論文

# The Establishment of Growing Stage Recognition Method by Wireless Wearable Acceleration Sensors and Support Vector Machine for the Movement Education and Therapy

Hidetaka OHSAKI　Keisuke SUWA

Recognition of handicapped person's movement ability with a quantitative underpinning is an important work for the movement education and therapy. This paper aims to establish an automatic human movement recognition system which is equipped with acceleration sensor nodes with built-in Bluetooth and a support vector machine. This paper compares several motion recognition methods by a new sensor network utilizing multiple acceleration sensor nodes. The recognition system is applied to measure the movement of the multi-handicapped persons and able-bodied persons. The acceleration data are measured and the movement is analyzed. An angular variability type log from the acceleration log is introduced, then each data can be recognized by applying a support vector machine. The evaluation in the differences from measured data of each subject is described. Support vector machine by the partial distance kernel can recognize a sensor data on the wrist of three classes with the precision of 85% in the range from 50% to 90% training data ratio.

Keywords: Acceleration Sensor, Support Vector Machine, Machine Learning, Bluetooth, Sensor Network, Movement Education and Therapy

## 1　Introduction

We have been studying a "ubiquitous network system" based on an acceleration sensor node to support a human life. The goal of this study is the automatic recognition of the case of the disable person with a handicapped in movement by utilizing the system equipped with acceleration sensor nodes built-in Bluetooth and a support vector machine. The system are adopted to a hoop movement in a rehabilitation menu. The acceleration sensor node measures person's joint range of motion. The support vector machine read the person's joint range of motion and recognizes three classes of physical ability. Traditional methods assessed classes of physical ability with visual or VTR. The advantage of this system is shown as follows:

* Devices are freely-movable.
* The user can share the recognition criterion with a remote place user.
* Sensor data supply classification with a quantitative underpinning.

A fieldwork of a circle of movement education and therapy is conducted. The recognition system measured multi-handicapped persons and able-bodied persons respectively and recognized the feature data. This paper decided a data extraction procedure and data recognize procedure.

We shall try to establish causal connections between paucity of available training data and recognition performance degradation. The selection of the kernels of support vector machine and the selection of a fixing point of sensor nodes on the body play a critical role in establishing. The candidate fixing points are "Wrist Only" and "Wrist & Upper Arm". The candidate Kernels are "Polynomial Kernels" and "Partial Distance Kernels". We evaluate the different Kernels and fixing points combinations. As a result, the trials revealed that the combination of "Wrist

OHSAKI Hidetaka
2008 Master of Graduate School of Environmental and Information Studies, Musashi Institute of Technology
SUWA Keisuke
Professor at the Graduate School of Environmental and Information Studies, Tokyo City University

Only" and "Partial Distance Kernels" is the best combination. The efficacy of percentage of training data in the recognition of three classes of physical ability is clarified.

## 2 Research Approach

This paper selects measurement devices and recognition algorithm for realize an automatically physical ability recognize system. The characteristics of the hoop movement and line up candidates of sensor nodes fixing points are studied. The recognition system can measure the acceleration data of multi-handicapped persons or able-bodied persons when a person is playing hoop movement. The featured data from the acceleration sensor nodes log should be extracted.

The main discussion shall try to recognize physical ability of multi-handicapped persons from the featured data. This paper clarifies the relationship between training data and recognition performance degradation.

## 3 Measuring Device and Machine Learning

### 3．1 Bluetooth-Compatible Acceleration Sensor Node

The WAA-001is utilized to measure the movement [1]. The WAA-001 is a wireless three-axis acceleration sensor node shown as in Fig 1.

