# A QUANTITATIVE OPERATIONAL PERFORMANCE MEASURING SYSTEM FOR A MYOELECTRIC HAND: A PRELIMINARY STUDY.

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## INTRODUCTION

We are developing a quantitative measuring system for basic operation abilities of myoelectric prosthetic hands. Preliminary results for the prosthetic hand users are shown in this report.

While there are numerous activities for developing dexterous---multi functional---prosthetic hands, most commercial electric powered prosthetic hands are limited to single active function systems. Such commercial prosthetic hand users, however, have abilities to perform various daily or work related activities effectively, when their prostheses are appropriately fitted.

Control methods of the commercial prosthetic hands were categorized into three distinct generations by a previous work [1]; first generation used an on-off switch type control scheme for hand motor activation. Second generation hands have ability to adjust thresholds for motor activation, and proportional controllability of motor speed was provided in this generation. In the third generation, control options can be modified easily, because they utilize programmable microprocessors. Even in the third generation or proportional control systems, motor activation is based on the threshold of controller input signal; therefore, appropriate adjustment of the threshold, or an amplifier gain in a myoelectric sensor, is a significant issue for high-performance uses of the prosthetic hand, which may leads to high acceptance ratio of myoelectric hand prostheses.

Performance of prosthetic hand use is also affected by clinical training: myoelectric signal training, control training and functional training. [2] Our target is the control training stage, in which both of ability to control remnant muscles and socket-sensor fitting have effects on myoelectric control; and therefore, it is crucial for clinicians to evaluate performance in this stage.

Such performance can be evaluated in terms of basic and functional operation ability; the functional ability is measured by various methods, such as a required period or quality of task completion with the hand prosthesis. [3][4] The basic operation ability relates to how the user can control the hand open-close function as they intend to, and this is affected by the adjustment of the threshold or the amplifier gain.

## METHODS

Figure 1 shows a configuration diagram of the measuring system, which consists of a personal computer (PC), a MyoBoy® (Otto bock HealthCare) and two myoelectric sensors. Two software tools---a “Switching Evaluation Tool” and a “COM Wrapper”---are installed on the PC. The first tool was developed to measure basic operation performance of a human-machine interface device (HID). The second tool receives data sets from the MyoBoy® and produces HID events--- keyboard inputs or mouse button clicks---that are used by the measuring tool.

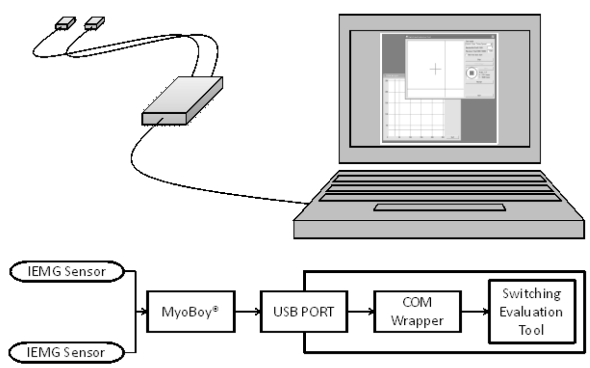


Figure 1: A measuring system configuration diagram.

### COM Wrapper

Figure 2 shows a window image of the COM Wrapper operation. The COM Wrapper reads a COM-port of the PC to obtain output data patterns from the MyoBoy®. Received data patterns are plotted on a two-dimensional graph as shown in Figure 2. There are two levels of thresholds for each axis. These thresholds correspond to the thresholds for the myoelectric prosthetic hand activation; when the myoelectric sensor output voltage exceeds one of the lower thresholds, the hand motor begins to rotate. (Note that the higher thresholds are used for ‘four-channel’ mode of MyoBock® system, and the higher thresholds are not used in this paper.) In a same way, the COM wrapper produces HID events that are used by the measurement tool. The HID events for these thresholds are defined by a configuration file.

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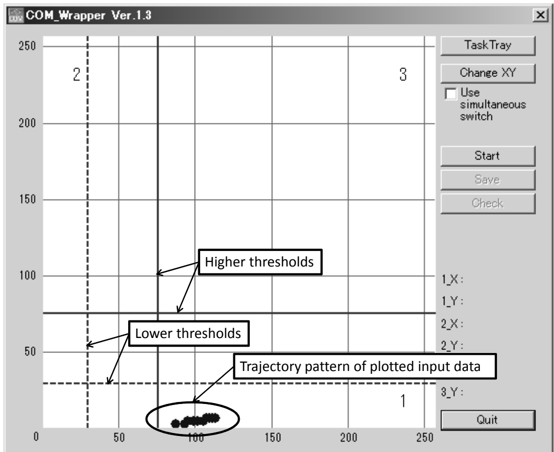


Figure 2: An example of a window image of the COM Wrapper operation.

