RoboART: Artistic Robot Programming in Mixed Reality

Felipe Fronchetti* Miles Popiela† Rodrigo Spinola‡ Shawn Brixey§

School of the Arts and College of Engineering
Virginia Commonwealth University

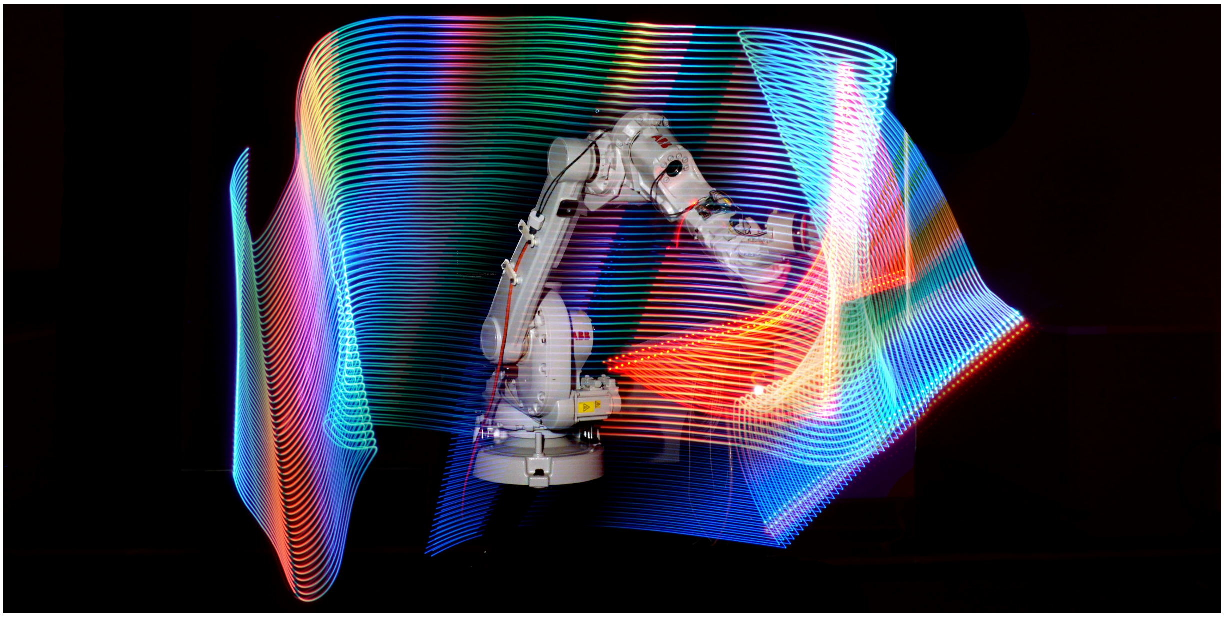

Figure 1: RoboART in practice: Creators use our tool to make art with light trails.

Abstract

Articulated robots are attracting the attention of artists worldwide. Due to their precise, tireless, and efficient nature, robots are now being deployed in different forms of creative expression, such as sculpting, choreography, immersive environments, and cinematography. While there is a growing interest among artists in robotics, programming such machines is a challenge for most professionals in the field, as robots require extensive coding experience and are primarily designed for industrial applications and environments. To enable artists to incorporate robots in their projects, we propose an end-user-friendly robot programming solution using an intuitive spatial computing environment designed for Microsoft Hololens 2. In our application, the robot movements are synchronized with a hologram via network communication. Using natural hand gestures, users can manipulate, animate, and record the hologram similar to 3D animation software, including the advantages of mixed reality interaction. Our solution not only gives artists the ability to translate their creative ideas and movements to an industrial machine but also makes human-robot interaction safer, as robots can now be accurately and effectively operated from a distance. We consider this an important step in a more human-driven robotics community, allowing creators without robot programming experience to easily script and perform complex sequences of robotic movement in service of new arts applications. Making robots more collaborative and safer for humans to interact with dramatically increases their utility, exposure, and potential for social interaction, opens new markets, expands creative industries, and directly locates them in highly visible public spaces.

