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Integrating Physical AI and Robotics into Artistic Practices

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Chunk 1

The advancement of digital technologies and automation, particularly through the integration of artificial intelligence (AI), sensors, and robotics, is opening up new possibilities not only in industrial sectors but also in creativity, art, and education. These innovations are increasingly finding applications in educational settings, especially in science and technology (STEM) fields .[1] [2] However, they remain less widespread in artistic disciplines, despite the growing presence of physical computing and creative coding in art education.[3] [4]

Recent developments have made hardware more easily integrated into artistic creations, while software has become more accessible, allowing even those with limited programming experience to engage with these technologies.

This article presents the outcomes and insights gained from teaching physical computing and AI, enabling students to explore advanced fields like robotics and successfully integrate these technologies into their creative practices. Building on previous educational initiatives, this work highlights how students can develop projects that combine robotics and AI through physical computing and computer vision within an artistic context.

To further support this approach, two courses were designed, a beginner course and an advanced course, to equip art and design students with basic

I. p. 83, Chunk 2: Robotik und Computer Vision…
II. p. 145, Chunk 27: Editorial: Physical AI
II. p. 249, Chunk 53: Der KITeGG Cluster – eine…

1: Wannemacher, K., & Bodmann, L. (2021). "Künstliche Intelligenz an den Hochschulen. Potenziale und Herausforderungen in Forschung, Studium und Lehre sowie Curriculumentwicklung". Arbeitspapier Nr. 59. Berlin: Hochschulforum Digitalisierung.

2: Darmawansah, D., Hwang, GJ., Chen, MR.A. et al. (2023). Trends and research foci of robotics-based STEM education: a systematic review from diverse angles based on the technology-based learning model. IJ STEM Ed 10, 12 (2023). https://doi.org/10.1186/s40594-023-00400-3

3: Grace, K., Klaassens, B., Bray, L., & Elton-Pym, A. (2022). An open-ended blended approach to teaching interaction designers to code. Frontiers in Computer Science, 4, 813889. https://doi.org/10.3389/fcomp.2022.813889

4: Kaivo, M., Cuartielles, D., & Spikol, D. (2024). Designing activities and tools to support university students' creative and collaborative exploration of physical computing. *Networked Learning Conference, 12*, 55–64. <https://doi.org/10.54337/nlc.v12.8636>

programming skills, with a particular focus on robotics and computer vision. The goal of these courses was to provide students with the necessary tools to integrate robotic technologies and computer vision systems into their creative workflows.

Educational Framework

To address the existing gaps in the integration of AI and robotics within art education, the Robotics Lab at the Hochschule für Gestaltung Offenbach has been offering courses since 2022 to art and design students, assisting them in incorporating these technologies into artistic and design processes and practices. Acknowledging the necessity for a cohesive educational framework to avoid student confusion, the lab set out to introduce an AI and robotics pathway, beginning with the established discipline of physical computing and progressively integrating machine learning workflows and technologies throughout the curriculum.

III. p. 22, Chunk 6: From Physical Computing to…
III. p. 23, Chunk 12: From Physical Computing to…
III. p. 26, Chunk 19: From Physical Computing to…

Chunk 2 This strategy provided both continuity and an initial foundation with the subject, crucial for learning intricate and unfamiliar topics. Through the course “Physical Computing und Computer Vision für Künstler:innen”, students acquired foundational knowledge in robotics and computer vision.[5] Technologies such as the Arduino microcontroller and the Mediapipe framework were employed to develop a computer vision pipeline in Python.[6] [7]

5: Iovine, I. (2023). Integrating artificial intelligence and robotics into art curriculum. In *INFORMATIK 2023 - designing futures: Zukünfte gestalten* (pp. 347–352). Gesellschaft für Informatik e.V. <https://doi.org/10.18420/inf2023_32>

6: https://ai.google.dev/edge/mediapipe/solutions/guide https://www.arduino.cc/

7: https://ai.google.dev/edge/mediapipe/solutions/guide

In the winter semester 2023/24 (WiSe 23/24) and summer semester 2024 (SoSe 24), the course expanded from a focus on physical computing and AI to more sophisticated systems incorporating physical AI and robotics.

Chunk 3 These courses not only enabled students to investigate AI and robotics, but also empowered them to integrate these technical solutions into their artistic endeavors.

Chunk 4 With guidance from the instructor, including practical examples and code demonstrations, students were able to explore the potential of robotics and computer vision pipeline technologies. This hands-on methodology, supported through practical code experimentation, encouraged active learning and innovation. The course structure promoted a sense of ownership and independence as students developed and executed their own projects, using their newfound skills to create innovative art forms or enhance existing creative practices with cutting-edge technological tools.

