Discrimination of Forearm Motions with Physical Deformation of Muscles and EMG

Takashi Yukawa and Takeo Iida

Faculty of Science and Engineering, Ritsumeikan University
1-1-1 Nojihigashi, Kusatu, Shiga, 525-8577, Japan

The purpose of the present study is to evaluate the basic upper-limb involved in products manipulation. Upper-limb muscular deformations and electromyography (EMG) measurements are used as indexes for estimated motion: hand opening and closing, wrist extending and flexing, pronation and supination, grasping conditions. Measured values are analyzed by multivariate analysis and a regression equation is obtained for estimating the characteristics of upper-limb performance. Muscular deformation is defined as a change in shape, such as a protrusion or depression on the skin surface. The pressure sensors attached to the measurement points detect pressure changes when the hand or wrist moves. Hand opening and closing can be discriminated at a higher percentage of accuracy by muscular deformation data than by EMG data. Muscular deformation measurements using air-pack pressure sensors were verified to be effective in motion estimation applications.

Keyword: EMG, pressure sensor, muscular deformation

1. Introduction

In daily life, humans manipulate a large variety of products. For example, we steer cars and motorbikes, open and close bottle caps, and light gas heaters. We generally manipulate these products using specific parts of our upper-limbs, such as wrists and fingers. To make products safer and easier to use, it is necessary to quantify upper-limb motion during products manipulation in order to evaluate the adaptability of products to manipulation.

The purpose of the present study is to evaluate the basic upper-limb involved in products manipulation: hand opening and closing, wrist extending and flexing, pronation and supination, grasping conditions. To estimate the basic upper-limb performance, physical muscular deformation and electromyography (EMG) measurements are used as indexes. Measured data are analyzed by multivariate analysis and a regression equation is obtained for estimating the characteristics of upper-limb performance.

In the present study, EMG and muscular deformations reflecting muscle action are measured in order to determine whether upper-limb performance can be estimated from the measured values. Thus, basic reference data is obtained for the estimation of upper-limb operations.

2. Experimental Method

In this study, contact pressure sensors for measuring muscular deformations and electrodes for measuring EMG were attached to various measurement points on the upper-arm. (Fig.1)

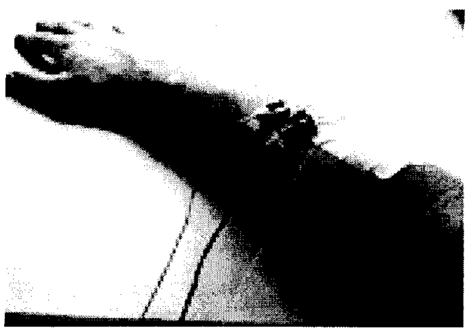

Fig.1 EMG and pressure sensor measurement

Muscular deformation is defined as a change in shape, such as a protrusion or depression on the skin surface, when the hand or wrist moves. The pressure sensors attached to the measurement points detect pressure changes when the hand or wrist moves. The amount of pressure change is related to the degree of deformation. The master unit of the air-pack contact pressure measurement system transmits the pressure from a contact pressure sensor as a voltage of 100 mV/kPa. The data is recorded by a data collector. The test subjects were five male college students, and were measured 20 times about the action at three-second intervals.

3. Experiment 1: (hand opening or closing; extending or flexing)

The first experiment measured hand opening and closing, and wrist extending and flexing as a basic hand motion. The extensor-carpi-radialis and flexor -carpi-radialis were selected as measurement points. Discriminant functions are derived from the discriminant analysis of each measured value. The graphs show the results of the motion of the extensor-carpi-radialis with respect to both EMG and pressure sensor measurements in one of the five subjects.

1) EMG measurement

Fig.2 shows the integral-electromyogram (IEMG) of the extensor-carpi-radialis when the wrist is extending or flexing. The vertical axis represents the three-second integral value and the horizontal axis represents the number of repetitions.

2) Pressure sensor measurement

Different from the data of EMG, the measuring output of pressure sensor is continuous. The vertical axis represents pressure (V) and the horizontal axis represents time. A change in pressure indicates muscular deformation at the measurement points. The graphs obtained here show certain sections sampled from continuous measurement data. Fig.3 shows pressure changes at the extensor–carpi-radialis when the wrist is extending or flexing. The extensor-carpi-radialis showed large excursions in extension and depressions in flexion.

