Developing Guidelines for In-The-Field Control of a Team of Robots

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ABSTRACT
In this work we explore the development of guidelines for creating "in-the-field" interfaces for enabling a single user to remotely control multiple robots. The problem of controlling a remote team of robots is complex, requiring a user to monitor and interpret robotic state and sensor information in real time, and to simultaneously communicate direction commands to the robots. The result is that a robot controller is often seated at a console; for many relevant applications such as search and rescue or firefighting this removes the user from the field of action, rendering them unable to directly participate in a task at hand.

Therefore, one challenge in HRI is to develop efficient interfaces that will enable a user to effectively control and monitor a team of robots in the field. In our project we explore various interface designs in terms of supporting this goal, taking the approach of involving a panel of professionals in the design process to direct exploration and development.

Categories and Subject Descriptors
I.2.9 [**Robotics**]: Operator Interfaces, H.5.2 [**User Interfaces**]: Interaction Styles, graphical user interfaces (GUI)

General Terms
Design, Experimentation, Human Factors

Keywords
Human robot interaction, Interface design, robot teams.

1. INTRODUCTION
Robots are emerging as important tools in professional contexts such as search and rescue, firefighting, or the military [1, 2]. In these situations robots are often even referred to as team members [3, 4], due to their complexity, capabilities, and semi-autonomous nature. However, this complexity means that it can be very challenging to both monitor the state of the robots, and their many environmental sensor readings, and to meaningfully give them instructions in real time. Thus an important goal is to create interfaces which effectively support interaction and collaboration between human and robotic team members.

One downside to many in-the-field robot control interfaces is that they often require a human team member to engage and immerse themself in complex laptop-like console interface, removing them from direct involvement in the task at hand (see, e.g., the iRobot Packbot control interface, and [5, 6, 7]).

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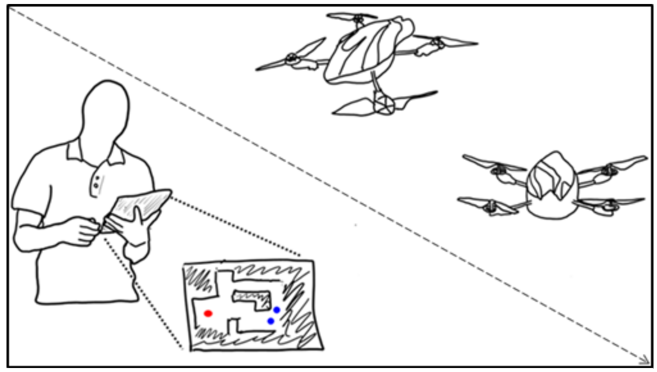

Figure 1-A user working with a remote team of quadrotor robots for a mapping task.

Further, many existing systems attempt to minimize the complexity by having multiple human controllers per robot [8, 9]. In our work, we will investigate methods for enabling a single user in the field to interact with a team of remote robots while still being involved with the task at hand.

Our strategy for investigating this problem will be to create an expert panel of relevant professionals, for example, police officers, fire fighters and search and rescue workers, and to leverage their expertise for driving our interface design. This task and user-centered design approach keeps our investigations grounded in practical application constraints and the expert users provide a valuable user base for evaluation.

As an initial step we will focus solely on the task of using a team of robots to map an unknown space. We selected this scenario as it will be relevant to many professional contexts, it requires real-time monitoring and direction of robots to relevant areas as a task unfolds, and would be useful by a person in the field versus being removed from action at a console.

Specifically, we intend to explore the following research questions related to this task:

1. How do various device formats (e.g., cell phone, smart phone, tablet PC and UMPCs) integrate into real use for the tasks and scenario? How do they differ?

2. How do different kinds of input mechanisms lend themselves to use in the field, for example, single or multi touch gestures (single-handed or two-handed), portable keyboards (e.g., strapped to an arm or single-handed keyboards), or trackballs?

3. How can such portable interfaces support sliding-scale autonomy for robot control, that is, to enable the user to seamlessly go from directing an entire team at a high level to taking control and reading sensor data of an individual robot?

Through investigating these questions with an expert panel we intend to develop initial grounded guidelines for creating in-the-field interfaces for controlling a remote team of robots

2. EXPLORATION FOCUS

Here we briefly outline our methodology for exploring each of our research points.

We will explore the use of various device formats for in-the-field use. In particular we are interested in a range of touch screens, from small smart phones to large tablets, as they provide flexible input and rich display output in a very portable and compact package. We will investigate how these devices can be carried by a user, e.g., mounted on a forearm for direct use, easy-to-access belt for quick retrieval, etc. In particular, we are curious as to how these formats relate to particular professional tasks and to any existing equipment that must be used.

Touch input offers the advantage of enabling complex interactions using a single hand, either through multi-touch gestures or even a single point (e.g., using a thumb on a smart phone), but has the disadvantage of being hindered by gloves or dirty hands. Not only will we explore these high-level practical technology issues, but further, we intend to investigate which kinds of gestures and touch methods may be best suited to the given tasks and constraints. Further, we will compare how the displays can be coupled with non-touch input devices such as portable keyboards and joysticks.

We will investigate how interface designs can support sliding-scale autonomy, that is, enabling the user to seamlessly move between low-level robot interaction (individual view, battery levels, etc.) and high-level group interaction (macro-control, task-level state). What differentiates this work from other sliding-autonomy research is that we have the additional constraint of keeping people in the field, and so we will take a minimalist and "glanceable" approach to interface design and data presentation. We will explore existing methods and new approaches, grounding our explorations in our expert-panel input.

3. INITIAL PROTOTYPE

We will develop an initial prototype using many of our above-mentioned assumptions; this prototype will serve as an important exploratory platform and initial discussion point for our expert panel. A high-level overview of the prototype is shown in Figure 1: a user remotely controls two quad-rotor robots using a hand-held iPad touch interface to complete a mapping task.

We use AR-DRONE quadrotor flying robots as they provide precise and robust control, are easily remotely controllable, and have embedded cameras which can be used for camera-based SLAM (e.g., as available using the ROS toolkit) for mapping.

4. FUTURE WORK

Ultimately, we aim to develop grounded and directed guidelines for the design of in-the-field remote control robot interfaces. Such guidelines will be useful to help direct the continued development of such effective and easy to use interfaces for human-robot team collaboration.

The primary next step of our exploratory work is to narrow our focus to more targeted aspects of the larger problem. We believe this initial exploratory step is important to help select future questions which will be relevant to the target professional users.

One particular future work question which we will investigate is the design problem of displaying real-time robot sensor and state data, perhaps through meaningful aggregates of team data, in clear and effective ways to the user. For example, providing data overlap and certainty estimates, team-level summaries of such statistics as battery level, and so forth.

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