Towards Accessible and Intuitive Shared Autonomy

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***Abstract*—The deployment of assistive robotics technologies in human environments is often hindered by the diverse personalization requirements of individual users. A promising solution to this challenge is shared autonomy, enabling collaboration between robots and users. The goal of my PhD is to develop shared autonomy methods that empower users with disabilities to control assistive robots efficiently in their daily lives. Specifically, I aim to address the dimensionality gap encountered when using simpler interfaces while maintaining an intuitive input mapping. Our prior work introduced a geometric shared autonomy approach based on canal surfaces and a dynamic input mapping framework, that serve as foundational efforts in this area. To gather preliminary feedback, I conducted a user study involving wheelchair users, utilizing a specialized joystick designed for accessible video gaming. In future work, I plan to incorporate computer vision to eliminate reliance on demonstrations and use participatory design to enhance our interface design.**

***Index Terms*—Shared autonomy, human-robot interaction, assistive robotics, accessibility**

I. Introduction

Assistive robotics is expected to be a valuable tool for providing support to individuals with disabilities [1]. Despite advancements in this field, the adoption of these technologies in human environments remains limited [2]. This is primarily due to the diverse personalization expectations of users [3]. Shared autonomy (SA) offers a way to provide this customization, enabling collaboration by blending inputs from both users and robots [4]–[7]. While SA enables users to maintain control over a robot's behavior, challenges arise as robots require control across six Cartesian dimensions (6D), whereas commonly used control interfaces, such as joysticks, typically provide only two-dimensional (2D) input [8], [9]. This dimensionality gap, require a mapping between user input and robot motions that is also challenging [10]–[12]. If the robot does not respond according to the user's expectations, users may need to perform taxing mental rotations to adjust their commands [11], [12]. Ultimately, these challenges can lead to a non-intuitive and frustrating control experience, which may diminish users' acceptance of assistive technologies over the long term [12].

I direct my research efforts toward addressing these challenges identified within SA. My approach centers on participatory design (PD), primarily involving wheelchair users, to develop assistive technologies that facilitate activities of daily living (ADLs) using the Lio robot platform [13]. I will explore the following research questions:

- ***(RQ1: Dimensionality gap)*** How can the dimensionality gap be effectively addressed to enhance robotic control?
- ***(RQ2: Input mapping)*** What methods can be developed to improve input mapping for intuitive robot control?

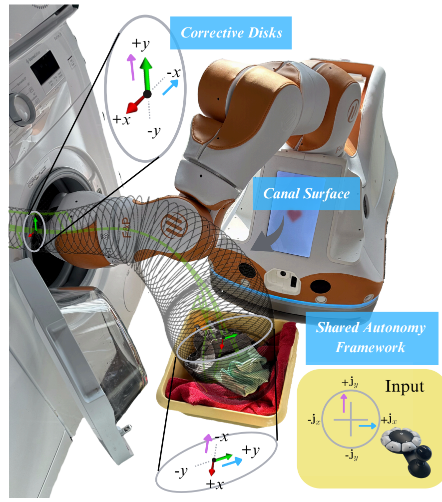

Fig. 1: Laundry loading, combining our foundational SA method, mapping framework, and the Sony access controller, was evaluated in an exploratory study with wheelchair users.

- ***(RQ3: Accessibility)*** How can accessibility be enhanced in SA systems to accommodate a wider range of users, including those with disabilities?

To explore these research avenues, I am following a three-step procedure: (1) develop a **base method** to address each research question, (2) assess the **feasibility** of the base methods through a user study involving both non-disabled users and individuals with disabilities, as appropriate, and (3) apply **iterative improvements** to the methods using PD.

II. Dimensionality Gap

Base Method *(Completed)*: Our prior work introduced a geometric-based SA framework [14] that utilizes canal surfaces [15], [16] to encode robot trajectories and allows users to control robots using 2D joystick inputs. The rationale for employing canal surfaces lies in their ability to effectively capture the structure of the task. Additionally, the cross-sections ("disks") of the canals provide a solid foundation for mapping 2D user inputs while maintaining motion in 3D.

Feasibility *(Ongoing)*: A comparative user study has been planned to evaluate our method against two SA baselines [5], [17]. Meanwhile, I conducted an additional study focusing solely on my method, incorporating an input mapping framework. More details can be found in section III. From this study, I identified that the method was *simple enough* for participants to control the robot. Initially, some participants expressed apprehension due to their lack of experience with robotic control. However, after an 8-minute training period, all participants gained *confidence* and at the end of the study, they assured us during the interviews that they were confident they would not cause damage to the robot or the environment. This underscores that our method paves the way for safer and more convenient robot control using 2D inputs.

