Building Interactive Systems

Embodied Representations

Professor Bilge Mutlu | Spring 2023

What will we cover today?

→ What is embodiment?

→ History of embodied representations

→ Designing and implementing embodied representations

What is embodiment?

In cognitive science: the role the body plays in supporting the computational circuits that realize cognition[1]

In computer science: the use of the human body* as the central representation for computer intelligence[2]

[1] Kiverstein (2012). The meaning of embodiment. *Topics in cognitive science.*

* Or the bodies of animals, fictional characters, etc.

[2] Cassell (2001). Embodied conversational agents: representation and intelligence in user interfaces. *AI Magazine.*

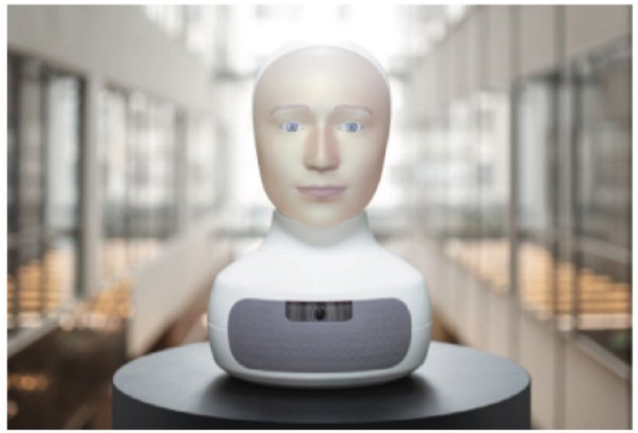
Types of Embodiments[3]

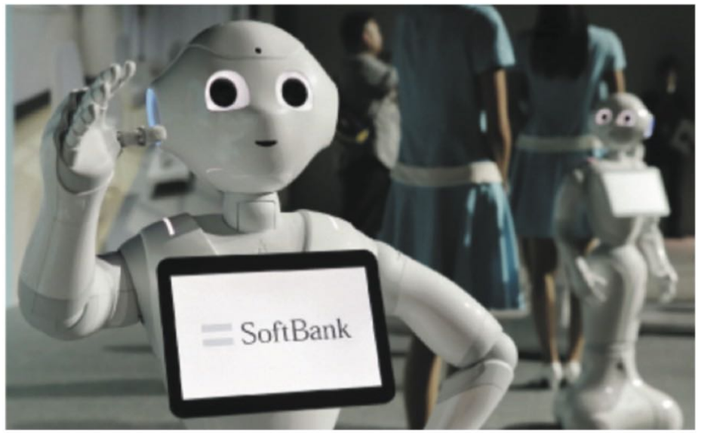
Virtual Embodiment: Two- or three-dimensional presentation of a character on the screen of a computer, a mobile device, or a large screen.

Physical Embodiment: Physical representations that are situated in the user's environment.

Blended Embodiments: Representations that integrate virtual and physical components (e.g., a robot with a screen-based face).

[3] Mutlu (2021). The virtual and the physical: two frames of mind. *Iscience*.





[4] McDonnell & Mutlu (2021). Appearance. *The handbook on socially interactive agents.*

Metaphors in Embodiment

Embodied representations follow **metaphorical design** — following a well-known metaphor to elicit familiarity and jumpstart user mental models of the agent's capabilities.[4]

[4] McDonnell & Mutlu (2021). Appearance. *The handbook on socially interactive agents.*

Why use metaphors?

Representations must:

→ Reflect the system's social role in relation to the user (e.g., a peer, a subordinate, a tool)

