Post-Printing Era
Revisiting Handwriting with Writing Robots

Atsunobu Kotani and Stefanie Tellex
Department of Computer Science
Brown University
{akotani,stefie10}@cs.brown.edu

***Abstract*— Our work, *Post-Printing Era*, is an interactive art-piece which we aim to demonstrate how robots augment our freedom to express ourselves in handwriting. Participants will be asked to write any characters or drawings on paper and to hand them to an ink-jet printer and our robot for scanning. Given an image of just-drawn handwritten characters or drawings, our writing robot immediately infers a plan to replicate the image with a writing utensil, and then reproduces the image. Unlike conventional printers, our system draws as we all do; each target stroke is produced in one continuous motion and it does not rely on handcrafted rules or on predefined paths of characters. Participants compare the two results and experience our innate attachment and respect to what handwriting does express.**

I. Introduction

Handwriting is an art of human expression that conveys not only information but also the writer's feeling and personality. Robots that operate in human environments should be able to participate in human tasks such as leaving a note or writing on a whiteboard.

The most recognized printing system today is an ink-jet printer. By moving back and forth and spraying ink to the desired locations, printers replicate input images in a bit-map format. However, it is not the case that an ink-jet printer draws with a writing utensil such as a pen or marker. In order to collaborate with humans, we would like for a manipulator robot to be able to draw on a white board, write a message with a pen on a post-it note, or draw a diagram. The ability to write would enable a robot to put up a sign directing people that a hallway was closed, to produce art using physical mediums such as a paint brush or a pen, or to address and mail a letter. Additionally, the robot could potentially engage in teaching activities at a white board, writing a math equation or drawing a diagram. These skills rely on the ability to produce a policy to draw with a writing utensil.

What differentiates handwriting from current printing technologies is its continuous drawing process. Shown an image of handwritten characters, robots should draw each target stroke in one consecutive drawing motion. Existing methods for robots that write with a utensil are unable to look at a bit-mapped image and directly produce a drawing policy. Instead, they require external information about the stroke order for character, such as human gestures [1, 2] or predefined paths for each letter [3]. This extra information makes it challenging for novice users to teach the robot how to draw new characters, because the stroke order information must be provided. A more recent reinforcement learning based approach [4] successfully learns to draw the target image, yet their model struggles to draw each target stroke in one continuous drawing motion, and frequently draws the same parts over and over to replicate the image. Our system, in contrast, takes as input an image to draw, then generates commands for robots to replicate the image with a writing utensil. This process is shown in Figure 1, and an example of drawing reproduction is in Figure 2.

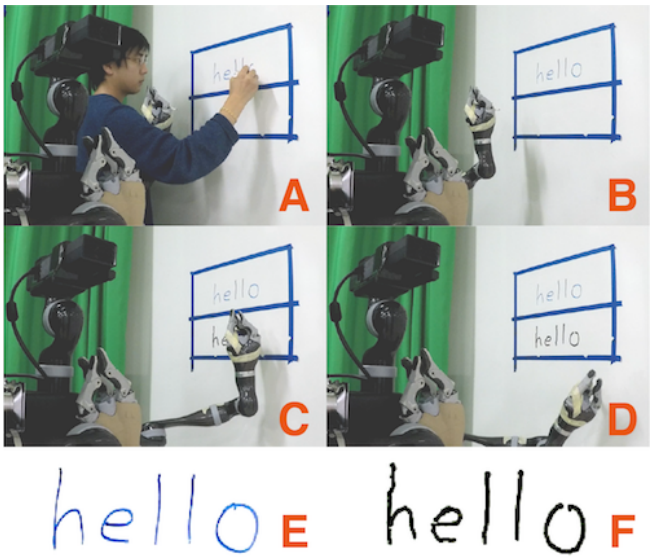

Fig. 1: Demonstration of our system reproducing the target image in a real robotic environment: A) a participant drawing characters on a whiteboard, B) a robot taking a bitmapped image from its camera, C) a robot executing commands predicted by our system in real-time D) finished process E) image of the user's drawing F) image of the robot's drawing

Many artists explore possibilities of robot writing (e.g. [5, 6]) under restrictions that drawing orders are not guaranteed to be preserved. And we believe that Human-Robot Interaction aspects on robot writing is enhanced with our technical advantage. We take this chance and compare our robotic printer to extant printers and invites participants to experience how robots preserve our

