Skill Evaluation and Education Services for Bed-Care Nursing with Sliding Sheet with Regression Analysis

Wen Wen[1], Xiaorui Qiao[1], Koshiro Yanai[1], Junki Nakagawa[1], Junko Yasuda[2], Atsushi Yamashita[1], and Hajime Asama[1]

[1] The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8856, Japan

Tel: +81 3 5841 6486, Fax: +81 3 5841 8547, E-mail: wen@robot.t.u-tokyo.ac.jp

[2] Japanese No Lifting Association, Japan

Abstract

Sliding sheet is a tool for changing position and posture of bedridden patients. In the present study, in order to provide education service of sliding sheet, we examined skill points during the pulling movement of sliding sheet with regression analysis, and proposed an automatic education system with Kinect camera basing on the results of the analysis. In the regression analysis, according to prior research, we included bending angle of waist, opening angle of legs, and angle of arm flex as three independent variables, and moment of lumbar extension as a dependent variable. According to the results of regression analysis, we found that in order to minimize the load of lumbar during the pulling motion, participant should bend their body close to the bed, spread their legs widely to lower their centre of gravity, and straighten their arms to the bed. Furthermore, basing on the results of our analysis, we proposed an evaluation service with Kinect camera, overlaying recommended posture on picture of learners' body, and giving evaluations on the load of their lumbar to the learners. We believe that our education service will be useful for the spread of sliding sheet.

Keywords:

Skill extraction, nursing, skill evaluation, sliding sheet, regression analysis, education

1 INTRODUCTION

Nursing care is important for the present aging society. However, occupational diseases of care workers became serious problems during the recent years and greatly impaired the quality of nursing service. Low-back pain is one of the commonest diseases among nursing personnel. It is usually caused by heavy physical work, such as moving and lifting bedridden patients [1] [2]. In order to reduce low-back pain of nursing personnel, lifting machines and nursing tools which reduce the physical labor of moving or lifting patients have been developed and widely used in some countries, such as Australia, in which nursing service is highly developed [3].

Sliding sheet is one of such tools that help to change the position of patients. Sliding sheet is made by nylon and has low frictional resistance. When changing the position of a patient on bed, a sliding sheet is folded into two layers and laid between the bed and patient. Then the nurse holds the upper layer of the sheet, pulling it towards her or his own body (Fig. 1). The patient's body will move together with the upper layer of the sheet (towards the nurse's body). Because the sliding sheet is easy to slide, nurse can move a patient with less strength, relative with the condition in which nurse directly holds the body of the patient. Also a patient would feel more comfortable laying on a sheet, relative to being hold by a nurse. In conclusion, sliding sheet is cheap but can significantly reduce the physical load of nurses, therefore it is greatly worth to be introduced to both hospitals and families. However, although the physical strength is much less to move a patient with the sliding sheet relative to the condition of moving a patient directly, it still brings loads to lumbar during repetition of this motion and involves the risk of low-back pain. In order to maximum the effect of the sliding sheet, it is necessary to extract the proper skill points in this motion and teach the skills to the users.

A previous study suggested several skill points which are important for reducing the load of lumbar significantly in this pulling motion [4]. Nakagawa and colleagues interviewed an expert about the skill of sliding sheet, and compared the motions between novel learners and the expert. They concluded that there are three skill points in

