Using motion sensors to support seating and positioning assessments of individuals with neurological disorders

Yu Iwasaki\textsuperscript{a,}\textsuperscript{*}, Tetsuya Hirotomi\textsuperscript{a}

\textsuperscript{a}Interdisciplinary Graduate School of Science and Engineering, Shimane University, 1060 Nishikawatsu-cyo, Matsue 690-8504, Japan

Abstract

Appropriate postural control can inhibit involuntary movements caused by neurological disorders. Physical and occupational therapists assess individuals with neurological disorders for recommending seating and positioning settings. This paper presents a system to support the therapists by providing acceleration, angular velocity, activity logs and video clips of touch panel operations. The system was used for assessing ten individuals. Root-mean-square values of acceleration and angular velocity of eight body sites reached 83.7\% and 74.4\% agreement with therapists’ ratings of involuntary movements. Therapists suggested that the data obtained from the system was satisfactory in accuracy and useful for confirming their decisions.

Keywords: Involuntary movement; Seating; Positioning; Motion sensor; Acceleration; Angular Velocity

1. Introduction

Individuals with disabilities often use a variety of assistive technologies (ATs) to improve their quality of life. In the International Classification of Functioning, Disability, and Health (ICF)\textsuperscript{1}, ATs are considered as one of the environmental factors to achieve higher performance in “activity” and “participation.” For example, an individual with complex communication needs uses a tablet computer as an AT to visualise messages and generate speech in conversation\textsuperscript{2,3,4}. Abnormal muscle tone, reflexes and uncoordinated movements caused by neurological disorders limit the use of ATs. Seating and positioning facilitating appropriate postural control can inhibit such involuntary movements\textsuperscript{5}. This means that appropriate settings of seating and positioning can be considered as a prerequisite to “activity” and “participation.”

Physical and occupational therapists assess individuals for the purpose of recommending the settings. This process requires systematic consideration of multifaceted factors: physical skills, sensory skills, cognitive/behaviour skills and functional skills, as well as the needs of the individuals, family members and caregivers\textsuperscript{6}. However, in most cases, it relies on interpreting observations based on the therapists’ professional experience and knowledge. The accuracy

\textsuperscript{*} Corresponding author. Tel.: +81-852-32-6480; fax: +81-852-32-6480.
E-mail address: s149801@matsu.shimane-u.ac.jp
and reliability of the process, particularly for inexperienced therapists, can be enhanced by the use of videography. Computerised tests and instrumental motion analyses are also useful to collect quantitative data, for example, the time taken to perform a task (time-on-task) and the number of errors.

We believe that combining qualitative and quantitative data can provide a much more detailed and complete picture of individuals. The aim of this research is to develop a system to support therapists those who conduct seating and positioning assessments by providing a variety of data. Our system records video clips and activity logs of touch panel operations. It also measures acceleration and angular velocity of several body sites to which portable motion sensors are attached. These data are analysed and presented from multiple views. In our previous studies, we proposed root-mean-square (RMS) values of acceleration as a quantitative measure for involuntary movements. In some cases, gravity makes it difficult to measure the actual acceleration of motions, especially when changing inclinations. That is why this system also analyses RMS values of angular velocity. The proposed system was evaluated through seating and positioning assessments of ten individuals with neurological disorders in cooperation with physical and occupational therapists in clinical settings. The results suggested that the data obtained from the system was satisfactory in accuracy and useful for confirming the therapists' decisions.

The rest of the paper is organised as follows. In the next section, related work are presented. In Section 3, a brief overview of our assessment support system are described. In Sections 4 and 5, the experimental user studies are discussed. Section 6 is a conclusion.

2. Related work

In rehabilitation, camera based motion capture devices, electromyographs, and motion sensors have been used to motivate patients and remedy their exercise when practicing the specific motion by presenting visual and auditory feedback to the patients. Motion sensors are rather easy to use in clinical settings because they are non-invasive, portable and low-cost. For example, accelerometers have been used to analyse the smoothness of reaching motion, detect the severity of Levodopa-induced dyskinesia and discriminate therapy tasks in combination with electromyography. Gyro sensors have been used to evaluate finger tap motion and gait.

These studies were focusing on quantifying motion at a specific body site. However, involuntary movement while conducting a specific task often appears at other body sites. Our proposed system analyses acceleration and angular velocity of several body sites and the results of the analysis are presented to therapists from multiple views for supporting their assessments.

