

Simultaneously Generating Multiple Mediums of Tactile Graphics

Katherine Clark
The University of Texas at Austin
Austin, Texas, USA
katieaclark@utexas.edu

Amy Pavel
University of California, Berkeley
Berkeley, California, USA
amypavel@eecs.berkeley.edu

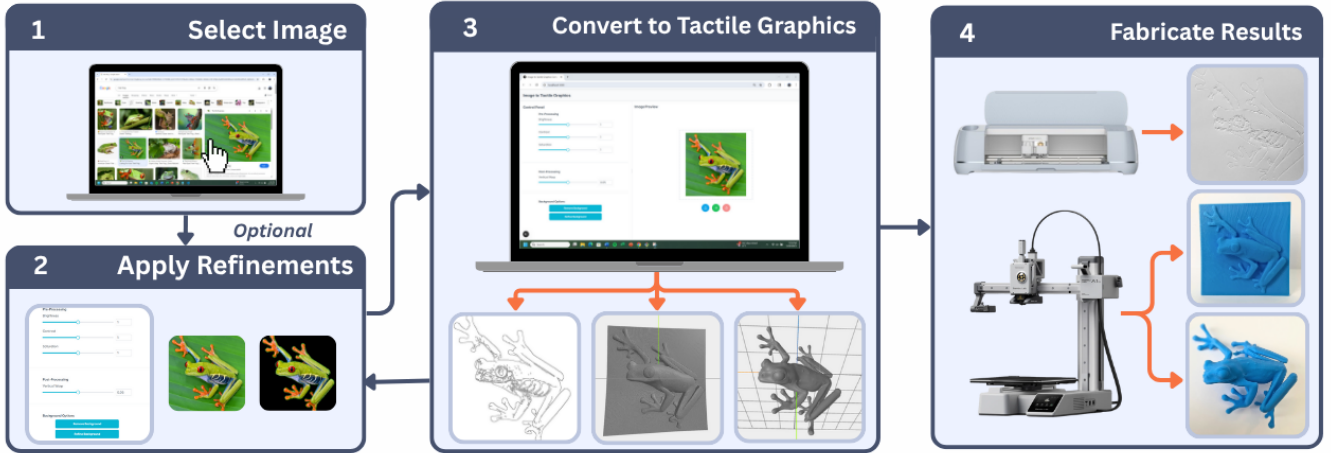


Figure 1: To use our system, users (1) select and upload an image, (2-3) iteratively convert the image to a set of tactile graphics and optionally apply refinements, then (4) fabricate the resulting tactile graphics via embossing and 3D printing.

ABSTRACT

Images like photographs, paintings, and illustrations are used to convey important information in educational, professional, and cultural settings. Blind and low vision (BLV) individuals can access such images via verbal or text descriptions, or *tactile graphics* that can capture rich spatial detail often lost from text alone. However, tactile graphics remain rare as they require specialized design and fabrication expertise to create. Prior work has explored approaches to take an image (e.g., a diagram) and automatically convert it into a given tactile medium (e.g., an embossing of the diagram outline with braille labels). However, the appropriate tactile medium depends on the image content and audience expertise such that a single medium may not be appropriate for all images or audience members. To lower the barrier of entry for non-experts designing and fabricating tactile graphics to meet diverse image and audience needs, we present a system that generates *multiple tactile mediums* at once for a given image: outlines for paper embossings, 2.5D or “bas-relief” models for 3D printing, and fully 3D models for 3D printing. A preliminary evaluation of our system with educators in museums and schools and BLV audience members indicated enthusiasm for integrating the system in existing programs, and revealed initial

benefits and tensions of presenting multiple tactile graphics from creation and consumption perspectives.

KEYWORDS

Human-Computer Interaction, Blind and Low Vision, Tactile Graphics, 3D Printing

ACM Reference Format:

Katherine Clark and Amy Pavel. 2025. Simultaneously Generating Multiple Mediums of Tactile Graphics. In *The 27th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '25)*, October 26–29, 2025, Denver, CO, USA. ACM, New York, NY, USA, 8 pages. <https://doi.org/10.1145/3663547.3759718>

1 INTRODUCTION & BACKGROUND

Images such as photographs, paintings, and illustrations communicate ideas across cultural, educational, and professional settings. BLV people access such images via verbal or written descriptions, but it is difficult to convey the full visual composition (e.g., relative size, spatial relationships, and textures) in descriptions [33]. In addition, excessively long descriptions can be cognitively taxing and remain prone to omitting important visual details, limiting the viewer’s independent interpretation of the image [33]. Tactile graphics, or accessible tactile representations of 2D images [27], address the limitations of descriptions by enabling BLV individuals to engage in tactile exploration. Such exploration fosters deeper understanding of an image’s composition [42] while supporting memory, problem-solving, and the development of richer spatial and conceptual models [12].