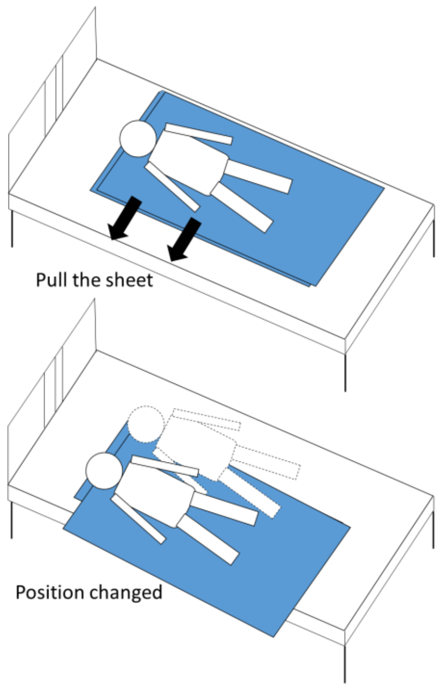

Fig. 1 An example of how to use the sliding sheet

this motion: refer to postures of trunk, legs and arms. Specifically, when pulling a sliding sheet, users should keep their trunks standing up (no bending), spread their legs to shift their weight during the motion, and put their arm as close to the trunk as possible. The authors also taught these skill points to an inexperience user, and found that the load of lumbar was reduced after carrying out the three skill points. However, in their study, the three skill points were extracted verbally and visually, therefore the quantitative contribution of each skill point is unknown. Furthermore, there was also inconsistency between the expert's instruction and her actual motion. Specifically, she told that users should keep their trunk standing straightly up, but actually she did bend her trunk during the motion (Fig. 2). In addition, learners might have difficulty in the comprehension of the three skill points by only verbally instruction.

Fig. 2 The motion of the expert when pulling the sliding sheet [4]

In the present study, we examined the attribution of the three skill points on the reduction of load of lumbar with regression analysis. Regression analysis is a statistical method for estimating the relationship between several independent variables and a dependent variable. Here we used the angle of lumbar extension (i.e., the bending angle of waist), the opening angle of legs and the angle of arm flex as the three independent variables (Fig. 3). The three variables represent the three skill points of trunk, legs, and arms in Nakagawa et al. [2014]'s study, respectively. Furthermore, we calculated the moment of lumbar extension with a 3D kinematics model as the dependent variable. The lumbar spinal moments have been reported to be accompanying with low-back pain [5] and increase the risk of low-back pain in normal people [6]. Correct pulling motion of the sliding sheet should minimum the moment on lumbar. According to the regression analysis, the attribution of each skill points on the moment of lumbar will be quantitatively clarified. Therefore, when teaching new users to use the sliding sheet, both teachers and learners would understand how each skill points attribute to the motion and which one takes priority. Moreover, according to the analysis, it is possible to estimate the load on lumbar with the one's posture during the motion. As an application of our analysis, we proposed an education service with a Kinect camera, in which recommended posture is overlaid on the picture of learner, and estimation of load on learner's lumbar is given after the pulling motion. We believe that our service will be useful for the education and promotion of the sliding sheet.

2 SKILL EXTRACTION

In the present study, we followed Nakagawa et al.'s suggestion [4] and focused on the three angles of body: the angle of lumbar extension, the opening angle of legs, and the angle of arm flex. Nakagawa et al. suggested that the angle of lumbar extension and arm flex should be kept nearly 0°, and the opening angle of legs should be kept widely during the pulling motion. We asked an inexperience learner to pull the sliding sheet with different postures. We measured the motions with a motion capture system, and measured reaction forces with force sensors. After the measurements, we calculated the moments of lumbar extension during the motions with a 3D kinematics model. At last, we conducted a regression analysis.

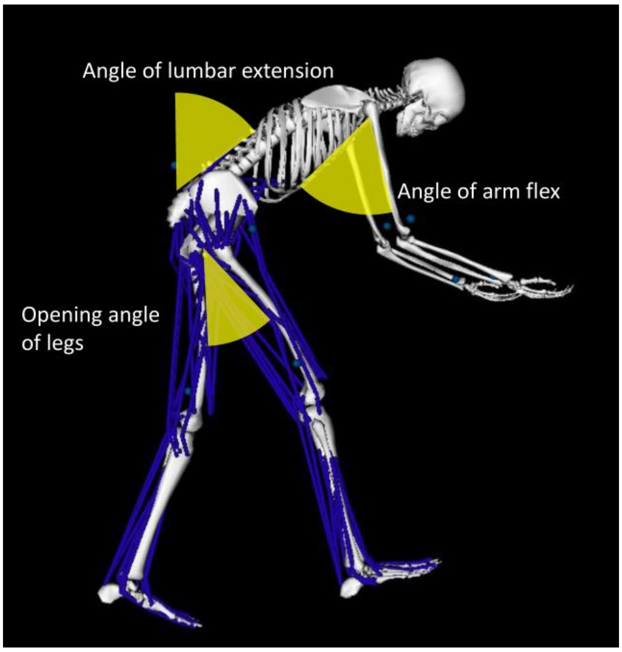

Fig. 3 The three independent variables in the regression analysis

2.1 Participant

An inexperience female users (weight = 51 kg, height = 155 cm, age = 32) participated the experience. The experiment was conducted with the approval of the ethics committee of the Faculty of Engineering at the University of Tokyo

