Chapter 63
Evaluation of Remote Interface Component Alternatives for Teaching Tele-Robotic Operation

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ABSTRACT

The Internet developments as well as the increase in PCs' capabilities and bandwidth capacity have made remote learning through the internet a convenient and practical learning preference, leading to a variety of new learning interfaces and methods.

This chapter discusses a remote learning study conducted at the Computer-Integrated-Manufacturing (CIM) Laboratory in Tel-Aviv University. The goal is to provide remote end-users with an interface that enables them to teleoperate a robotic arm in conditions as close as possible to hands-on operation in the laboratory. This study evaluates the contribution of different interface components to the overall performance and the learning ability of potential end-users. Based on predefined experimental tasks, the study compares alternative interface designs for teleoperation. The three performance measures of the robot operation task are (1) the number of steps that are required to complete the given task, (2) the number of errors during the execution stage, and (3) the improvement rate of users. Guidelines for a better design of remote learning interfaces in robotics are provided based on the experimental results.

DOI: 10.4018/978-1-4666-1945-6.ch063

INTRODUCTION

This chapter focuses on the design of an interface for remote learning of robotics operations. The interface design, which is supported by technical guidelines, is general and applicable for a wide variety tools for teaching tele-robotic operation. It differs from previous research in the field, which often focuses on a specific applicative interface.

The proposed interface includes aspects of remote manipulation of robots with aspects of remote learning. The motivation for such integration is to enable users to practice not only the remote activation of a robotic cell but also the availability of learning, redesigning and optimizing the work plan in the cell. The chapter starts by considering three possible design schemes: a "Home-based," a "Lab-based" and a "Website-based." It identifies different interface components that support a remote telerobotic-learning. Then it measures and evaluates the interactions among these components as well as their effects and usability within a proposed remote learning interface. Such an evaluation is conducted by running a set of experiments, requiring the users to execute specific robotic tasks from a remote location while examining their performance over various interface settings. The performance of the remote users is also compared with hands-on operation, which is used as a benchmark setting.

The evaluation tool of the web-based interface for the telerobotic learning is called the *Test-Oriented-Interface* (TOI). As the chapter unfolds, elements within this interface are evaluated, focusing on their contribution to the remote learning assignments. A full set of guidelines for designing a remote learning interface is extracted from the evaluation of the TOI. The objective of these guidelines is to maximize the benefits obtained from the interface for the users (e.g., students) as well as for the hosting institute (e.g., university). Finally, we present how the new web-interface for remote learning of robotic operations is implemented and fully operated in the CIM laboratory.

BACKGROUND

Remote Learning Interfaces for Robotics

Remote control and manipulation of robots has been used to perform predetermined tasks, often in a hostile, unsafe, inaccessible or remote environment (Siegwart and Saucy, 1999 and Bukchin et al., 2002). NASA, for example, keeps track and provides free access to active telerobotic systems through the NASA Telerobotics Web-page.

Architecture of a WWW-based system for a remote telerobotic operation was presented in 1999 by Belousov et al. (1999). Their system was mainly oriented for reliability and efficiency and was based on a 3D Java visualization tool that overcame bandwidth restrictions that existed at the time. Belousov et al. (2001) presented a similar architecture with an addition of a tool that supports the remote programming of the robot.

Among many variations of teleoperation systems, one can mention Wang and Liu (2004) with a teleoperation paradigm for Human-Robot interaction, Hu et al. 2001)) with a system for remote controlling a robot with visual feedbacks over a simulated map, Kofman et al. (2005) with a hand-arm-gesture method for teleoperation, Hu et al. (2001) with a pioneering work networked telerobotic systems for tele-training, and Siegwart and Saucy (1999) with a modular framework for mobile robots on the web and many other applications.

New integration protocols were used to combine 3D simulation tools with remote control and manipulation interfaces, enabling the management of complicated tasks in flexible robotic cells. Candelas et al. (2005) present a system focused on the training of kinematics and trajectory design of robotic arms. Their work was among the first to use a learning platform with full interactivity in the teleoperation process. Michau et al. (2001) present in detail the expected benefits of web-based learning for engineers. They express the need for

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