Prior research has explored how tactile graphics may support greater image understanding in STEM [24, 30], arts [6, 7, 19], cultural [41], and other educational contexts [18]. Tactile mediums include embossed paper [14], refreshable 2D tactile displays [17], refreshable 2.5D shape displays [32, 38], 2.5D bas-relief models [7, 33], 3D printing [18, 28, 36, 39], and handmade models [14]. While each of these formats has unique advantages and disadvantages (e.g., cost, ease of creation, ease of understanding, resolution, expressivity), our work considers static tactile graphics as they are the most widely used in such settings and have the capability for high resolution and expressivity compared to their refreshable alternatives (e.g. Graphiti board [34], Dot Pad [22]). Creating effective static tactile graphics is a costly, labor-intensive process that often requires professional designers [24] as the steep learning curve of required technologies and the lack of accessible tools and training present significant barriers of entry for non-experts [3, 40]. Thus, interest to automate all or part of the tactile graphic design process has increased (e.g., automatically translating single-point perspective artworks [13], data visualizations [24], and naturalistic paintings [33] into tactile graphics).

However, prior tools assume there is one optimal tactile graphic for each type of image (e.g., an embossing for a data visualization or a bas-relief for a painting) and that the creator will know the type to create in advance. In practice, tactile graphics must be tailored to both the image and the audience as not all images can be represented with a single medium, and not all audience members have the same tactile literacy and preferences. Prior work emphasizes these challenges and establishes that the best medium for a given tactile graphic is context and user dependent (e.g., to account for tactile literacy level, Hathazi and Bujor describe the process of building tactile literacy by exposing BLV children to 3D, real-world objects before moving to 2D abstractions [16]). Thus, when considering automated workflows, providing a single representation as output is insufficient to communicate a broad array of 2D imagery to a wide range of audiences. Our work builds upon prior approaches by exploring the potential to create multiple tactile graphics from a single image at once thereby providing novice creators with output comparisons and giving BLV users access to the information they want. We first present a tactile graphics creation tool that generates multiple types of tactile graphics at once (embossing, bas-relief 2.5D model, and 3D model) based on the same input image. We then conduct a preliminary study with people who teach and/or provide accessibility services to BLV people (in education or museum settings) and gain feedback on the tactile graphics from BLV individuals. Our exploration on the use of multiple mediums can inform design of future tactile graphics tools.

2 SYSTEM

To support creators in making tactile graphics that address a wide range of image and audience needs, we present a web application that allows users to upload an image then automatically and simultaneously generate three downloadable tactile graphics in three different mediums (outlines for paper embossing, 3D-printable 2.5D or “bas-relief”, and 3D-printable full 3D models) using Computer Vision models (Figure 1). Our system also allows users to iteratively

refine their image to improve the tactile graphics (e.g., with background removal). Following the findings of Prescher, et al., that complex graphics (like photos) require detailed descriptions to be fully understood [31], our prototype generates image descriptions for both the main image and the individual tactile graphics to provide complementary visual and contextual information as well as suggested touch strategies to match each tactile graphic back to the original image. The descriptions provide non-experts a starting point for crafting supplemental descriptions while also increasing accessibility for users with screen readers when evaluating output (e.g., by identifying obvious errors in the generated 3D model similar to GenAssist for generated 2D images [21] and similar to A11yShape for generated 3D models [25]).

Image Enhancement Control Panel Options: When uploading an image, users can apply image processing techniques to enhance the input image before processing (Figure 1). Our panel includes sliders to adjust brightness, saturation, and contrast, and two tools to remove the background: (1) an automated background removal tool that uses Rembg [15] to segment the foreground from the background, and (2) a brush tool to make pixel-level refinements by either blacking out pixels in “draw” mode or returning original pixel colors in “erase” mode. Together, these refinements can enhance the output and remove distracting artifacts (Figure 2, left). During initial testing, bas-relief representations were often too flat (see Figure 2, right), so we added a “vertical warp” option to exaggerate texture and depth.

