Cooperative Handheld Robots: Anticipating Users and Assisted Remote Collaboration

Janis Stolzenwald and Walterio W. Mayol-Cuevas

Abstract— **Handheld robots share the shape and properties of handheld tools while being able to process task information and aid manipulation. In our recent work we explore intention inference for user actions. The model derives intention from the combined information about the user's gaze pattern and task knowledge. Based on a generic pick and place task, the intention model yields real-time prediction capabilities and reliable accuracy up to 1.5 s prior to actions. Furthermore, we evaluate a system that allows a remote user to assist a local user through diagnosis, guidance and physical interaction as a novel aspect with the handheld robot providing assistive motion. We show that the handheld robot can mediate the helper's instructions and remote object interactions while the robot's semi-autonomous features improve task performance and verbal communication demands.**

I. Introduction

Handheld robots [1]–[5] are intelligent tools that process task knowledge and environment information, which allows for semi-autonomous assistance in collaborative task solving, and combine these with the natural competences of human users for negotiating obstacles and resolving complex motion planning tasks effortlessly. Since the robot holds task knowledge, such a system could help cutting workers' training times, as less user expertise is required for task solving. While this can arguably be beneficial for the task performance, the high proximity between the user and the robot also leads to co-dependencies that create the need of communication methods between the user and the robot for efficient collaboration. We argue, that the robots decisions should not solely be based on task knowledge but also be biased by the users' intention for efficient teamwork. At the same time, it is unknown, how the robot can retrieve this knowledge e.g. through learning from demonstration or by involving another human in the task.

In our research, we propose a gaze-based intention model for the handheld robot which we assess through user studies using a generic block copy task. Furthermore, we explore the application of the handheld robot in a semi-automated remote assistance setup, where it is used to mediate task knowledge between a local worker and a remote expert.

II. Intention Inference

In the context of our handheld robot task, we define intention as the user's choice of which object to interact with next. Our model design is guided by the assumption that an intended object attracts the users' visual attention prior to interaction. In terms of the assessment of the model's accuracy, we also assume that if the predicted intention is the true intention, a robot that rebels against following the predicted goals induces user frustration. With this in mind, we argue that the level of frustration is easier to be reported by users, thus better serves as an indirect measure of intention prediction accuracy.

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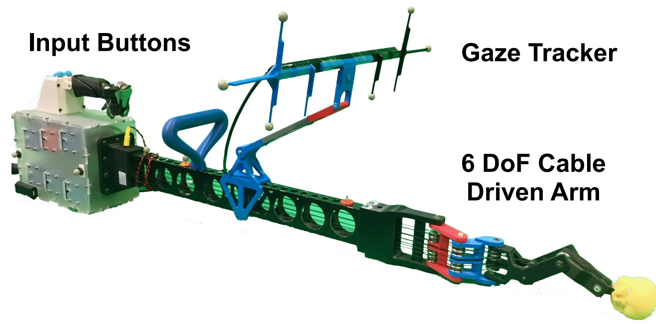

Fig. 1: Handheld robot with extended user perception capabilities through a newly integrated eye tracking system.

A. Data Collection and Intention Modelling

For the user studies, we chose an on-screen simulated block copying task to be completed using the handheld robot. The robot was equipped with a gaze tracker (cf fig 1) which was used to derive users' visual attention as per [4]. For the data collection, 16 participants were recruited and gaze histories of 912 episodes of picking and dropping actions were recorded. This data was used to train a predictive SVM model and we obtained a prediction accuracy of up to 87.94% 500 ms prior to user actions.

B. Validation of Intention Model

To validate the intention model in action, the experiment was repeated with 20 new participants and the intention model was used to bias the robot's assistive motion in two different modes:

1) Follow Intention: The robot moves towards the target with the highest predicted intention.

2) Rebel: The robot avoids the target with the highest prediction.

Each participant completed the pick and place task in both modes, followed by a NASA TLX questionnaire [6]. The results show a significant drop of the TLX frustration component for the *Follow Intention* mode compared to the *Rebel* mode.