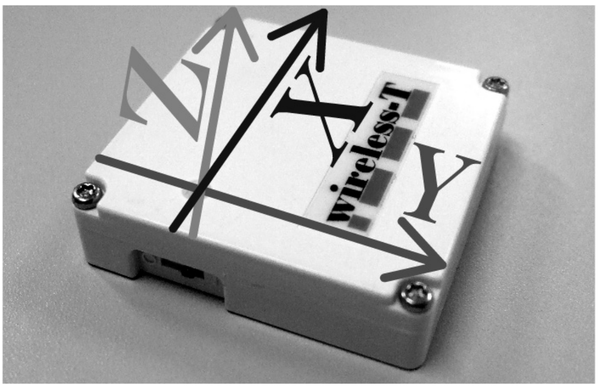



Fig 1 The Outline of the WAA-001

The sensor node has a Bluetooth module for transmission acceleration sensor log. The receiver computer can communicate seven sensor nodes at a same time. Always the sensor in the node measure acceleration of gravity. Therefore, the user can measure angle of fixing point with the sensor nodes. We use the sensor node for measure person's joint range of motion with the WAA-001. Fig 2 shows a three-axis acceleration diagram with the WAA-001.

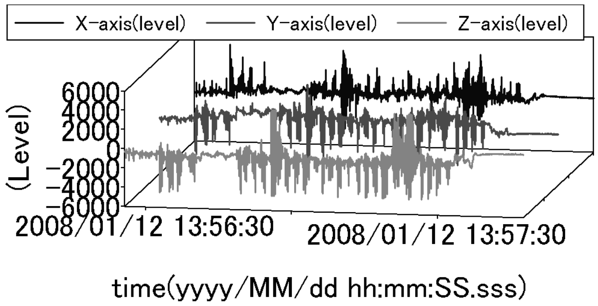



Fig 2 Three-Axis Acceleration Log of the WAA-001

### 3．2 Support Vector Machine

Support Vector Machine (SVM) is a kind of binary supervised machine learning. A machine leaning is a kind of algorithm of an artificial intelligence. SVM learns how to distinguish an element of a set from an element of a complement with input data vector. A training data is a pair label of correct answer with feature data. SVM recognizes an element of a set and element of a complement using minimal training data. The input data vector is an n-dimensional space called feature vector or feature data. A kernel is a kind of SVM component. A characteristic of recognition with SVM vary with the kernels. For example, some kernels have tolerance for noise.

The kemba-svm1-ts-070802win is applied in this study as SVM application [2]. Fig 3 shows execution example of the application.

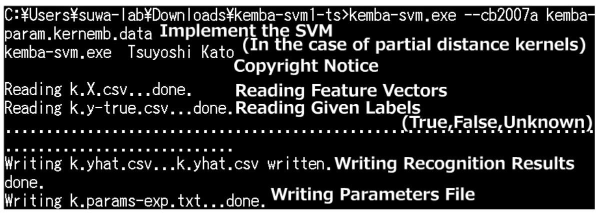



Fig 3 Execution Example of the SVM Application

## 4 Movement Education and Therapy

### 4．1 Outline of Movement Education and Therapy

The movement education and therapy is a kind of education program for multi-handicapped persons advocated by Marianne Frostig [3]. This program assists the development of multi-handicapped persons with play equipment and assistance [4]. The assistant needs to get a handle on object person's physical ability.

### 4．2 Hoop Movement

Hoop movement is a kind of movement education and therapy [5]. A hoop is comfortable to grip. Using this behavior, the assistant promotes hand and arm exercise for handicapped person. This movement is a kind of range of motion exercise. Fig 4 shows specific steps of the exercise. Joint range of motion affects handicapped person's quality of life. A motion model figure of joint in the exercise is shown in Fig 5. The motion in the hoop movement is created from a collaboration of a wrist and an upper arm with bending of an elbow. The measurement instrument needs to measure individual a wrist and an upper arm.