Below is a detailed description of the educational framework of the two courses conducted in WiSe 23/24 and SoSe 24.

Introducing the fundamentals of robotics and computer vision

In the WiSe 23/24 semester, 10 students participated in the course “Robotik und Computer Vision für Künstler:innen”. Four students had previously attended lab courses, giving them experience with the technologies used. Six students were beginners.

Chunk 5 The course introduced students to the core principles of robotics and computer vision. It employed a physical computing and AI pipeline based on Arduino and the Mediapipe framework. The teaching approach followed previous educational initiatives from the lab, ensuring continuity. [8]

In the first six sessions, students focused on physical computing, exploring and developing small personal projects. The next four sessions introduced an Arduino-Python pipeline, using Mediapipe for facial recognition, hand gesture recognition, and pose tracking. The final four sessions allowed students to develop their own projects using the proposed technologies and pipeline, either in its entirety or partially, depending on their focus and project goals.

Chunk 6 For those who had previously attended courses, it was possible to experiment with an industrial robotic arm (a cobot UR10e),[9] allowing them to explore its creative potential.

At the semester’s end, students presented their experiments, either as completed artistic projects or as concepts and prototypes to be developed further in future semesters.

8: Iovine, I. (2023). Integrating artificial intelligence and robotics into art curriculum. In *INFORMATIK 2023 - designing futures: Zukünfte gestalten* (pp. 347–352). Gesellschaft für Informatik e.V. <https://doi.org/10.18420/inf2023_32>

9: https://www.universal-robots.com/de/produkte/ur10-roboter/

10: https://www.raspberrypi.com/products/raspberry-pi-5/

11: Zhang, F., Bazarevsky, V., Vakunov, A., Tkachenka, A., Sung, G., Chang, C.-L., & Grundmann, M. (2020). MediaPipe hands: On-device real-time hand tracking. *ArXiv, abs/2006.10214*. <https://api.semanticscholar.org/CorpusID:219792872>

Integration of Physical AI and Robotics in Artistic Practices

In the summer semester of 2024 (SoSe 24), the course “Robotik und Computer Vision für Künstler:innen” was expanded into an advanced program with nine participants, seven of whom had taken the introductory course in the previous winter semester (WiSe 23/24), and two who had completed it earlier. The course focused on integrating Physical AI and robotics into artistic practices.

Students were introduced to single-board computers like the Raspberry Pi 5[10] and taught the core principles of on-device AI, which involves deploying and running lightweight machine learning models.[11] They worked with frameworks such as Mediapipe and TensorFlow Lite to implement these concepts.

Chunk 7 By connecting a camera to the computer, they conducted real-time experiments in facial recognition, hand gesture tracking, and pose estimation. This setup, running entirely on the device, minimized latency and reduced the need for external servers, making it an efficient solution for physical installations where space and energy are limited.

Chunk 8

The course demonstrated how these AI systems could be embedded into artworks or installations, expanding creative possibilities.

Throughout the 12-unit course, students had the freedom to build on knowledge gained from previous semesters, applying new concepts to further integrate AI, robotics, and computer vision into their work (Figure 1).

Figure 1: A student is enhancing her sculpture by incorporating physical AI technologies into her project.

III. p. 26, Chunk 19: From Physical Computing to…
III. p. 25, Chunk 18: From Physical Computing to…
III. p. 27, Chunk 22: From Physical Computing to…

Chunk 9

Participants from various artistic disciplines—including sculpture, performance art, and digital electronic arts—used the proposed pipeline to create hybrid artworks that incorporated elements of Physical AI, robotics, and computer vision into their creative processes. In the final four sessions of the course, students particularly interested in using on-device AI pipelines for controlling robotic arms had the chance to experiment with this technologies. They developed custom hand recognition models using TensorFlow Lite's Model Maker library (Figure 2),[12] which they then applied to control an industrial UR10e cobot (Figure 3) via the python-urx library,[13] further expanding their creative exploration of robotics and AI integration.

12: https://ai.google.dev/edge/litert/libraries/modify

13: https://github.com/SintefManufacturing/python-urx

Figure 2: Students are working on creating a data collection for the custom training of a hand gesture recognizer.

Figure 3: Testing the hand gesture recognize custom model for controlling a UR10e Cobot.

III. p. 24, Chunk 13: From Physical Computing to…
I. p. 86, Chunk 14: Robotik und Computer Vision…
I. p. 51, Chunk 7: Robotik Lab (HfG Offenbach)

Chunk 10

Student Projects and Outcomes

Among the 12 students who participated in the WiSe 23/24 and SoSe 24 courses at the Robotics Lab, seven of whom attended both courses, seven projects were developed.