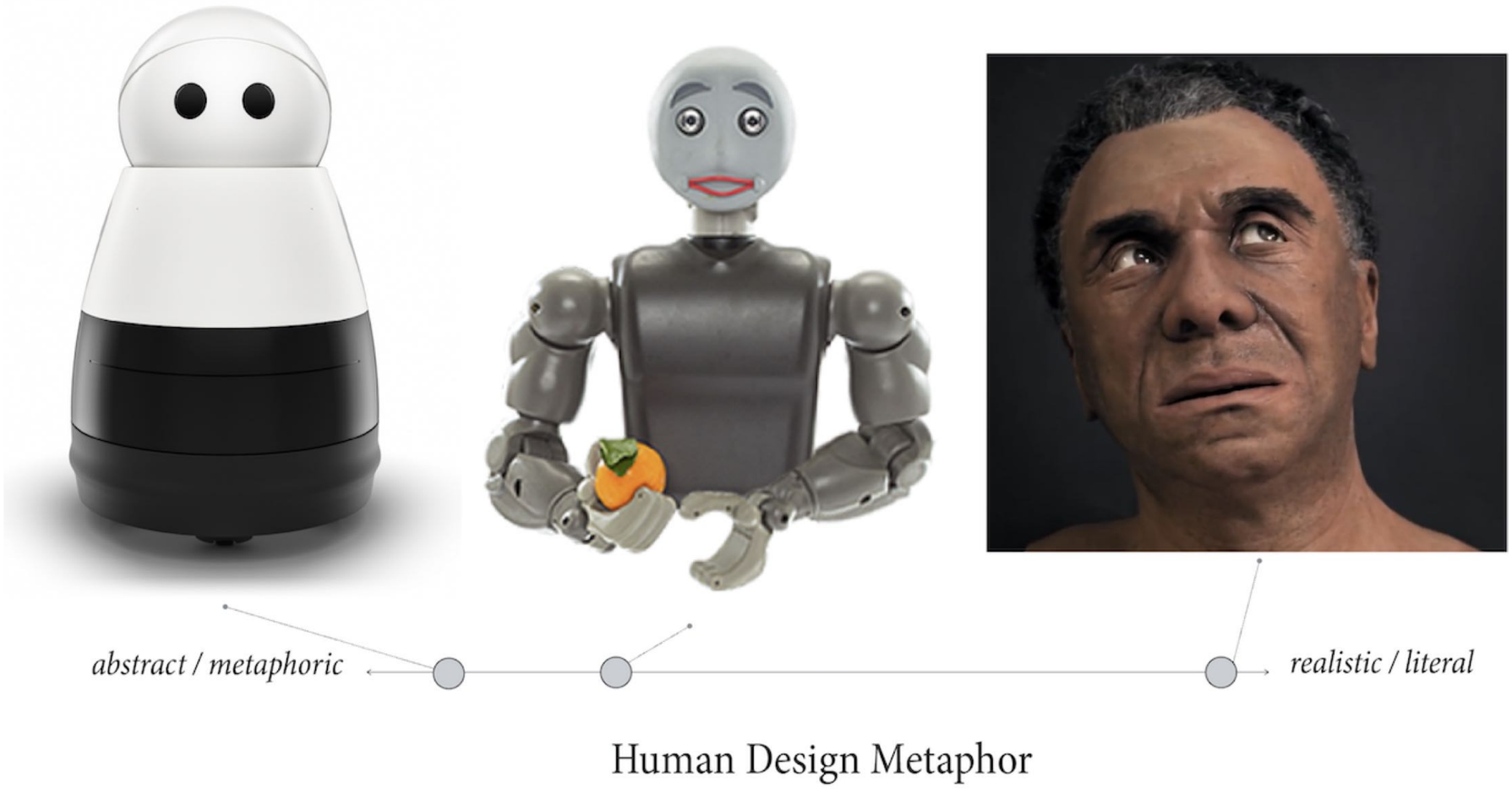
→ Communicate the system's task role and capabilities (e.g., a seal can't talk, but a parrot can)

→ Follow a consistent design in its appearance and behavior

Metaphorical design can achieve these, **but** we still have to overcome the limitations of the *global metaphor*.[5] We can achieve that through *abstraction*!

[5] Cooper et al., 2014, *About Face*. Wiley.

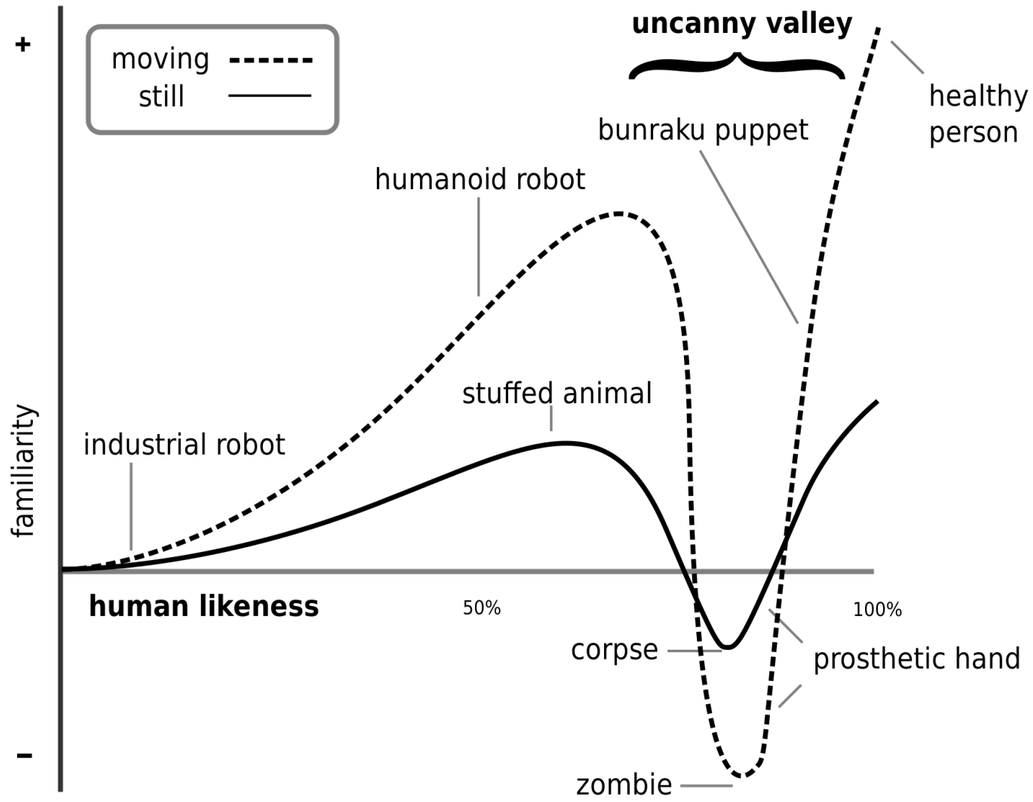
Abstraction in Metaphorical Design[6]