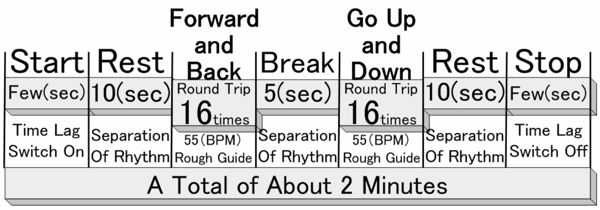
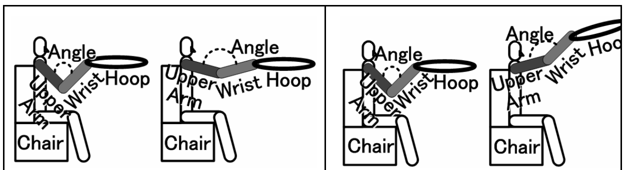



Fig 4 Steps of Hoop Movement




Forward and Back Movement | Go Up and Down Movement

Fig 5 Motion Model of the Hoop Movement

## 5 System Structure

### 5．1 Purpose of the Present System

The research aims to construct the system which recognizes automatically the hoop movement player's physical ability by means of a wireless sensor nodes and a SVM. The system uses a three-grade evaluation. The three-grade evaluation follows in the wake of traditional qualitative assessment for handicapped person's physical ability. Fig 6 is a network diagram of this study. Bluetooth-compatible acceleration sensor nodes measure object person's movement. A personal computer recognizes physical ability of the person with acceleration sensor log.

The user can adjust numbers of wearable sensor node. The personal computer fills both roles as a Bluetooth-compatible sensor data receiver and a recognition processor with SVM. The system can distribute acceleration sensor log, specification of SVM and result of recognition by the Internet. As a result, a user can share the recognition criterion with a user in a remote place each other.

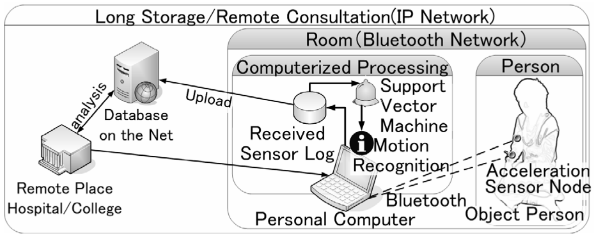



Fig 6 Network Configuration

### 5．2 Implementation

The measurement and recognition in a movement education and therapy circle with the present system are executed. Fig 7 depicts a measurement and recognition system.

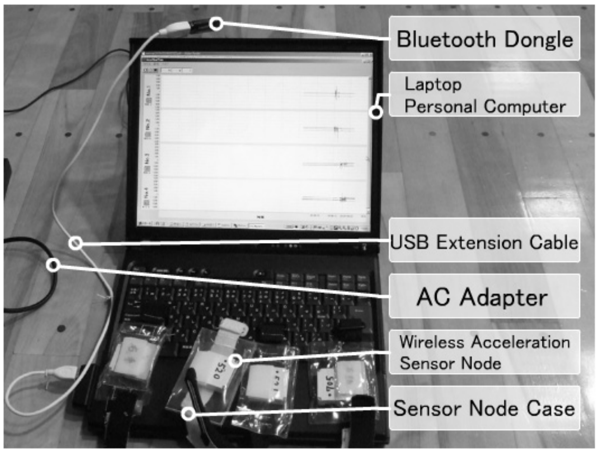



Fig 7 Measurement and Recognition System

Table 1 and 2 are the specification of present system. An object person wears sensor nodes at the wrist and upper arm with belt on the body.

Table 1 Specification of Personal Computer

| | |
|---|---|
| Type of Machine | ThinkPad T40 |
| Operating System | Windows 2000 |
| Bluetooth Utility | BlueSoleil 2.3.0.0 |
| Sensor Node Application | AccelRealTime Version 1.0.4 |
| Support Vector Machine | Kemba-svml-ts-070802win |

**Table 2 Specification of Acceleration Sensor Node**

| | |
|---|---|
| Type of Machine | WAA-001 |
| Maximum Range of Measurement (G) | ±3 |
| Minimum Unit of Measurement (mG) | 8.8 |
| Sampling Frequency (cycle/sec) | 100 |

## 6 Measurement and Recognition Results

### 6．1 Measurement Acceleration Data

The measurement for three classes' persons in the movement circle is carried out. Table 3 is an attributes sheet of object persons. Fig 8 is a picture of segment shot in the measurement.

