"You two, join Green": A Human Multi-Robot Interface for Creating and Commanding Teams of Robots

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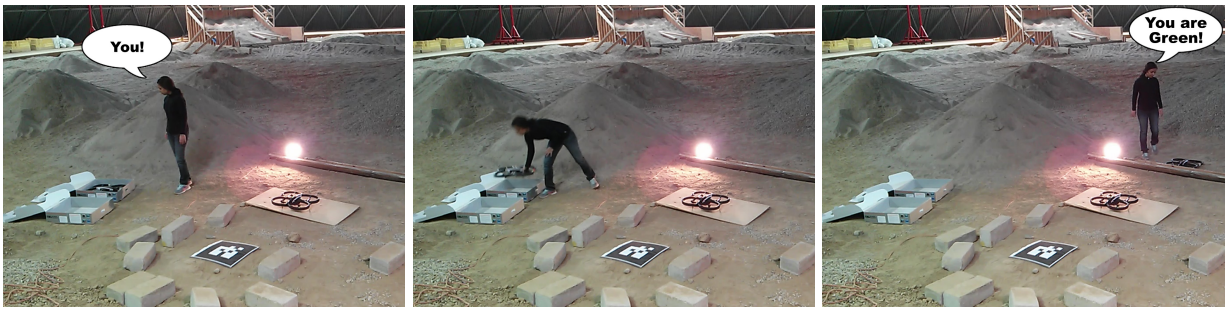

Figure 1: The touch-to-name interaction: The user first announces the desired number of robots with "You" or "You N" where N is the desired number of robots (left), then handles the intended robot(s) (middle); and finally assigns a name to the selected robot(s) that can subsequently be used to address this robot or team.

ABSTRACT

We present a novel multimodal system for creating and commanding groups of robots from a population. Extending our previous work on dynamically creating groups of robots using face engagement and voice commands, we show that we can identify an individual or a group of robots using haptic stimuli, and name them using a voice command (e.g. *"You two, join Green"*). Subsequent commands can be addressed to the same robot(s) by name.

1. MOTIVATION AND BACKGROUND

In multi-robot systems performing complex missions, it is expected to be beneficial to integrate human cognitive capabilities for high level supervisory control. A key enabler to allowing a human operator to control a large population of robots is the ability to select and/or command multiple robots in parallel. Single or multiple robots can be selected and identified as a group, and the whole group is commanded with a single interaction. This is a challenging problem since each robot must decide if the user is paying attention to it or its peers. We have been working on methods for a single human operator to dynamically select and command individual or groups of robots from a population. The motivation for these interface designs is to increase the span of control (one operator to multiple robots) which can broadly benefit in several applications (e.g. coordinated exploration).

Olsen and Wood [2] introduced the concept of *Fan-out* which posits a model-based upper-bound on the number of independent homogeneous unmanned vehicles (UVs) that a single human can interact with. *Fan-out* is defined as the ratio of activity time (the time a robot operates autonomously), to interaction time (the expected amount of time that a human must interact with one or a group of robots). We have previously shown that interaction time can be reduced by creating groups of robots and doing concurrent interactions that exploit locality [4]. This can be led to an increase in the robot/human Fan-out ratio.

We focus on designing spatially embedded interfaces for human multi robot systems (HMRS) that provide an efficient and natural way to form and interact with groups of robots. By *spatially embedded interfaces*, we mean those in which the interaction occurs directly between human and robots in a shared physical workspace, mediated at least partly by the robot's sensors. This is an important class of interfaces, since it allows for what can be called "natural" means of communication such as speech, gestures, haptic and face engagement. We have developed interfaces using these modalities, for systems that require dynamic task allocation, team composition and team re-composition.

We have previously shown that the user can dynamically create groups of desired number of robots, by verbally announcing the desired number of robots and simply looking directly at them [3][1]. The robots wirelessly exchange their independent observations of the user's face to determine which robots are selected. The team can then be commanded as a

[1]This paper was nominated in the *"New Technology Foundation Award for Entertainment Robots and Systems"* at IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'13).

unit with e.g. *"Take off!"*. The video demonstration of the system is available here: `http://www.youtube.com/watch?v=I8sJud-OApw`

2. THE TOUCH-TO-NAME INTERACTION

Extending our previous work, we have developed a new multi-modal HMRS interface whereby a user can name individual or teams of autonomous robots from a cooperating population. In the *Touch-to-Name* interaction the user verbally announces the desired number of robots N in the form "You N". If $N = 1$ the number can optionally be omitted as in Fig. 1 (left). The user then physically handles the desired set of robots one after the other (Fig. 1 (middle)). Once the robots are thus selected, the user names the individual or group with a second verbal announcement, of the form "You are <NAME>" (e.g. *"You are Green"* as in Fig. 1 (right)) to create a team or "Join <NAME>" or "Leave <NAME>" to modify a team. The user can thus create a direct addressing scheme to previously anonymous robots, and can command a team of arbitrary size with a single subsequent command (e.g. *"Green! Take off!"*). The team manipulation interactions can happen at any time.

2.1 Implementation

In our demonstration system each robot is equipped with a 3-axis accelerometer, a voice recognition system and a wireless communication channel to compare sensor information with its peers. For simplicity we used a centralized voice recognition system and a bluetooth microphone worn by the user during our experiments. But our method will also work with audio processing onboard the robots.

To determine which robot is selected by the user, all robots wait for the keyword *"You"*. When it is detected, the robots communicate over the wireless channel to compare their accelerometer readings with each other. The one with the highest acceleration magnitude in a recent time window is considered the one being touched by the user. Fig. 2 shows the acceleration magnitude of two robots, robot 1 is the one gently moved by the user and robot 2 is untouched. This election mechanism avoids the use of a predefined acceleration threshold by assuming that the robot that is being touched by the user has the highest recent acceleration readings.

The robots indicate their current state to the user with bright colored LEDs. We found that compared to vision-based selection methods [3], using accelerometer data is much faster and computationally less expensive. It requires the human operator to touch the robot platform, but this interaction is simple and straightforward to implement.

Using voice input gives the user the ability to control teams of robots hands-free. Draper et al. [1] showed that using voice commands can significantly improve an operator's ability to control teams of UAVs, compared to manual controls. While our demonstration shows the human handling each robot to provide the haptic input, the same effect can be achieved by pushing or kicking the robot, nudging a joystick that drives the robot, or moving an actuator that has sensor feedback.

3. CONCLUSION

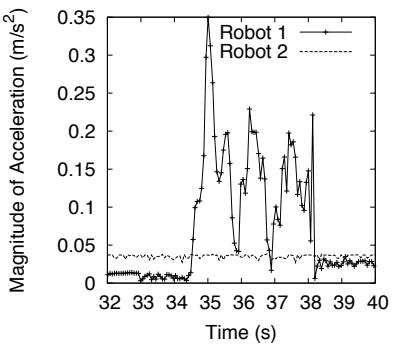

Figure 2: Accelerometer readings of two robots during the selection procedure. Robot 1 is selected and Robot 2 is untouched.

Extending our previous work on designing spatially embedded HMRS interfaces, we described the new *Touch-to-Name* interaction. We demonstrated that it works as part of an integrated system to allow a single user to control a multi-robot system in a coordinated exploration mission in a semi-realistic setting. The system can be seen working in the video `http://youtu.be/SxeVZdJFB4s`.

4. REFERENCES

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