Paper Embossings: Prior work for producing comprehensible outlines uses a combination of grayscale, edge detection, and image segmentation [1, 11, 23, 43]. We followed this workflow, using OpenCV’s Canny edge detector [2, 5] to create embossing outlines. We convert the output to a PNG image format with black lines on a white background for paper embossing with a Cricut Maker [8]. We followed a YouTube embossing tutorial by Kelly Rossouw [35] and made adjustments based on results (print settings in Appendix A.1). We used a Cricut Maker due to its low cost of acquisition (\$400 [9] vs. \$4,000 for typical embossers [20]), but our output can also be used on higher quality embossers.

Bas-Relief Models (2.5D): We use DepthAnythingV2’s [44] depth estimation pipeline to generate a bas-relief mesh from the uploaded image. We chose this model for its high detail retention. The output of the model is a depth map of the perceived distance to each pixel in the image. We then apply the user’s choice of vertical warp to either exaggerate or dampen the depth of the mesh and construct the bas-relief mesh by creating faces using the points contained in the depth map. The resulting 2.5D mesh is exported as an STL file for 3D-printing (see Appendix A.2).

3D Models: We use the TripoSG [26] model to convert the user’s uploaded image into a 3D model. We selected TripoSG for its available open-source code base and for its ability to generate a high-quality 3D-printable model from a single input image. After running an inference on the user’s uploaded image, we convert the resulting GLB format mesh into an STL file using the Trimesh [10] library’s export feature to ensure compatibility with standard 3D printers.

Previewing Tactile Graphics: After users make all image processing selections, they can simultaneously convert their image into all three available tactile graphic types. Previews of each are available under the tabs marked “Embossing,” “Bas-Relief,” and “3D Model.”

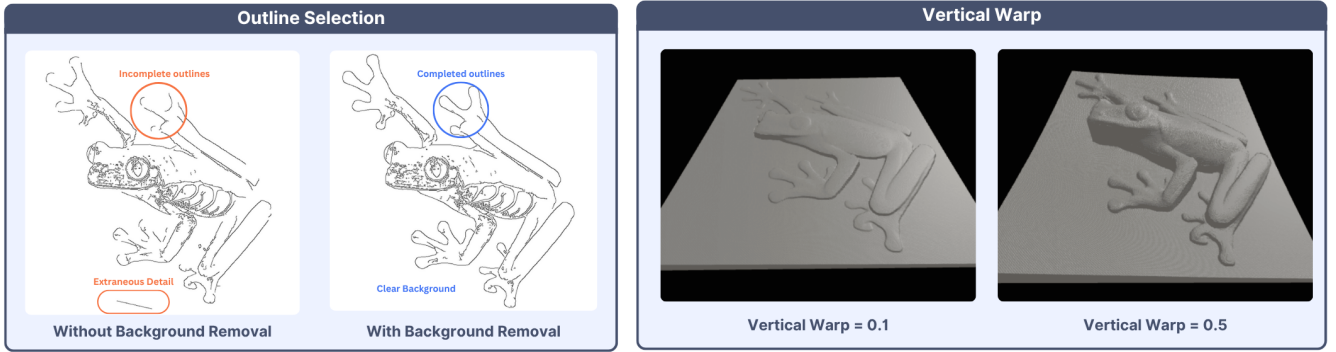


Figure 2: Left: Background removal for with extraneous detail. Right: Effect of increasing vertical warp for bas-relief models.



Figure 3: Example of printed tactile graphics: cardstock embossed outline, 3D printed bas-relief model, and 3D printed fully 3D model. The back view of the 3D model is entirely hallucinated by TripoSG.

Each tab also has the option to download the tactile graphic(s) as well as the option to generate image descriptions. Because proper thresholds for edge detection vary from image to image, we provide users with three preset outline results in the "Embossing" tab with a range of edge detection sensitivity for more flexibility when choosing which output best represents the original image. While the embossing outline tab displays a simple image preview, the bas-relief and 3D model tabs have interactive previews implemented with three.js [4], which allow the user to zoom in and/or rotate the models to assess the final output.

3 PRELIMINARY USER EVALUATION

We conducted semi-structured preliminary user evaluations with eight participants (six sighted participants, two blind participants) recruited via local mailing lists to collect initial feedback on the usability of our creation tool and the printed results. The sighted participants were either teachers of students with visual impairments (TSVIs) or museum professionals. Six participants (four sighted, two blind) had prior experience with either creating and/or using tactile graphics while two participants (both sighted museum professionals) had no prior experience. Sessions were conducted in-person and took 60 minutes. Our institution's IRB approved the study.