**Table 3 Object Persons Attributes**

| Class | Ability of Hoop Movement (age) | Number of People (person) | Number of Times (times) |
|---|---|---|---|
| G1 | Dislikes Type Handicapped Person (8,20) | 2 | 4 |
| G2 | Likes Type Handicapped Person (15,21) | 2 | 8 |
| G3 | Able-Bodied Person (21,29) | 3 | 8 |

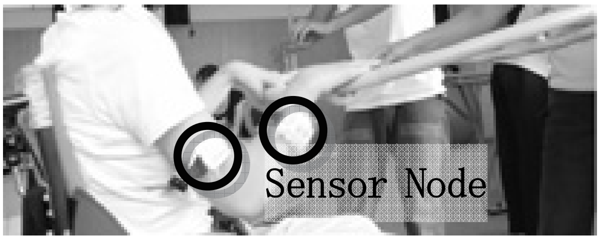



Fig 8 Nodes are measuring the "G2" object person

### 6．2 Measurement Results

We convert Y-axis acceleration data of log into angle data. Fig 9 shows an angle data of "G1" object person on a wrist. "G1" data is characterized by a low amplitude and an irregular rhythm. Fig 10 shows the angle data of "G3" object person on a wrist. "G3" data is characterized by high-amplitude waveform and rhythmical. Both figures have a flat wave of break between two amplitude patterns respectively.

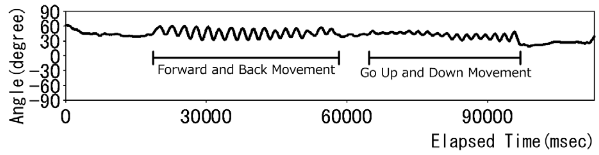



Fig 9 Angle Data of the "G1" Object Person on a Wrist

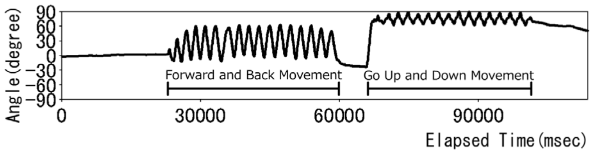



Fig 10 Angle Data of the "G3" Object Person on a Wrist

### 6．3 Recognition Joint Range of Motion Data

The representative values from each angle data are extracted. The representative values are maximum value, third quartile point, median, second quartile point and minimum value from all angle data of each motion. Fig 11, Fig 12, Fig 13 and Fig 14 show the representative values. Each representative values means objective person's joint range of motion.