Index Terms: Software and its engineering—Software notations and tools—Context specific languages—Programming by example; Applied computing—Arts and humanities—Performing arts

*e-mail: fronchettl@vcu.edu
†e-mail: popielamc@vcu.edu
‡e-mail: spinolaro@vcu.edu
§e-mail: brixey@vcu.edu

1 Introduction

The popularity of articulated robots has been increasing rapidly over the years [6]. Thanks to their ability to execute precise and continuous movements, robots are gaining the attention of non-industrial domains like arts, entertainment and healthcare [5]. In the artistic spectrum, articulated robots are seen in leading and supporting roles. Behind the scenes, robots are used in areas such as cinematography, precisely moving cameras at complex angles and takes [3]. On stage, robots express their artistic traits in areas like drawing (e.g., [1]), sculpting (e.g., [2]), and painting (e.g., [4]). While certain artistic expressions may not require human-like movements from a robot, choreography, for example, depends on anthropomorphic movements to immerse spectators in their artwork. Within this challenge, most articulated robots are also designed with engineering applications in mind, creating a barrier between artists and robot programming solutions.

2 RoboART

To overcome this problem we introduce RoboART, an end-user-friendly robot programming solution in mixed reality. With our tool, artists can translate human-object interactions in mixed reality to an articulated robot in real-time, resulting in creative ideas expressed by robot motions (See example in Figure 1). Two programming interfaces are available in our solution: animation and creation. In **animation mode**, developers record a motion path using an interactable pen in mixed reality (See Figure 2). The holographic pen copies the hand movements, translating translation and rotation values to the robot. In animation mode, creators can also visualize the motion path created and make the pen (*and consequently, the robot*) repeat the path in a loop. For convenience, users can also delete existing paths and save them in memory for future use.

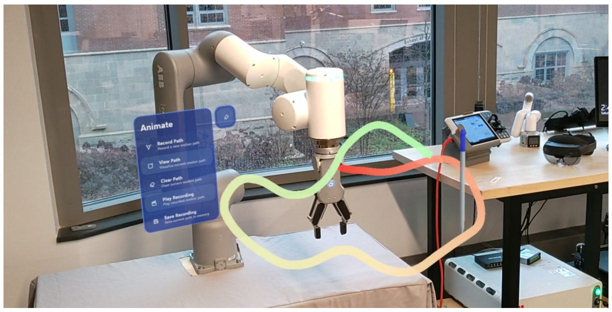

Figure 2: Animation mode: A motion path is created via object interaction in mixed reality.

In **creation mode**, a similar approach is given using the holographic pen as a reference (See Figure 3). Instead of recording a robot trajectory with their hands, developers create a sequence of points in space to represent the motion path. Each point is represented by an adjustable sphere that can be moved and resized at any time. Just like in animation mode, users can also visualize, delete, and replay the motion path created, making the robot mimic the holographic model. To give developers better precision over their movements, we also provide an axes control interface, from which they lock the holographic pen from specific axes. A hand-following menu interface is also available, providing users control over which of the three interfaces should be displayed, besides robot status information and basic settings (e.g., a button to disable robot-pen synchronization).

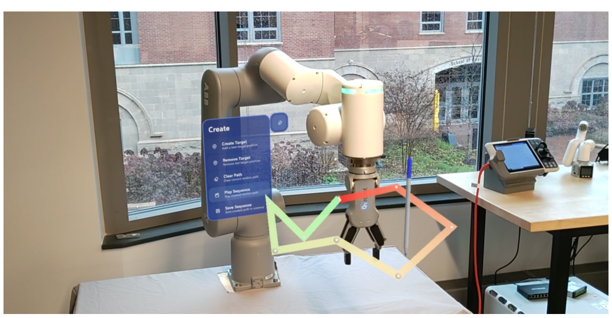

Figure 3: Creation mode: The motion path is implemented using a sequence of three-dimensional points in space.

