Daigo Aikawa, Yasutaka Asai and Hironori Egi: A Method to Estimate Interest of Learner Based on Leg Condition,
The 18th International Conference on Information Technology Based Higher Education and Training (ITHET2019), No.127, pp.1-6, 2019.9
(Magdeburg, Germany)

A Method to Estimate Interest of Learner Based on Leg Condition

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***Abstract*—In this paper, we propose a method to estimate a learner ' s interest from the condition and motion of the legs. To properly support learning activities, it is important that a teacher grasps the learner's situation. Efficient learning can be achieved when the learner progresses toward the goal based on his or her interest level. However, in a class with a large number of learners, it is difficult for the teachers to grasp the situation of all the learners. A teacher ' s proficiency is necessary to grasp the situation from the learner's response in the class. To solve this problem, we developed a device to measure the leg condition of the learner. Furthermore, we investigated the learner's leg condition and the degree of interest using this device. As a result, it was revealed that there was a significant correlation between the number of changes in the leg condition and levels of understanding, difficulty, and concentration.**

***Index Terms*—Interest Estimation, Leg Posture, Leg Condition, Behavior Sensing, Teaching and Learning Support System**

I. Introduction

In this study, we proposed an estimation system of interest levels based on the leg condition and designed and developed a device to measure the leg condition of a learner.

It is important that teachers grasp learner's conditions in a class. As a model of the motivation to learn, Keller [1] proposed the ARCS model. The ARCS model consists of the four elements: Attention, Relevance, Confidence, Satisfaction. This model asserts that classes should be able to stimulate learners' curiosity and to motivate them. Mind wandering is a phenomenon in which attention shifts from a task being carried out to other internal thinking. It is considered to increase as time progresses and thus inhibits learning [2] [3]. Therefore, it is important to grasp learner's degree of interest, such as paying attention to the contents of the learning and feeling the relevance. The teachers are expected to proceed with the lecture according to the degree of the interest. It is possible to avoid the occurrence of mind wandering and promote highly effective learning. However, in large-scale classes, such as university lectures, it is difficult to grasp the condition of each learner. Although it is possible for the teacher to roughly grasp the condition by observing the learner's reaction, such actions require the teacher's proficiency, making it challenging for teachers who have little teaching experience. The feedback method can be introduced as a class evaluation questionnaire. But such a method requires learners' active expression. Moreover, it cannot necessarily grasp the condition of all the learners.

This work has been partly supported by the Grants-in-Aid for Scientific Research (No. JP18K02911 and JP19H01710) by MEXT (Ministry of Education, Culture, Sports, Science and Technology) in Japan.

The purpose of this research is to develop a system that supports communication by estimating the level of interest of multiple learners. To estimate the level of interest with little influence on the learners, we focus on the learner's leg condition. The leg condition classification is created in advance. To automatically estimate the degree of interest through the leg condition, we design a leg condition measurement device which uses photo reflectors. Using the developed device, we verify whether the leg condition can be measured correctly by acquiring the data of the contact position of the foot at the time of sitting. In addition, the validity of the design of the leg state measurement device is examined. Finally, the relationship between the learner's leg condition and degree of interest is clarified.

II. Related Works

The research study on the relationship between physical movement and interest and the research study on the condition estimation of learners are considered.

A. Physical Movement and Mental State

Bull investigated the relationship between posture and subjective mental state [4]. The subjects sat in a chair and watched videos on eight topics for 5 min. The content of the videos varied, with some being interesting and some tedious. The subjects' postures were taken using a hidden video camera. After watching the videos, the subjects rated and ranked the eight topics. The results of the experiment showed that there was a significant correlation between the degree on the interest of the topics and several leg postures, as well as other upper body postures. Specifically, correlations between interest and the action of pulling back the leg and between boredom and the the action of extending the leg were reported. From these results, it is considered that there is a relationship between unconscious body movement and subjective mental state. It is possible to estimate the mental state, such as the degree of interest, by measuring the leg state while sitting. However, since the study of Bull does not target learners, it is inappropriate the results to our study.

B. Estimation of Student ' s Condition

Zaletelj used Kinect to record the learner's actions during the lecture and acquired data on body direction and gaze point

features [5]. Zaletelj proposed a machine learning model that estimates the learner's attention level based on the obtained features. It is necessary to shoot the face of the learners to estimate his or her state based on the feature extraction of the images. This kind of situation has a large influence on the learner and may inhibit learning.