Chunk 11 These projects made use of frameworks and technologies like single-board computers, such as the Raspberry Pi 5, and the UR10e robotic arm. The students demonstrated skills in physical computing, Edge AI, and robotics, successfully implementing projects using sensory technologies like cameras, and actuators such as servo motors and LEDs. They also managed to control the robotic arm using a pipeline built with Python and the Mediapipe framework.

The goal of the introductory course offered during the winter semester (WiSe 23/24) was to provide students with a theoretical foundation on these technologies in the first part of the course, and offer support and space for experimentation in the latter half. Although students were not required to develop specific projects, those who already had basic knowledge of physical computing were able to experiment with a cobot in the final sessions.

Chunk 12 Figure 4 illustrates a project from the first semester, utilizing a cobot. The project, “Schlag auf Schlag” by Nelli Gomez-Baumert, is a performative work blending dance and combat. The student and the cobot interacted by exchanging strikes with batons.

Chunk 13 Although this project did not integrate AI technologies, it demonstrated the students' ability to creatively engage with industrial technologies even during the introductory course.

Figure 4: The performative art project "Schlag auf Schlag" by Nelli Gomez-Baumert. Credits: Philomena Hummel

II. p. 192, Chunk 1: Work in Progress

Chunk 14 In SoSe24, students were encouraged to create projects with an on-device AI pipeline. Building on the solid foundation gained in the previous semester, they had full creative freedom to develop their works, integrating them into their artistic practices. One representative project is “Stalking” by Soyeon Park.

Chunk 15 The student, with a background in sculpture, created an interactive installation that incorporated Physical AI (see Figure 5). The technological aspect of the sculpture consisted of two servo-controlled eyes placed on the chest, and a microcamera embedded in the sculpture’s navel. Using this camera and a face recognition model deployed and run locally on a Raspberry Pi 5, the system detected the facial position of the nearest visitor in real-time, allowing the mechanized, responsive eyes to track the audience's movements.

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Chunk 16 In the last sessions of the advanced course, students were given the opportunity to develop projects using on-device AI pipelines to control a robotic arm. Using this workflow, the student Rahel Pabst created her interactive piece, DoorBot (Figure 6).

Chunk 17 DoorBot is a cobot bouncer equipped with a camera and a stamp. Visitors who smile at the camera receive a stamp on their hand, mimicking the process at nightclub entrances.

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Chunk 18 To achieve this, the student developed a custom facial expression recognition machine learning model, which was deployed and executed locally on a Raspberry Pi 5. These projects highlighted the students' ability to creatively apply advanced technologies like AI and robotics to their artistic work.

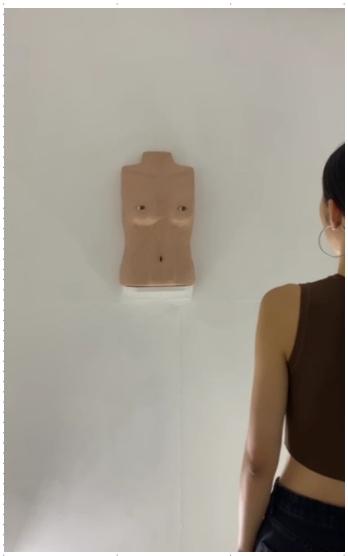

Figure 5: The interactive sculptural project "Stalking" by Soyeon Park. Credits: Lena Bils

II. p. 150, Chunk 1: Controller
II. p. 30, Chunk 7: Offenbach

Chunk 19 By the end of the course, they had not only developed functional interactive systems

but also explored new ways to integrate technology into their creative processes.

Chunk 20

Figure 6: Rahel Pabst's robotic project, "DoorBot". Credits: Rahel Pabst

Chunk 21

Conclusion

The integration of AI, physical computing, and robotics into artistic education has enabled students to explore new creative possibilities. Advancements in hardware, such as single-board computers, and the optimization of lightweight machine learning model architectures have played a crucial role in this transformation. These technological developments have not only benefited industries but also made it easier for artists to experiment with and embed these tools into their creative processes and artworks.

The courses at the Robotics Lab of the Hochschule für Gestaltung Offenbach demonstrated that art and design students can adopt these technologies to enhance their artistic practices. By providing foundational knowledge and hands-on experience, students were able to create innovative projects that blend technology with art. This approach shows the potential of AI and robotics not just in technical fields but also in expanding the boundaries of creative expression within artistic disciplines.

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