Embodied human-AI collaborative drawing

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Abstract—Recent advances in generative artificial intelligence have enabled increasingly sophisticated forms of collaborative drawing within digital environments. However, comparatively little research has explored how such collaboration may be embodied physically through robotic systems operating within a shared workspace alongside a human participant. This paper presents the design rationale and proposed hardware architecture for a physical human-AI collaborative drawing platform. The system consists of a small mobile robot capable of autonomous movement across a drawing surface while carrying a pen or pencil, localised through an overhead computer vision system. The platform is intended not merely as an automated plotting device, but as an embodied co-creative agent capable of participating in collaborative art and spatial interaction. The paper outlines the mechanical, sensing, localisation, and computational requirements of the system and discusses its implications for embodied AI, co-creative systems, and human-robot interaction research.

I. Introduction

AI-assisted drawing systems have traditionally operated within screen-based software environments, where users collaborate with generative systems through graphical interfaces. These systems increasingly support co-creative paradigms such as turn-taking, stroke completion, and iterative suggestion generation. Despite their sophistication, such approaches remain confined to virtual interaction spaces.

This project investigates the development of a physical collaborative drawing system in which an AI-driven robotic agent participates directly in the act of drawing on paper alongside a human user. The objective is not simply robotic image reproduction or autonomous plotting, but the creation of a physically embodied system capable of participating in shared creative activity.

Physical embodiment fundamentally changes the nature of interaction between users and AI systems. In collaborative physical environments, factors such as spatial occupation, movement behaviour, interruption, visibility, and bodily access become central components of the interaction experience. Consequently, the design requirements for a collaborative drawing robot differ substantially from those of traditional plotting systems, which typically prioritise precision and repeatability above interaction quality.

The proposed system therefore prioritises shared workspace accessibility, expressive robotic motion, real-time spatial awareness, and collaborative interaction dynamics.

II. Related Work

Recent work in AI-assisted drawing has increasingly explored co-creative interaction between humans and generative systems [1]. Software-based systems such as Drawing Apprentice [2, 3], Collabdraw [4], and DuetDraw [5] support collaborative sketching through turn-taking, asynchronous drawing, sketch completion, and real-time visual response. These systems demonstrate how AI can participate in drawing as an improvisational collaborator rather than solely as a generative tool.

More recent work has further explored collaborative dynamics within co-creative drawing systems. AI Drawing Partner [6], for example, supports both turn-taking and simultaneous interaction while also analysing interaction patterns such as pauses, turn duration, and idea exchange. Across these systems, collaboration is treated as an interactive process shaped by timing, response, and shared contribution.

Alongside digital co-creative systems, research in robotic drawing has explored physical art and embodied interaction. Existing robotic drawing systems include robotic portrait artists [7], reinforcement learning sketch agents [8], teleoperated drawing robots [9], and collaborative robotic art installations[1]. These systems demonstrate the creative potential of embodied robotic drawing, particularly through physical presence and movement.

However, a gap remains between software-based co-creative sketch systems and embodied robotic drawing systems. Digital systems commonly support rapid turn-taking and seamless shared canvas interaction, while physical robotic systems often focus on autonomous drawing or sequential collaboration due to the temporal and mechanical constraints of physical movement.

The proposed project builds upon both areas by investigating how collaborative turn-taking and co-creative interaction may operate within a physically embodied robotic drawing system. In doing so, it explores how embodiment changes the experience of collaboration, transforming AI from a reactive software tool into a physically situated creative partner.

[1] https://sougwen.com/

III. Design rationale and motivation

Several robotic drawing architectures were initially considered during the conceptual development of the project, including gantry-based plotters and suspended polargraph systems. While these approaches provide reliable motion control and high positional accuracy, they introduce limitations for collaborative interaction.

Gantry systems physically surround the drawing area, constraining user movement and partially obstructing the workspace. Suspended systems offer greater openness but introduce mechanical instability and reduced precision. Both approaches position the robotic system as infrastructure surrounding the user's activity.

In contrast, a small mobile robot operating directly on the drawing surface allows the workspace to remain largely unobstructed while enabling the robotic agent to exist within the shared drawing environment itself. This approach better supports the project's emphasis on embodied collaboration, spatial coexistence, and shared access to the drawing process.

A central motivation for the mobile robotic approach is the importance of embodied interaction within collaborative creative systems. Unlike fixed robotic infrastructures, the proposed platform minimises physical obstruction and enables the robotic agent to exist within the workspace rather than enclosing it. This positioning allows robotic movement itself to become part of the interaction language of the system. Variations in speed, hesitation, proximity, and trajectory may contribute to user perceptions of intentionality, responsiveness, and agency. As a result, robotic movement is treated not solely as a functional transport mechanism, but as a communicative and expressive component of the collaborative experience.