3. Seating and positioning assessment support system

Fig. 1 shows an overview of the seating and positioning assessment support system, which comprises “motor performance test module,” “motion-recording module,” and “motion analysis and presentation module.”

3.1. Motor performance test module

This module examines motor performance of individuals with neurological disorders by touch panel operations. Firstly, therapists select a symbol set taking into account the patient’s preference. Each symbol has an image and its caption. It can also have a sound file to play after speech synthesis of its caption. In our user study discussed in Section 4, the dynamic and resizable open picture symbols (Drops) were mainly used as shown in Fig. 1. Secondly, therapists input the number of rows and columns for arranging buttons on the operation panel by reflecting the patient’s capability. After completing these configurations, the start panel is presented. The patient has to press the start button positioned at centre. After releasing the start button, the screen changes to the operation panel. This panel has a set of buttons with symbols. One of the buttons are highlighted and the patient has to press it. Once the patient released the highlighted button, the screen changes to an enlargement and speech panel. The symbol from the highlighted button is enlarged and its caption is spoken. Three seconds after the completion of the speech, the screen returned to the start panel. In the test, the patient repeatedly touch all the buttons on the screen. This module records activity logs including the time of the touch event, the event type (press or release), the coordinates of the event, and the highlighted button’s id. The activity logs are sent to the motion analysis and presentation module.
3.2. Motion-recording module

This module records motions while conducting the test by using video cameras and portable motion sensors. Four video cameras record from the following directions: the patient’s upper- and lower-bodies from front, dominant-hand by side and the tablet screen from rear. The eight motion sensors (Microstone Inc., MVP-RF8-GC-500), each contains an accelerometer and gyro sensor, and the measurement ranges of each sensor are $\pm 60$ m/s$^2$ and $\pm 500$ deg/s. As shown in Fig. 2, these sensors are attached to the forehead (head), thoracic vertebra 7 (trunk), the central part of the humerus of the dominant-hand (shoulder), cubitus of the dominant-hand, dorsum manus of both hands and the left and right ankles. The therapists decided the attachment positions where involuntary movements often occurred and confirmed that the sensors did not interfere with the patient’s movement. Motion data (acceleration and angular velocity) are recorded by Bluetooth communication and two PCs using a special software (Microstone Inc., MVP-RF-S). The measurement cycle are set at 2 ms. Three wireless synchronisation event markers (Microstone Inc., MVP-RFTRG-BNC/RF8-04/1CH) are also used. The first event marker connects the four motion sensors. The second connects another four. The third connects tablet executing the motor performance test module through a special adapter. Four LEDs of the adapter blink at receiving the synchronous signal from the event marker. The video cameras record these lights. Other devices record the synchronous signal in their data. Acceleration, angular velocity, and video data with the synchronous signal are sent to the motion analysis and presentation module. In the current implementation, the beginning of video data until the synchronous signal should be trimmed manually before sending.
3.3. Motion analysis and presentation module

This module synchronises and segments motion data and video data, calculates RMS values of acceleration and angular velocity and presents videos, waveforms and heat maps of the data. The motion data, video data and activity logs are synchronised by the use of a recorded signal from the event markers. After that, data were segmented using activity logs. This module performs segmentation from when the patient released the start button until when he/she released the highlighted button. Segmented data were calculated for all buttons operated by the patient.

From the segmented data, this module calculates RMS values for every body site. For example, the x-axis acceleration and angular velocity of a specific body site when touching a button on the l-th row and m-th column are calculated using the following formulas:

\[
RMS_{Ax(l,m)} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (Ax_{l,m,i} - M_{Ax(l,m)})^2}, \quad RMS_{\omega x(l,m)} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \omega x_{l,m,i}^2}
\]

where \( N \) is the number of data measured while the operation, \( Ax_{l,m,i} \) and \( \omega x_{l,m,i} \) are i-th x-axis acceleration and angular velocity of the body site, and \( M_{Ax(l,m)} \) is a median of \( \{Ax_{l,m,1}, Ax_{l,m,2}, \cdots, Ax_{l,m,N}\} \). In calculating the RMS of acceleration, the median is subtracted to minimize the effect of gravity.

