male to USB-B Male	Generic	1
5	CNC Compatible Shield	V3.0	RedTagCanada	1
6	Stepper Motor Drivers	DRV8825	HiLetgo	3
7	Jumpers	2.54mm	ZYAMY	6
8	DC Power Supply	12V DC, 2A max	ALITOVE	1

Custom 3D Printed Parts

#	Description	Weight(g)	Materials	Count
1	Tool Head - Pen holder	36.81	PETG	1
2	Tool Head - Z-axis stepper motor mount	70.81	PETG	1
3	Tool Head - Threaded rod holder	42.81	PETG	1
4	Threaded rod holder Y axis	31.34	PETG	1
5	Gantry motion motor mount	26.10x2	PETG	2
6	Plywood adaptor	3.78x4	PETG	4
7	Clamshell top	28.47	PETG	1
8	Clamshell bottom	35.23	PETG	1
9	Bearing holder	1.33	PETG	4
10	Y axis bearing holder	8.79	PETG	1
11	CAM	3.37	PC	1
12	Pulley Spacer	0.7x4	PETG	4
13	Handles	36.61x2	PETG	2

Mechanical Off The Shelf Bill of Materials

#	Description	Size	Vendor	Count
1	Plywood	60.96 x 60.96 x 1.27 mm	Home Depot	1
2	Linear Rod	M8 x 450mm	ReliaBot	2
3	Linear Rod	M8 x 350mm	ReliaBot	2
4	Linear Rod	3 x 100mm	Uxcell	2
5	Threaded Rod	M8 x 500mm 1.25mm	Meccanixity	2
6	LM8UU Linear Ball Bearings	8 x 15 x 24mm	Uxcell	8
7	624ZZ Deep Groove Ball Bearing	4 x 13 x 5mm	Uxcell	5
8	Mini Ball Transfer Bearing	8mm bore	EINGSDFGCH	2
9	GT2 Pulley 16 Teeth	5mm bore 6mm width	WinSinn	2
10	GT2 belt	2mm Pitch 6mm Width	FYSETC	1
11	Nut	M3 0.5mm	Vifmy	7
12	Nut	M4 0.7mm	Vifmy	5
13	Nylon Insert Hex Lock Nuts	5/16in -18	Carlwin	4
14	Phillips Screws	M3 0.5 x 16mm	EASTLO	13
15	Phillips Screws	M3 0.5 x 6mm	EASTLO	12
16	Phillips Screws	M4 0.7 x 35mm	EASTLO	15
17	Hex Socket Head Cap Screws	M3 0.5 x 20mm	NIULUNBAO	4
18	Round Flat Washer	M3 6 x 0.5mm	Uxcell	4
19	Flat Finish Washers	5/16" x 3/4" OD	BCP Fasteners	4
20	Pen Spring	0.4x4.5x18mm	StoreHouse	1
21	Sewing Needle	size 5	Dritz	1
22	Foam	23 x 34 x 0.5mm	Generic	1

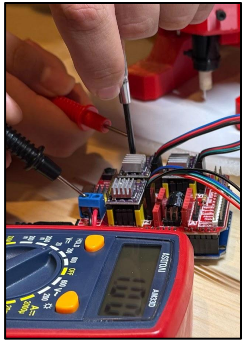
Software

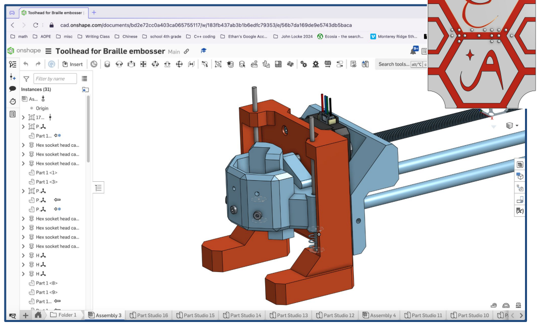
#	Description	Specification	Vendor
1	Arduino IDE	v2.3.4	Arduino
2	GRBL	v1.1	GRBL
3	GRBL-Plotter	v1.7.4.0	GRBL-Plotter
4	Text-Braille-To-SVG converter	v1.0	Open Source