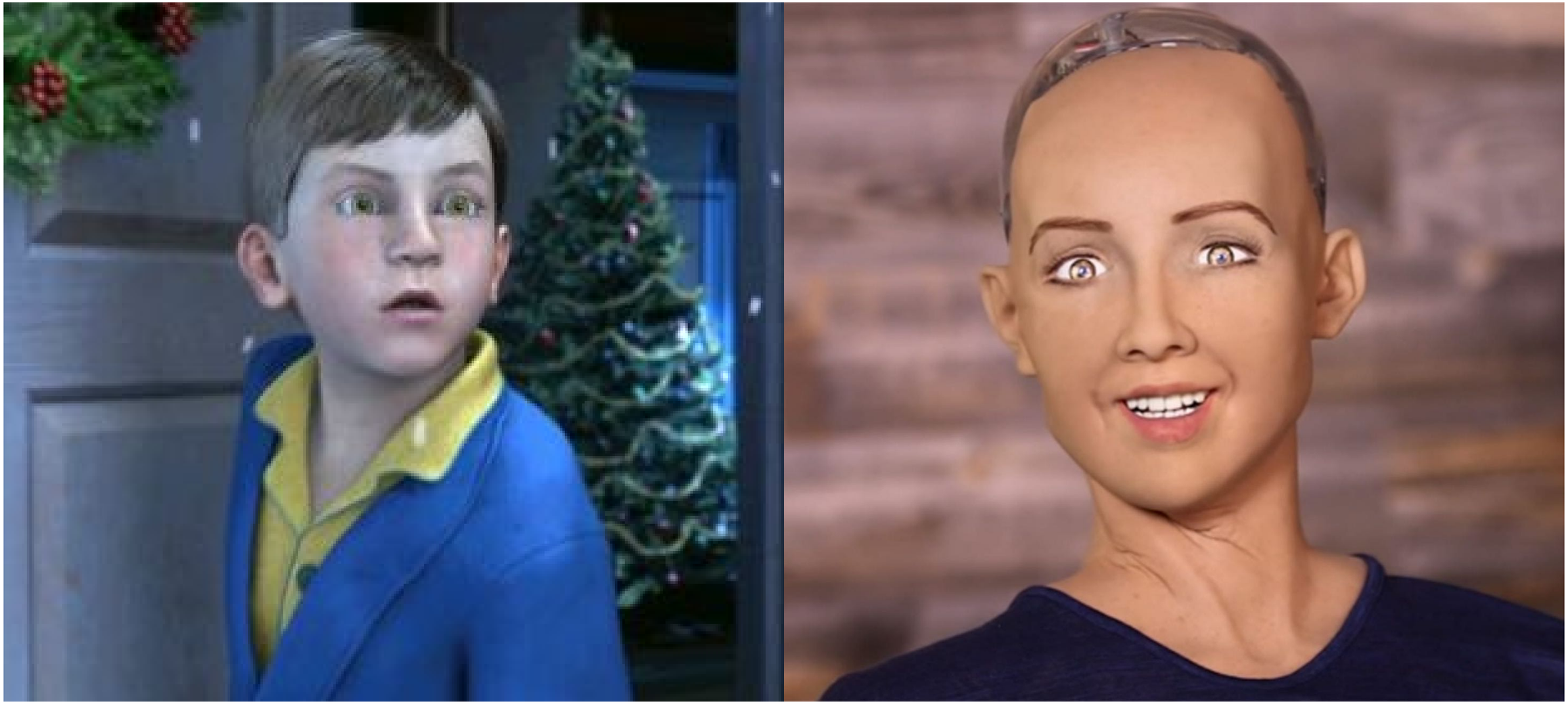
[6] Deng et al. (2019). Embodiment in socially interactive robots. *Foundations and Trends® in Robotics*.

