

# TOWARD IMPLICIT COMMUNICATION OF OBJECT PROPERTIES FOR HUMAN-ROBOT INTERACTION

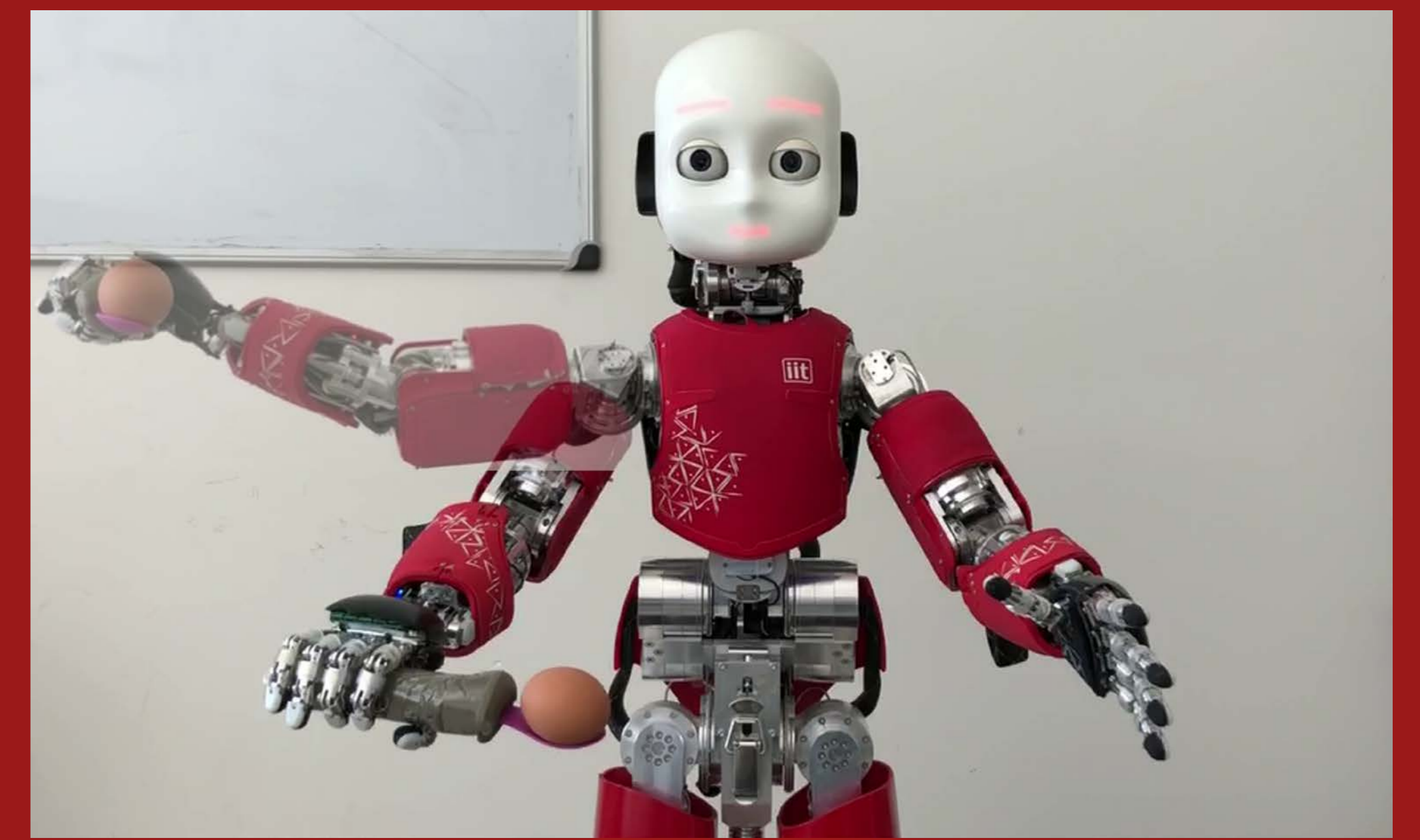
Linda Lastrico, Alessandro Carfí, Francesco Rea, Fulvio Mastrogiovanni, Alessandra Sciutti

As humans, being sociable is fundamental, and communication underpins our interactions. **Implicit communication** contributes significantly to the flow of information, since humans can interpret the unspoken from the actions of others.