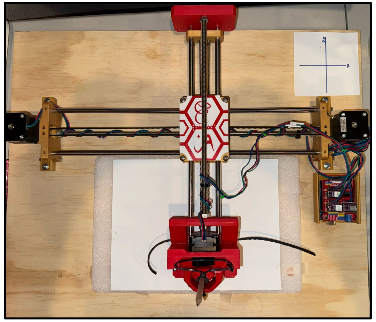
MECHANICAL DESIGN

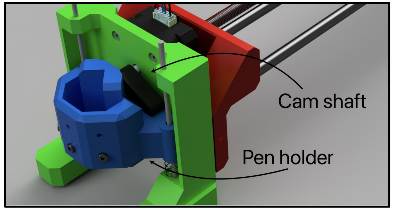
Design Process:

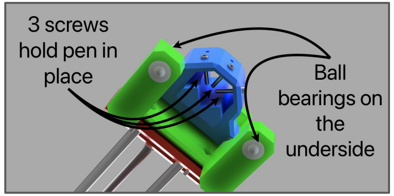
1. Conduct research on existing Braille embossers on the market
2. Define project objectives & create design requirements
    a. The tool head needs to be able to travel to coordinate positions on the paper accurately
    b. The embosser needs to travel relatively fast.
    c. In order to be accurate while being fast, the embosser needs to be rigid and sturdy.
    d. In order to be portable, the embosser also needs to be lightweight
3. Use Computer-Aided-Design(CAD) software Onshape to design the Braille embosser
4. Purchase materials & 3D print custom parts based on CAD designs
5. Assemble and connect electronics
6. Calibrate Braille embosser
7. Record and observe Braille results and make design iterations for robust improvements











Design Process 3 - 7

Important Notes:

1. Sturdy structure allows for more accurate Braille character spacing. (Apply for both Gantry design and tool head design)
2. Easy accessible off the shelf components and easily 3D printed parts are a priority when designing. Parts are also conveniently replaceable by users
3. Minimizing on-board circuit components takes into consideration simpler software integration, overall low cost, and less maintenance

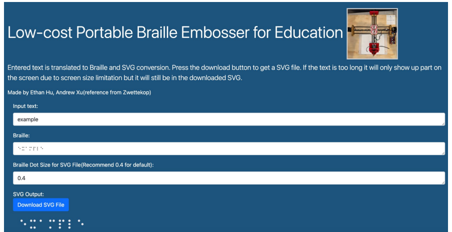
SOFTWARE ARCHITECTURE

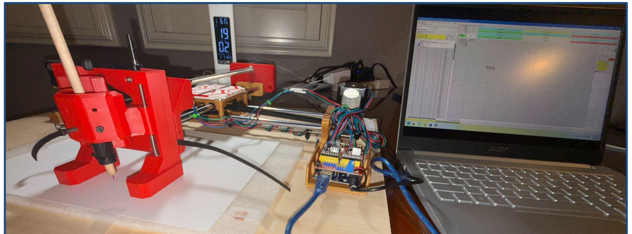
Software Requirements:

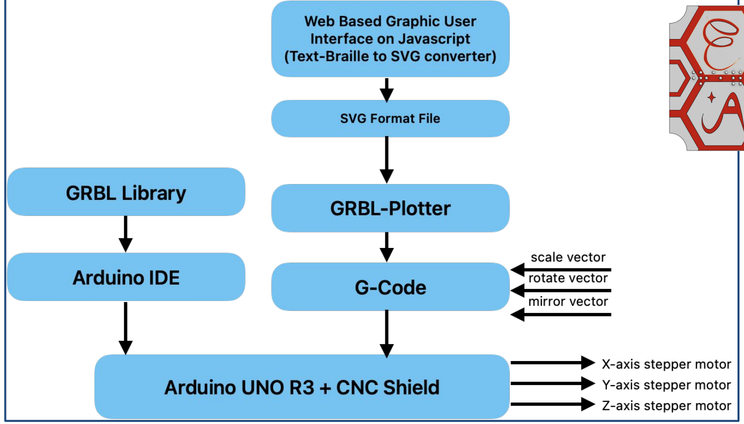
1. Easy accessibility
2. Reliable and simple for user to install
3. User friendly and simplify the user interface and workflow

Software Components:

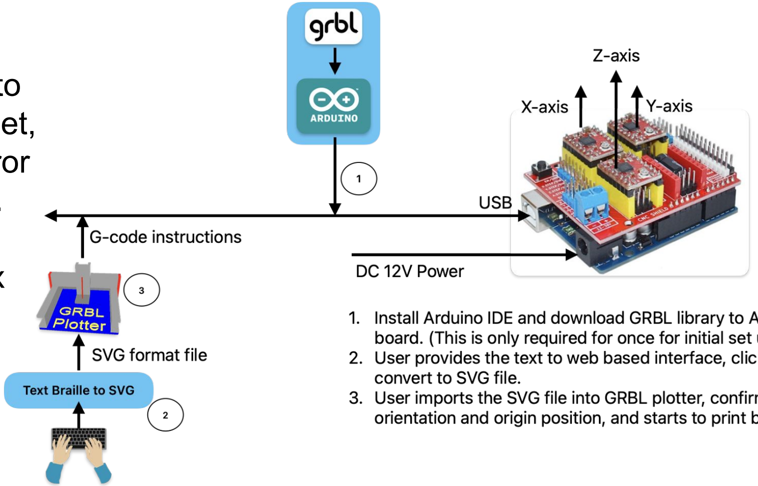
1. *Arduino IDE*: It is widely used to connect to the Arduino hardware to upload programs and communicate with them
2. *GRBL*: An open source, embedded, high performance g-code-parser and CNC milling controller written in optimized C that will run on a straight Arduino
3. *GRBL-Plotter*: A graphics converter and G-code sender for CNC plotters based on GRBL. The main benefit of this software is its post-processing of vector graphics which we use in our text-Braille to SVG converter. It allows modification of the generated G-code: Offset, Mirroring, Rotation, Scaling, i.e. we can print Braille in opposite mirror directions so that the end result can be read in the correct direction.
4. *Text-Braille to SVG converter*: A web based open source Javascript that converts text or Braille to SVG format. (See notebook Appendix for code)







Software Solution/Flow Chart



1. Install Arduino IDE and download GRBL library to Arduino board. (This is only required for once for initial set up)
2. User provides the text to web based interface, click to convert to SVG file.
3. User imports the SVG file into GRBL plotter, confirms the orientation and origin position, and starts to print braille.

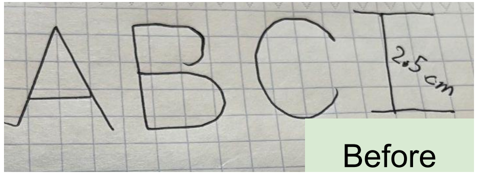
Software Deployment Workflow

RESULTS & DISCUSSION

Calibration:

- Aimed to obtain accuracy on X, Y, and Z-axis, so that Braille shows the correct space, plus a balance between the speed of X or Y movement and Z movement.
- Workholding is important during the calibration. If the paper moves around, the corresponding points on paper will move as well which causes error. The accompanying picture shows an example of when paper is moved during printing.

Text would have been extremely large before tuning.



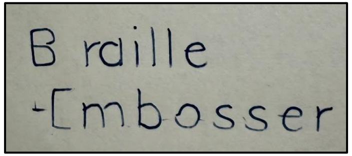
The text is now the size it should be and would result in accurate Braille, along with being able to make full use of a page.

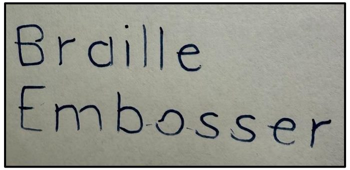
Tool Head Stylus:

- We mainly experimented with 4 types of stylus to consider its robustness and consistantness.



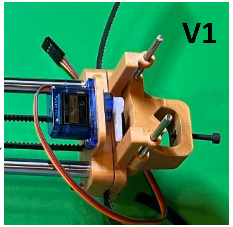

Description	Result
3D printed needle shaped stylus	The tip is too dull to puncture the paper. It causes a lot of friction when it travels up and down in the cylinder, making this inefficient.
Mini steel pick and hook tool	The diameter for the hole is relatively large and it is still hard to puncture the paper consistently.
Hypodermic needle	Hypodermic needles have a hollow tube with one sharp tip with a cannula-cannon junction. Due to this, when it travels through the paper, it causes unnecessary friction and tends to lift up the paper when it exits.
Stylus with a sewing needle	The diameter for the hole is the right size with proper spacing. Most importantly the friction is minimal, thus can travel in-and-out the paper smoothly.