Importantly, the system does not aim to reproduce the precision or visual polish of commercial plotting systems. Instead, the project explores how imperfection, unpredictability, and physical presence may contribute positively to collaborative creative interaction. Slight inaccuracies in motion or drawing may reinforce perceptions of liveliness and participation, supporting a more experimental and co-creative form of drawing practice.

IV. System overview

The proposed platform consists of four primary subsystems:

1. A mobile robotic locomotion platform
2. A pen actuation mechanism
3. A vision-based localisation and perception system
4. An AI control and interaction layer

Together, these components enable the robot to navigate freely across a drawing surface, create physical marks, perceive user activity, and respond dynamically during collaborative drawing sessions.

A. Mobile robotic platform

The robot is designed as a compact tabletop vehicle capable of omnidirectional movement. A holonomic drive configuration using three omni wheels arranged at 120-degree intervals is proposed. This configuration enables translation in any planar direction, in-place rotation, and smooth, low-speed movement suitable for drawing tasks.

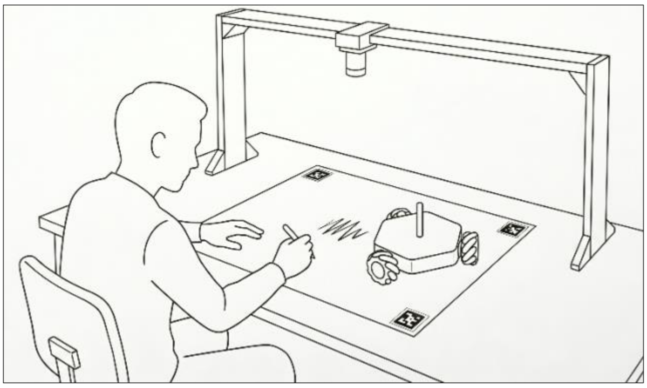

Figure 1: Main system concept. Shows the robot, the shared workspace, the overhead tracking, and collaborative interaction.

The locomotion system may be implemented using miniature DC gear motors controlled through an onboard microcontroller such as an ESP32. Compared to fixed robotic infrastructures, this approach minimises obstruction of the workspace and allows the user to interact naturally with the drawing surface.

The robot carries a physical drawing implement, such as a pen or pencil, mounted beneath the chassis. A servo-actuated mechanism enables the pen to be lifted or lowered during operation. To compensate for variations in paper height and robot movement, the pen assembly should incorporate a compliant spring-loaded mount to reduce mechanical stress while improving drawing consistency.

B. Localisation and perception

Robot localisation is achieved using an overhead camera mounted above the drawing surface. Fiducial markers such as AprilTags or ArUco markers are positioned on the corners of the paper, and on the robot body itself. The vision system then estimates the robot's position, orientation, and the coordinate frame of the drawing surface.

As users will frequently occlude portions of the workspace with their hands and arms, the system combines visual tracking with wheel odometry and inertial sensing to maintain robust localisation during temporary interruptions in visibility. An onboard inertial measurement unit and motor encoder estimates may be fused with camera observations through a Kalman Filter or Extended Kalman Filter. The use of

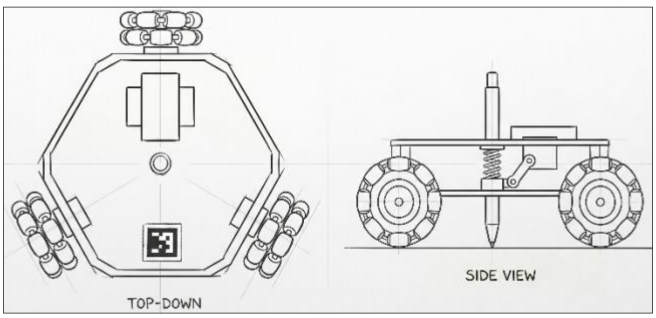

Figure 2: Robot design sketch. Shows the omni wheels, pen mechanism, spring-loaded servo lift and fiducial marker.

multiple fiducial markers placed on the robot body further improves robustness under partial occlusion conditions.

The overhead camera additionally enables awareness of user activity within the workspace. Computer vision techniques can estimate hand position, occupied drawing regions, and newly created marks. This information enables context-aware collaborative behaviour in which the robot may avoid occupied regions, pause during active user drawing, or contribute marks within unoccupied areas of the page.