III. Interest Estimation Based on Leg Condition

In this study, we considered an approach of measuring the leg movement and estimating the learner's situation while minimizing the influence on the learner's mental state, avoiding the inhibit of learning. We focused on the leg as a measurable part of the body without affecting the learners as much as possible. By installing a sensor array on the floor and measuring the leg condition of the learner, it is considered that data measurement and state estimation can be performed in the same environment as the normal learning environment. In the situation where learners are learning toward the desk while sitting, the sensors installed on the floor cannot be seen by them. Therefore, the influence on the learning activity is considered to be small. Furthermore, we designed and developed a leg condition measurement device that can measure the leg condition of the learner in a natural way and proposed a method that can be used to estimate the system interest level.

Before developing the system, leg posture classifications were created. The leg posture classification tree is shown in Figure 1. Using the leg posture classification tree, we investigated and classified the kind of leg posture the actual learner executed, and we recorded the learner's situation in the class using a camera. The topic of the class was learning sciences offered in an interdisciplinary department of a university. We visually classified the leg posture of each learner from the recorded video. As a result, the type of leg posture and the standard deviation of the number of transitions were huge as well as the individual differences. In general, looking at the leg posture classification, it was possible to classify in the classification tree of the leg posture which is 98 % or more of the whole time. From this result, it is considered that leg posture classification is generally appropriate. Also, periodic movements, such as the so-called shaking leg, were hardly performed. Thus, periodic movements were excluded from the classification, not the target of the detection of the leg condition measurement device.

To measure and detect classified leg states, we designed and developed a leg condition measurement device. Using the developed leg state measurement device, we verified whether it is possible to determine the leg posture and examine the validity of the design of the leg condition measurement device. In addition, using a leg condition measurement device, we measured the leg condition of the learner who was watching a lecture video and verified the relationship between the leg condition and degree of interest.

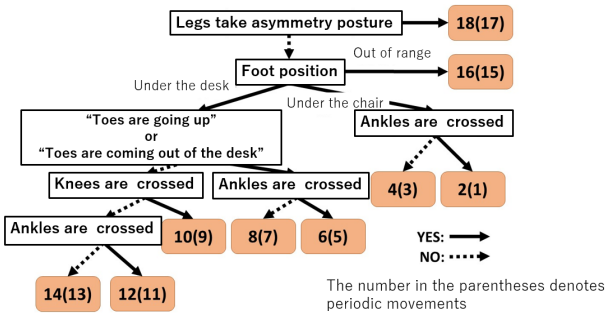

Fig. 1. The leg posture classification tree

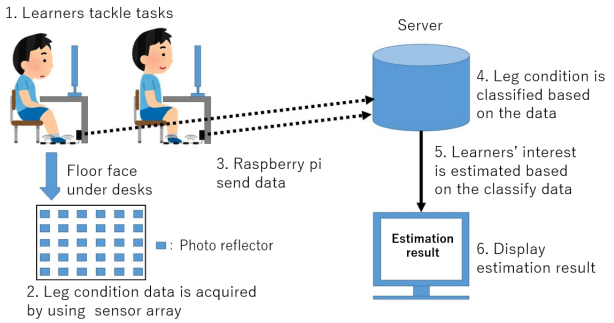

Fig. 2. Configuration of interest level estimation system

IV. Design and Development of Leg Condition Measurement Device

To reduce the influence on the learner and make it possible to perform activities in the same environment as possible, we developed a non-contact type leg condition measurement device that can be installed on the floor, making it invisible to the students during learning. In addition, the presence of the leg condition measurement device is unlikely to affect learning because there is little opportunity to look at the feet while learning.

The flow of the interest level estimation system proposed in this research is shown in Figure 2. The learner performed a learning activity by putting a foot on a leg condition measurement device installed on the floor. The device has multiple photo reflectors installed at regular intervals. The device measures the position and size of the contact surface of the foot. The photo reflectors are controlled by single-board computers (Raspberry Pi). The acquired data from the photo reflectors is sent to the server. The server determines the leg condition from the transmitted foot data. The degree of interest is estimated from the learner's leg condition data.