Sighted participants selected three to five images from a set of 14 (architecture, realistic art, abstract art, nature photography, anatomical diagrams, and museum artifact photography) and used our tool to iteratively create three tactile graphics for each. These categories were chosen to reflect participants' professional environments (e.g., paintings for museum officials; educational photography for TSVIs)

and to cover a range of image complexity and style. All participants expressed enthusiasm about using the tool in their institutions and about having access to multiple tactile graphics for an image — either to directly provide all graphics to BLV audiences or to decide between multiple graphics in selecting one to fabricate. For example, TSVIs highlighted that typical 2D tactile graphics used for standardized tests (e.g., STAAR) were difficult for BLV students to understand. TSVIs were interested in using our system's multiple representations for educational scaffolding, moving from a full 3D model to a bas-relief, and then to the embossed image. While creating their graphics, participants previewed multiple alternatives to determine the best medium for the image content. For example, a sighted museum professional examining a 3D model of a portrait noted that the original painting did not depict the back of the subject's head, so the hallucinated back view in the model was unexpected. In this case, the participant selected the bas-relief model to avoid confusion. Interestingly, when asked to select their preferred representation for each set of tactile graphics created, sighted participants most frequently preferred 3D models (e.g., for photographs of real objects like a fish or a frog) followed by bas-relief (e.g., for 2D art), and then embossings (e.g., only for technical illustrations). They also reported that the tool was easy to use and would fit well with their existing resources (e.g., a 3D printer at their school or museum).

In our preliminary evaluation, blind users explored 15 of 21 available printed tactile graphics previously generated using our creation tool with five randomly selected images. Each of the five images were available for users to manipulate in three different

tactile mediums (embossing, bas-relief, and 3D). Blind users also received image descriptions containing contextual information and suggested touch strategies. In the end, blind evaluators appreciated access to multiple models, but when we asked them to select their preferred model for each image, they always preferred the 3D model (or equally preferred 3D and bas-relief) as the 3D models allowed them to create more accurate mental pictures. In contrast to sighted participants who preferred bas-relief for 2D paintings, blind users favored 3D models (even if the back of the object was hallucinated). This preference is consistent with prior findings that exact proportional or positional accuracy of 3D model segments is of low importance when understanding a graphic's overall content [29]. By providing multiple mediums, blind users can access models they want to use rather than those filtered through sighted people's preferences, which aligns with GenAssist's emphasis on reducing dependence on sighted intermediaries [21].

During both the sighted and blind preliminary evaluations, beyond representing 2D images, participants raised the potential use case of creating 3D models for real-world objects that are otherwise inaccessible due to their large size and/or unobtainability (e.g., architecture, monuments, animals). Both sighted and blind users highlighted the importance of our tool synching tactile output with specific user goals (e.g., whether the goal was simply to build abstract concepts or to directly represent real-life physical forms). They also liked the possibility further customizing output based on the intended audience's tactile comprehension level and the actual object's dimensionality. Given this, providing multiple tactile representations of the same image was deemed essential for supporting a diverse set of end users.

4 LIMITATIONS & FUTURE WORK

Greater Support for Blind Users: The core functionality of our current prototype is screen reader accessible. However, previews of resulting tactile graphics are primarily visual such that BLV users rely on descriptions or print out their results to fully assess output. Our future work will implement greater support for BLV users to gauge how well their results represent the input image (e.g., via a scoring system, validated descriptions, refreshable displays).

Direct Manipulation: Participants expressed the desire to have finer control over adjustments to both the input image and the resulting tactile graphics. Suggestions included directly applying shape annotations or textures to output, blending or merging output files, having tools to further edit input images, and supporting braille labelling. One TSVI said that she could apply braille stickers to her printed results, but it would be more convenient to have within the application.

Textural Feedback: Sighted and blind participants noted that texture is important for differentiating regions of a tactile graphic and conveying real-world appearance. Our prototype provides limited variation in textural feedback due to material constraints required for fabrication (i.e., plastic filament for 3D printing and cardstock paper for embossing). Several TSVIs suggested using tactile graphics strictly to convey shape and size while supplying students with additional materials to better represent real-world textures. In the future, similar to a suggestion made in a previous study [37], we will

explore using texture to map tactile regions to image descriptions for ease of interpretation.

