Chapter 15

Discrimination of Dual-Arm Motions Using a Joint Posterior Probability Neural Network for Human-Robot Interfaces

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ABSTRACT

This chapter describes a novel dual-arm motion discrimination method that combines posterior probabilities estimated independently for left and right arm movements, and its application to control a robotic manipulator. The proposed method estimates the posterior probability of each single-arm motion through learning using recurrent probabilistic neural networks. The posterior probabilities output from the networks are then combined based on motion dependency between arms, making it possible to calculate a joint posterior probability of dual-arm motions. With this method, all the dual-arm motions consisting of each single-arm motion can be discriminated through leaning of single-arm motions only. In the experiments performed, the proposed method was applied to the discrimination of up to 50 dual-arm motions. The results showed that the method enables relatively high discrimination performance. In addition, the possibility of applying the proposed method for a human-robot interface was confirmed through operation experiments for the robotic manipulator using dual-arm motions.

INTRODUCTION

Gestures include a variety of information no less than voice signals. Estimation of human intentions from them can be applied to the development of communication tools such as gesture translators and human-machine interfaces. However, it is quite difficult to perform accurate gesture discrimination due to the large variety of possible gestures that can be made.

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This chapter outlines a novel dual-arm motion discrimination method and its application to human-robotic manipulator control using acceleration signals. With the proposed method, all dual-arm motions consisting of individual single-arm movements can be discriminated through just learning of single-arm motions by combining posterior probabilities estimated independently for left and right arm movements. The user can then control the robotic manipulator based on the proposed method using a variety of gestures.

BACKGROUND

Many researchers have tried to accurately measure and discriminate the biological signals generated by gestures using various types of sensors and discriminators. The results clearly indicate that the gestures can be used for purposes such as automatic sign-language recognition, and operation of machine control interfaces.

Gesture discrimination studies investigate either static gestures or dynamic gestures. The former are based on hand/arm shapes, and the latter involve time-series patterns of hand/arm motion. In the area of static gestures, a number of studies using a probabilistic neural network (PNN), hidden Markov model (HMM), etc. have been investigated to discriminate several hand shapes (such as the “V for victory” gesture) (Bowden et al., 2002, Bailador, 2007, Okamoto et al., 2008). These techniques can be used to robotic manipulator operations (Brethes et al., 2004, Raheja et al., 2010, Habib, 2011, Devine et al., 2016, Fall et al., 2017). Additionally, Bu et al. proposed a motion discrimination method based on the recurrent probabilistic neural network called a recurrent log-linearized Gaussian mixture network (R-LLGMN) for prosthetic control (Bu et al., 2003, Tsuji et al., 2003, 2006). The generic NN has some drawbacks such as a large-scale network structure and many learning iterations, so that some studies have investigated to integrate domain/task specific knowledge into the architecture of NN (Bridle, 1989, Specht, 1990, Richard and Lippmann, 1991, Caelli et al., 1993). The proposed method integrated hidden Markov model (HMM) and Gaussian mixture model (GMM) into the architecture of NN, and achieves high discrimination performance, even with non-stationary EMG signals during continuous motion. In dynamic gesture discrimination, Liu et al. applied a template-matching method to classify gestures based on acceleration signals relating to three dimensions, then discriminated eight dynamic gestures with an accuracy level of 98% and developed a gesture-based interface for a cellular phone. Solís et al. also investigated the discrimination of 21 gestures with 93% accuracy using an artificial neural network based on RGB images while gestures were being made. However, these studies focused exclusively on single-arm motion discrimination (Liu et al., 2009, Huang et al., 2015, Solís et al., 2016). As gestures include both left- and right-arm motion among their characteristics, it is necessary to discuss a discrimination method for dual-arm motion in addition to considering single-arm motion.

Sawada et al. also applied a dynamic programming (DP) matching method to classify gestures based on the characteristics of hand ACC signals, positions and finger joint angles calculated using ACC sensors and data gloves attached to the subject’s left and right arms, and achieved discrimination of nine gestures involving dual-arm motion with 94% accuracy. Kim et al. also focused on and investigated the discrimination of 25 dual-arm dynamic gestures using a fuzzy min-max neural network based on hand trajectories and finger angles measured using data gloves. Here, since dual-arm motions have a wide variety of single-arm motion combinations, discriminating them becomes very complex, which in turn makes the learning time potentially excessive for the classifier. Increasing the number of motions also results in similar issues for considerations such as hand shapes and movement directions, which can re-