Kinematics modulations naturally occur when transporting objects and they can reveal some item characteristics to an external observer, facilitating mutual coordination.

Findings on human behavior inspired robotic applications to:

- automatically detect, from **how** human move, if they are being careful when transporting an object
- exploit the robot **embodiment** to communicate the same information



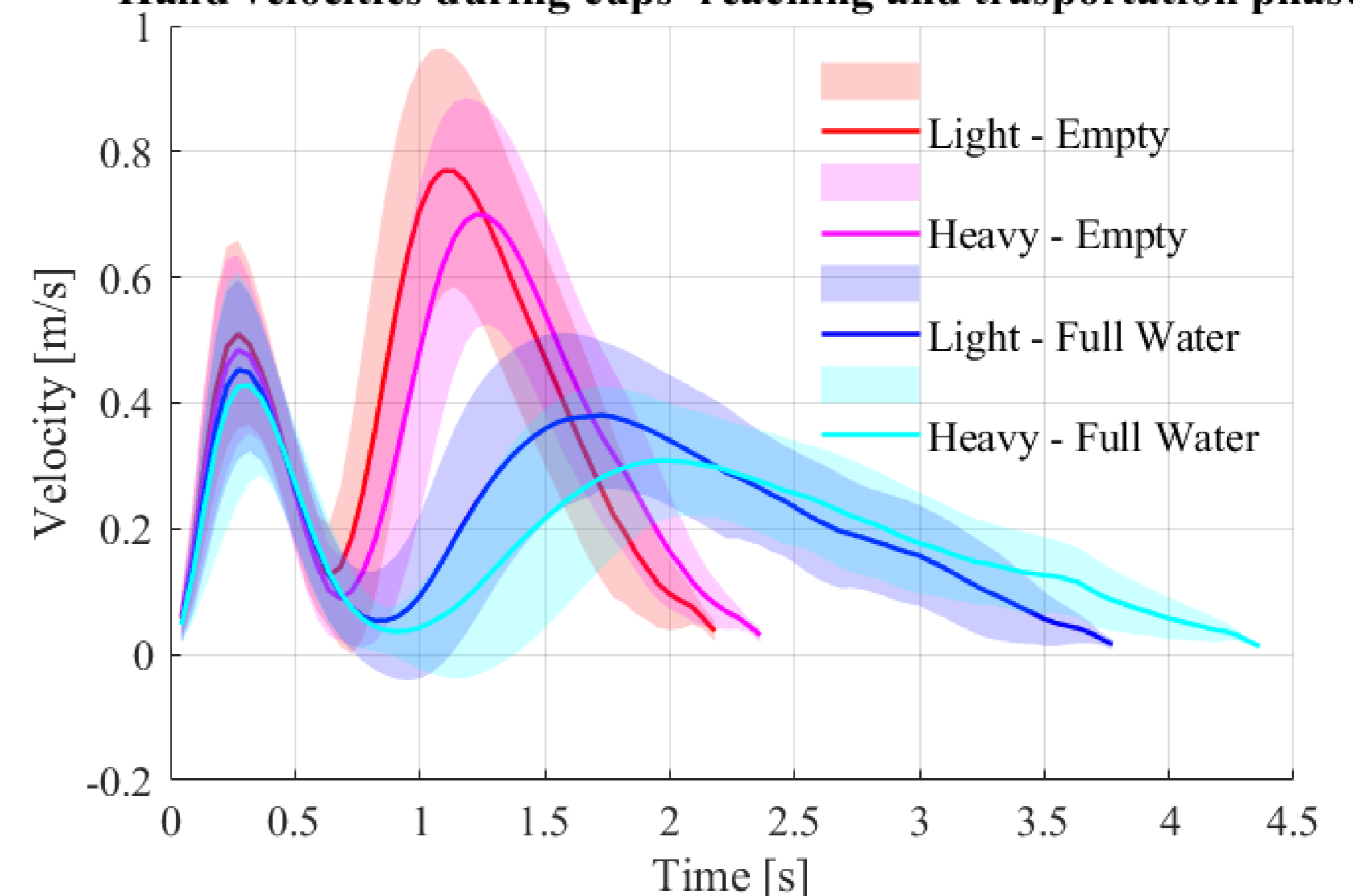
## RECOGNIZING OBJECT PROPERTIES FROM HUMAN MANIPULATION

Cups characteristics such as the **weight** and the content impact human kinematics, enabling automatic inference of such object properties. The **water** filling, if present, induces **Careful (C)** manipulations.

From complementary sensors we investigated motion descriptors, as the action velocity, to use in the classification process (Lastrico et al., HFR 2020).