2.2 Equipment

A 48-kg mannequin with movable joints was used in the experiment as a bedridden "patient". The mannequin was laid on a bed of 74 cm in height. The bed was the same as the one using in nursing care. A sliding sheet was folded into two layers and laid between the mannequin and the bed. The motion of the participant was measured by eight cameras (HMK-200RT) of a motion capture system (Motion Analysis, MAC3D). The sampling rate was 200 Hz. Markers were attached to the shoulders, elbows, hands, lumbar, hips, and knees of the participant (11 markers in total). The reaction forces were measured by five reaction sensors (Nitta Corp.) in a sampling rate of 64 Hz.

2.3 Procedure

Before the experiment, the participant received a brief description of the sliding sheet, watched videos of an expert using this tool, and did several trials of practice. The participant was told to pull the sheet as carefully and slowly as possible, to make sure that the "patient" won't feel uncomfortable. Furthermore, the participant was instructed to change the angle of lumbar extension, the opening angle of legs and the angle of arm flex as much as possible between trials (in possible range). During each trial, the sheet was pulled about 30 cm towards the participants (i.e., the "patient" was moved 30 cm laterally) in about 5 sec. The measurement of each trial lasted for 10 sec, including about 1 sec and 4 sec before and after the motion, respectively. The participant conducted 30 trials in total.

2.4 Results

The average moment of lumbar extension of each trial was calculated with OpenSim (Sun Microsystems Inc., version 3.2) from the 3D motion data and reaction forces of each foot. Two trials were excluded because of technical problem. Therefore data from 28 trials was analysed. The average moment of lumbar extension was ranged from 71.1 Nm to 165.9 Nm (M = 121.9 Nm, SD = 27.0 Nm). The angle of lumbar extension ranged from 45.4° to 89.9° (M = 67.6°, SD = 13.3°). The opening angle of legs ranged from 18.2° to 68.1° (M = 40.6°, SD = 15.3°). The angle of arm flex ranged from 32.6° to 71.6° (M = 52.8°, SD = 11.3°).

The results of the regression analysis are shown in Table 1. The regression predicted the data well ($F(3, 24) = 5.13$, $p < .01$), and all the three independent variables significantly attributed to the dependent variable. The p parameter βs represent the quantitative attribution of each independent variables on the dependent variable, and the p-values represent whether these contributions are significant. According to the result of the analysis, in order to reduce moment of lumbar extension, people should increase all the three angles.

Table 1 The results of the regression analysis

	β
Angle of lumbar extension	-0.85 **
Opening angle of legs	-0.89 **
Angle of arm flex	-0.58 **
R^2	0.39

Note: $^{**}p < .01$

2.5 Discussion

In the present study, we aimed to examine the relationship between posture and load of lumbar during the pulling motion of sliding sheet. To do this, we conducted a regression analysis, including three independent variables which describe the user's posture and reflect the three skill points suggested by a previous study. The dependent variable was the moment of lumbar extension, which reflects the load on lumbar and should be minimum during the sheet pulling motion. According to the results of the regression analysis, we found that all the three body angles significantly attributed to the lumbar extension moment negatively. Specifically, in order to reduce the load of lumbar, all the three angles should be magnified. We discuss the relationship between three independent variables with the load of lumbar respectively as follows.

First, for the angle of lumbar extension, we surprisingly found an opposite result with the prior study. In Nakagawa et al.'s study, the authors reported that the expert told learners to keep their trunk straight up and do not bend down during the pulling motion [4]. However, according to our regression analysis, the angle of lumbar extension (equals to the extent of bending) attributed negatively to the moment of lumbar extension. That is, to reduce the moment of lumbar extension, users should bend their lumbar down. We suggest that the expert might have given a wrong instruction. Because according to our measurement, fewer bending did induce more moment of lumbar extension. Actually after reviewing the videos of three experts (including the expert in [4]) using the sliding sheet, we found that all of them bended forward during the pulling motion, to make their body close to the bed. We suggest that during a lifting motion, bending of lumbar might increase the load on it. But during a pulling motion, bending probably do not increase the load of lumbar. By contrast, it might help people to produce more physical strength and reduce the load on lumbar if they could keep their body close to the pulling object.

