EVALUATION OF THE VECTOR PROJECTION ALGORITHM FOR TRANSHUMERAL AMPUTATION CASES

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ABSTRACT

Improving the controllability of a prosthetic limb for high-level amputation cases has always been a challenging problem for researchers and clinicians. This complex problem arises, in part, due to the limited number of input sources available from the user to control multiple degrees of freedom in a prosthesis. Further problems can occur as a result of the control system's sensitivity to the overall adjustment and tailoring of the socket and sensors.

The work presented in this paper extends a previous implementation of the vector projection algorithm to include transhumeral amputation cases. It is shown that a short data collection enables the system to adapt to several user and input sensor variables to produce robust and repeatable control signals based on both shoulder and humeral motions.

INTRODUCTION

Typical solutions for high-level upper extremity amputation cases have often relied on using the available input sources to sequentially control the prosthetic limb's actuators by shifting the control between actuators through the use of either a switch or, in the case of myoelectric inputs, a co-contraction [1]. Previous work [2,3] has shown that it is possible to enhance the reliability and robustness of the prosthesis' control system by using the amputee's residual shoulder position as the input source in combination with a mathematical framework termed vector projection. This algorithm optimizes the dynamic range of position sensors, and has been shown to remove many issues relating to the sensor characteristics and user's range of motion for shoulder disarticulation cases. As a result, many users favored the use of this approach over a myoelectric alternative [2]. The work presented in this paper illustrates the applicability of the vector projection algorithm for transhumeral amputation cases.

METHODOLOGY

The vector projection algorithm requires input sensor signals that can be used to discriminate between the desired motions. Using a short training session, the system is automatically tailored to an individual in order to provide robust output signals, which can be used by commercially available prosthetic limb control systems [3]. For a transhumeral amputee, the system would ideally allow the user to use both shoulder and humeral movements to control the prosthetic limb.

Experimental Protocol

Three sensors were used to capture user motion. A two-axis joystick monitored shoulder displacement while two S700 ShapeSensor™ devices (Measurand Inc.) were used to capture humeral movement (Figure 1). Previous studies have shown the ability of these types of sensors to reliably monitor joint position within a clinical setting [4,5]. Two subjects with intact shoulders and arms were used as part of this case study.

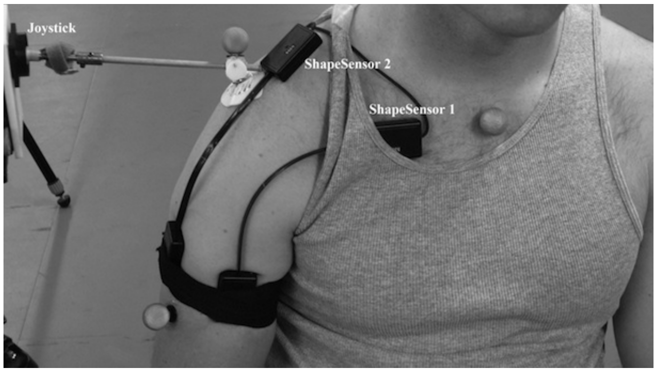

Figure 1: Experimental Setup for the evaluation of the vector projection algorithm for transhumeral amputation cases

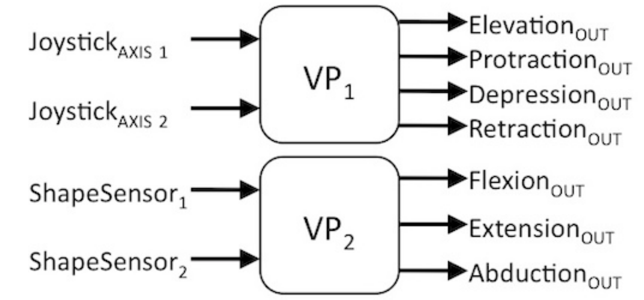

Figure 2: Block diagram illustrating the vector projection algorithm's input and output configuration

Subjects were instructed to complete four shoulder motions (elevation, protraction, depression, and retraction), three humeral motions (flexion, extension, and abduction), and a no movement/rest position. Each motion was performed both statically and dynamically. In the dynamic case, the subjects started from the rest position, performed the desired motion, and returned to the rest position. The static data were used as training data while the dynamic data were used for the evaluation of the system.

<u>Data Processing</u>

Two separate vector projection blocks were created using the available input sources (Figure 2). The first, termed VP_1, used the joystick sensor inputs to produce shoulder motion-based outputs. The second, termed VP_2, used the ShapeSensor™ devices to calculate the appropriate output amplitudes for the humeral motions. The static data were used to calibrate both blocks.

RESULTS

The projection vector outputs, shown in Figure 3, illustrates the performance of the system for the seven motion cases for one of the subjects in this study. Each column represents a motion elicited from the user while the rows show both the input and output signals captured during the dynamic motion trials. Presenting the results in this format illustrates the system's ability to produce the desired motion-related output while also demonstrating any inadvertent activation of the other outputs.

