Adaptive DoF: Concepts to Visualize AI-Generated Movements in Human-Robot Collaboration

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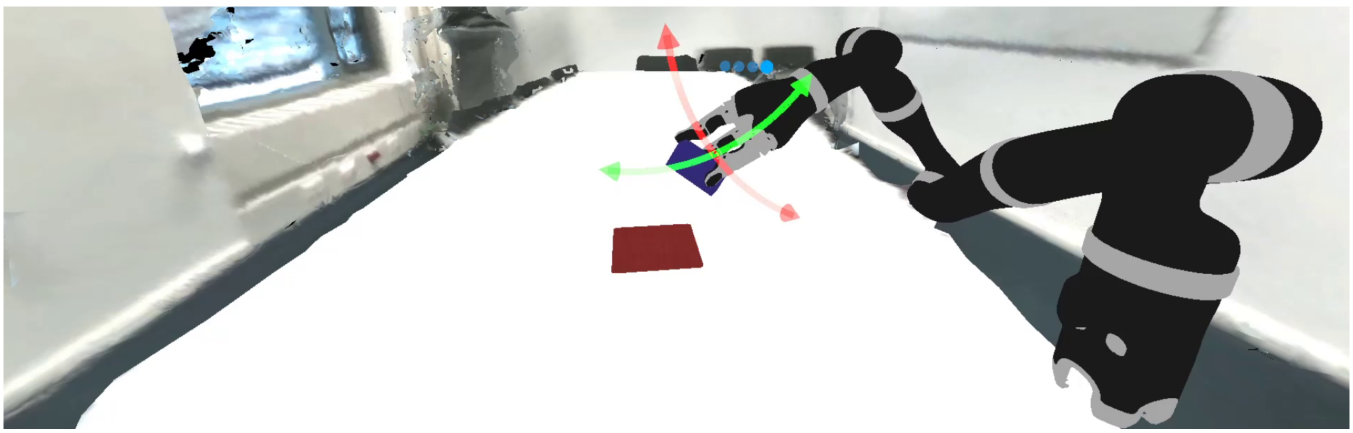

Figure 1: Communicating Cobot's Motion Intent Feedback via Gizmo Approach

ABSTRACT

Nowadays, robots collaborate closely with humans in a growing number of areas. Enabled by lightweight materials and safety sensors, these cobots are gaining increasing popularity in domestic care, supporting people with physical impairments in their everyday lives. However, when cobots perform actions autonomously, it remains challenging for human collaborators to understand and predict their behavior. This, however, is crucial for achieving trust and user acceptance. One significant aspect of predicting cobot behavior is understanding their motion intent and comprehending how they "think" about their actions. We work on solutions that communicate the cobots AI-generated motion intent to a human collaborator. Effective communication enables users to proceed with the most suitable option. We present a design exploration with different visualization techniques to optimize this user understanding, ideally resulting in increased safety and end-user acceptance.

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CCS CONCEPTS

• **Computer systems organization** → *Robotic control*; *Robotic autonomy*; • **Human-centered computing** → **Visualization techniques**.

KEYWORDS

cobot, human-robot collaboration, visualization techniques, neural network, intention feedback

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1 INTRODUCTION

Robotic solutions are becoming increasingly prevalent in our personal and professional lives, and have started to evolve into close collaborators [3, 7, 10]. These so-called cobots support humans in various ways that were unimaginable just a few years ago. Enabled by technological advances, newer lightweight materials, and improved safety sensors, they are gaining increasing popularity in domestic care, supporting people with disabilities in their everyday lives [11].

However, new potential issues arise when cobots are tasked with (semi-)autonomous actions, resulting in added stress for end-users [13]. Particularly close proximity collaboration between humans and cobots remains challenging [8]. These challenges include effective communication to the end-user of (a) motion intent and (b) the spatial perception of the cobot's vicinity [12].

2 RELATED WORK

In recent years, Augmented Reality (AR) technology has been frequently used for human-robot collaboration [2, 6]. Previous work focused primarily on the use of Head-Mounded Displays, Mobile Augmented Reality, and Spatial Augmented Reality for the visualization of cobot motion intent [8, 14, 16]. Rosen et al. showed that AR is an improvement compared to traditional desktop interfaces when visualizing the intended motion of robots [14]. Previous literature has focused mainly on visualizations of motion intent for autonomous robotic systems [1, 4, 5, 8, 15, 17], communicating recommended cobot intention and its control methods has however not attracted as much attention.