When metaphors go wrong

Uncanny valley: that humanoid objects that *imperfectly* resemble actual human beings provoke uncanny or strangely familiar feelings of uneasiness and revulsion in observers.[7]



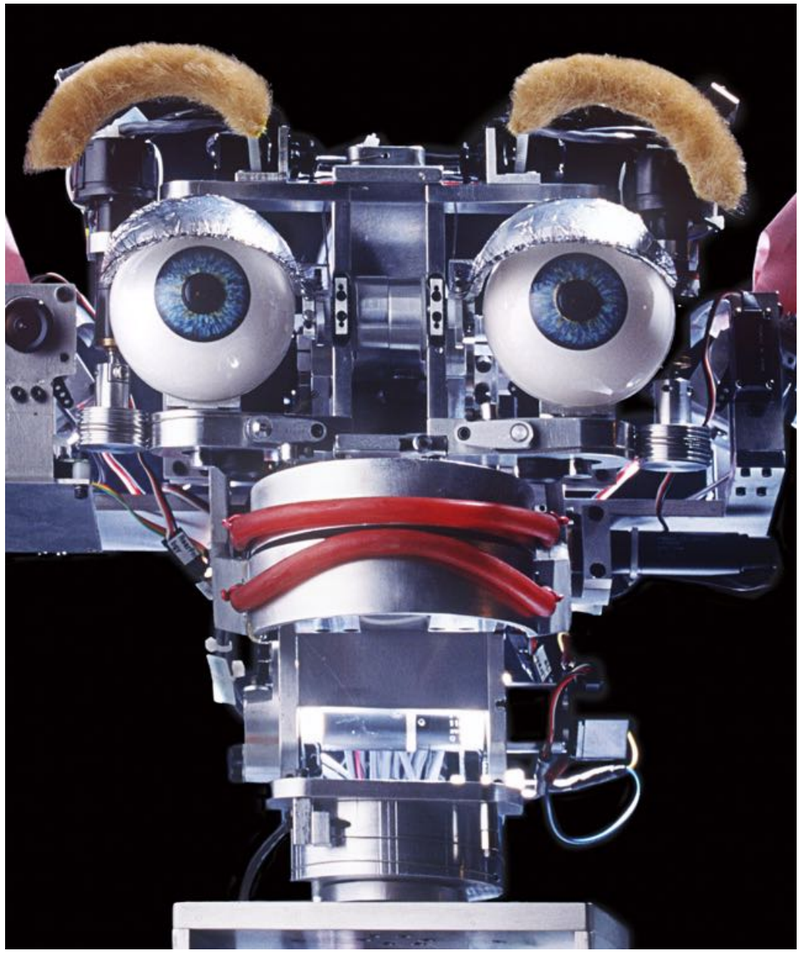
[7] Uncanny valley via Wikipedia



[8] Image sources: left, right

History of embodied representations

Physical embodiments[9]



[9] Image sources: Karakuri Ningyo (17th Century), Kismet (1998), Pearl Nursebot (2002)

[10] Source: Karakuri Robot [NHK World via YouTube]

Virtual embodiments[11]

[11] Image sources: Knowledge Navigator (1987), Herman the Bug (1997), Cosmo (1998), Rae (2000)

