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A Web-Based User Interface for HRI Studies on Multi-Robot Furniture Arrangement

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ABSTRACT

This video presents a remote user interface (UI) for controlling a multi-robot furniture system intended to enable human-robot interaction studies safely during the COVID-19 pandemic. The three primary features of the system are detailed. The first, a **web-based architecture**, allows the operation of our chair robots (ChairBots) over the internet. Second, **multiple ChairBots** are simultaneously operable. Third, **variable levels of autonomy** allow an operator to send both high-level, with robots autonomously moving to goals, or low-level motion commands. This work presents advances in the technical capabilities of our ChairBot system, representing progress towards a viable multi-robot furniture system.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; Web-based interaction; • **Computer systems organization** → *External interfaces for robotics.*

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1 INTRODUCTION AND BACKGROUND

During the COVID-19 pandemic, robots are increasingly being deployed in social environments. Ironically, the COVID-19 pandemic has also made it challenging for the community to conduct human-robot interaction (HRI) research with many traditional study methods have become unsafe. In this video, we present our solution for safely continuing our research on multi-robot furniture: the Tele-ChairBots UI.

The Tele-ChairBots UI represents an interface for controlling multiple chair robots (ChairBots) over the internet using multiple modes of operation with varying levels of autonomy. Such an interface enables remote HRI studies based on multi-robot tele-operation. This setup is intended to enable future user studies where local control is unfeasible, such as during COVID related quarantine restrictions, or in situations where remote control is preferred, as in an offsite event organization company. Primarily, this video details three innovative features of this system: a web-based architecture, ability to control multiple robots, and modes of operating at variable levels of autonomy.

The ChairBot design was initially introduced by Knight et al. [9], following upon earlier work demonstrating the social communication capabilities of robot furniture by [11] and more. Since then, ChairBot gestures have been studied relative to their use in chairs

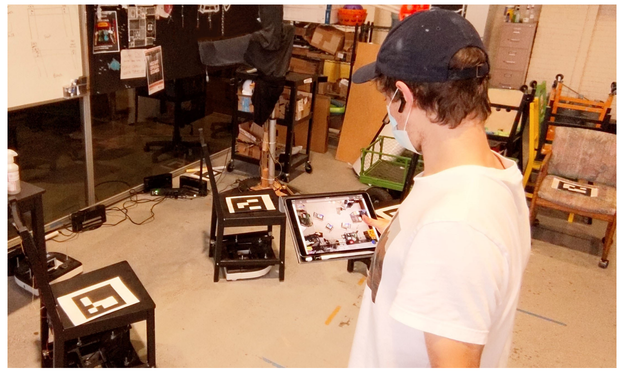

Figure 1: A user interacts with the Tele-ChairBots interface on their mobile tablet to control multiple ChairBots.

Figure 2: Screen capture of the Tele-Chairbot user interface. The user interface consists of several components: a livestream of the scene (top), a component to select which of multiple ChairBots to control (left), a joystick for low-level control (right), and buttons to control the autonomous modes of operation (center). Screen overlays show helpful information about autonomous motion which were disabled during filming.

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navigating [9][11], communicating [1][3], and entertaining [14][4] in shared human-robot spaces. Other notable work has evaluated the application of modular robots as pieces of furniture [6] and for VR [13]. In a large majority of these efforts, joystick controllers are used conduct "wizard-of-oz" studies where the robot interacts physically with a participant. As far as we know, no one has examined the controllers for such multi-robot furniture systems from a social robotics perspective as we intend to do with the Tele-ChairBots UI.

2 PRIMARY FEATURES

The Tele-ChairBots UI presented in this video was developed following a companion participatory study considering usability and functionality criteria for multi-robot furniture. We further suggests that our tele-operation system could be used in remote user studies with remote operators. We present three primary features of this interface that would enable such an exploration: (1) a **web-based architecture** that enables remote control, (2) **control of multiple ChairBots** which approximates the reality of furniture, and (3) **variable levels of autonomy** giving the user powerful modes of interaction.

Web-Based Architecture. A prospective operator only needs to open a custom URL in their web browser of choice to operate the Tele-ChairBot system. This enables remote operation from a user's laptop, tablet or phone (using responsive web styling). The Tele-ChairBots UI predominantly includes a live overhead video stream that can be enhanced with video overlays or other virtual fixtures [10] as shown in Figure 2. The implementation of this system includes a Flask server hosted in custom ROS node, and a HTTP tunnel to expose this server to the public internet. A demo was published in an open-source Github repository [12]. The server uses REST-like APIs, similar to ROSful[8], which allows web developers to contribute to the system without having to change network settings [5], or learn the topic/subscribe ROS model [2].

Multi-Robot Control. This feature implements multi-ChairBot control for the first time.In the Tele-Chairbots interface, a user can select one, multiple, or all ChairBots to move simultaneously using a list of available ChairBots on the bottom left of the screen. With multiple ChairBots selected, the user can send low-level movement commands using a virtual joystick on the UI. All selected ChairBots will then move relative to their respective reference frames (up mapping to a forward command, right to clockwise, etc).

Variable Autonomy. The complexity of controlling an increasing number of robots at once has been shown to negatively impact operator workload and performance [7], thus successful remote operation of robotic furniture may benefit from the use of easy-to-use and efficient high-level commands. However, manual control can also be important in particular situations: recovering from failures, experimenting, preventing accidents, and accomplishing tasks outside the limits of the autonomous system. Therefore, we implemented variable levels of autonomy into the Tele-ChairBot system. Low-level motion commands can be sent via a virtual joystick to all selected ChairBots. In this way, the user can directly control ChairBot motion. Additionally, we implemented three methods for setting goals that a robot could autonomously achieve: recalling a previously saved **arrangement**, rotating ChairBots to **snap-to** an orientation, and maintaining relative positions to move in **formation**.

3 CONCLUSION

This demo presents the design of Tele-ChairBot, a multi-robot furniture controller. In future work, we are developing a study in which a remote operator will be able to use this interface to create arrangements dynamically, for example, over the course of a multi-phase event such as a birthday party. We share this work in part, to share ideas with the HRI community about how to continue running user studies safely during the COVID-19 pandemic. In future work, we also plan to validate and improve this multi-robot furniture interface by evaluating usability (in terms of operator's workload, efficiency, and satisfaction), and functionality (in terms of using the system for an actual application case and seeing what users or even trained event planners believe to be helpful or necessary features in the system). Finally, our previous results demonstrate the viablity of single ChairBots in communicating with one or many people. Perhaps future extensions of this system could seek to further scaffold the social communication aspects of this interface, once the basic application needs are successfully conquered.

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