Applications Beyond Accessibility: Tactile graphics have the potential to engage children as a complement to visual exhibits that they are not able to touch (a benefit raised by a participant in our study). Future work will explore how to optimize tactile graphic design and creation tools for different populations.

5 CONCLUSION

We presented a tool to facilitate the simultaneous creation of tactile graphics for complex images (paintings, diagrams, and illustrations) by non-experts. Preliminary evaluations show that automatically generated tactile graphics provide teachers, museum professionals, and other non-experts with an easy, cost-effective way to make complex images more accessible to BLV people. Our prototype allowed users to customize their tactile graphic designs to produce ready-to-print tactile graphics in three different mediums at once. Evaluators agreed that 3D models generated using monocular depth reconstruction and image-to-3D inferences are a viable and promising medium for communicating complex imagery to the BLV community in an engaging, comfortable, and comprehensible way.

REFERENCES

- [1] Catherine M Baker, Lauren R Milne, Ryan Drapeau, Jeffrey Scofield, Cynthia L Bennett, and Richard E Ladner. 2016. Tactile graphics with a voice. *ACM Transactions on Accessible Computing (TACCESS)* 8, 1 (2016), 1–22.
- [2] G. Bradski. 2000. The OpenCV Library. *Dr. Dobbs's Journal of Software Tools* (2000). Canny Edge Detection Implementation.
- [3] Matthew Butler, Leona M Holloway, Samuel Reinders, Catagay Goncu, and Kim Marriott. 2021. Technology developments in touch-based accessible graphics: A systematic review of research 2010–2020. In *Proceedings of the 2021 Chi conference on human factors in computing systems*. 1–15.
- [4] Ricardo Cabello. 2010. Three.js. <https://threejs.org/>.
- [5] John Canny. 1986. A computational approach to edge detection. *IEEE Transactions on pattern analysis and machine intelligence* 6 (1986), 679–698.
- [6] Luis Cavazos Quero, Jorge Iranzo Bartolomé, and Jundong Cho. 2021. Accessible visual artworks for blind and visually impaired people: comparing a multimodal approach with tactile graphics. *Electronics* 10, 3 (2021), 297.
- [7] Jun Dong Cho. 2021. A study of multi-sensory experience and color recognition in visual arts appreciation of people with visual impairment. *Electronics* 10, 4 (2021), 470.
- [8] Cricut. 2021. Cricut Maker 3 Cutting Machine.
- [9] Cricut. 2025. Cricut Maker 4 Cutting Machine. <https://cricut.com/en-us/cutting-machines/cricut-maker/cricut-maker-4/cricut-maker-4/2011084.html>
- [10] Dawson-Haggerty et al. [n. d.]. *trimesh*. <https://trimesh.org/>
- [11] Tyler J Ferro and Dianne TV Pawluk. 2013. Automatic image conversion to tactile graphic. In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–2.
- [12] Lucia Foglia and Robert A Wilson. 2013. Embodied cognition. *Wiley Interdisciplinary Reviews: Cognitive Science* 4, 3 (2013), 319–325.
- [13] Rocco Furferi, Lapo Governi, Niccolò Vanni, Yary Volpe, et al. 2014. Tactile 3D bas-relief from single-point perspective paintings: a computer based method. *Journal of Information and Computational Science* 11 (2014), 5667–5680.
- [14] John A Gardner. 1996. Tactile graphics: an overview and resource guide. *Information Technology and Disabilities* 3, 4 (1996).
- [15] Daniel Gatis. 2020. Rembg. <https://github.com/danielgatis/rembg>.
- [16] Andrea Hathazi and Mihaela Bujor. 2013. Development of tactile strategies and use of tactile resources in emergent literacy at children with visual impairment. *Psychol. Paedagog* 13, 2 (2013), 41.
- [17] Leona Holloway, Swamy Ananthanarayan, Matthew Butler, Madhuka Thisuri De Silva, Kirsten Ellis, Catagay Goncu, Kate Stephens, and Kim Marriott. 2022. Animations at your fingertips: using a refreshable tactile display to convey motion graphics for people who are blind or have low vision. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–16.
- [18] Leona Holloway, Matthew Butler, and Kim Marriott. 2022. 3d printed street crossings: Supporting orientation and mobility training with people who are blind or have low vision. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–16.