Workholding during calibration

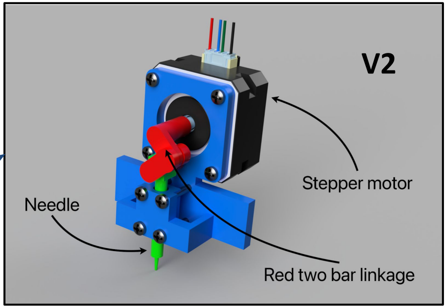
RESULTS & DISCUSSION (Cont'd)



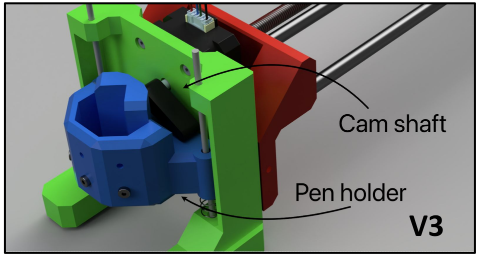
<u>Tool Head</u>:

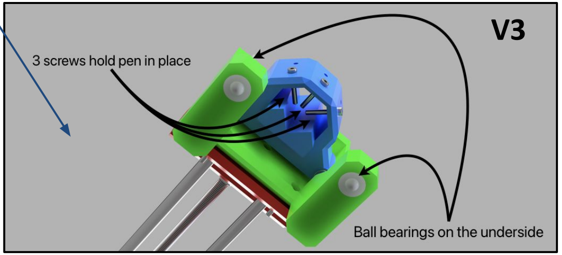
We went through various design improvement on the tool heads.
Below are the major changes for each revision

- ***<u>Version 1:</u>*** We started with a SG90 90g servo. While this servo is cheap and light, it doesn't have much torque and speed. This wasn't able to push it through the paper.
- ***<u>Version 2</u>***:
  - We switched to a Nema 17 pancake stepper motor, which has a lot more torque(16Ncm) and speed as it is a motor and we can use it to push through the paper using a needle. We designed a new version based on this stepper motor and a two bar linkage to move a 3D printed needle up and down.
  - However, the needle moving up and down had a lot of friction. The two bar linkage was also extremely wobbly so it couldn't reliably put dots down on the paper. Lastly, it was really hard to swap the needle when it became dull.



- ***<u>Version 3</u>***:
  - We redesigned a pen holder that slid up and down on two metal rods. There were two springs under the pen holder pushing it up, and a cam shaft attached to the pancake stepper motor that pushed the pen holder up and down. The pen was held in place with three screws, ensuring that it didn't wiggle and produce inaccurate dots.
  - The result turns out to be sturdy and strong. However, it would also sometimes lift the paper up as the needle went up. To solve this issue, we used some metal balls on the bottom to press down on the paper and make sure it stayed at the same height.

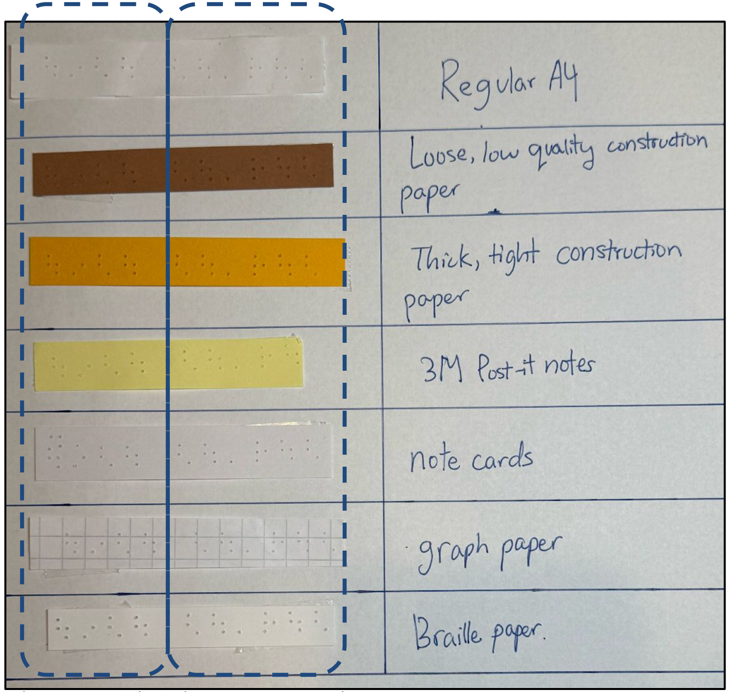




RESULTS & DISCUSSION(Cont'd)

Paper:

- We aim to make a low cost Braille embosser that can be compatible with most commonly used paper types instead of just specialized Braille paper. With this in mind, we experimented with 7 paper types
- From the results, our Braille embosser is friendly with the most commonly used paper in the household. If the printed Braille is intended to be used many times, it is recommended to use Braille paper. If the printed Braille is not intended to be used many times, then most regular paper can be used with this Braille embosser to save cost.



untouched | touched 100 times

Fresh Printed Braille | Braille after 100 times use

Paper Type	Does the dot fall apart?	Wear out after 40 passes?	Percentage worn out after 100 passes?
Regular A4	No	No	18%
Loose low quality construction paper	No	No	18%
Thick tight construction paper	No	No	5%
3M Post-it notes	No	No	20%
Note cards	No	No	8%
Graph paper	No	No	33%
Braille paper	No	No	3%

* The above results are based on visual inspection of the flatness of the dots

RESULTS & DISCUSSION (Con'd)

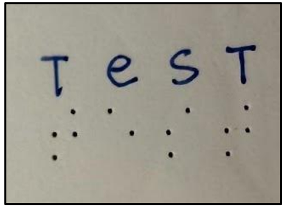
SVG Vector,:

- ***Generation***: We first tried to generate the SVG for the Braille in Inkscape. However, it was impossible to modify the sizes of the dots in Inkscape causing inconsistent dot positions when we tried to emboss on paper. We used a SVG converter where it was possible to modify the sizes of the dots produced while still being able to see the dots regularly. This way, the toolhead always puts the dots in the place we want it so the Braille is accurate. (See "Text-Braille-to-SVG Java scripts and web interface" in Notebook Appendix)

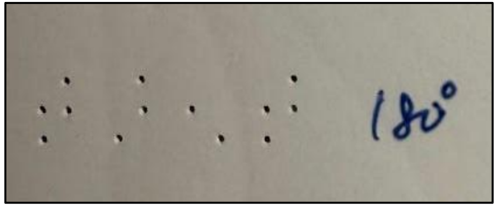
- ***Rotation, Mirror Conversion***: Reverse dot forming a flipped and rotated image. GRBL-Plotter software provides features that can rotate or mirror the vector graph. To produce the expected result, after importing the SVG file into GRBL-Plotter, we rotate it 180 degrees, and mirror it along the y-axis. The images below are examples of how "test" is printed as is, rotated 180 degrees, and rotated 180 degrees plus mirrored on the Y-axis. The rightmost ultimately is what the user needs to do to print Braille.

```
<svg id="svgBraille" xmlns="http://www.w3.org/2000/svg"
xmlns:xlink="http://www.w3.org/1999/xlink" width="100%"
height="100%"><circle fill="#6666FF" cx="25" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="35" cy="30" r="0.4"></
circle><circle fill="#6666FF" cx="53" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="53" cy="40" r="0.4"></
circle><circle fill="#6666FF" cx="63" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="63" cy="40" r="0.4"></
circle><circle fill="#6666FF" cx="81" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="109" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="109" cy="40" r="0.4"></
circle><circle fill="#6666FF" cx="119" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="137" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="137" cy="30" r="0.4"></
circle><circle fill="#6666FF" cx="137" cy="40" r="0.4"></
circle><circle fill="#6666FF" cx="147" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="165" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="165" cy="30" r="0.4"></
circle><circle fill="#6666FF" cx="165" cy="40" r="0.4"></
circle><circle fill="#6666FF" cx="193" cy="20" r="0.4"></
circle><circle fill="#6666FF" cx="203" cy="30" r="0.4"></
circle></svg>
```

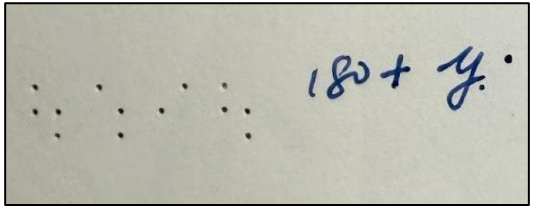
Example of SVG Vector



Print Left-to-Right



Print with 180 degree rotation



Print with 180 degree rotation and Y-axis mirror

CONCLUSION

Features & Differentiations

Category	This project	Commercial Braille embosser
Cost	Low	High
Material Accessibility	High	Low
Scalability	Yes	No
Portability	High	Medium - Low
Software	Open Source	Proprietary
Maintenance Effort	Low	High
Paper Compatibility	Most commonly used paper	30 – 108 lb
Weight	~5 lbs	11+ lbs

Real-world Applications

- The potential of this Braille Embosser reaches the great unknown. This type of machine can be installed in classrooms, libraries, homes, public areas, exactly what we need to assist visually-challenged communities to enrich their life and education level.