<u>Switching Evaluation Tool</u>

Developments of the "Switching Evaluation Tool" started in 2006, in order to conduct engineering evaluations of a general purpose myoelectric switch interface. [5] The tool is an application program running on a Windows™ (Microsoft Corporation) operating system.

An external switch interface device, which translates switch operation into HID events, is required to measure switch operation ability, but in this paper, the COM Wrapper deals with this function.

This tool evaluates operation ability of switch-type interface in terms of 'Quickness', 'Timing controllability' and 'Sustainability', as listed below.

1. Quickness

   ① Switch Close Delay: Response time for a switch closure.

   ② Switch Open Delay: Response time for a switch opening.

   ③ Switch Repetition Time: Required period for switch close-open repetitions. The number of repetition time is defined by a configuration file. The default number is ten.

   ④ Switch Repetition Time (2ch): The 'Switch Repetition Time' with two switches alternation.

2. Timing Controllability

   ① Switch Close Timing Spread: Variation in switch close timings.

   ② Switch Open Timing Spread: Variation in switch open timings.

   ③ Switch Repetition Timing: Variation in close-open repetition timings. The number of repetition time is defined by a configuration file. The default number is ten.

   ④ Switch Repetition Timing (2ch): The 'Switch Repetition Timing' with two switches alternation.

3. Sustainability

   ① Switch Endurance Period: Time period for sustaining switch closure.

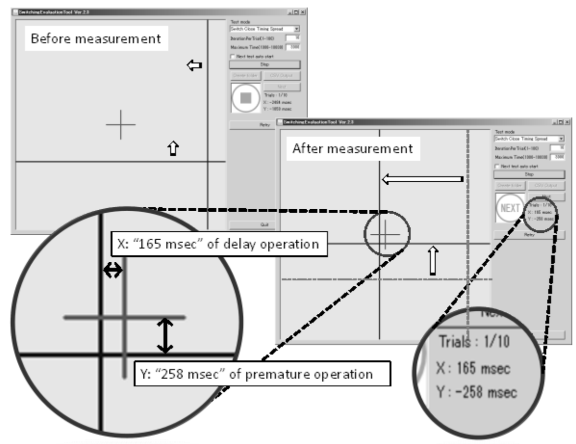


Figure 3: An example of the measurement of the timing controllability with the switching evaluation tool.

Figure 3 shows an example of a measurement with the switching evaluation tool. The tool window consists of two areas, a measuring area (left) and an operation area (right). In the measuring area, there are a target cross-shape at the centre, a vertical line and a horizontal line. The operator is asked to align both vertical and horizontal lines to overlap the centre of the cross-shape.

The operation procedure is similar to that of a claw vending machine or a toy crane machine. The example in Figure 3 shows a measurement of the "Switch Close Timing Spread", where we can estimate switch operation timing controllability from distances between the target cross-shape and the vertical or horizontal line.

These lines initially locate at arbitrary distance from the centre, as shown in a left panel of Figure 3. When output voltage of the myoelectric sensor exceeds the threshold, the COM Wrapper sends the corresponding HID command to the measuring tool, and one of the lines begins to move toward the centre. The operator can relax after the line movement started. Then the operator needs to predict the timing when the line reaches to the centre, and to contract the muscle again, in order to stop the line movement. In the case of measuring the "Switch Open Timing Spread", the operator requires to continue muscle contraction during the line movement, and to relax the muscle for stopping the line motion.

Measurements for the "Switch Close Delay" or "Switch Open Delay" proceed in a similar way, but the line motion are hidden before the line reaches the centre, and therefore, the operator cannot predict line motion, as shown in Figure 4. When the line reaches the centre and the operator finds the line movement, the operator needs to stop line movement. Reaction time can be calculated from the distance of lines and the target cross-shape.

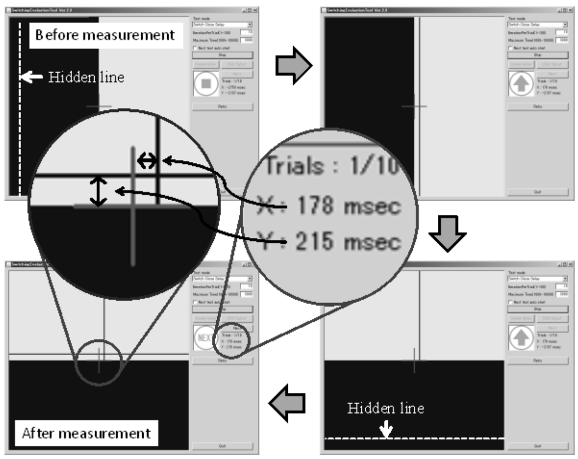


Figure 4: An example of the measurement of the response times with the switching evaluation tool.