Nakagawa et al. also suggested that the variation of lumbar extension might be critical to reduce load of lumbar [7]. That is, a learner should keep their lumbar extension unchanged, either standing up or bending down. However, the lumbar extension moments did not correlated with the standard deviation significantly (r = .34, *n.s.*). Actually, the participant did not alter her lumbar extension drastically, since it is unnatural in such puling motion (the standard deviation of lumbar extension ranged from 0.01° to 16.88°, with an average of 3.44°)

Second, the opening angle of legs also negatively attributed to the load of lumbar, and it was the strongest factor to reduce the load of lumbar. People should spread their legs as much as possible to reduce the load on lumbar during the pulling motion. This is consist to the previous study, which suggested that people should lower their body, spread legs and shift their weight during the motion [4]. Moreover, spreading legs also helps to make the body closer to the bed and therefore might help to produce more physical strength during the pulling motion.

At last, we found that larger angle of arm flex reduced the load of lumbar. However, the attribution of this factor was relatively smaller than the former two. The previous study, which suggested that people should keep their arms as close to the body as possible [4]. We suggest that keeping arms close to body might not reduce the load on lumbar, but probably helps to produce more strength relative to the condition of just using muscles of arms. In summary, there probably are merits if people keep their arms close to body, but it might slightly increase the load of lumbar during the pulling motion.

3 SKILL EVALUATION

3.1 Verification of the Analysis

According to the results of the regression analysis, we acquired a formulation as follows, which gives prediction of lumbar extension moment from one's posture (i.e., the three angles shown in Fig. 3). Y (in low case) represents the load of lumbar, and x_1, x_2, and x_3 represent the angle of lumbar extension, the opening angle of legs, and the angle of arm flex, respectively.

$$y = -1.72 \times x_1 - 1.58 \times x_2 - 1.38 \times x_3 + 374.94$$

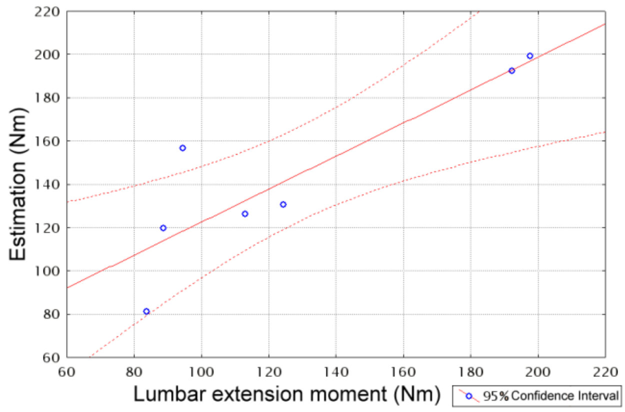

Fig. 4 The scatter plot of participant's lumbar extension moments and estimated moments

However, there is doubt whether it is able to predict the load on lumbar for other people. We believe it is true, because healthy adults generally have common kinematical features in basic motions, such as standing, walking, pulling, and pushing. We also conducted another experiment, using the same procedure described above, to examine whether the estimation of lumbar load matches the actual load from another individual. We asked another inexperience user (female, weight = 50 kg, height = 158 cm, age = 26) to pull a sliding sheet, and calculated the moments of lumbar extension from 20 trials. Because of technical problem, only 7 trials were analysed. The estimated values and measured values are plot in Fig. 4. The estimations well matched the actual loads (r = .87, p < .05). In conclusion, our results of regression analysis are able to correctly estimate the extent of load on lumbar from one's posture during the pulling sheet motion. Therefore, it is possible to use a simple 3D motion device to estimate the quality of a pulling motion.

3.2 Skill Education and Evaluation System

As an application of our study, we developed a system with Kinect camera (Microsoft) to give visual instruction of the skill points and quantitative evaluation of lumbar load during the pulling sheet motion. Kinect camera is a device which measures 3D motion of human. The cost of introduction of a system with Kinect is much lower than a system with motion capture and force sensors. Therefore it is feasible for hospitals and nursing schools to introduce such system to teach their nurses and students the correct motion of using sliding sheet [8].