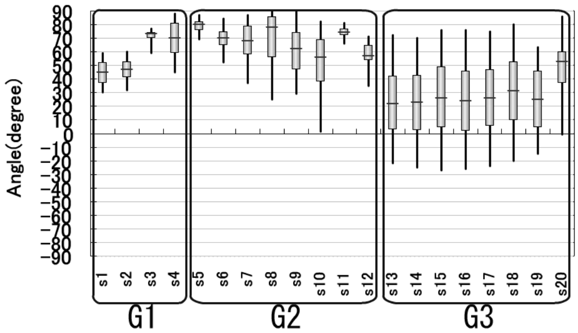



Fig 11 Angle Data of Forward and Back on a Wrist

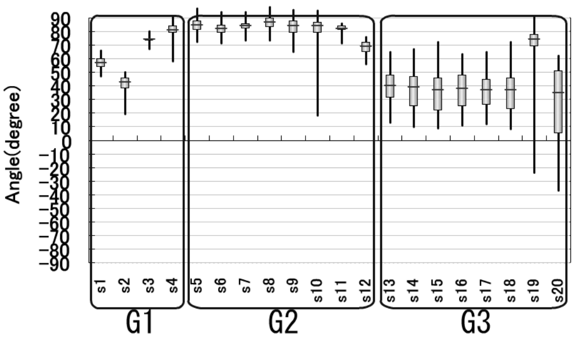



Fig 12 Angle Data of Go Up and Down on a Wrist

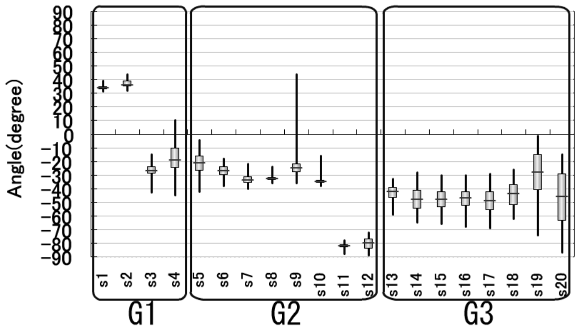



Fig 13 Angle Data of Forward and Back on an Upper Arm

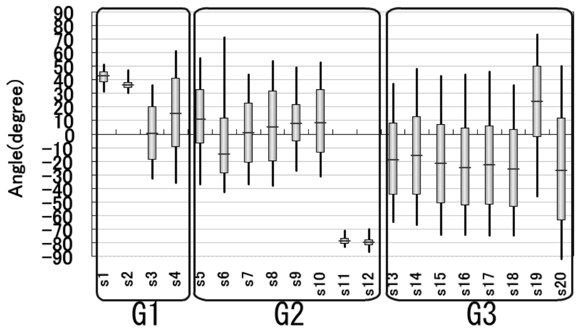



Fig 14 Angle Data of Go Up and Down on an Upper Arm

The SVM on the present system is a binary recognition machine. Therefore, the system needs to recognize with SVM in twice for three-grade evaluation. Fig 15 is a flow chart of classification steps for three-grade evaluation. Each recognition step uses all feature data.

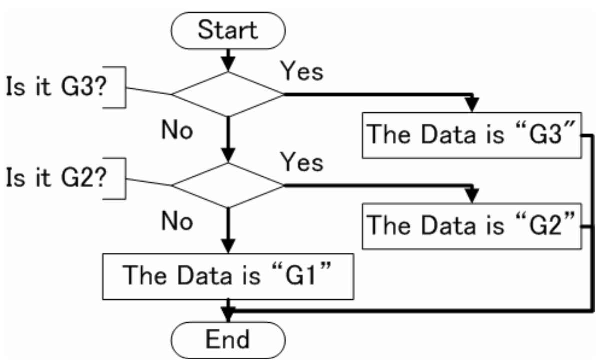



Fig 15 Steps for Three-Grade Evaluation

## 6．4 Result of Recognition

A correct answer in terms of classification between fact and the system output is defined. Training data must be saved because a sampling training data is an operational cost. Shortages of training data for SVM are posing susceptibility to noise. The research shows an effect of percentage of training data on percentage of correct answer. Percentage of training data represents the proportion of number of training data to number of input feature data. Percentage of correct answer represents the proportion of number of correct answer to number of output recognition result data and contains the number of learning outcome with training data. The experiments excluded an alternative of "Upper Arm Only" based on prior experiments. Polynomial Kernel is a popular kernel of SVM. Partial Distance Kernel is perceived as a noise tolerance kernel. The experiments are performed for those SVM respectively.

Fig 16 shows the result of "G3" recognition based on the procedure shown in Fig 15. There is little difference in two options of sensor node fixing point. Therefore, the present figure excluded an alternative of "Wrist & Upper Arm" with the intention to saving of calculation. Fig 17 depicts the result of the three-grade evaluation based on the procedure in Fig 15. Support vector machine with the partial distance kernel can recognizes sensor data on the wrist of three classes with the precision of 85% in range from 50% to 90% training data ratio. The "Partial Distance Kernels, Wrist Only" series is 5% points higher than the "Polynomial Kernels, Wrist Only" series in an identical percentage of training data.