For data measurement of the learner's leg condition, a photo reflector (QTR-1RC made by Pololu) is chosen. The object detection distance of the photo reflectors is less than 5 mm. Figure 3 shows an overview of the created leg condition measurement device. The size of the leg condition measurement device is 900 mm in width, 1200 mm in depth, and 47 mm in height. It is designed on the assumption that a learning desk

Fig. 3. Leg condition measurement device

is attached a chair. The size of the learning desk is 800 mm in width, 500 mm in depth, and 700 mm in height. The size of the chair is 450 mm in seating height of and 500 mm in width, with fixed legs. The wooden bases are piled up in a box and the photo reflectors are installed inside at fixed intervals. The distance between the photo reflectors is determined based on the foot size measurement business report published by the Japan Leather Industry Association. The smallest width of the foot is considered to be the width of the heel. Since the minimum value in the data on the width of the ridge was 49 mm, the contact distance of the photo reflector was 40 mm.

A breadboard, integrated circuits, and wiring for connection were stored under the left and right wooden bases of the acrylic board. In order to prevent the photo reflectors placed on the pedestal from being broken by the load of the foot, the detection of the ground contact surface of the foot by the photo reflectors is performed while passing through the 2 mm thick acrylic board. There are a total of 176 photo reflectors, 16 horizontally and 11 vertically below the desk. The integrated circuit (MCP 23017) was used to control multiple sensors using Raspberry Pi.

The program was executed on Raspberry Pi to read the value of the photo reflectors at a frequency of once every 2s and save it as a comma-separated values file together with the data of the current date and time.

TABLE I
THE HEIGHT AND FOOT SIZE OF SUBJECTS

subject	foot size(cm)	height(cm)
A	27.0	173
B	27.5	169
C	27.5	168
D	25.5	174
E	26.0	173

Fig. 4. The arrangement of the desk and chair during the experiment

V. EVALUATION EXPERIMENT

An experiment was conducted to evaluate whether the developed leg condition measurement device could correctly detect the leg posture. The subjects were five undergraduate and graduate students of a science and technology university who agreed to measure the leg condition. The height and foot size of each of the five subjects are shown in Table I. Figure 4 shows the arrangement of the desk and chair during the experiment.

The subjects took off their shoes, wore socks, and sat down on the chair on which the leg condition measurement device was installed. Two experiments were conducted. After obtaining the consent of the subject, all situations of the experiment were recorded using a video camera.

A. Measurement Experiment for Each Leg Posture Classification

The subjects were presented with pictures of the leg condition according to the leg posture classification. The measurement was performed for 20 s, three times in each leg posture. Table II shows the condition of the legs taken by the subject. Since the classification number of the leg condition classification was defined, including the periodic movements, the odd classification number was excluded.

The subjects were asked to keep their postures as natural and comfortable as possible. If they could not execute the leg posture presented due to reasons such as body pain in, they were asked to perform the leg posture within a reasonable range.

TABLE II
MEASUREMENT OF EACH LEG POSTURE CLASSIFICATION

Posture number	Posture
2	Pulled and crossed in knee
4	Pulled
6	Extended and crossed in ankle
8	Extended
10	Crossed in knee
12	Crossed in ankle
14	Standard posture

TABLE III
LECTURE VIDEOS

Number	Play time	Lecture title
1	0:09:12	Change of body with aging
2	0:08:22	Relationship between muscle loss and disease
3	0:12:19	Muscle synthesis by protein intake
4	0:09:05	Protein intake and muscle mass in the elderly
5	0:09:28	Resistance exercise and muscle synthesis
6	0:10:47	Health effects of resistance exercise

B. Leg Posture Measurement During Learning

To investigate the relationship between the leg condition and the degree of interest, subjects watched a lecture video on health while sitting on a chair. The video was "Science of muscle training" of Week 1 in "practice of exercise for health promotion and nutrition intake". The video was offered at gacco,[1] which is an online university course site as a lecture video taught by Prof. Minoru Fujita at the Department of Sports and Health Science, Ritsumeikan University. The reason for selecting the lecture video is that the topic can be related to any person and is interesting.