After the synchronisation and segmentation, as well as RMS calculation, the data obtained from motor performance module and motion recording module are presented to the therapists from multiple views. “Heat map view” is for understanding spatial characteristics of touch panel operations. The colour of each rectangle represents the RMS value of acceleration or angular velocity at a specific body site when touching a button located there. These values are classified into five grades; “serious” is defined as an RMS value of more than the 95th percentile for all operation buttons, “severe” is defined as an RMS value of more than the 75th percentile and less than the 95th percentile, “substantial” is defined as an RMS value of more than the 25th percentile and less than the 75th percentile, “slight” is defined as an RMS value of more than the 5th percentile and less than the 25th percentile, and “normal” is defined as an RMS value of the 5th percentile or less. If therapists find the concerned area, they can drilldown to “waveform view” and/or “video view.” The waveform view displays the waveform of acceleration or angular velocity measured at the corresponding body site in the segment. The x-axis represents the time and the y-axis represents the motion data. The time bar shows current time in video clips displayed by the video view. The video view plays the four synchronised video clips, showing one clip per camera in each segment. In this module, a variety of views were implemented to present motion and other data, including time-on-task and the number of errors, in the form of heat map, box-plot, etc.

4. User studies

We conducted user studies of the seating and positioning assessment support system in cooperation with therapists and their patients. They were in the process of being subjected to the assessment for the use of tablet computers. The aim of the user studies were to examine the accuracy and usefulness of the system through the examination in real
Table 1. Demographic data of patients and experience of therapists

<table>
<thead>
<tr>
<th>ID</th>
<th>Sex</th>
<th>Age</th>
<th>Diseases</th>
<th>GMFCS</th>
<th>MAT</th>
<th>Number of rows</th>
<th>Number of columns</th>
<th>Experience of therapists</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Male</td>
<td>9</td>
<td>Cerebral palsy</td>
<td>IV</td>
<td>23</td>
<td>12</td>
<td>4</td>
<td>36/211 96/115</td>
</tr>
<tr>
<td>S2</td>
<td>Male</td>
<td>9</td>
<td>Pelizaeus-Merzbacher disease</td>
<td>IV</td>
<td>20</td>
<td>16</td>
<td>5</td>
<td>7/114 7/198</td>
</tr>
<tr>
<td>S3</td>
<td>Male</td>
<td>10</td>
<td>Cerebral palsy</td>
<td>IV</td>
<td>6</td>
<td>12</td>
<td>5</td>
<td>43/187 76/199</td>
</tr>
<tr>
<td>S4</td>
<td>Male</td>
<td>16</td>
<td>Cerebral palsy</td>
<td>IV</td>
<td>58</td>
<td>20</td>
<td>5</td>
<td>16/163 108/115</td>
</tr>
<tr>
<td>S5</td>
<td>Female</td>
<td>17</td>
<td>Cerebral palsy</td>
<td>II</td>
<td>20</td>
<td>21</td>
<td>5</td>
<td>43/187 19/115</td>
</tr>
<tr>
<td>S6</td>
<td>Male</td>
<td>8</td>
<td>Cerebral palsy</td>
<td>IV</td>
<td>31</td>
<td>6</td>
<td>5</td>
<td>48/163 48/223</td>
</tr>
<tr>
<td>S7</td>
<td>Female</td>
<td>15</td>
<td>Cerebral palsy</td>
<td>IV</td>
<td>61</td>
<td>56</td>
<td>5</td>
<td>43/187 24/72</td>
</tr>
<tr>
<td>S8</td>
<td>Male</td>
<td>14</td>
<td>Sequelae of cerebral infarction, nontraumatic subdural haemorrhage, quadriplegia and epilepsy</td>
<td>IV</td>
<td>3</td>
<td>29</td>
<td>4</td>
<td>8/20 8/68</td>
</tr>
<tr>
<td>S9</td>
<td>Female</td>
<td>11</td>
<td>Cerebral palsy</td>
<td>II</td>
<td>61</td>
<td>58</td>
<td>5</td>
<td>18/212 69/118</td>
</tr>
<tr>
<td>S10</td>
<td>Male</td>
<td>11</td>
<td>Unknown (spastic paraplegia)</td>
<td>V</td>
<td>12</td>
<td>14</td>
<td>5</td>
<td>39/212 39/104</td>
</tr>
</tbody>
</table>

*a Dominant-hand is underlined.
*b Experience of working with the patient/experience of working as a professional therapist.

clinical context, as well as to elicit the requirements of therapists regarding the system. The studies consisted of the following two parts: motor performance tests and unstructured group interviews. The test part was conducted from October 22, 2013 to December 13, 2013. The interview part was conducted from March 3, 2014 to March 18, 2014.

4.1. Participants

The participants of our studies were ten patients (seven males and three females) with neurological disorders and their therapists. We explained the gist of the study to all patients and informed consent was obtained from them or their legal representatives.

