Development of myoelectric controllers for hand prostheses

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1. INTRODUCTION

This paper describes a research project at the National Institute of Advanced Industrial Science and Technology (AIST) to develop a myoelectric controller. The myoelectric controller interprets control intentions from the operator by recognizing myoelectric signals. This kind of controller has typically been applied to control electric-powered prostheses. The most notable advantage of using the myoelectric controller is its capacity to utilize the residual muscular functions of physically-impaired persons. For example, in the case of a hand prosthesis, the myoelectric controller enables the amputee to utilize the residual functions of remnant muscles at their stump.

Within the project, we initially designed a pattern classification LSI (Large Scale Integration) in 1998 [1], and as one central application of the LSI, we have subsequently been developing compact controllers for multi-functional prosthetic-hands. Employing this pattern classification LSI, the controller can adapt itself to the unique characteristics of a myoelectric signal distribution for a given individual user [1].

Moreover, in order to realize hand-prostheses that could become widely accepted, we started developing a basic functional hand prosthesis in 2002. This prosthesis has undergone some clinical evaluations, and the technology has already been transferred to a private company for commercialization.

This paper outlines the development of the multi-function and basic function controller, as well as a basic functional mechanical hand.

2. THE MULTI-FUNCTIONAL CONTROLLER

While single functional hand prosthesis are already accepted by many amputees, it is also true that there have been calls to develop multi-function systems, capable of carrying out more than one function [2]. In response to the demand for greater prosthetic-hand functionality, recently, much research has been conducted on multi-function forearm prosthesis, applying pattern-classification methods, such as neural networks [3,4], in order to determine the hand actions. However, in this application, compact implementation is one of the most important issues, therefore we adopted a logic circuit pattern classifier with the pattern classification LSI.

In the case of myoelectric pattern classification with a logic circuit, it is necessary to quantize myoelectric signals into discrete numbers, which must then be coded as binary bit patterns. An efficient quantization method is, therefore, essential to the realization of high-accuracy myoelectric pattern classification.

Figure 1 shows a typical example of myoelectric pattern distributions and their quantization with linear quantization [5], which is the most basic quantization method. Myoelectric patterns that distribute within the same cell of the grid in Figure 1 are quantized as the same integer numbers. For example, in the worst case of quantizing for the patterns in Figure 1, three different actions--forearm supination (19 patterns), forearm pronation (20 patterns) and hand opening (2 patterns)--would all be are quantized as (0,0). This would result in the distinct
patterns being classified as the same pattern, i.e., as being generated from the same action. This kind of quantization error is an obstacle for high-precision pattern classification.

In order to overcome this quantization problem, we have proposed employing $\mu$-LAW quantization [6,7], where the transformation characteristics can be adapted to the distribution characteristics in terms of a $\mu$-value. The effectiveness of $\mu$-LAW quantization has been confirmed by the pattern classification of myoelectric signals, which were sampled from five subjects, including one experienced person, who has repeatedly participated in our experiments, and four new users joining our experiments for the first time.

By applying the $\mu$-LAW quantization, the pattern classification rate increased by 11.1% (averaged for the five subjects) and by 15.5% (maximum). Furthermore, the classification rate for the experienced subject was 97.8% (averaged over ten trials), demonstrating that skilled individuals are able to operate a multi-functional myoelectric hand with high-accuracy.

![Figure 1 - An example of myoelectric pattern distributions and their quantization with linear-quantization](image)

3. THE BASIC FUNCTIONAL PROSTHESIS

Given the current situation of myoelectric hand prostheses in Japan, where even single function hand-prostheses are not widely accepted, we began developing both of a basic function (less than two functions) controller and a mechanical hand.

3.1. The controller

Control for one or two function systems has already realized in a number of commercialized hand prostheses, such as an OTTOBOCK or a Motion Control hand. Accordingly, we have adopted the control methods used for such commercial hand prosthesis.

These methods can be divided in two modes. The first is a switch mode, where each myoelectric signal channel has a threshold, and if the signal intensity exceeds the threshold, then the corresponding function, such as hand-open or hand-close, will be activated. Each threshold can be easily adjusted by using a graphical user interface (GUI) on a personal computer (PC).

The second mode is a proportional mode. Although the motor for the activated function rotates at a constant speed in the switch mode, in the proportional mode, the motor rotates at a speed which is proportional to signal intensity.

Hardware specifications of the developed controller are as listed below.
1. Microprocessor: H8/3664F (Renesas technology corporation)
2. Size of the controller board: 6cm × 3cm
3. Battery: 7.2V (Lithium-ion)
4. Number of input myoelectric channels: 2
5. Number of controllable motors: 2

In addition to these specifications, the controller can also execute a software program for the logic circuit pattern classifier. This means that the controller handle more than three functions for the prosthetic hand, although the controller has not yet been clinically evaluated at such levels of functionality.

3.2. The mechanical hand

We are developing two basic function mechanical hands, which utilize two different technologies. The first technology is the “leadscrew”, which is a fundamental decelerator and converts a rotation motion into a linear motion. Figure 2 shows the mechanical hand with the leadscrew technology. The specifications of this hand are as follows.
1. Length: 141mm (from the finger tip to the wrist)
2. Weight: 290g
3. Number of functions: 2 (hand open-close and wrist flex-extend)
4. Power of finger (three-point) pinch: 2.5kg (measured by North Coast™ Hydraulic Pinch Gauge NC70141)

The prosthesis, which incorporates this mechanical hand and the basic function controller, has undergone some clinical evaluations, as shown in Figure 3.

The second technology is the “harmonic drive”, which is a state-of-the-art decelerator that provides a high speed-reduction ratio with a single harmonic drive component. Figure 4 shows a harmonic drive embedded mechanical hand, with the following hardware specifications.
1. Length: 140mm (from the finger tip to the wrist)
2. Weight: 420g
3. Number of functions: 1 (hand open-close)
4. Power of finger (three-point) pinch: 4.5kg (measured by North Coast\textsuperscript{TM} Hydraulic Pinch Gauge NC70141)

These specifications indicate that the harmonic hand is heavier than the leadscrew hand, however, this harmonic hand has greater finger power for three-point pinching, making for a stable pinch function.

![Image of mechanical hand with harmonic drive decelerator]

**Figure 4** - The mechanical hand with the harmonic drive decelerator

4. CONCLUSION

This paper briefly discussed the multi-function and the basic function controller, as well as the basic function mechanical hand. The basic function controller and the mechanical hand with the leadscrew have already undergone some clinical evaluations. Although clinical evaluations for the multi-functional controller and the harmonic drive embedded mechanical hand have not begun yet, they are due to commence this year. In addition to these developments, we are also carrying out other projects to broaden the range of applications for myoelectric controllers, and reports concerning those projects will appear in the future.

REFERENCES

5. Lee Potter, "Linear and Logarithmic Quantization", Connexions, http://cnx.rice.edu/content/m10051/2.9/, February 25, 2004,