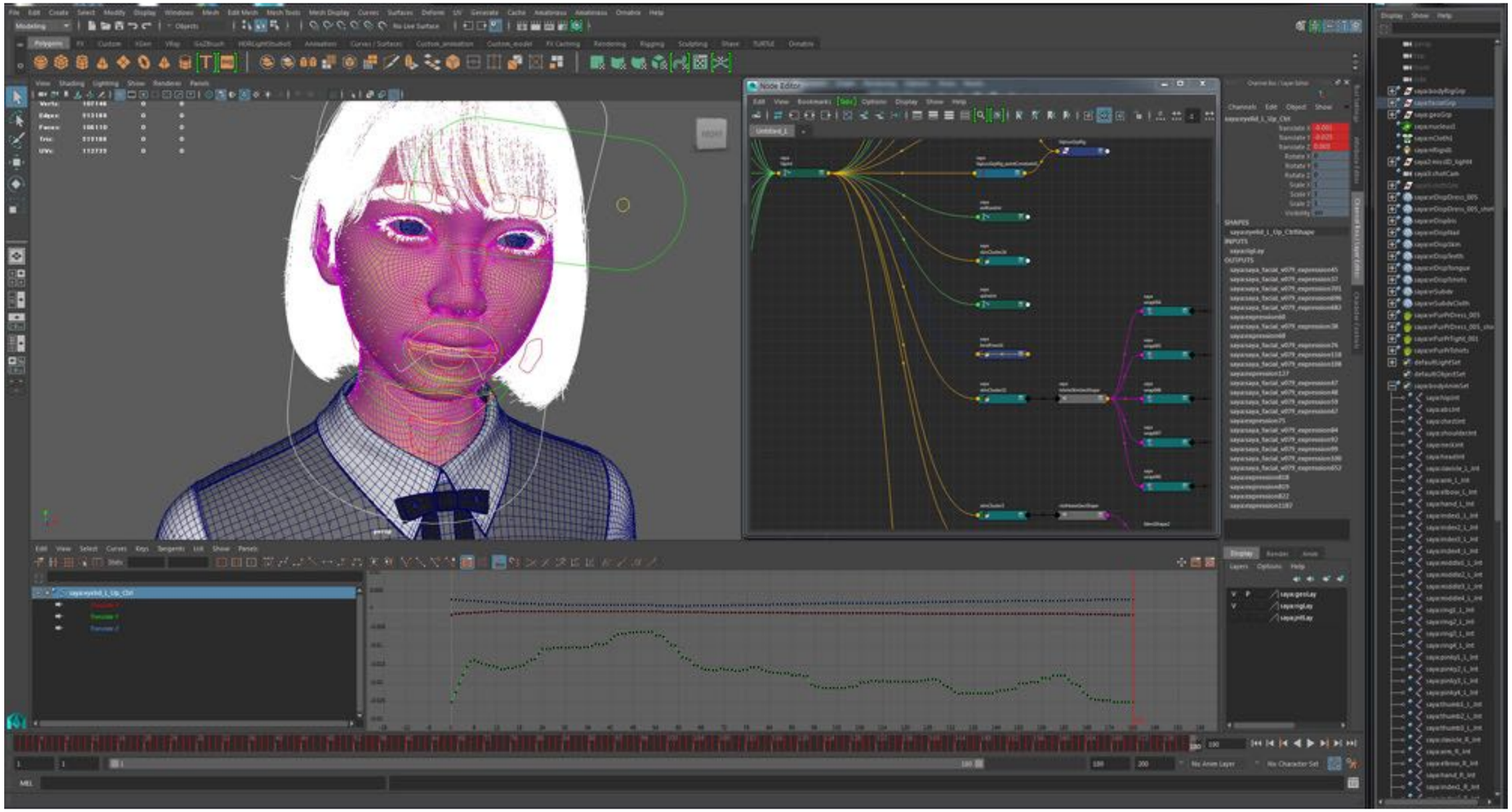
Designing and Implementing Embodiments

Virtual or Physical?[3]

Characteristics	Physical	Virtual
Applications	Physical, situated collaboration, assistance	Counseling, instruction, education, coaching
Activities	Activities interspersed across time and space	Focused, time-bound activities
Interactions	Interactions situated in day-to-day life	Metaphorical, rich, crafted interactions