Implementation Details

Our solution was implemented using a Microsoft Hololens 2, the Mixed Reality Toolkit 3, and the GoFa collaborative robot[1] from ABB. The mixed reality application, including the interactable interfaces and holographic pen, was entirely made in Unity using the toolkit provided by Microsoft. The pen was adapted to mixed reality using the `BoundsControl` and `ObjectManipulator` components from the toolkit, and the interfaces based on the pre-built UX components available in the same solution.

The pen-robot synchronization was made using network communication methods in C# and RAPID languages (See description in Figure 4), including the assistance of the robot manufacturer's externally guided motion programming interface. For readers interested in how to connect external devices with ABB robots, we provide an additional repository[2] including examples in Unity and Windows-based platforms. Our implementation is also available on GitHub[3], and a video demonstration is provided on YouTube[4].

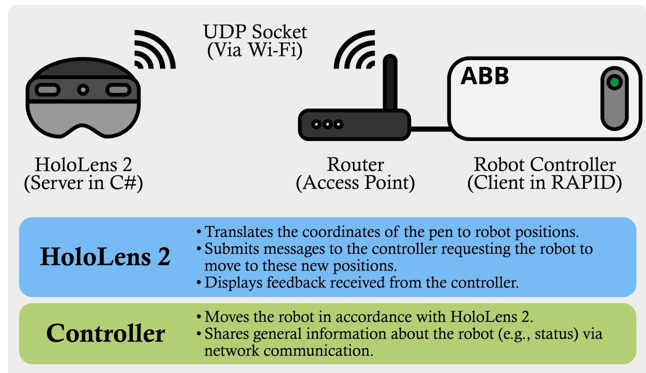

Figure 4: Pen-robot synchronization system description.

Future Work

For future releases, we plan to increase the creative features available in our tool, including new modes of path control and animation. For the creation mode, we plan to include the ability for users to adjust the curvature of linear movements with standard bezier tools like those found in design and video editing software. These tools will operate the same as in traditional robot programming instructions (e.g., MoveC, MoveJ). To make our solution more inclusive, we also plan to expand the number of robots supported in our code. A usability study involving artists is also planned.

Acknowledgments

This work has been supported by the NSF (Award #2024561).

References

[1] T. Löw, J. Maceiras, and S. Calinon. drozbot: Using ergodic control to draw portraits. *IEEE Robotics and Automation Letters*, 7(4):11728–11734, 2022.
[2] Z. Mingyuan, C. Zhaolin, S. T. R. Shiu, J. Liang, C. Fang, Z. Ma, and S. J. Wang. Cosculpt: An ai-embedded human-robot collaboration system for sculptural creation. *Human Systems Engineering and Design (IHSED2023): Future Trends and Applications*, p. 73, 2023.
[3] P. Praveena, B. Cagiltay, M. Gleicher, and B. Mutlu. Exploring the use of collaborative robots in cinematography. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, pp. 1–6, 2023.
[4] P. Schaldenbrand, J. McCann, and J. Oh. Frida: A collaborative robot painter with a differentiable, real2sim2real planning environment. In *2023 IEEE International Conference on Robotics and Automation (ICRA)*, pp. 11712–11718. IEEE, 2023.
[5] J. S. Thurow, Kerstin. 8.2.2 market potential, 2023.
[6] V. Verlag. 51.3 cobots on the rise, 2022.

[1] Collaborative robots (also known as *cobots*) are a category of articulated robots designed to work safely around humans.

[2] `https://github.com/fronchetti/egm-for-abb-robots`
[3] `https://github.com/fronchetti/roboart`
[4] `https://www.youtube.com/watch?v=LXDUrxYXdPw`