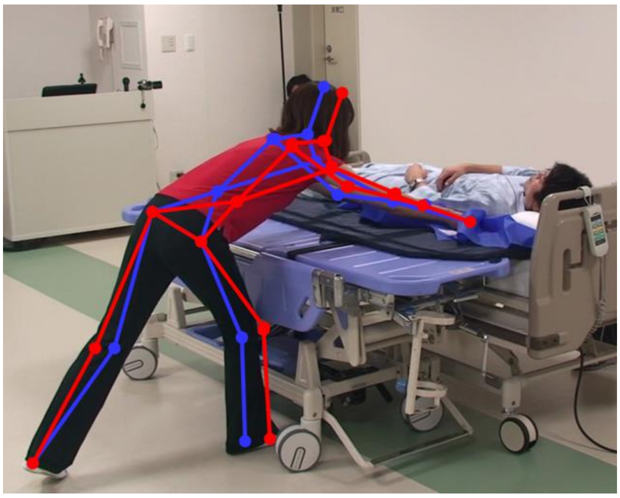

Fig. 5 An example of visual instruction of recommended pose during the sheet pulling motion

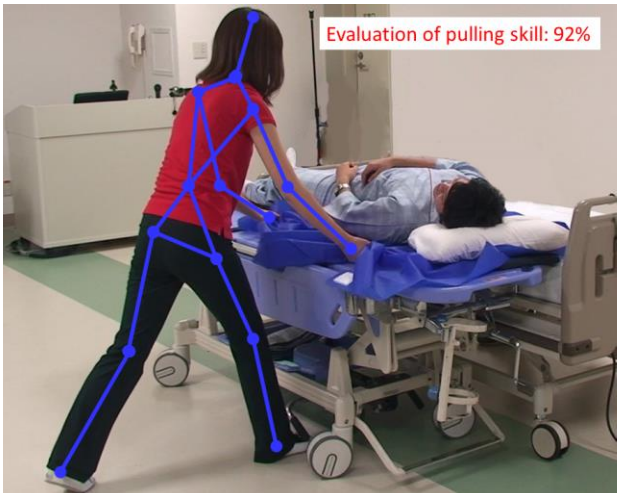

Fig. 6 An example of of evaluation of pulling skill after completing the motion

In our system, the Kinect camera was connected to a computer with Windows 7. After sheet pulling motion being recognized by Kinect, the three angles showed in Fig. 3 were calculated from skeleton positions. User's skeleton and recommended skeleton were overlaid on the RGB video during the pulling motion of sliding sheet (Fig. 5). Recommended posture was represented in red skeleton, and leaner's actual posture was represented in blue skeleton. Furthermore, after completing a pulling motion, the system estimated the load of lumbar from the three body angles, and showed a percentage which described the quality of the motion on the screen (Fig. 6).

In the skeleton recommended pose during sheet pulling, coordinates of hip joints were duplicated from learner's pose, and the rest coordinates of joints were modified from the actual pose. For the torso and shoulder joints, coordinates were modified to increase the angle of lumbar extension by 10% without exceeding 90°. For the elbow and hand joints, coordinates were modified match the modified position of shoulder joints and original position of hand joints and maximum the angle of arm flex. For the knee and foot joints, coordinates were modified to increase the opening angle of legs by 20% without exceeding 90°.

To present the evaluation of sheet pulling skill after completing the motion, average values of angle of lumbar extension, angle of arm flex, and opening angle of legs were measured by Kinect. Then moment of lumbar extension was estimated with the regression formulation that was acquired in the regression analysis (section 3.1). To give a valuation of sheet pulling skill in percentage, lumbar extension moments in "perfect" motion and "worst" motion were set to 50 Nm and 200 Nm, respectively. The percentage was calculated from the estimated moment to describe how close it reaches to the perfect motion. In summary, our education service was able to give visual instruction of skill points during real-time movement, and give approximate estimation of one's pulling motion with the posture information. Our system is easy for learners to improve their sheet pulling skills, and it is also suitable for e-learning.

4 CONCLUSION

In the present study, we examined the relationship between the body postures and the load of lumbar when one was pulling a sliding sheet. Sliding sheet is a useful tool to reduce the necessary strength to move a bedridden patient, and proper motion should minimum the load of lumbar. A previous study proposed three skill points of posture—refer to trunk, legs, and arms—during the pulling motion via interview and comparisons between expert and naïve people [4]. However, the quantitative attribution and the authorities of these skill points were unclear.