C. *Computational architecture*

The proposed system separates low-level robotic control from higher-level AI and perception processes. An embedded microcontroller handles:

- Motor control
- Wheel kinematics
- Servo actuation
- Wireless communication

Higher-level processing is performed externally on a laptop or embedded computing platform such as a Raspberry Pi. This layer manages:

- Computer vision
- Localisation
- AI inference
- Collaborative behaviour generation

Communication between the robot and external system may occur through Wi-Fi or Bluetooth.

V. Conclusion

This project proposes a physical human-AI collaborative drawing platform based on a small mobile robot localised through overhead computer vision. Unlike conventional robotic plotting systems, the platform prioritises embodied interaction, shared workspace accessibility, and expressive movement behaviour over geometric precision.

By situating the AI system directly within the drawing environment as a physically present participant, the project aims to explore new forms of co-creative interaction between humans and embodied generative systems. The proposed platform contributes towards broader investigations into embodied AI, human-robot collaboration, and experimental creative technologies.

VI. Responsible innovation

The project positions AI as a collaborative participant rather than a replacement for human artistic activity. By emphasising shared interaction, interruption, and co-creation, the system seeks to highlight human agency within the creative process, intentionally prioritising embodied interaction and imperfect physical art over seamless automation or technical precision. This approach explores alternative relationships between humans and generative systems that emphasise experimentation, interpretation, and collaborative process. The idea contributes towards broader discussions concerning how AI systems may be integrated into creative practices in ways that support human agency, curiosity, and collaborative exploration rather than passive consumption of generated outputs.

Practical considerations relating to safety and comfort are addressed through the use of a small, lightweight, slow-moving robot operating within an open tabletop workspace. The prototype is also designed with accessibility and sustainability in mind through low-power embedded electronics, reusable hardware components, and standard drawing materials. The small-scale robotic platform minimises material and energy requirements compared to larger industrial robotic systems.

VII. Author bio(s) / experiences

Saskia is a final-year PhD researcher exploring the intersection of immersive technologies and affective computing, with a particular focus on understanding relationships between physiological and emotional responses. Her research interests include immersive application development, biosensing and physiological signal processing, and virtual exposure therapy. Her work is motivated by human-centred approaches for the design and application of AI technologies for societal benefit.

She is currently undertaking a Research Officer role within Swansea University's FIT Lab, focusing on AI development for embodied physical technologies such as supernumerary robotic limbs. Her work investigates how digital-physical interfaces can be designed to support creative expression, participation, and richer forms of human connection in everyday life.

VIII. Acknowledgements

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IX. References

[1] C. Jansen and E. Sklar, "Exploring Co-creative Drawing Workflows," Frontiers in Robotics and AI, vol. 8, p. 577770, 2021, doi: 10.3389/frobt.2021.577770.

[2] N. Davis et al., "Co-Creative Drawing Agent with Object Recognition," Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment, vol. 12, no. 1, pp. 9–15, Oct. 2016, doi: 10.1609/aiide.v12i1.12863.

[3] N. Davis et al., "Empirically Studying Participatory Sense-Making in Abstract Drawing with a Co-Creative Cognitive Agent," pp. 196–207, Mar. 2016, doi: 10.1145/2856767.2856795.

[4] J. E. Fan Met al., "collabdraw: An Environment for Collaborative Sketching with an Artificial Agent," pp. 556–561, Jun. 2019, doi: 10.1145/3325480.3326578.

[5] C. Oh et al., "I Lead, You Help but Only with Enough Details," pp. 1–13, Apr. 2018, doi: 10.1145/3173574.3174223

[6] N. Davis and J. Rafner, "AI Drawing Partner: Co-Creative Drawing Agent and Research Platform to Model Co-Creation," arXiv, Jan. 2025, doi: 2501.06607v1.

[7] A. T. Hoang et al., "Poktor-O-Bot: Integrated Image Processing Algorithms for Portrait Drawing Robot Applications," Measurement: Sensors, vol. 38, p. 101592, May 2025, doi: 10.1016/j.measen.2024.101592.

[8] G. Lee et al., "From Scratch to Sketch: Deep Decoupled Hierarchical Reinforcement Learning for Robotic Sketching Agent," 2022 International Conference on Robotics and Automation (ICRA), pp. 5553–5559, 2022, doi: 10.1109/ICRA46639.2022.9811858.

[9] L. Chen et al., "Autonomous and Teleoperation Control of a Drawing Robot Avatar," 2024 IEEE International Conference on Robotics and Automation (ICRA), pp. 15714–15720, 2024, doi: 10.1109/ICRA57147.2024.10610310.