DISCUSSION

The algorithm generated the appropriate proportional output signal for each motions based on the dynamic input data from the sensors. The motions used for each vector projection block did not interfere with the other blocks as no inadvertent activation occurred for any other motions in any of the tested cases. The absence of non-elicited activation for any of the motions highlights the algorithms ability to produce independent, robust output signals that can, in turn, be used to drive a commercially available prosthetic limb control system. The effectiveness of the system also highlights the effectiveness of a short training protocol to tailor the system for the user.

A practical implementation of this system would be for a short transhumeral amputee with good humeral movement who also lacks the strength necessary to make a suction socket-based prosthesis viable. In such a case, the user typically has good control of the humeral segment and its movement is intuitive when compared to typical input sources. These other input options at this level often include a myoelectric site which tends to be non-intuitive in nature and therefore an inherently abstract form of controlling the prosthetic limb.

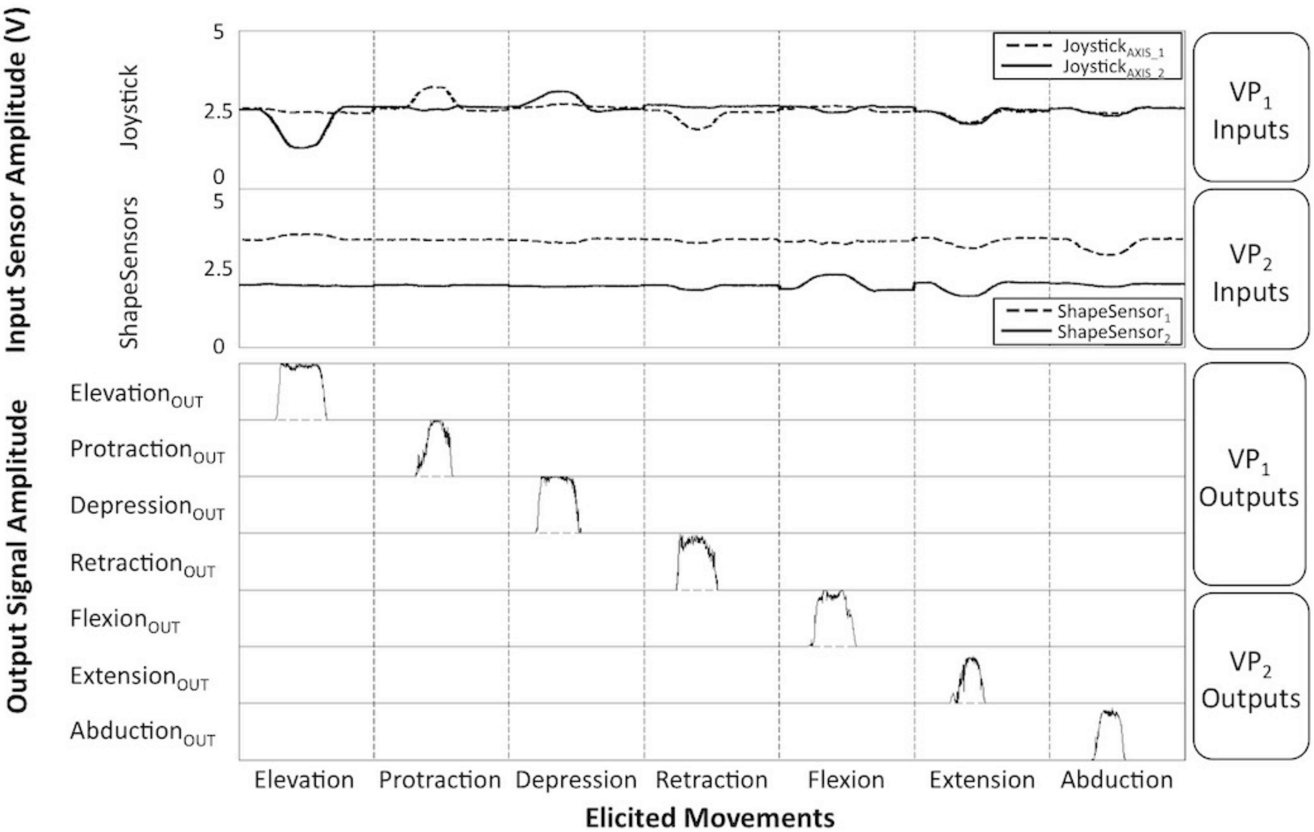

Figure 3: Vector projection algorithm outputs based on input sensors monitoring shoulder displacement and humeral motion

CONCLUSION

The case study presented illustrates the applicability of the vector projection algorithm for transhumeral amputation cases. Results showed that the system is capable of producing robust output signals without the presence of non-elicited outputs.

Work is currently ongoing to optimize the implementation of the algorithm within a prosthetic limb's embedded system in order to evaluate its ability to facilitate the performance of various activities of daily living. This work is being done in conjunction with the New Brunswick Limb Deficiency Clinic at the University of New Brunswick.

ACKNOWLEDGMENTS

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