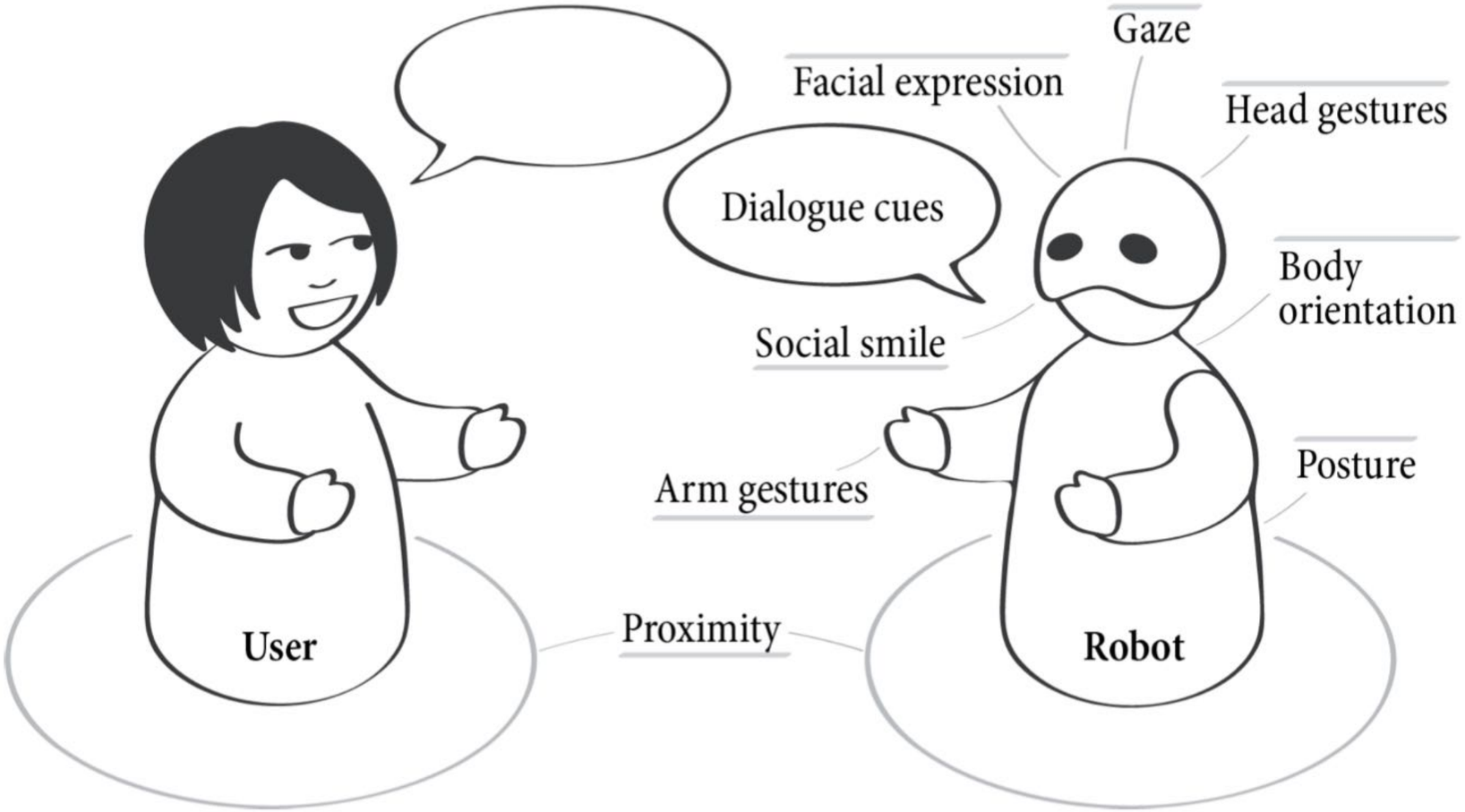
[3] Mutlu (2021). The virtual and the physical: two frames of mind. *Iscience*.

Building virtual embodiments[12]



[12] Image source

Building physical embodiments[6]



[6] Deng et al. (2019). Embodiment in socially interactive robots. *Foundations and Trends® in Robotics*.

[4] McDonnell & Mutlu (2021). Appearance. *The handbook on socially interactive agents.*

Programming (virtual or physical) embodiments

Approaches include:

→ Manufacturer-supplied APIs

→ Robot Operating System (ROS)[13]

→ Visual programming (e.g., Rover)[14]

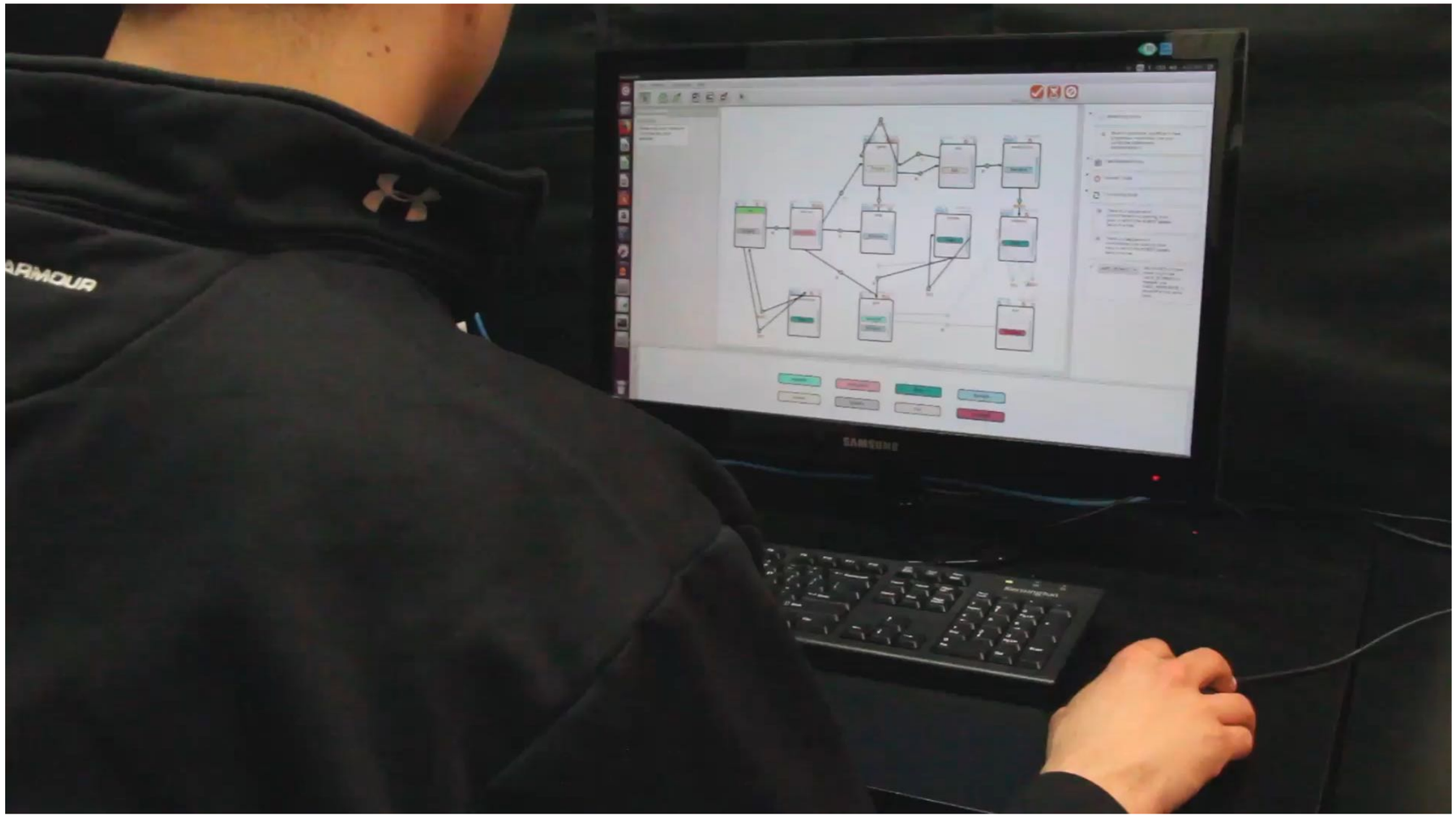
→ Demonstration-based programming (e.g., Tabula)[15]