- [19] Leona Holloway, Kim Marriott, Matthew Butler, and Alan Borning. 2019. Making sense of art: Access for gallery visitors with vision impairments. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.
- [20] American Printing House. 2025. PixBlaster. <https://www.aph.org/product/pixblaster/>
- [21] Mina Huh, Yi-Hao Peng, and Amy Pavel. 2023. GenAssist: Making image generation accessible. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*. 1–17.
- [22] Dot Incorporation. 2023. Dot Pad. <https://pad.dotincorp.com/>
- [23] Chutian Jiang, Yinan Fan, Junan Xie, Emily Kuang, Kaihao Zhang, and Mingming Fan. 2024. Designing unobtrusive modulated electrostatic feedback on fingertip edge to assist blind and low vision (BLV) people in comprehending charts. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–20.
- [24] Richard E Ladner, Melody Y Ivory, Rajesh Rao, Sheryl Burgstahler, Dan Comden, Sangyun Hahn, Matthew Renzelmann, Satria Krisnandi, Mahalakshmi Ramasamy, Beverly Slabosky, et al. 2005. Automating tactile graphics translation. In *Proceedings of the 7th International ACM SIGACCESS Conference on Computers and Accessibility*. 150–157.
- [25] Haichang Li, Chun Meng Yu, Faraz Faruqi, Junan Xie, Gene SH Kim, Mingming Fan, Angus G Forbes, Jacob O Wobbrock, Anhong Guo, Liang He, et al. 2025. A11yShape: AI-Assisted 3-D Modeling for Blind and Low-Vision Programmers. *arXiv preprint arXiv:2508.03852* (2025).
- [26] Yangguang Li, Zi-Xin Zou, Zexiang Liu, Dehu Wang, Yuan Liang, Zhipeng Yu, Xingchao Liu, Yuan-Chen Guo, Ding Liang, Wanli Ouyang, et al. 2025. TripoSG: High-Fidelity 3D Shape Synthesis using Large-Scale Rectified Flow Models. *arXiv preprint arXiv:2502.06608* (2025).
- [27] Irene Miller, Aquinas Pather, Janet Milbury, Lucia Hasty, Allison O'Day, Diane Spence, and S Osterhaus. 2010. Guidelines and standards for tactile graphics. *The Braille Authority of North America* (2010).
- [28] Moritz Neumüller, Andreas Reichinger, Florian Rist, and Christian Kern. 2014. 3D printing for cultural heritage: Preservation, accessibility, research and education. *3D research challenges in cultural heritage: a roadmap in digital heritage preservation* (2014), 119–134.
- [29] Athina Panotopoulou, Xiaoting Zhang, Tammy Qiu, Xing-Dong Yang, and Emily Whiting. 2020. Tactile line drawings for improved shape understanding in blind and visually impaired users. *ACM Transactions on Graphics (TOG)* 39, 4 (2020), 89–1.
- [30] Isabella Pedraza Pineros, Arvind Satyanarayan, Jonathan Zong, et al. 2025. Tactile Vega-Lite: Rapidly Prototyping Tactile Charts with Smart Defaults. *arXiv preprint arXiv:2503.00149* (2025).
- [31] Denise Prescher, Jens Bornschein, and Gerhard Weber. 2014. Production of accessible tactile graphics. In *International Conference on Computers for Handicapped Persons*. Springer, 26–33.
- [32] Andreas Reichinger, Anton Fuhrmann, Stefan Maierhofer, and Werner Purgathofer. 2016. A concept for re-useable interactive tactile reliefs. In *Computers Helping People with Special Needs: 15th International Conference, ICCHP 2016, Linz, Austria, July 13-15, 2016, Proceedings, Part II 15*. Springer, 108–115.
- [33] Andreas Reichinger, Stefan Maierhofer, and Werner Purgathofer. 2011. High-quality tactile paintings. *Journal on Computing and Cultural Heritage (JOCCH)* 4, 2 (2011), 1–13.
- [34] Orbit Research. [n.d.]. Graphiti Tactile Graphics Display. <https://www.orbitresearch.com/product/graphiti/?srsltid=AfmBOoq-aOkzE-a4pkjtxO74iFnp2ckMdVJBx6tJOo9S7Z2LvxxDGe>
- [35] Kelly Rossouw. 2022. How to Emboss *and Deboss* with Your Cricut Maker. <https://www.youtube.com/watch?v=Jlm4gR1nfbQ>
- [36] Roberto Scopigno, Paolo Cignoni, Nico Pietroni, Marco Callieri, and Matteo Dellepiane. 2014. Digital Fabrication Technologies for Cultural Heritage (STAR). *GCH* (2014), 75–85.
- [37] Lei Shi, Holly Lawson, Zhuohao Zhang, and Shiri Azenkot. 2019. Designing interactive 3D printed models with teachers of the visually impaired. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–14.
- [38] Alexa F Siu, Son Kim, Joshua A Miele, and Sean Follmer. 2019. shapeCAD: An accessible 3D modelling workflow for the blind and visually-impaired via 2.5 D shape displays. In *Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility*. 342–354.
- [39] Abigale Stangl, Chia-Lo Hsu, and Tom Yeh. 2015. Transcribing across the senses: community efforts to create 3D printable accessible tactile pictures for young children with visual impairments. In *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility*. 127–137.
- [40] Abigale Stangl, Jeeun Kim, and Tom Yeh. 2014. Technology to support emergent literacy skills in young children with visual impairments. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems*. 1249–1254.
- [41] Alberto Urcia, Simone Zambruno, Antonino Vazzana, Michael Anderson, and Colleen M Darnell. 2018. PROTOTYPING AN EGYPTIAN REVIVAL. LASER SCANNING, 3D PRINTS AND SCULPTURE TO SUPPORT THE ECHOES OF EGYPT EXHIBITION. *Archeologia e Calcolatori* 29 (2018).
- [42] Yary Volpe, Rocco Furferi, Lapo Governi, and Giovanna Tennirelli. 2014. Computer-based methodologies for semi-automatic 3D model generation from paintings. *International Journal of Computer Aided Engineering and Technology* 6, 1 (2014), 88–112.
- [43] Thomas P Way and Kenneth E Barner. 1997. Automatic visual to tactile translation. II. Evaluation of the TACTile image creation system. *IEEE Transactions on Rehabilitation Engineering* 5, 1 (1997), 95–105.
- [44] Lihe Yang, Bingyi Kang, Zilong Huang, Zhen Zhao, Xiaogang Xu, Jiashi Feng, and Hengshuang Zhao. 2024. Depth anything v2. *Advances in Neural Information Processing Systems* 37 (2024), 21875–21911.