By using this tool, we have conducted measurements to a muscular dystrophy patient group and sound volunteer participants through 2008-2009. In these measurements, we used mechanical switches and the myoelectric switch; results indicate that the response time of the muscular dystrophy group tends to increase, and the myoelectric switch shows shorter response time than mechanical switches. [6]

## RESULTS

Participants for this preliminary study are a user of a forearm prosthetic hand (MyoBock® digital hand) and a user of an upper arm prosthetic arm (hybrid system of a MyoBock® DMC hand and a cable control elbow). Both of the participants have over five-year prosthetic use experience, and written informed consents and agreement of a local ethics review board was obtained prior to the measurements. We measured "Switch Close Delay" and "Switch Close Timing Spread" for both participants, and "Switch Open Delay" and "Switch Open Timing Spread" were obtained only from the second participant.

Figure 5 and 6 shows measured data pattern distribution for switch closures and switch openings, where X-axis is results for response time and Y-axis for timing controllability. Each plot is the average of twenty-time repetition. In these graphs, "HAND_A" and "HAND_B" represent the first and second participants; "inner" and "outer" are sensor locations on the remnant part of the limb. "Non-disabled volunteer Group" and "Muscular dystrophy Group" are results with mechanical switches from previous research projects. These results show that the participants for this preliminary study show high response speed and high timing controllability, and there are no considerable differences in response speeds between myoelectric hand users and the non-disabled volunteer group.

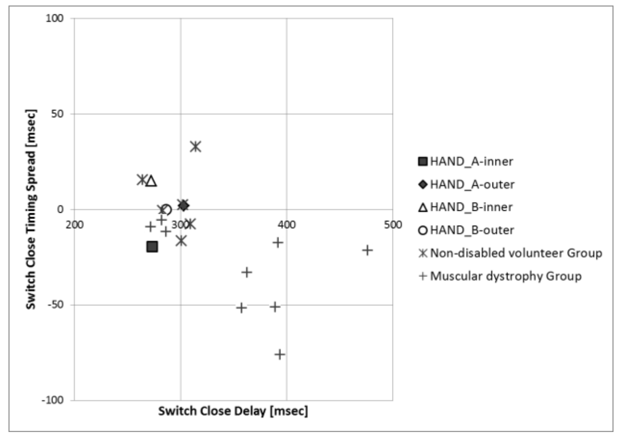


Figure 5: Measured data distribution of switch closures.

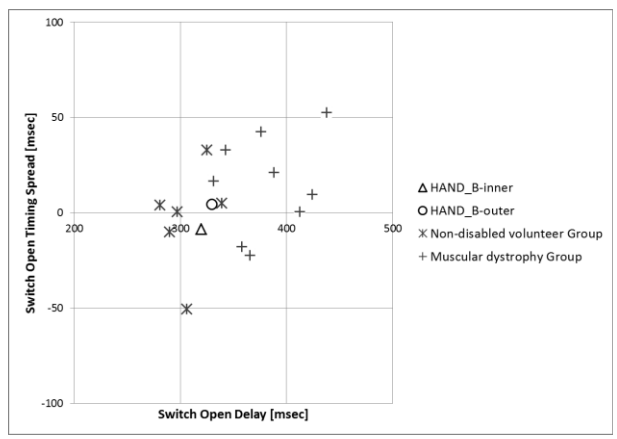


Figure 6: Measured data distribution of switch openings.


Figure 7: Distribution diagram of output data patterns of the MyoBoy®.

The reason why we did not measure "Switch Open Delay" and "Switch Open Timing Spread" for the first participant is that he is the user of the digital hand system. Figure 7 shows an example of a distribution diagram for output data patterns from the MyoBoy® for both of the participants. It is clear that the distribution range for the HAND_A (digital hand user) is smaller than that for the HAND_B (DMC hand user). In the case of the digital system; when the myoelectric sensor output exceeds the lower threshold, the hand motor is activated with a constant speed. Therefore, the user does not need high myoelectric sensor output and this makes difficult for the digital hand user to keep high signal intensity, which are required for measuring the "Switch Open Delay" and "Switch Open Timing Spread".

## DISCUSSION AND FUTURE WORKS

This report introduced a measuring tool for basic operation abilities of myoelectric prosthetic hands. Results indicate that the participants for these preliminary measurements have high response speed and high timing controllability, and we believe that these factors have much impact on satisfaction or acceptance ratio.

From the results in Figure 5 and 6, some participants in the muscular dystrophy group showed long response times (400 or 500 milliseconds); but even with such long response times, they showed better timing controllability than we expected. This means that they compensate the response delay by using higher brain function of prediction. It is possible that this is not the case for the muscular dystrophy patients group but the prosthetic hand user group. When prosthetic user candidates have long response time; even if they can operate the prostheses well, they may feel mental burden to use their prostheses.

This preliminary study is limited to the measurements of two myoelectric hand users, and both of the users have long experience of the prosthetic use. It is required to make further measurements for prosthetic hand users and other patients. These tools are distributed at some hospitals in Japan from this year, and we believe that the tools support their daily activities.

## ACKNOWLEDGEMENTS

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