[13] What is ROS?

[14] Porfirio et al. (2018). Authoring and verifying human-robot interactions. *UIST 2018.*

[15] Porfirio et al. (2023). Sketching Robot Programs On the Fly. *HRI 2023.*

Visual Programming Example[14]

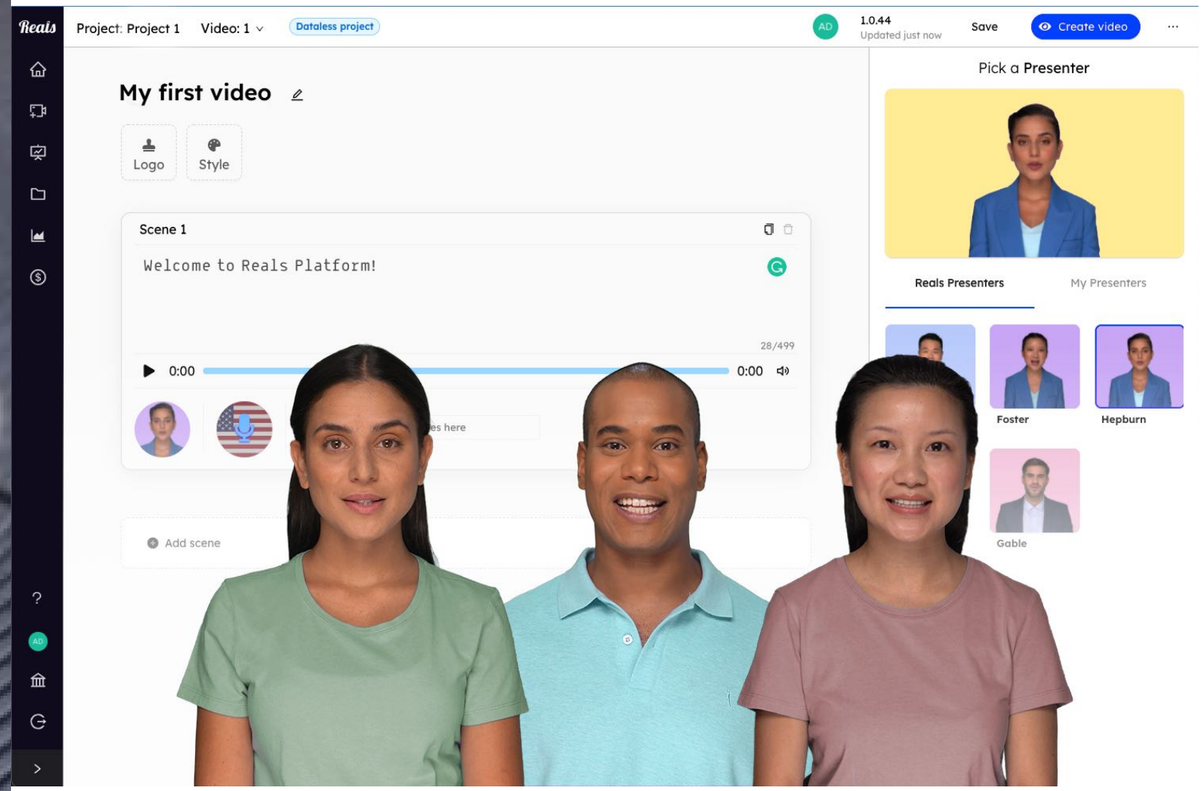


[14] Porfirio et al. (2018). Authoring and verifying human-robot interactions. *UIST 2018.*