In the present study, we followed the suggestion of prior studies and focused on the three body parts. The three independent variables in the regression analysis were angle of lumbar extension, opening angle of legs, and angle of arm flex. The dependent variable was moment of lumbar extension, which was calculated from a 3D kinematical model. According to our regression analysis, we found that all the three angles of body negatively attributed to the load of lumbar. Specifically, in order to reduce the load of lumbar during the pulling sheet motion, people should bend their body close to the bed, spread their legs widely to lower their centre of gravity, and straighten their arms to the bed. The skill points of trunk and arms were inconsistent with Nakagawa et al.'s study. After reviewing the motions of experts, we found that experts actually did the same motion as our analysis suggested, instead of what the expert verbally described. In conclusion, we suggest that bending one's body towards the bed will not increase the load of lumbar during the pulling motion, but will help to produce more strength to pull. And spreading one's legs will help to fix one's centre of gravity, procedure more power and reduce the load of lumbar. At last, although straightening one's arms slightly attributed to the reduction of load of lumbar, it might impair the strength of pulling. Therefore as a strategy, keeping arms close to trunk might bring merits (i.e., more strength) along with slight increment of load of lumbar. In summary, according to our analysis, we suggest that the previous suggested skill points should be reconsidered carefully, because experts might tell differently from what they actually act.

Furthermore, we verified the results of our regression analysis on another participant, and found that the results were effective in estimating the extent of load of lumbar from one's posture during the pulling motion. As an application of our results, we developed a system using the Kinect camera, which can measure the 3D motion of human with a low cost. The system gives real-time visual recommendation of ideal posture to minimum load of lumbar during the sheet pulling motion (Fig. 5). Moreover, after completing the sheet pulling motion, our system gives a quantitative valuation of leaner's motion to estimate the moment of lumbar extension during the motion. The design of our system was based on the results of the regression analysis. We believe our system is useful for learners to recognize the quality of their motion and helps them to improve it.

At last, the regression analysis in the present study was based on a small sample size. Therefore the individual differences of physique (e.g., weight, height, muscle strength) were not considered. The appropriate skill points might change between people with different body sizes. This issue is worth to examine carefully in the future study.

ACKNOWLEDGMENT

This work was supported by the JST RISTEX Service Science, Solutions and Foundation Integrated Research Program.

REFERENCE

[1] The Policy and Strategic Projects Division Victorian Government Department of Human Services, 2002, Victorian Nurses Back Injury Prevention Project Evaluation Report 2002.

[2] Engkvist, I.L., Kjellberg, A., Hjelm, E. W., Hagberg, M., Menckel, E., Ekenvall, L., 2001, Back Injuries Among Nursing Personnel – Identification of Work Conditions with Cluster Analysis, Safety Science, 37:1-18.

[3] Engkvist I.L., 2006, Evaluation of an Intervention Comprising a No Lifting Policy in Australian Hospitals, Applied Ergonomics, 37: 141-148.

[4] Nakagawa, J., An, Q., Ishikawa, Y., Yanai, K., Wen, W., Yamakawa, H., Yasuda, H., Yamashita, A., Asama, H., 2014, Extraction and Evaluation of Proficiency in Bed Care Motion for Education Service of Nursing Skill, Proceedings of the 2nd International Conference on Serviceology (ICServ2014), pp.91-96.

[5] Wilson, D.J., Hickey, K.M., Gorham, J.L., Childers, M.K., 1997, Lumbar Spinal Moments in Chronic Back Pain Patients During Supported Lifting: A Dynamic Analysis, Archives of Physical Medicine and Rehabilitation, 78: 967-972.

[6] Callaghan, J.P., Cunning, J.L., McGill, S.M., 1998, The Relationship Between Lumbar Spine Load and Muscle Activity During Extensor Exercises, Physical Therapy, 78: 8-18.

[7] Nakagawa, J., An, Q., Ishikawa, Y., Yanai, K., Yasuda, H., Wen, W., Yamakawa, H., Yamashita, A., Asama, H., 2014, Prioritization of skill points in nursing movements with sheet for education service, the 32th Annual Meeting of the Robotics Society of Japan.

[8] Huang, Z., Nagata, A., Kanai-Pak, M., Maeda, J., Kitajima, Y., Nakamura, M., Aida, K., Kuwahara, N., Ogata, T., Ota, J., 2014, Automatic Evaluation of Trainee Nurses' Patient Transfer Skills Using Multiple Kinect Sensors, IEICE Transactions on Information and Systems, 97: 107-118.