Before watching the lecture video, subjects were told to watch the lecture video with full concentration as a confirmation test will be taken right after. The position of the chair was adjusted to the landing position of the foot just under the desk when sitting in posture 14 (standard posture 14) in the leg state classification. After that, the lecture video was played on the display in front of the subjects and their leg conditions ware recorded. The lecture video is composed of six short lecture clips, with a duration of around 10 min. The subjects were asked to watch these six videos continuously. The contents of the lecture video and the playback time are shown in Table III. While the subjects ware watching the lecture video, the experimenter left the room so as not to affect the learning.

After watching the lecture video, a confirmation test was conducted. For the confirmation test, we prepared a total of 12 questions for each content, which can be answered with True or False. The subjects answered the confirmation test questions which were randomly rearranged for each content, and during that time, data on the leg condition was obtained.

After the confirmation test, we conducted an evaluation questionnaire. All the questions are answered by five Likert-scale ("5: Strongly agree," "4: Agree," "3: Neither," "2: Disagree," and"1: Strongly disagree") for each content of the lecture video. There were a total of 60 questions (10 questions each for the 6 contents). The questions are shown in Table IV.

[1]http://gacco.org/

TABLE IV
QUESTION ABOUT EACH CONTENT OF LECTURE VIDEO

Question number	Question
1(comprehension)	I was able to understand the content
2(difficulty)	I felt that the content was difficult
3	There was prior knowledge about the content
4(concentration)	I was able to watch the video intensively
5	The video was eye-catching
6	The content stimulated curiosity
7	I did not feel bored while watching
8	I felt the meaning of understanding the content
9	The video was useful for me
10	The content feels familiar to me

TABLE V
THE AVERAGE NUMBER OF RESPONSES OF THE PHOTO REFLECTORS AND THE AVERAGE VALUE OF THE COORDINATES OF THE PHOTO REFLECTORS

Leg posture	Number of respondents	X-coordinates average	Y-coordinates average
Standard	14.5	7.5	6.3
Ankle crossing	6.0	7.7	5.0
Knee crossing	8.2	6.8	5.1
Extending	6.3	7.4	2.9
Extending, ankle crossing	2.1	7.8	2.5
Pulling, ankle crossing	0.0	0.0	0.0
Pulling	0.2	8.0	10.0

For questions about the lecture video, questions 1 to 3 relate to the contents of the lecture video to confirm the level of understanding. Question 4 asks about the concentration when watching the lecture video. Questions 5 to 10 are the subdivision of Attention and Relevance in the ARCS model.

VI. EXPERIMENTAL RESULT

A. Measurement of Each Leg Condition Classification

To specify the position of the photo reflectors, the front and back direction of the leg measurement device is taken as the X-axis and the left and right direction as the Y-axis. The coordinates with the left corner of the opposite side viewed from the learner as the origin are defined. Table V shows the average number of responses of the photo reflectors in each subject's leg posture and the average value of the coordinates of the photo reflectors that responded.

The experimental data of the subjects shown for each subject tended to be almost the same. The number of responses of the photo reflectors was the largest in the standard posture, and the number of responses decreased in the order of the crossed knee posture (posture 10) and the crossed ankle position (posture 12). The Y-coordinate became smaller when the legs were extended (postures 6 and 8). When the ankle was crossed with the leg extended (posture 6), there were cases where the number of responses decreased, and cases where no change was observed. This was due to the fact that when the leg was extended, there were subjects that touched with only heels and those that touched with whole foot on the device. In addition, there were cases where no photo reflector responded when in

TABLE VI
CORRELATION BETWEEN QUESTIONNAIRE RESPONSE AND LEG CONDITION DATA

Question	Data	Correlation coefficient	p-value
1	Number of change / min	-0.53	0.003
1	Total amount of change / min	-0.48	0.007
1	Naximum stopping time	0.46	0.009
2	Number of change / min	0.53	0.003
4	Number of change / min	-0.52	0.003
4	Maximum stopping time	0.46	0.011

contact only with the heels. When the foot was pulled out (postures 2 and 4), the foot came out of the installation area of the photo reflectors in most subjects. Therefore, regardless of whether or not the ankle was folded in most cases of these postures, the number of responses was 0.

