Collaboration, Dialogue, and Human-Robot Interaction

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Abstract. Teleoperation can be improved if humans and robots work as partners, exchanging information and assisting one another to achieve common goals. In this paper, we discuss the importance of collaboration and dialogue in human-robot systems. We then present collaborative control, a system model in which human and robot collaborate, and describe its use in vehicle teleoperation.

1 Introduction

1.1 Robot as Partner

A robot is commonly viewed as a tool: a device that performs tasks on command. As such, a robot has limited freedom and will perform poorly whenever it is ill-suited for the task at hand. Moreover, if a robot has a problem, it has no way to ask for assistance. Yet, frequently, the only thing a robot needs to work better is some advice (even a small amount) from a human.

Consider the situation in which a mobile robot is driving outdoors when it encounters tall grass in its path. Depending on its sensors, the robot’s perception system may have difficulty deciding if the grass poses a danger. Thus, the robot may be unable to proceed or may take a long, resource consuming detour. If, however, the robot is able to discuss the situation with a human, a better solution can be found. For example, if the robot asks “Is there an obstacle ahead?” and shows a camera image, the human can help decide that it is safe to drive forward.

Generally speaking, robots are more adept at making some decisions by themselves than others. For example, structured planning (for which algorithms or well-defined solutions exist) has proven to be quite amenable to automation. Unstructured decision making, however, remains the domain of humans, especially whenever common sense is required (Clarke, 1994). In particular, robots continue to perform poorly at high-level perceptual functions, including object recognition and situation assessment (Milgram et al., 1993).

In order for robots to perform better, therefore, they need to be able to take advantage of human skills (perception, cognition, etc.) and to benefit from human advice and expertise. To do this, robots need to function not as passive tools, but rather as active partners. They need to have more freedom of action, to be able to drive the interaction with humans, instead of merely waiting for (or blindly executing) human commands.

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1.2 Collaborative Control

To address this need, we have developed a new system model for teleoperation called collaborative control (Fong, 2001). In this model, a human and a robot work as partners (if not peers), collaborating to perform tasks and to achieve common goals. Instead of a supervisor dictating to a subordinate, the human and the robot engage in dialogue to exchange ideas, to ask questions, and to resolve differences.

With collaborative control, the human functions as a resource for the robot, providing information and processing just like other system modules. In particular, the robot can ask questions to the human as it works, to obtain assistance during task execution. With this approach, the robot has more freedom in execution and is more likely to find good solutions when it has problems.

Collaborative control is a radical departure from traditional teleoperation, from the conventional “robot as tool” system model. Collaborative control encourages human-robot interaction to be more natural, more balanced, and more direct. Collaborative control also allows robots to benefit from human assistance during perception and cognition, and not just planning and command generation.

1.3 Key Issues

To build a collaborative control system, we have found that there are four key issues that must be addressed. First, the robot must have self-awareness. This does not imply that the robot needs to be fully sentient, merely that it be capable of detecting limitations (in what it can do and what the human can do), determining if it should ask for help, and recognizing when it has to solve problems on its own.

Second, the robot must be self-reliant. Since the robot cannot rely on the human to always be available or to provide accurate information, it must be able to maintain its own safety. Specifically, the robot should be capable of avoiding hazards, monitoring its health, and taking action to “safe” itself when necessary.

Third, the system must support dialogue. That is, the robot and the human need to be able to communicate effectively with each other. Each participant must be able to convey information, to ask questions and to judge the quality of responses received. To an extent, traditional teleoperation has dialogue (i.e., the feedback loop), but the conversation is limited. With collaborative control, dialogue is two-way and requires a richer vocabulary.

Finally, the system must be adaptive. By design, collaborative control provides a framework for integrating users with varied skills, knowledge, and experience. As a consequence, however, the robot has to be able to adapt to different operators and to adjust its behavior as needed, e.g., asking questions based on the operator’s capacity to answer.