Table 1 shows the demographic data of the patients and experience of their therapists. The mean age of the patient was 12.0 years (SD 3.2). Gross Motor Function Classification System (GMFCS)\textsuperscript{22} classifies the patient’s motor function, with particular emphasis on sitting (truncal control) and walking, into five levels (Level V is with the severest functional limitation). Motor Age Test (MAT)\textsuperscript{23} evaluates the motor function of upper extremities, trunk, and lower extremities. In Table 1, GMFCS level and the motor ages of upper extremities in month is presented. To conduct our motor performance test, therapists decided the physical size of buttons and the number of touch panel operations in accordance with the patient’s capabilities. A Nexus 10 tablet (Google Inc.) with a screen size of 10 inches was used for the test. Its screen was divided into areas specified by the number of rows and columns described in Table 1. Five occupational therapists (OTs) and seven physical therapists (PTs) participated in the user studies. Table 1 shows their experience of working with the patients and working as professional therapists. In the cases of S1, S2, S5, S8 and S10, speech-language pathologists also participated. School teachers in charge of the patients (with parents of the patients in the cases of S4, S5 and S9) were observed the test and participated in group interviews.
4.2. Motor performance test

Therapists planned two different seating and positioning settings for their patients to use tablets. In most cases, one of the settings was the usual one in the patient’s school life and the other was an unusual one recommended by his/her therapists on the basis of the patient’s needs at that time. The therapists decided the size of the buttons and the number of touch operations in accordance with the patient’s capabilities. Each patient’s task was to perform the motor performance test in these settings. To reduce the learning effect, patients practiced the test from one week before the test. Additionally, they practiced it again immediately before the experiment.

The therapists’ task was to observe and analyse the involuntary movement of the eight body sites in both settings (A and B) without any presentation of results from our system. If necessary, they could use videography. In a pilot study, two of the therapists evaluated involuntary movement by a five-point rating scale where “1” means that the involuntary movement in setting A was more excessive, “3” means no difference between the settings and “5” means that the involuntary movement in setting B was more excessive. The inter-coder reliability was tested by Cohen’s Kappa. The ratings of the two therapists were in fair reasonable agreement ($\kappa=0.21, p<0.01$). A well-accepted interpretation of Cohen’s Kappa is that a value above 0.60 indicates satisfactory reliability. The therapists coded the same involuntary movement inconsistent way because the difference between “4” and “5” or between “1” and “2” was ambiguous. We analysed rating-scale data by looking at top-2- and bottom-2-boxes. A top-2-box score referred to cases choosing a “4” and “5” and a bottom-2-box score referred to cases choosing a “1” and “2.” The results of Cohen’s Kappa on the classified data had satisfactory agreement ($\kappa=0.681, p<0.01$). Therefore, we decided that the therapists’ ratings could be classified into a binary scale in the analysis. However, the therapists commented that they probably evaluated very slight differences in case of “3” if rating scale had more points. Accordingly, in this study, the rating scale was increased to a 9-point rating scale where “1” means that the involuntary movement in setting A was more excessive, “5” means no difference between the settings and “9” means that the involuntary movement in setting B was more excessive. In the analysis in Section 5.1, we calculated Cohen’s Kappa on top-4- and bottom-4-boxes scores. The therapists also described the reason why they selected the rating. That was for gaining insights and understandings on what they placed prime importance when evaluating involuntary movements.

4.3. Group interviews

We conducted ten unstructured group interviews to report and discuss the results of each patient independently analysed by therapists and the proposed system. The usefulness of our system on the seating and positioning assessments had also examined. The occupational and physical therapists were absent from the interviews for S1 and S5.

In an unstructured interview, a set of topics are explored in a depth and breadth as follows: a moderator starts off with an initial question for interviewee, and then moderator would listen, letting the interviewee respond as the moderator sees fit, discussing topics chosen by the moderator. The interview involves therapists and teachers as well as parents in some cases. One of the author acted as a moderator for discussion. An overview of the results analysed by the system were reported in the beginning of the interview by presenting heat maps and box-plots of RMS values of acceleration at eight body sites with video clips. These views were also presented during the discussion on demand. Each session was about 30 minutes. RMS values of angular velocity were omitted because of the time limitations. All interviews were recorded and transcribed.

The analysis of the collected data consisted of careful reading of the transcripts and marking parts that seem related to the issues of the proposed system. We then organised the relevant parts into common themes and coded the documents using the themes emerged.