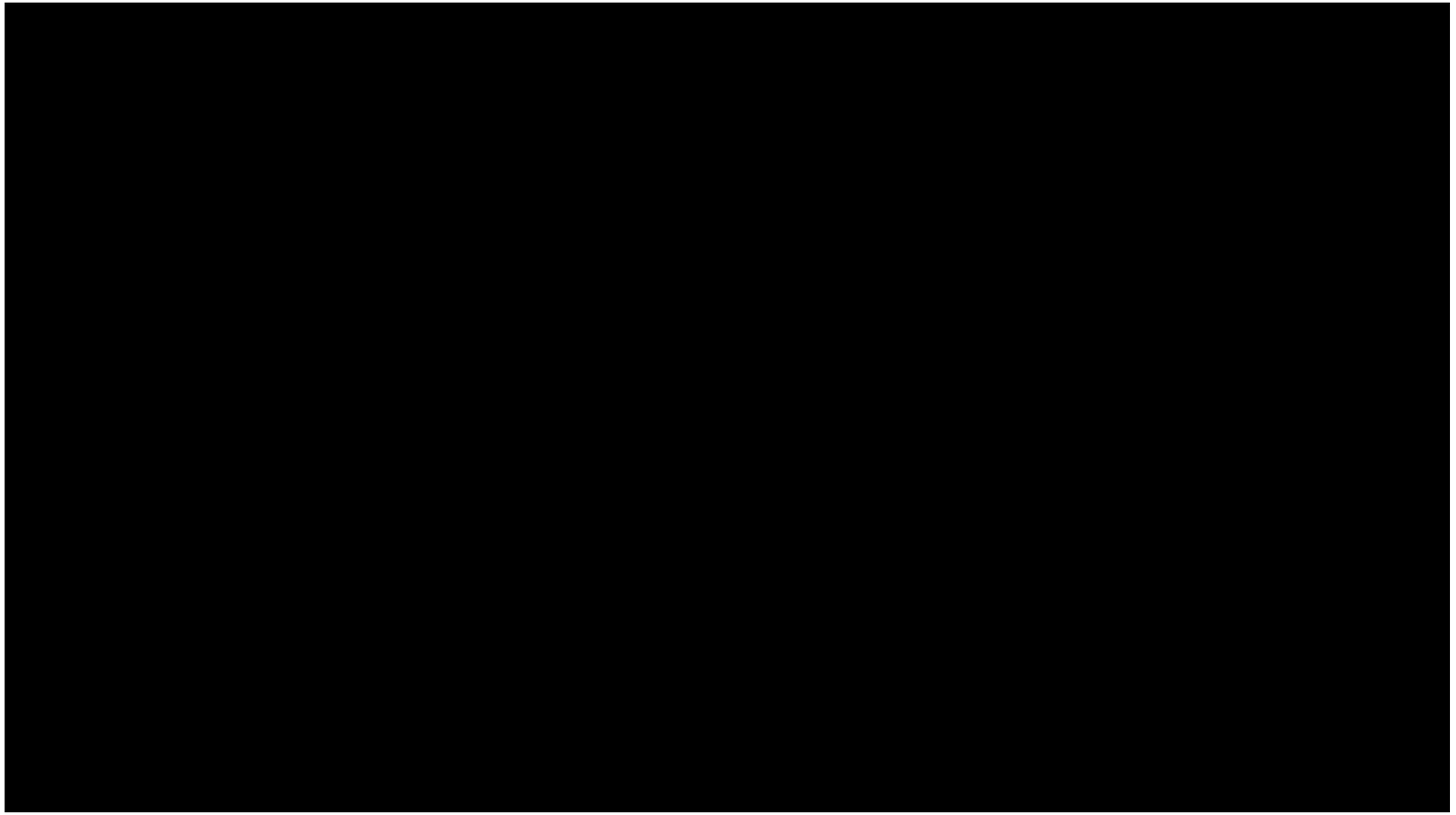
Demonstration-based programming[15]

[15] Porfirio et al. (2023). Sketching Robot Programs On the Fly. *HRI 2023.*

Integrating embodiments in interactive systems[16]



[16] Image sources: left, right



[17] The Reals Platform

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