A TACTILE GRAPHICS PRINT SETTINGS

A.1 Paper Embossings

To achieve the final printing strategy for paper embossings using the Cricut Maker 3's debossing tip, we tested three different methods of creating texture on paper. For all three methods, we first upload the resulting outline image to the Cricut Maker Design Space application and select the "single layer" option in order to recognize all outlines.

- (1) Within the design space, we selected the outline and changed the maker setting to "Deboss." Using the highest pressure option on 100 pound heavyweight cardstock on top of a Cricut cutting mat, we were then able to create debossed lines.
- (2) Within the design space, we duplicated the outline. Selecting one outline, we created a rounded "offset" edge with a value of 0.05 to create extra space surrounding the outline itself. Making sure that the outline and the offset were aligned properly, we changed the maker setting to "Deboss" on the outline itself and to "Cut" on the offset. Using normal pressure with the Cricut Maker's cutting tip, we first cut out the offset selection on 100 pound heavyweight cardstock on top of a Cricut cutting mat. We then removed the offset area so that there was no cardstock where the outlines would later be drawn and regions between outlines did have cardstock. This allows for the ability to create deeper embossed lines in the final graphic. We then taped or glued a second piece of 100 pound heavyweight cardstock on top of the first (still on the cutting mat). Using a high pressure setting and the debossing tip, we were then able to create deeper debossed lines.
- (3) Within the design space, we selected the outline and created a rounded "offset" edge with a value of 0.05. We then changed the maker setting "Cut." Using normal pressure with the Cricut Maker's cutting tip, we cut out the offset selection on 100 pound heavyweight cardstock on top of a Cricut cutting mat. We then removed the offset area so that there was no cardstock where the outlines would be. Finally, we glued the resulting cardstock pieces to a second sheet of paper to create a paper cutting that depicted separate raised areas of the image.

In our study, we opted to use the second creation method as it produced the deepest embossed lines.