5. Results

In this section, the results of the studies are presented and discussed in the following aspects: agreement ratios between therapists’ ratings and RMS values obtained from the proposed system, the usefulness of the system for the therapists conducting seating and positioning assessment and other implications related to the system.
5.1. Agreement ratios between therapists’ ratings and RMS values

To evaluate the accuracy of the RMS values obtained from the proposed system, we compared them with the therapists’ ratings.

Eight body sites of ten individuals were evaluated in the studies, but malfunctions of motion sensors occurred in nine cases. Fig. 3 shows the distribution of 71 ratings given by the therapists. The most frequent rating was “5”, in 39.4% (28/71) of cases the amount of involuntary movement was evaluated to be the same in both settings. Other 43 cases were classified into top-4- and bottom-4-boxes. For each case, the proposed system compared the sum of the triaxial RMS values of acceleration or angular velocity of a specific body site. The sum in a setting was higher than one in another setting, the system analysed the involuntary movements in the former setting was greater than ones in the latter setting. Table 2 shows agreement ratios and Cohen’s Kappa between the classified therapists’ ratings and the sum of RMS values obtained by the system.

Table 2. Agreement ratios and Cohen’s Kappa between therapists’ ratings and RMS values

<table>
<thead>
<tr>
<th>RMS values</th>
<th>Agreement ratio</th>
<th>Cohen’s Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration</td>
<td>83.7%</td>
<td>0.67*</td>
</tr>
<tr>
<td>Angular velocity</td>
<td>74.4%</td>
<td>0.48*</td>
</tr>
</tbody>
</table>

It was found that for 83.7% of cases (36/43), the analysis of RMS values of acceleration was in agreement with the therapists’ ratings of the involuntary movement. The reliability of the analysis was satisfactory ($\kappa=0.67$, $p < 0.01$). The participants exhibited a variety of involuntary movements as combinations of abnormal muscle tone, reflexes and uncoordinated movements. The cases showing good agreement included involuntary movements caused by cervical spine flexion, thoracic flexion, knee flexion, lumbar lateral bending, shoulder girdle elevation, shoulder abduction, shoulder adduction and equinovarus foot.

Although we expected that RMS values of angular velocity were more accurate than ones of acceleration, the result was opposite. The agreement ratio was 74.4% (32/43). The reliability of the analysis was moderate ($\kappa=0.48$, $p < 0.01$). Patient S10 conducted the motor performance test in seated and recumbent positions in settings A and B, respectively. RMS values of acceleration measured at two body sites, cubitus of dominant-hand and right ankle was not in agreement, but RMS values of angular velocity was in agreement. Fig. 4 shows a scatter plot for the cubitus. The x-axis shows RMS values of angular velocity, the y-axis shows RMS values of acceleration, circle represents an RMS value in setting A and a star represents a value in setting B. We calculated the regression formula for both settings. The relationship between the RMS values of angular velocity and acceleration was linear in both setting A ($R^2 = 0.90$, $p < 0.01$) and setting B ($R^2 = 0.82$, $p < 0.01$). A similar relationship was also found in the right ankle. A higher RMS value of acceleration was observed in setting B for given value of angular velocity. This result confirms the effect of gravity. Therapists should refer RMS values of angular velocity rather than those of acceleration in such a case.
5.2. Usefulness in seating and positioning assessments

We were interested in the usefulness of the proposed system for the therapists conducting the seating and positioning assessments. In the user studies, therapists evaluated involuntary movements without the system and then the multiple views of the results obtained by the system were presented for the therapists in group interviews. We analysed eight group interviews that occupational and physical therapists attended. In the seven interviews, therapists commented that the effect of the data presented by the system. Therapists did not comment any positive or negative comments about the effect in another interview. The comments were classified into the following three themes.

5.2.1. Gaining insights and understandings of patients

In the cases of S2, S7 and S8, therapists suggested that the multiple view presentation of the results supported them for gaining insights and understandings of the patients. For example, the occupational therapist of S2 and the physical therapist of S8 commented: “The results suggests that S2’s shoulder position was maintained well (by increasing the height of the table), but S2’s elbow moved a lot because S2 should perform touching operations by controlling the forearm and hand,” and “S8 exhibited involuntary movements while touching upper-left area of the screen, it makes sense (the therapist understood the phenomenon in detail by interpreting the heat map view and watching video clips).”