III. Input Mapping

Base Method *(Completed)*: Building on the proposed geometric SA framework, I developed an online input mapping system for intuitive control [18]. This approach was *informed by pilot studies* and tailored to align with user expectations. The mapping process involves aligning the joystick axes with the correction axes corresponding to the disks of the canal and varies based on how the user perceives the disks from their perspective, as identified during the pilot studies.

Feasibility *(Completed)*: I conducted a user study with 20 abled participants, utilizing three types of tasks: an object relocation task, a painting task inspired from [19], and a more complex laundry loading task to assess the feasibility and usability of our system. Specifically, we sought to investigate how our method can extend beyond ADLs to encompass more creative and expressive tasks. The evaluation was conducted against our previously proposed SA method [14] without the input mapping. Both quantitative and qualitative assessments revealed that our input mapping approach allowed participants to control the robots *with little efforts*. Usability and overall workload were evaluated using the USE [20] and NASA-TLX [21] questionnaires, and it was *statistically demonstrated* that our input mapping framework *significantly enhances robot control*. Additionally, participants were able to create *meaningful paintings*, demonstrating the potential of our method for expressive tasks such as painting.

IV. Accessibility

Base Method *(Completed)*: In both the ongoing study and the completed study (n=20), I used a standard Xbox gamepad. Its buttons and joysticks are relatively small, which may limit accessibility for individuals with disabilities. Inspired by the accessible gaming community [22], [23], I discovered the recently released Sony Access Controller[1]. This features *customizable buttons* and a *larger joystick* that is easier to manipulate, resembling those on electric wheelchairs. Consequently, I decided to use this controller in my future work.

Feasibility *(Completed)*: I conducted an exploratory study with three wheelchair users on the same three tasks as earlier, integrating our canal surface-based SA method, input mapping framework, and accessible controller (see Figure 1). The wheelchair users successfully completed all three tasks, with occasional assistance from the experimenters. Participants reported that the system was useful, particularly for tasks like laundry, lifting objects from ground, or reaching items that are high up. They believed it would be even more beneficial for individuals with severe mobility limitations: "with this type of things we could do a lot of things, especially for disabled people with [heavier pathologies]". One participant remarked that the gamepad reminded them of a joystick used in wheelchairs, which aligned with our intention behind its selection, providing positive feedback for our future accessibility work. Overall, participants found the method to be *easy to use and enjoyable*: "It was rather fun because, with my small joystick here, I'm moving a machine that can lift things". The feedback from participants and their willingness to participate in future studies indicated that our method is feasible for further experimentation with wheelchair users.

[1]Sony Access Controller: https://www.playstation.com/en-gb/accessories/access-controller/

V. Future work

Considering the requirement for kinesthetic demonstrations in my proposed method and the limitation of robot movements confined to the canal, I am currently working on integrating vision-based techniques to enhance the generalization and practicality of my method by facilitating the creation of demonstration-free, lightly constrained canals. All my future work will be based on PD, placing a special emphasis on in-situ methods [24], [25] tailored for wheelchair users.

In line with *RQ1*, I aim to expand my proposed method, which currently works with only a single canal, to accommodate orientation corrections and multiple canals as needed. Additionally, I plan to develop a multi-modal intent prediction algorithm that integrates natural language processing with joystick control inputs. This method will utilize a vision-language model to identify the user's targeted objects based on their commands. Following this, lightly constrained canals will be generated. As the robot navigates these canals, users can provide corrections using either a joystick or voice commands (building on our prior work that introduced a voice-based robot teleoperation framework as an initial step [26]) on 2D planes orthogonal to the robot's navigation direction.

Regarding *RQ2*, I aim to focus my research on identifying what information can be extracted from user inputs for input mapping. Specifically, some inputs may serve merely as corrections to the nominal behavior, while others might be intended to change that behavior. This distinction could facilitate the regeneration of a new canal by leveraging the multi-canal generation approach I will be exploring in addressing *RQ1*.

With the multi-modal input method, I aim to utilize PD to determine how best to leverage natural language and joystick control motions to create an optimal interface for various individuals with disabilities, directing my efforts toward addressing *RQ3*. I will specifically focus on two scenarios: (1) providing primary instructions to generate the base motion, and (2) making corrections for precise manipulation, balancing the use of joystick and voice inputs for increased accessibility.

In summary, my future focus is on enhancing the practicality of the foundational system through PD by enabling it to: (1) operate fully online without the need for physical demonstrations; (2) improve the intuitiveness of control and the flexibility; and (3) enhance accessibility by allowing the system to respond to various modalities while creating a more interactive environment with feedback mechanisms.

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