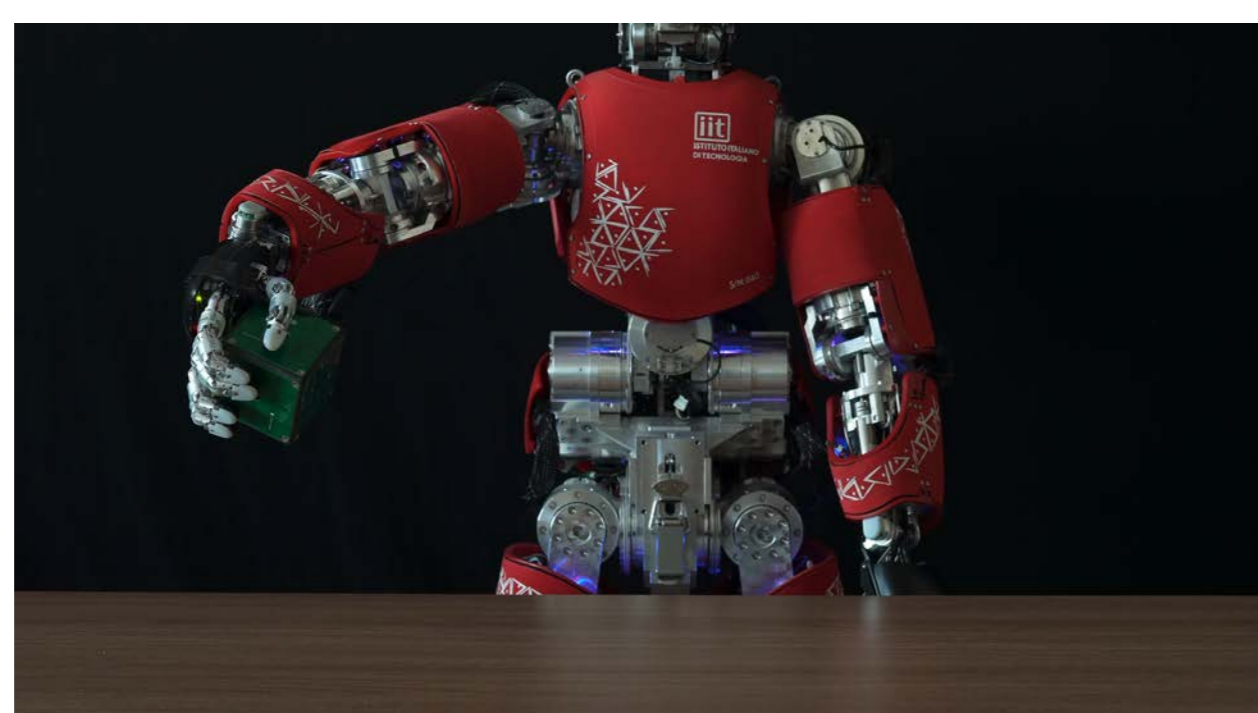
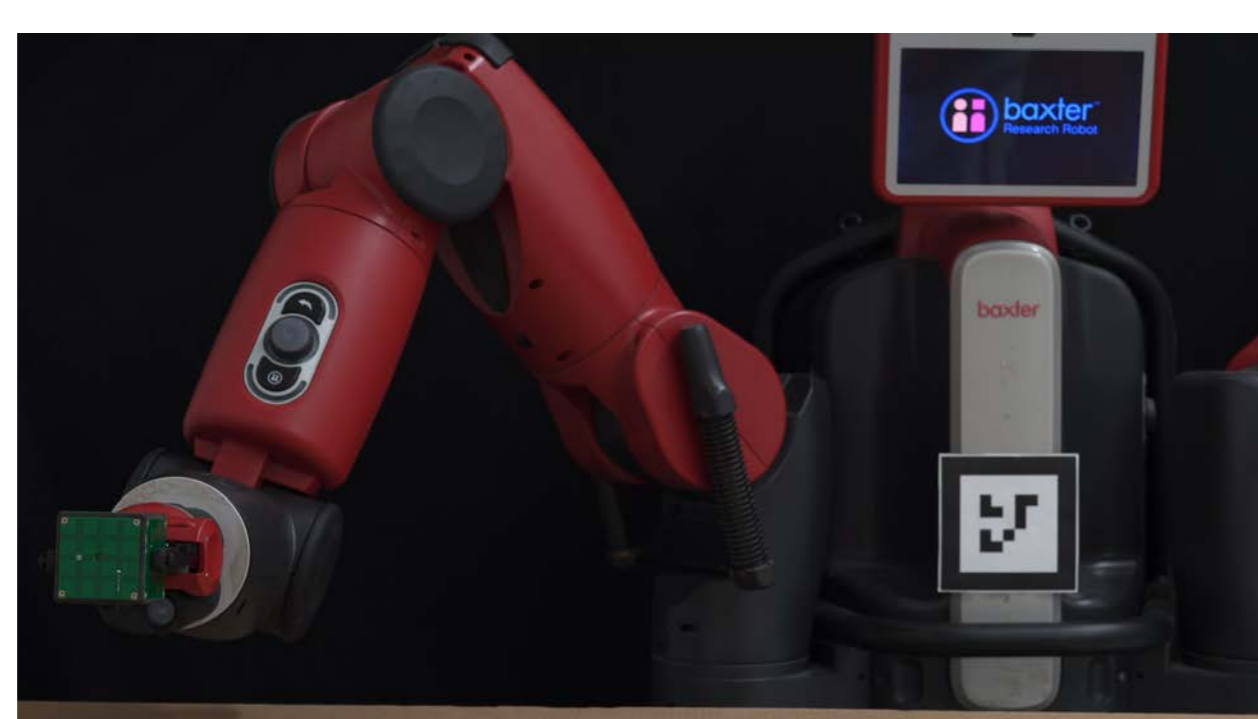
An architecture based on a Long Short Term Memory (**LSTM**) neural network allowed to detect **online** the presence of carefulness, even in new scenarios and with novel participants, reaching a F1-Score up to 82.4% (Lastrico et al., ICSR 2021).