5.2.2. Confirming interpretations of observations

In the cases of S3, S6 and S9, therapists confirmed their interpretations of observation by the multiple view presentation of the results. For example, the physical and occupational therapists of S9 said: “I can confirm that S9 increased muscle tone of the right foot resulting from using the right hand,” and “I can easily understand that S9’s trunk was leaned leftward.”

5.2.3. Correcting misunderstandings

In the case of S4, one of the results obtained from the proposed system was different from the therapists’ initial assessment. The therapists changed their opinion after watching video several times. The occupational therapist of S4 said: “I know S4 moved the elbow in association with the movement of the trunk. I evaluated that S4’s hand was moved, too. But, actually, S4 maintained the hand position well.” Therapists could correct their misunderstandings and increased the accuracy of the assessment.

5.3. Other implications related to the system

We were also interested in other implications related to the proposed system. We classified comments from occupational and physical therapists, as well as speech-pathologists, teachers and parents into the following themes.

5.4. Presenting results to patients, teachers and speech-pathologists

The possibilities to present the results obtained by the proposed system to patients, teachers and speech-pathologists were commented by one physical therapist, one occupational therapist, two speech-pathologists, two teachers and
three parents. Patients those who can understand the meaning of the results can have positive and negative reactions. On the one hand, they can improve their performance by recognizing the result. On the other hand, they can dent the confidence. In Japan, there is no AT practitioners. Speech-pathologists, in some case teachers or parents, play the greater role in selecting and maintaining ATs. They considered that the results obtained from the system can support these activities.

5.4.1. Understanding changes in long-term

The patient’s capability of touch panel operations may be changed while long-term rehabilitation. Therapists are repeatedly assess the patient on weekly, fortnightly, monthly or yearly basis. The system should report changes from previous assessments. Two occupational therapists and one speech-pathologist requested this function.

5.4.2. Understanding changes in short-term

Some patients have difficulties to maintain the appropriate posture. The perturbation of postural control affects the patient’s function. The system should report changes in accordance with the number of touch operations. One physical therapist and one occupational therapist requested this function.

5.5. Shooting video from a front camera of a tablet

Some patients have difficulties on the control of eye movements. The coordination of eyes and touch operations are one of the important factors for the assessments. The system should shoot a video from a front camera of a tablet to record the patient’s eye control. Two occupational therapists and one speech-pathologist requested this function.

5.6. Discussion

After the correction of one of the therapists’ ratings mentioned in Section 5.2.3, the agreement ratio between the ratings and the RMS values of acceleration and angular velocities became 86.0% (37/43) and 79.1% (34/43), respectively. The collected comments from the group interviews indicated that this level of accuracy were satisfactory to support the therapists conducting the seating and positioning assessments. The therapists could gain their insights and understandings of the patients, confirm their interpretation of observation and correct their misunderstandings by the use of the quantitative outcomes from the analysis of acceleration presented through multiple views. If the gravity seriously affects the results, the quantitative outcomes from the analysis of angular velocity should be used.

A more sophisticated approach, for example, involving motion capture devices and machine learning techniques, may improve the accuracy of assessment. However, the use of larger and more expensive devices is less attractive in clinical settings, and gathering a huge volume of involuntary movement data for classifications is not realistic. Our portable and simple approach seems better than the sophisticated approach.

The system should support the views to present changes on the results within short- and long-terms, as well as the video view shot from a front camera of a tablet. Multiple views of the results seem useful for speech-pathologists, teachers, parents, and patients, too. However, some patients need to be taken into account that their confidence should not be dented.

6. Conclusions

We developed a seating and positioning assessment support system consisting of (1) a motor performance test module based on touch panel operations, (2) a motion-recording module using four video cameras and eight motion sensors and (3) a motion analysis and presentation module which synchronised and segmented the motion data, calculated RMS values of acceleration and angular velocity and presented multiple views including videos, waveforms and heat maps of the data.

In our user studies on ten individuals with neurological disorders, the RMS values of acceleration and angular velocity respectively had agreement ratios of 83.7% and 74.4% with the initial ratings of involuntary movements exhibited at corresponding body sites given by physical and occupational therapists. Our goal is to help therapists
to interpret the involuntary movements of patients by providing quantitative measurements. The accuracy of our approach appears to be sufficient to detect body sites to be focused on and/or to confirm decisions made by therapists.

Our future work is to implement more views requested in the studies and conduct in-depth case studies for using the system in long-term rehabilitation.

Acknowledgements

We thank the participants for their generous contributions. A part of this work was supported by JSPS KAKENHI Grant Number 25870454 and a Shimane University Grant for Exploratory Research.

References