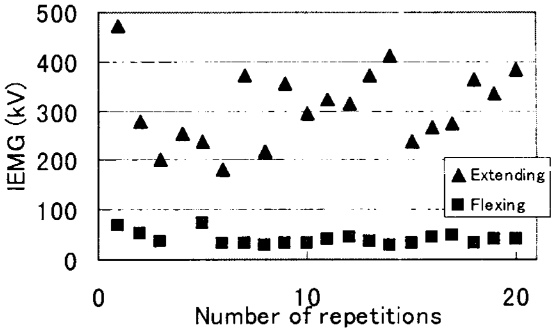

Fig.2 Hand extending or flexing in EMG measurement

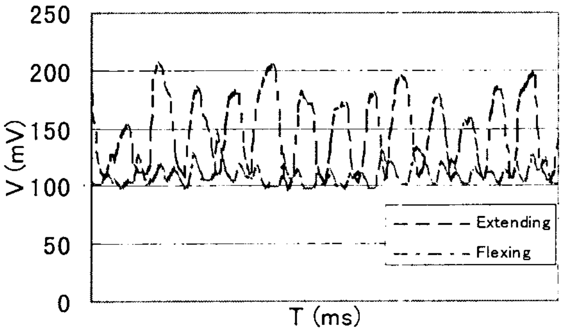

Fig.3 Hand extending or flexing in pressure sensor

3) Discriminant analysis

To verify the effectiveness of EMG and muscular deformation as discriminant indexes, discriminant functions were derived from the values in each measurement graph by discriminant analysis. By assigning 40 IEMG values of the extensor-carpi-radialis for wrist extensions and flexions to X1 and 40 IEMG values of the flexor-carpi-radialis to X2, the discriminant regression equation for predicting Y (extension or flexion) is as follows:

$$Y = -0.4106 + 0.0055X1 - 0.0099X2$$

In this relation, $Y \geqq 0$ indicates extension and $Y < 0$ indicates flexion. The pressure change (balance between the maximum and minimum values) is used instead of IEMG when analyzing pressure sensor measurement.

The discriminant average from EMG measurement between hand closing and opening was found to be as high as 77.5% after discriminant analysis. However, pressure sensor measurement showed almost 100% between wrist extension and flexion and between hand opening and closing. Tab.1 shows results of the discrimination in each measurement conditions.

Tab.1 Results of the discrimination

Measurements	Conditions	Discriminant average
EMG	Opening or Closing	77.5%
	Extending or Flexing	100%
Sensors	Opening or Closing	100%
	Extending or Flexing	100%

4. Experiment 2: (hand grasping conditions and pronation or supination)

Hand pronation and supination and hand grasping conditions were analyzed. Hand pronation and supination measurement points were the biceps-brachii and extensor-carpi-ulnaris. The analysis of hand grasping conditions involved the subject grasping to fit around cylinders of 40, 60, and 90 mm diameter (Fig.6). The measurement points were the extensor–carpi-radialis and flexor - carpi-radialis.

As in Experiment 1, the discrimination between muscle motions was studied using the measurement indexes. Hand pronation or supination and hand grasping conditions were discriminated from the measured values by multiple regression analysis. The graphs show the results of both measurements from one of the five subjects.

1) Hand pronation and supination

While the hand pronation or supination, a three-second IEMG and changes in pressure for pressure sensor from each measurement points were obtained.

Fig.4 shows the IEMG of the biceps-brachii when the hands pronation and supination. The biceps-brachii showed a large output in supination. Fig.5 shows the pressure changes at the biceps - brachii when the hand is pronated or supinated. The biceps-brachii exhibited large excursions in supination, and the extensor-carpi-ulnaris showed depressions in pronation. According to the results of discriminant analysis, the coefficient of correlation is 0.97 for EMG measurement and 0.99 for pressure sensor measurement. This demonstrates that discriminant average is close to 100% for both types of measurements.

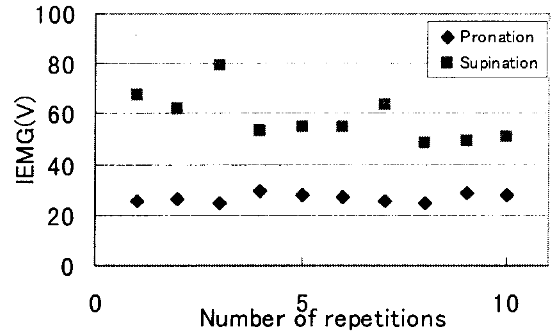

Fig.4 Hand pronation or supination in EMG measurement

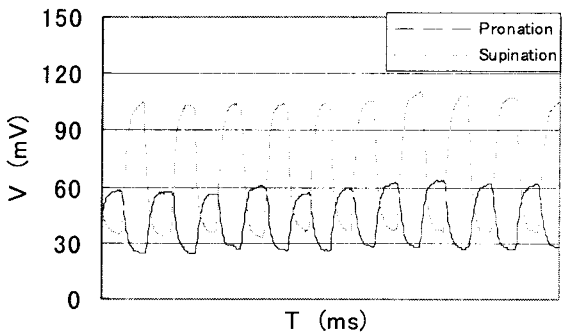

Fig.5 Hand pronation or supination in pressure measurement

2) Hand grasping conditions

A three-second IEMG value was obtained from each measurement points for EMG measurements together with a pressure increase for pressure sensor measurement while the hand was fitted around cylinders of three different diameters.