Hand velocities during cups' reaching and transportation phase

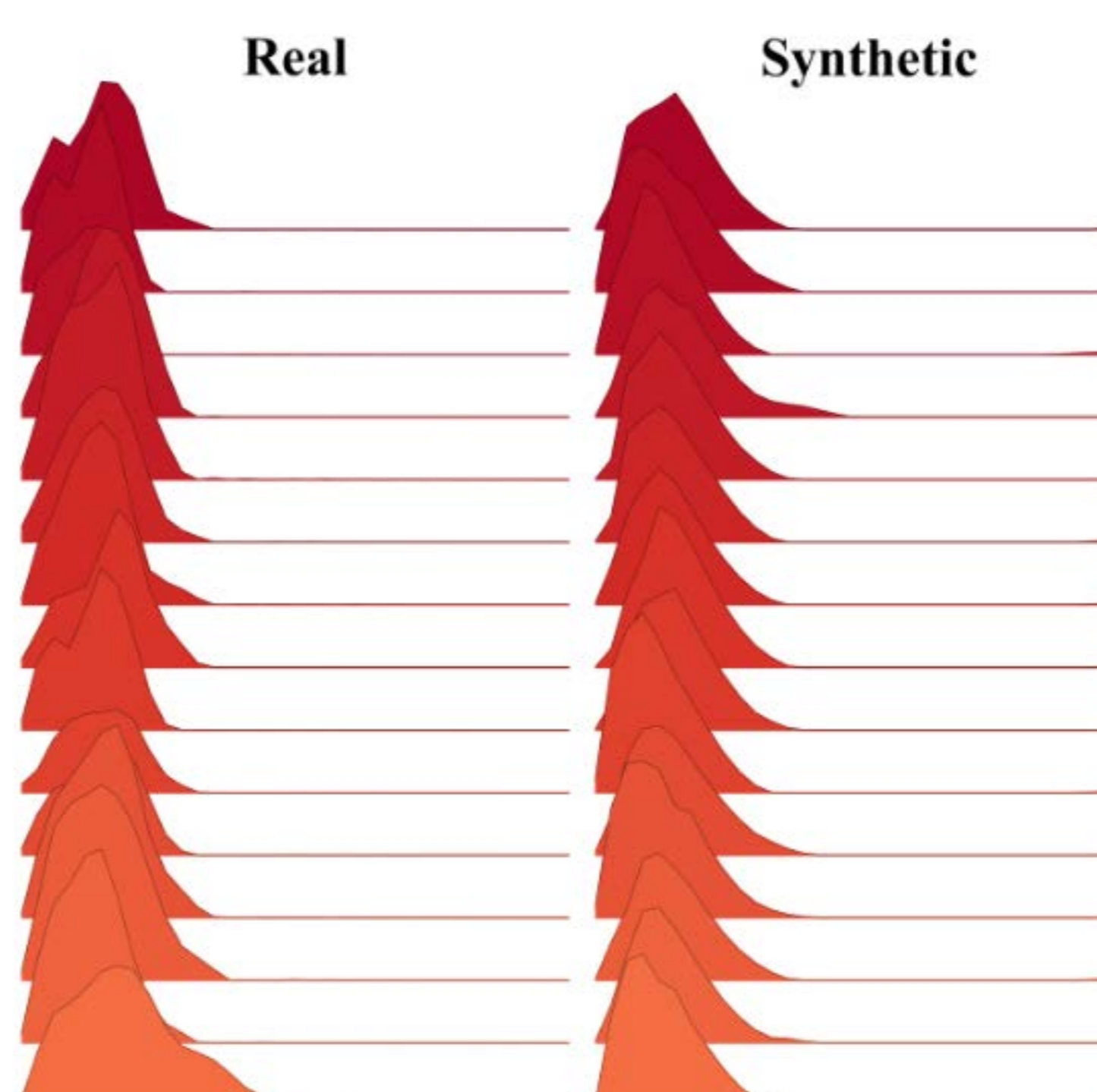


Hand kinematics during objects manipulation

Related videos:



Baxter and iCub showing careful or not careful attitudes



Real and GAN-generated velocity profiles for not careful motions

## GENERATING COMMUNICATIVE ROBOT MOVEMENTS

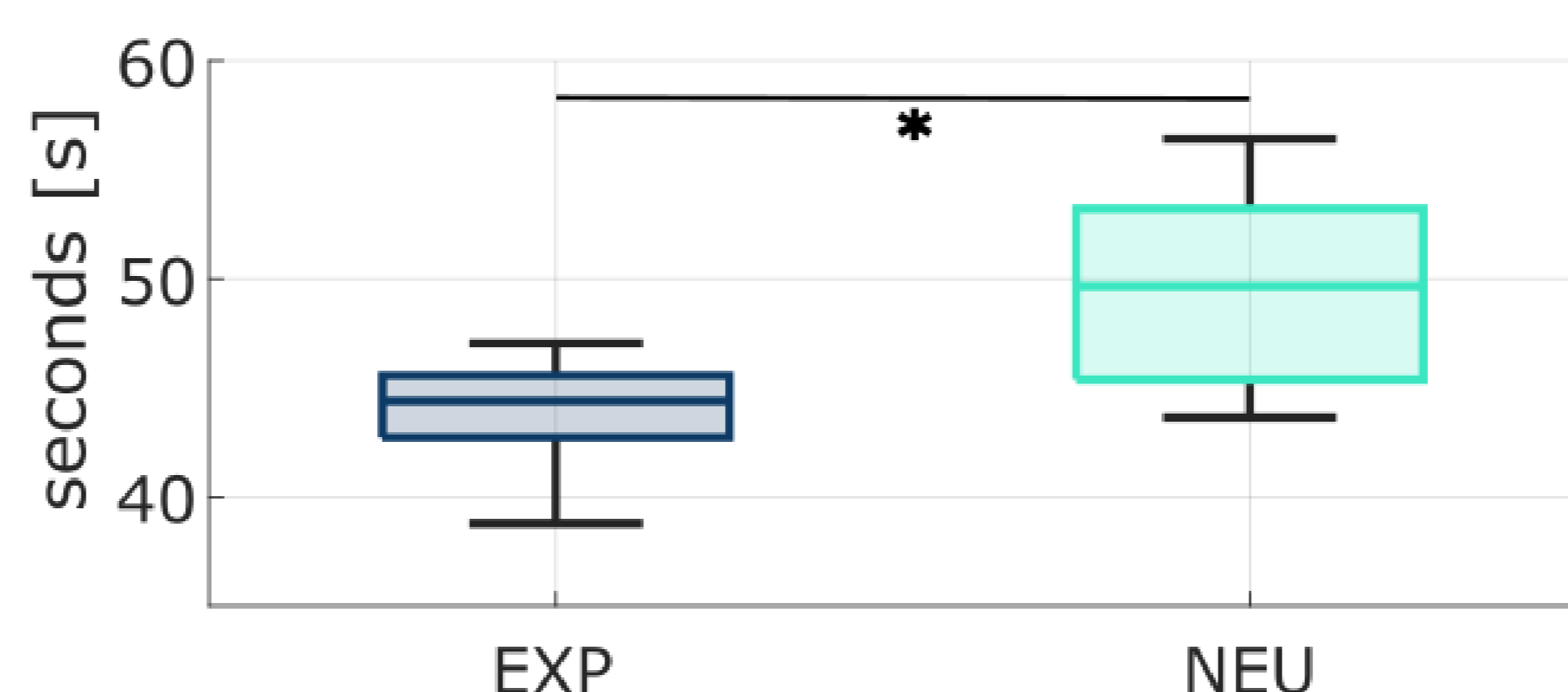
We aimed to generate human-inspired robotic actions, capable of conveying a specific attitude such as the carefulness. We used **Generative Adversarial Networks** to synthesize suitable velocity profiles (Garello, Lastrico et al., ICDL 2021).

Implicit communication is achieved by controlling the velocity followed by the end-effector, hence by adding a communicative layer to a task-oriented action (Lastrico et al., ICDL 2022).

## THE EFFECT OF IMPLICIT COMMUNICATION OF OBJECT PROPERTIES: TOWARD THE INTERACTION

We assessed the perception of carefulness in transport actions with **iCub**, **Baxter** and **Kinova** robots, finding that participants not only recognized the intended care but also exhibited **emerging coordination** (Lastrico et al., ICDL 2022).

Our expressive (EXP) approach granted robot **motion plausibility** and improved **task efficiency** and **fluency** in collaborative handovers even with non-humanoid manipulators (Lastrico et al., submitted to IROS 2023).



Task duration in Expressive vs Neutral robot conditions



Collaborative handover of a full cup