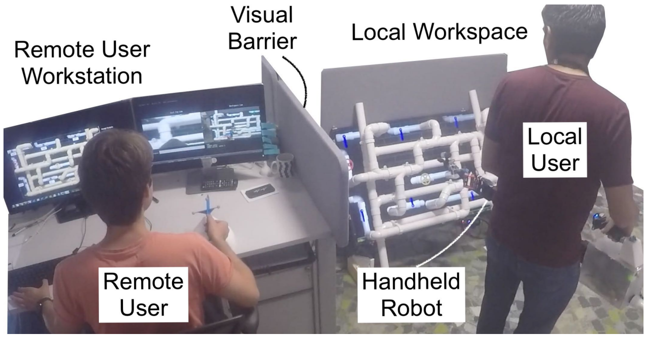

Fig. 2: Overview of the remote assistance experiment setup. A remote user controls the semi-autonomous handheld robot to support the local user in the workspace.

III. Assisted Remote Collaboration

As part of our exploration of new application of the handheld robot, we propose and test a remote assistance system which consists of two main parts. On the local workspace site, a camera-equipped handheld robot with 5-DoF motion capabilities (displayed in figure 3) is carried by a local user. A remote user accesses the robot through a remote interface, which allows them to control the robot for inspection, manipulation and gesturing. We investigate the collaborative interaction between the three agents involved in the task that is the remote user, the local user and the handheld robot. Our main focus lies on the effect of the robot's semi-autonomous assistance features on the collaborative task performance and communication strategies. Figure 2 shows an overview of the experiment setup.

A. Study Design

For our experiments we use a within-participant design to compare the performance of the 15 remote user and local user pairs using our proposed remote assistance system in two different conditions:

1) Non-Assisted: The remote user has to request information about the task state and steers the robot manually.

2) Assisted: The remote user can select an object to interact with and then the robot assists through locally fulfilling the task within its workspace.

The setup is a semi-simulated pipe system, which we use as an example for a collaborative maintenance task. As a measure of performance, the completion time and the word count of the teamwork dialogue was recorded. To assess perceived workloads, each trial was followed by a TLX questionnaire for both team members.

IV. Findings and Argument

Our studies on intention prediction show that the combination of gaze data and task knowledge enable accurate predictions of intended user actions within 500 ms. The decreased level of frustration in the *Follow Intention* group, indicates that, when the model is used for the robot's control, it can adapt its plans to the ones of users.

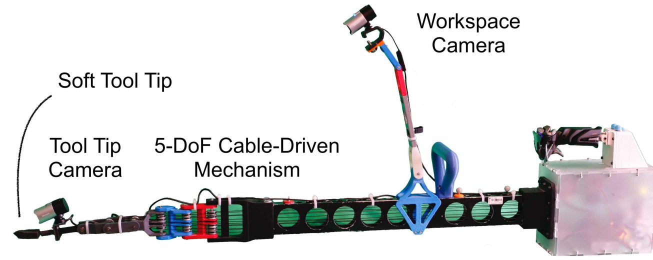

Fig. 3: Handheld Robot with remote-controlled 5-DoF tooltip and equipped cameras and a tooltip for sensor simulation .

In terms of the robot's application in an assisted remote control setup, we found that the proposed semi-autonomous assistance features improve the performance metrics. Furthermore, as the robot takes over local task solving, less verbal communication between the remote user and the local user is required to solve the task.

V. Conclusion

We investigated the effect of gaze-based intention prediction on handheld robot collaboration. Within user studies based on a pick and place block copy task, the proposed system infers intention which was validated using frustration as an indirect measure for intention prediction accuracy.

Furthermore, the robot was tested in the context of a semi-automated remote assistance setup where a remote expert helps a local worker through the handheld robot using a camera system and the 5-DoF mechanism. Testing involved a semi-simulated pipe maintenance task and revealed an improved performance and a decreased required bandwidth as the main benefits of the robot's incorporated assistance features. Robot designs and further information are available from [7].

References

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