Fig.7 shows the results of multiple regression analysis of the EMG measurement data. The correlation coefficient is 0.56. Since the IEMG did not show significant differences due to cylinder diameter, the actual diameters and predicted values are not in good agreement. Fig.8 shows the results of multiple regression analysis of the pressure sensor measurement data. The correlation coefficient is 0.97. Different from in EMG measurement, the actual diameters and predicted values are in good agreement.

In this experiment, the subjects did not behave actively, as they did in Experiment 1, but instead behaved passively. Since the subject only fit the hand around a cylinder presented to the hand, the muscle motions were passive. This is probably why muscle activity potentials became too weak to measure in the experiment. However, although the muscle motions were passive, the contact pressure sensors detected the changes because the muscle diameters changed.

5. Conclusions and the Future

In this study, basic hand muscle motion was measured in terms of EMG and muscular deformation, and approximated by multivariate analysis. Consequently, the following reference data was obtained to help estimate upper-limb motions:

1) Hand extending and flexing, and pronation and supination can be estimated from the indexes of EMG and muscular deformation.

2) Muscular deformation may become an effective index for estimating the phased hand grasping conditions.

3) Hand opening and closing can be discriminated at a higher percentage of accuracy by muscular deformation data than by EMG data.

4) Muscular deformation measurements using air-pack pressure sensors were verified to be effective in motion estimation applications.

However, the above data is insufficient with regard to the objective of this study, which was to clarify upper-limb motions related to the products manipulation. Therefore, measurement parts and methods will be reviewed in an attempt to obtain a more accurate estimation of upper-limb motion during the manipulation of products.

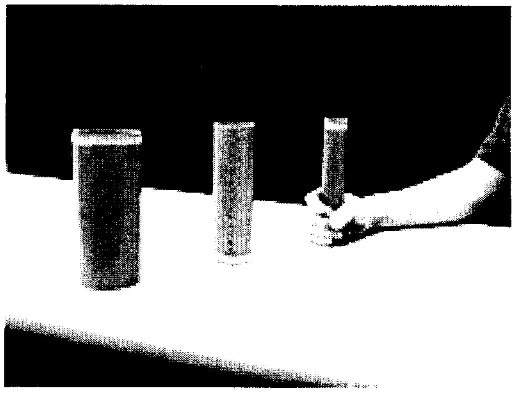

Fig.6 Hand grasping conditions measurement

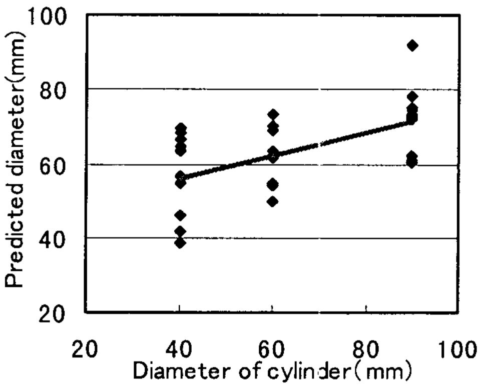

Fig.7 Correlation between predicted diameter and diameter of cylinder (EMG)

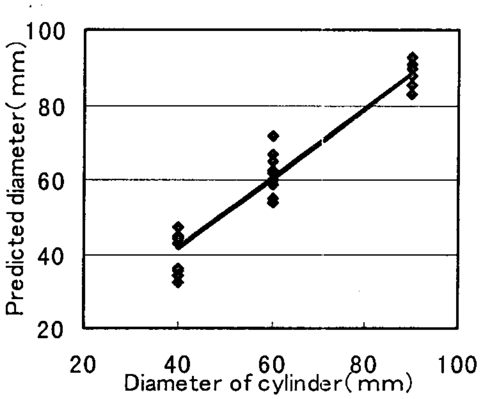

Fig.8 Correlation between predicted diameter and diameter of cylinder (pressure sensor)

6. References

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