B. Leg Condition Measurement During Learning

At the start of the watching the lecture video, the legs of the subjects hardly moved. However, the number of changes in the leg posture increased as time passed, and there were timings where times when the total number of changes increased. The frequency of change in the leg posture varied widely among subjects. No significant change was found in the X-coordinate average and Y-coordinate average, except for subject A, who frequently changed his or her leg posture.

Based on the responses of the photo reflectors, while the subjects were watching the lecture video, they were found to execute the standard leg posture (posture 14) as the home position. All subjects had almost the same feet position, except for one.

Next, Spearman's rank correlation coefficient was calculated for the questionnaire responses for each content of the lecture video and the leg condition data for each content of the video for each subject. The results are shown in Table VI.

Question No. 1 asked about the degree of understanding of the lecture video contents. Question No. 2 asked about the difficulty of the lecture video. Question No. 4 asked whether the lecture video was viewed intensively. Thus, it is clear that there is a negative correlation between comprehension and the number of changes per minute and total amount of change, and between concentration and the number of changes per minute. In addition, it is revealed that there is a positive correlation between comprehension and the maximum stopping time, between difficulty and the number of changes per minute, end between concentration and the maximum stopping time.

VII. DISCUSSION

A. Measurement of Each Leg Condition Classification

From the results of this experiment, it can be easily seen that the number of photo reflector responses decreases when the legs are crossed compared with when the legs are in the standard posture. When the legs are extended, the average value of the Y-coordinate decreases. Thus, it seems possible to determine the leg condition by setting simple threshold values. However, if only the heels touch the device, the photo reflectors may not respond depending on the position. The subject watching the lecture video might execute postures in which only the lateral side of the foot is touching the device. When the foot is pulled down, it touches the ares which is beyond the range of the the photo reflectors are installed. Therefore, it could not be determined by using only photo reflectors when the foot is pulled under the chair. Although not seen in this experiment, it is also impossible to assume the action such as a floating posture which does not touch the device. However, it is considered difficult to cope with various leg conditions by using only photo reflectors.

B. Leg Condition Measurement During Learning

This experiment elucidated that the leg condition is related to comprehension of and concentration on the content and its difficulty. These results support previous research studies, and estimating the degree of concentration by measuring changes in leg conditions seems possible. Although the correlation is somewhat strong, it is considered that the tendency of the leg conditions to differ depends on the subject. The condition of the leg and frequency of change may significantly differ.

There was no significant correlation between the question and leg condition based on the subclasses of Attention and Relevance in the ARCS model. It is considered that setting the theme about health for learning contents caused the correlation not seen. Health-related topics are considered to be relevant and interesting to everyone. Thus, it is possible that the results of the questionnaire were biased toward the higher evaluation, and no significant correlation was found.

Although a previous research suggests that the actions of pulling and extending the foot have strong correlation with being interested and bored, the average of the Y-coordinate related to bending and extending of the foot did not change much throughout the experiment. One of the reasons is that the confirmation test was announced before the lecture video was watched. As the subjects knew that a confirmation test would be conducted right after, they may have seriously watched the lecture video and continued to watch the lecture video in a posture near the standard posture. Also, the theme was highly relevant for all subjects. Hence, they did not extend their legs, which would have been a sign of boredom. Furthermore, since the leg condition measurement device restricts the chair movement only to backward and forward, there is a possibility that the subject could not relax and freely execute the leg posture.

VIII. CONCLUSION

In this study, we developed and evaluated a leg condition measuring device using photo reflectors to estimate the learner's degree of interest based on the leg condition. The leg condition measurement device detects the contact between the learner's foot and device and records the changes in the leg posture every 2 s. An experiment was performed to measure the leg condition of university students using the created leg condition measurement device.

Thus, it was found that although it was possible to determine the leg posture to a certain extent, it was difficult to detect some leg states, and it was necessary to use other types of sensors in combination. In addition, it was revealed that there is a significant correlation between the number of changes and amount of change per minute of the leg condition and the maximum stopping time, the degree of understanding of the content, the difficulty of the content, and the concentration while watching.

As a future study the leg condition measurement device is expected to improve. Since it is difficult to detect and measure a specific leg posture using only photo reflectors, it is necessary to use another sensor, such as a laser distance sensor. In addition, since the condition of the legs is different among individuals and the tendency could not be grasped completely because of a small number of data, it is necessary to continue the experiment and collect more data.

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