Chapter 3
EMG-Based Control of a Multi-Joint Robot for Operating a Glovebox

Toshio Tsuji
Hiroshima University, Japan

Taro Shibanoki
Ibaraki University, Japan

Keisuke Shima
Yokohama National University, Japan

ABSTRACT

This chapter describes a control method for a multi-joint robotic manipulator using Electromyogram (EMG) signals for operating a glovebox. The system uses a Probabilistic Neural Network (PNN) to estimate the user's intended motion from EMG patterns, and generates a control command for the glovebox and robotic manipulator corresponding to the estimated motions. The user can therefore control the manipulator as well as various functions of the glovebox system through his/her EMG signals while performing some manual operations through gloves. With this system, the authors produce intuitive control of the glovebox with the robotic manipulator. The authors confirm the effectiveness of the proposed system with an experiment using the developed prototype.

INTRODUCTION

Research and development activity in industry and many fields such as chemistry has become more technical and complex in recent years, and it is important to secure the safety of researchers and provide them with an optimal environment suited to the purpose of the studies and/or experiments. The glovebox (or glove box) is a piece of equipment that is widely used in various research institutions to overcome these problems.

DOI: 10.4018/978-1-4666-7387-8.ch003

In this chapter, we outline a novel glovebox operation system with a multi-joint robotic manipulator controlled by an electromyogram (EMG) signal. The proposed system estimates the user's intended motions from extracted EMG patterns for each motion using a probabilistic neural network (PNN) called a log-linearized Gaussian mixture network (LLGMN). The user can then control the environment in the glovebox in addition to the room environment based on the estimated motion, and also simultaneously perform tasks with the robotic manipulator in the box based on an EMG signal. We designed a set of experiments to demonstrate the effectiveness of the developed prototype.

Background

During the handling of dangerous chemicals such as radioactive substances and poisons, it can be difficult for users to share their workspace and to work in direct contact with these substances. The glovebox, in which a leak-tight environment can be produced inside a sealed container and the user works through gloves set into the sides of the container, is used for such situations in many research institutions. This device provides a specific environment by controlling the humidity and atmospheric pressure in the box, and adjusting an internal gas (a very high purity inert atmosphere, such as argon or nitrogen). It is therefore possible to indirectly perform tasks involving hazardous substances using this device. The user's safety is also secured through the gloves installed in the box.

Research on the glovebox has focused on improving its performance, such as increasing its mechanical strength and decreasing the effects of radiation, but how best to support the task being performed in the box is little discussed (Sinski, 1968; Boylen, 1971; Crowder, 1991; Whitmore, McKay & Mount, 1995; Park, Pines & Counrnoyer, 2010; Castro et al., 2012; Coumoyer et al., 2013). However, the fact that the gloves are fixed to the container limits the usability of the device. Not only is the working range limited to the range of motion of the gloves, but it is also difficult to perform simple tasks such as transporting a heavy sample. A foot pedal can be used for the simple control of the glovebox, but the functions that can be performed are limited (e.g., atmospheric pressure control in the box). Furthermore, the user has to remove the gloves any time they want to adjust the environment in the box. The touch panel for the glovebox control is generally installed on the side of the container, which also causes a decrease in working efficiency. Thus, there are several avenues to explore in terms of the improvement of working efficiency and greater support for the glovebox operator.

The field of robotics and mechatronics has been instrumental in the design and construction of machines for safety and dependability (Habib, 2007). Many teleoperation systems have been used that allow the user to operate a robot to perform work from a remote location. The first system was developed in Argonne National Laboratory in the late 1940s, and these systems have been used effectively in various situations such as in space and at the bottom of the ocean, in the disposal of hazardous substances, and in telesurgery. The fundamental concept of current teleoperation technology using electrical signals was proposed by Goertz (1954), and since then, many studies have explored different aspects of teleoperation systems (Shimamoto, 1992; Sheridan, 1995; Yokokohji & Yoshikawa, 1994; Yoon et al., 2001; Ueda & Yoshikawa, 2004; Shull & Gonzalez, 2006). However, controlling a slave-arm robotic manipulator using a conventional interface system, such as a joystick and a master-arm robot, is difficult for the user, as a high level of skill and experience is required to control the robot naturally. To address this problem, experimental studies have been performed that use bioelectric signals such as the electromyogram (EMG), electroencephalogram (EEG) or electrooculogram (EOG) as a control signal for the interface system. Moreover, researchers have also proposed various human-