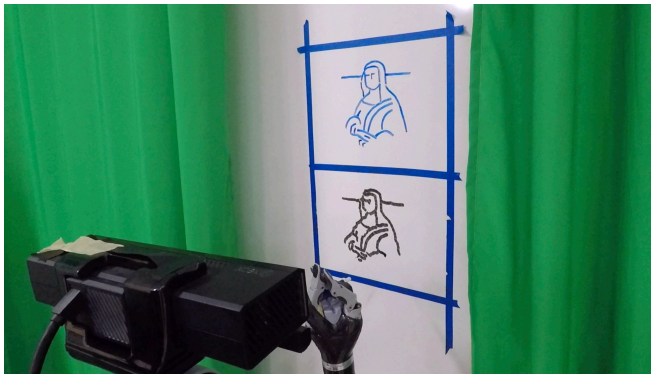

Fig. 2: Our system reproducing the Mona Lisa drawing

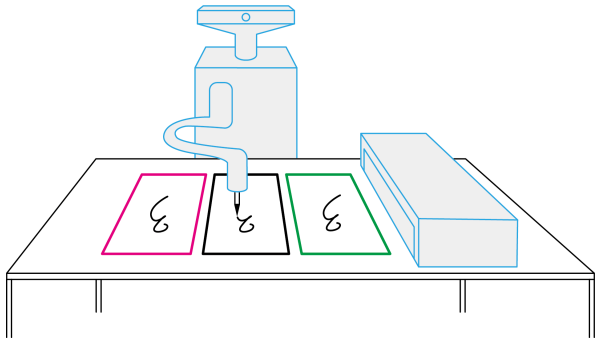

Fig. 3: Illustration of our work: 1) A participant places the written paper in the pink region, 2) our robot takes a picture and reproduce it in the black region, 3) an ink-jet printer also prints the target image to the green region.

"styles" unlike conventional printers. The communication between humans and robots can be enhanced by this expressivity of our human-centered writing robot.

II. Post-Printing Era

We first ask participants to write anything on paper, such as characters and drawings. They are guided to place their handwriting in front of our robot. The pictorial information of the original drawing is then obtained by the robot's camera, and this will be sent to the connected ink-jet printer. Once all commands are generated, our robotic printer executes them to replicate the original. When the printing process terminates, there will be three drawings; the original, the copy made by the ink-jet printer and our robotic printer. These drawings will be displayed on the wall in three rows, matching the type in the same row. Figure 3 shows this setting.

Our robot platform is the 7-DOF Kinova Jaco arm [7] with a Kinect camera. We used ROS kinetic [8] to interface with the robot, and MoveIt! with TRAC-IK kinematics solver [9] to control the motion of the arm. For installation, we would also need a table to put three letter-size papers and a standard ink-jet printer .

This artwork does not only focus on the power of handwriting but also question what we may have missed through rapid advance in technology. When participants witness our robotic printer writes stroke by stroke, they will be objectively observing their real-time handwriting for the first time. Juxtaposing with an ink-jet printer, the robotic printer would be much slower and inefficient, yet participants would grow attachment to the robot and might realize that we are sacrificing rich information of texts as we choose efficiency and speed, symbolized by the ink-jet printer. Handwriting embodies humanity, and we believe that robots can fill the gap between us and this rapidly changing society and speak for ourselves.

Finally, this paper contains materials from the previously published paper by the authors [10].

III. Acknowledgments

This work is supported by the National Science Foundation under grant number IIS-1652561.

References

[1] Sylvain Calinon and Aude Billard. Learning of gestures by imitation in a humanoid robot. Technical report, Cambridge University Press, 2007.

[2] Fei Chao, Yuxuan Huang, Xin Zhang, Changjing Shang, Longzhi Yang, Changle Zhou, Huosheng Hu, and Chih-Min Lin. A robot calligraphy system: From simple to complex writing by human gestures. *Engineering Applications of Artificial Intelligence*, 59:1–14, 2017.

[3] Deanna Hood, Séverin Lemaignan, and Pierre Dillenbourg. When children teach a robot to write: An autonomous teachable humanoid which uses simulated handwriting. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 83–90. ACM, 2015.

[4] Yaroslav Ganin, Tejas Kulkarni, Igor Babuschkin, SM Ali Eslami, and Oriol Vinyals. Synthesizing programs for images using reinforced adversarial learning. In *International Conference on Machine Learning*, pages 1652–1661, 2018.

[5] Patrick Tresset. `http://patricktresset.com`.

[6] Sougwen Chung. `https://sougwen.com`.

[7] Kinova movo. `https://www.kinovarobotics.com/en/products/assistive-technologies/kinova-jaco-assistive-robotic-arm`.

[8] Morgan Quigley, Ken Conley, Brian Gerkey, Josh Faust, Tully Foote, Jeremy Leibs, Rob Wheeler, and Andrew Y Ng. Ros: an open-source robot operating system. In *ICRA workshop on open source software*, volume 3, page 5. Kobe, Japan, 2009.

[9] Patrick Beeson and Barrett Ames. Trac-ik: An open-source library for improved solving of generic inverse kinematics. In *Humanoid Robots (Humanoids), 2015 IEEE-RAS 15th International Conference on*, pages 928–935. IEEE, 2015.

[10] Atsunobu Kotani and Stefanie Tellex. Teaching robots to draw. In *IEEE International Conference on Robotics and Automation (ICRA), 2019*. IEEE, 2019.