Future Improvements

Mechanical:

- The **mechanical performance** can be further achieved by improving the **Z-axis speed** which regulates the needle's up and down movement.
- A deep study on the spring length and strength is needed to reach optimal balance between X, Y, and Z axis speed.
- Another improvement we are aiming at for future development is to design a **better workholding** that can secure the paper automatically, as we currently have to tape it down. One of our ideas is to use a photo frame.
- We could also attempt to make the **Braille different sizes** for readers of different experience levels.

Software:

- We believe it has a potential to enable it with **a mobile app** and to combine everything into one place.
- The Braille embosser mobile app could convert user specified content into some G-Code that is then sent to the printer.
- In addition, users would **monitor the progress remotely**.
- One day, we might even make the embosser **compatible with documents** like google docs or microsoft word.
- Allow for **text to speech** functionality

REFERENCES

1. Ryles, Ruby. “The Braille Literacy Crisis.” *National Federation of the Blind*, 26 March 2009, https://nfb.org/images/nfb/documents/pdf/braille_literacy_report_web.pdf. Accessed 31 December 2024.
2. Sheffield, Rebecca, and Sarah Chatfield. "How Many Braille Readers Are There." *American Foundation for the Blind*, 23 Mar. 2022, www.afb.org/blog/entry/how-many-Braille-readers. Accessed 30 Dec. 2024.
3. "Global blindness was slowing prior to pandemic study reveals." *Orbis*, www.orbis.org/en/news/2021/new-global-blindness-data. Accessed 30 Dec. 2024.
4. "Louis Braille." *Wikipedia*, Wikimedia Foundation, Inc., en.wikipedia.org/wiki/Louis_Braille. Accessed 30 Dec. 2024.
5. *Irie at*. Irie-AT, irie-at.com/product-category/Braille/Braille-embossers/. Accessed 30 Dec. 2024.
6. Sullivan, Joe. "Early History of Braille Translators and Embossers." Edited by David Holladay. *Duxbury Systems Inc.*, Duxbury Systems, www.duxburysystems.com/bthist.asp. Accessed 30 Dec. 2024.
7. Norway, Braillo. "What Makes a Braille Printer a True Production Braille Printer?" *Braillo*, braillo.com/Braille-printers/true-production-Braille/. Accessed 30 Dec. 2024.
8. *Onshape*. 2014, onshape.com. Accessed 31 Dec. 2024.
9. "Arduino Uno Rev3." Arduino Store, Arduino, store-usa.arduino.cc/products/arduino-uno-rev3. Accessed 1 Jan. 2025.
10. *Arduino*. www.arduino.cc/en/software. Accessed 31 Dec. 2024.
11. "Grbl." *Github*, github.com/grbl/grbl. Accessed 31 Dec. 2024.
12. "Welcome to GRBL-Plotter." *GRBL-Plotter*, grbl-plotter.de/. Accessed 31 Dec. 2024.
13. Arnold, Henry, and Jonathon K. *Drawing Robot Assembly and User Guide*. E-book ed. PDF.
14. MyTechTutor. mytectutor.com/ controlling-stepper-motors-using-arduino-cnc-shield-v3-and-grbl/. Accessed 1 Jan. 2025.
15. *Google Shopping*. www.google.com/search?sca_esv=5b22f5787084afa3&rlz=1C1CHBF_zh-CNUS974US974&q=Braille+embosser&udm=28&fbs=AEQNm0Aa4sjWe7Rqy32pFwRj0UkWd8nbOJfsBGGB5IQQO6L3J03RPjGV0MznOJ6Likin94o1r5LfEXWFkRDyPajU30-jlDcXwRVTByGx4VdKZ6GPzFySITPBGOjLRBdHTKxeZmdeIA02KMtcmXYbZ9s2Kwl2xj5KMk3FW13OuMR1VH1zYgWAk0ArXQEf7T3DGJM9HnfG-20ubQhN1hlsmfo2u2xXJCINMg&ved=1t:220175&ictx=111&biw=1536&bih=730&dpr=1.25. Accessed 30 Dec. 2024.
16. Anna Seda, Aim Gilstrap, and Sharon Bacon, on-site interview, San Diego Center, Braille Institute (https://www.brailleinstitute.org), Feb. 18, 2025