3 TESTBED ENVIRONMENT

In earlier work, we developed an adaptive control interaction method based on a recommendation system generated by a Convolutional Neural Network [9]. From the cobot's seven Degrees of Freedom (DoF), the adaptive control combined several DoFs to provide a more straightforward control to the user with fewer necessary mode-switches.

The virtual environment, including a virtual model of the *Kinova Jaco*[1] robot arm was developed to be compatible with the *Oculus Quest 2*[2] VR headset (see Figure 1). This provided us with a VR testbed environment for developing and evaluating further feedback techniques.

4 VISUALIZATION CONCEPTS

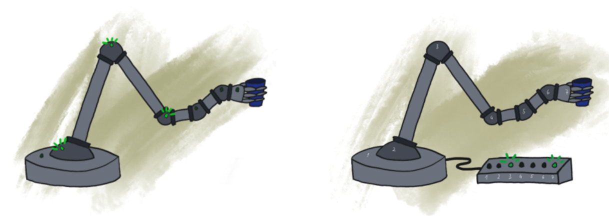
Our proposed concepts fall into a spectrum with two extremes — indicative and explanatory. **Indicative:** Focus on crucial information only, quick and easy solution, suitable for experienced cobot users. **Explanatory:** Movements are shown in great detail, high level of information, especially helpful for new users.

DoF-Indicator: LEDs attached to the cobot's axis and joints - or mounted on a bar in front of it - communicate active and nonactive DoFs (see Figure 2). Likely more suitable for experienced users, allows understanding of current DoF mapping by the recommendation system plus resulting movement abilities.

DoF-Combination-Indicator: Movement ability is communicated by a simplified representation of the cobot only showing two modalities, e. g. rotating and extending (see Figure 3). The AR representation (aka "fake joint") either overlays the real cobot or can be displayed separately in the corner of the AR screen.

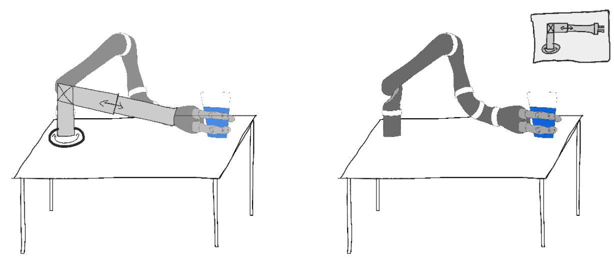
Gizmo Visualisation: Arrows, planes and point clouds communicate the current movement ability of the cobot (see Figure 4). This allows for several different design options. A first arrow-based approach was already successfully evaluated in a previous study [9].

[1]Kinova Jaco robot arm: https://assistive.kinovarobotics.com/product/jaco-robotic-arm, last retrieved April 29, 2022
[2]Oculus Quest 2: https://www.oculus.com/quest-2/, last retrieved April 29, 2022



(a) (b)

Figure 2: DoF-Indicator: (a) LEDs attached to the cobot; (b) LEDs mounted on a bar.



(a) (b)

Figure 3: DoF-Combination-Indicator: (a) as an AR overlay; (b) as an icon in the screen corner.

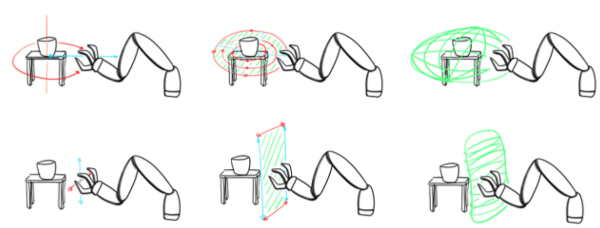


Figure 4: Gizmo Visualization: (left) simple: straight and curved arrows; (center) planar: planes of movement; (right) cloud: 3D-cloud of possible boundary positions.

Demonstration: Current movement possibilities are demonstrated through either the actual cobot or an AR representation. With both options a quick movement indicates the intended motion.

Future work will see the implementation of the various visualization options. Through this, we expect to gain a number of valuable insights regarding the explainability of AI behavior in the context of robotic movements.

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