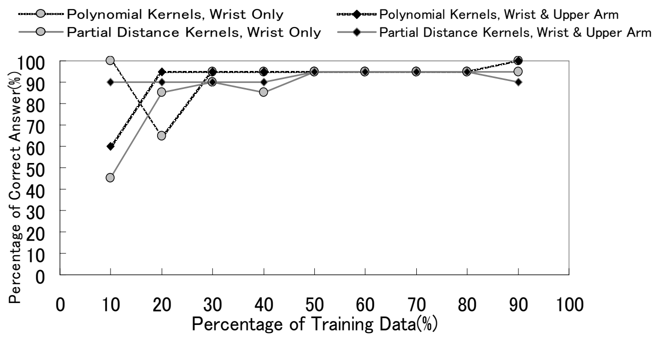



Fig 16 Result of the "G3" Recognition

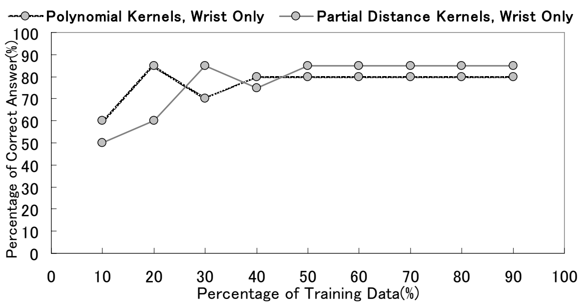



Fig 17 Result of the Three-Grade Evaluation

### 6．5 Discussion

As shown in the Fig 17, the method of combine Partial Distance Kernels with a feature data with a sensor node on a wrist can recognize three classes of target people's physical ability with 85% precision in range from 50% to 90% percentage of training data. Based on the results, we have concluded that the system can recognize handicapped person's physical ability.

The percentage of correct answer with each series is precarious in from 10% to 40% percentage of training data. The shortages of training data destabilize recognition performance of the system.

We can clarify that automatic physical ability recognition system for the movement education and therapy with wearable wireless acceleration sensor node and support vector machine is feasible.

In the future work, we must consider the performance of a system equipped with a many-valued support vector machine.

## 7 Conclusions

An automatic recognition system with a wearable wireless acceleration sensor node and support vector machine has several advantages including portability of equipment, remote sharing the recognition criterion and verifiability with quantitative data.

This paper shows a network diagram for the recognition with Bluetooth-compatible sensor and an application of support vector machine.

The joint range of motion in hoop movement up off of the movement education and therapy for a handicapped person is clarified. We focus the movement on a wrist and upper arm in hoop movement.

An algorithm for classification of handicapped person's physical ability with three-grade evaluation is proposed.

Through the field-test of the present recognition system in a movement education and therapy circle, the representative values are obtained. The proposed recognition system tried to physical ability classification with the feature data. The present study considered options of sensor node fixing point and options of Kernels for SVM.

The proposed system with the partial distance kernel can recognize a sensor data on the wrist of three classes with the precision of 85% in the range from 50% to 90% training data ratio.

## Acknowledgments

We would like to thank the considerable assistance of the movement circle "Andante" for through the work.

## References

[1] Wireless Technologies Co., Ltd., "Wireless Acceleration Sensor Model: WAA-001 Manual(Ver. 2.1.0 2006.9.20)" (in Japanese), Wireless Technologies Co., Ltd., 2006.9

[2] Tsuyoshi Kato, "Support Vector Machine, kemba-svm.exe", http://www.net-machine.net/~kato/kemba-svm1-ts/index.html , 2007.7

[3] Marianne Frostig, translator: Yoshifumi Kobayashi, "MOVEMENT EDUCATION: THEORY and PRACTICE" (in Japanese Version), Nihon Bunka Kagakusha Co., Ltd., p6, 2007.6

[4] Keiko Ohsaki, Yoshiyasu Arai, "Case studies of movement method put into practice for family support: through profile of MEPA-2 during 17 years" (in Japanese), Nihon Jidou Gakkai, Jidou Kenkyu ,87,2008,pp.21-29,2008

[5] editor: Yoshifumi Kobayashi, "Support guide for movement therapy "(in Japanese), Nihon Bunka Kagakusha Co., Ltd., p10, 2006.2