A.2 3D Prints

Aside from the default settings within the Bambu Studio application, we used the following print settings:

- (1) **Layer height:** 0.1 mm
- (2) **Initial layer height:** 0.2 mm
- (3) **Sparse fill density:** 10%
- (4) **Enable support**
- (5) **Support type:** Tree
- (6) **Support threshold angle:** 20°

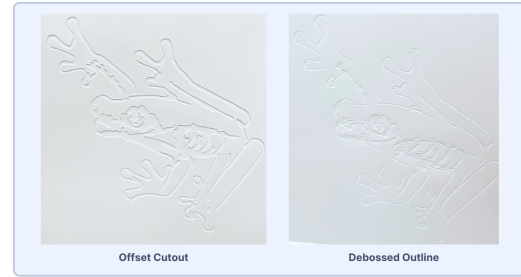


Figure 4: Left: The offset cutout pasted on a second sheet of cardstock. Right: Result of debossing the outline on a separate piece of paper placed on top of the offset cutout.

B PRELIMINARY STUDY PARTICIPANT INFORMATION

B.1 Participant Demographic Information

Authoring Study Participant Information							
ID	Age	Gender	Vision	Occupation	Experience Creating Tactile Graphics	Frequency	Preferred Mediums
1	54	Female	Sighted	Natural History Museum Program Coordinator	None	N/A	N/A
2	50	Female	Sighted	Teacher of BLV Students	15 years	Occasionally	Handmade materials; paper and art supplies, felt board
3	50	Female	Sighted	Teaching Assistant of BLV Students	7 years	Monthly	PIAF machine, swell paper
4	31	Female	Sighted; Convergence Insufficiency	Teacher of BLV Students	7 years	Monthly	Dependent on content; PIAF machine, handmade models
5	47	Male	Sighted; High Myopia	Teacher of BLV Students	16 years	Weekly	Dependent on content; graph and peg boards, paper and art supplies
6	30	Female	Sighted	Art Museum Assistant Curator	None	N/A	N/A

Table 1: Demographics of authoring study participants.

Interpretation Pilot Study Participant Information								
ID	Age	Gender	Visual Impairment	Onset	Occupation	Experience Using Tactile Graphics	Frequency	Preferred Mediums
7	43	Female	Totally blind	Acquired; age 2	Tech Support Specialist	Some; Educational context	Occasionally	Raised line
8	36	Female	Totally blind	Acquired; age 10	Teacher of BLV Students	Expert; Educational context	Weekly	Dependent on content; thermoform, 3D printing

Table 2: Demographics of interpretation study participants.

B.2 BLV Participant Usability Ratings

P7 Usability Ratings					
Statements for each Tactile Graphic Medium	Image Category				
Embossed Outlines	Animals	Architecture	Naturalistic Art	Museum Artifacts	Nature
Comfort of use	3	3	1	2	3
Comprehensibility	3	3	1	2	3
Communication of spatial relationships	3	2	1	1	3
Composition of image as a whole	2	2	1	1	2
Bas-Relief Models	Animals	Architecture	Naturalistic Art	Museum Artifacts	Nature
Comfort of use	4	4	4	4	4
Comprehensibility	4	4	4	4	4
Communication of spatial relationships	4	4	4	5	4
Composition of image as a whole	4	4	3	5	4
3D Models	Animals	Architecture	Naturalistic Art	Museum Artifacts	Nature
Comfort of use	5	5	5	5	5
Comprehensibility	5	5	5	5	5
Communication of spatial relationships	5	5	5	5	5
Composition of image as a whole	5	5	5	5	5

Table 3: P7’s Likert scale usability ratings for each tactile graphic medium and image category.

P8 Usability Ratings					
Statements for each Tactile Graphic Medium	Ratings for each Image Category				
Embossed Outlines	Anatomical Diagrams	Animals	Architecture	Museum Artifacts	Abstract Art
Comfort of use	3	5	3	3	1
Comprehensibility	3	5	3	3	1
Communication of spatial relationships	3	5	3	3	1
Composition of image as a whole	3	4	3	3	1
Bas-Relief Models	Anatomical Diagrams	Animals	Architecture	Museum Artifacts	Abstract Art
Comfort of use	4	5	4	4	3
Comprehensibility	4	5	4	4	3
Communication of spatial relationships	4	5	4	4	3
Composition of image as a whole	4	5	4	4	3
3D Models	Anatomical Diagrams	Animals	Architecture	Museum Artifacts	Abstract Art
Comfort of use	5	4	4	5	5
Comprehensibility	5	4	4	5	5
Communication of spatial relationships	5	4	4	5	5
Composition of image as a whole	5	4	4	5	5

Table 4: P8’s Likert scale usability ratings for each tactile graphic medium and image category.