Nurse Bed Care Activity Analysis for Intelligent Training Service

Xiaorui QIAO[1], Junki NAKAGAWA[1], Koshiro YANAI[1], Junko YASUDA[2], Wen WEN[1], Atsushi YAMASHITA[1], and Hajime ASAMA[1]

[1] The University of Tokyo, Tokyo, 113-8656, Japan

Tel: +81 3 5841 6456, Fax: +81 3 5841 8547, E-mail: qiao@robot.t.u-tokyo.ac.jp

[2] Japanese No Lifting Association, Japan

Abstract

Bed care skills are highly demanded in an elderly society. Therefore, intelligent training service begins to appear for automatically transferring a skill. In this paper, we proposed a bed care activity analysis framework containing three entities: nurse, patient and environment. Nurse activity was represented by actions with patient or environment. These interactions were recognized by body part gesture and represented by agent-motion-target type in linguistics. The bed care task-patient repositioning carried out in motion capture system was analyzed by proposed framework and represented by linguistic description. Thus, activity was automatically observed in the training service.

Keywords:

Activity analysis framework, training system, semantic motion recognition

1 INTRODUCTION

Fast growing aging population in the world and the chronic illness increasing with age results in increased demand for health care service. Especially the bed care nursing skill that helps a patient move and be comfortable positioned is one of the most important things as a nurse. Correspondently, the need for new nurses to master the bed care skill is highly demanded. To acquire proper bed care skill is not only can provide comfortable care for the patients but also can reduce the risk of musculoskeletal disorders especially low back pain [1]. One to one training mode brings better learning achievements for learners, but the actual trainers are usually insufficient to support this training mode. Instead, a one-to-many training approach is used in actual training activities. Such an approach to learn often affects learners' effectiveness [2].

Therefore, more researches are beginning to analyze the nursing skill and to construct a training system [1][3][4]. Meanwhile, skill training has evolved from real tutor face-to-face training to intelligent training system that a computer system aims to provide immediate and customized instruction or feedback to trainees [5]. Therefore, intelligent training system will provide trainees with the benefits of one-to-one instruction. In order to effectively transfer the skill to a trainee without intervention from a real human trainer, the system should have enough knowledge and observe the trainee's motion. Thus, a key part in the intelligent system is to let computer know what is happening in the system. According to the knowledge and the observation, the head of the system-computer can give specific interpretation and diagnosis in training for each individual trainee.

Before providing intelligent training diagnosis, the system should have the capability to observe trainees' motion. What should be observed and how to observe will be the first step for the system. Therefore, what bed care task aspects should be observed and how to observe will be analyzed. We understand the bed care situation contains three aspects: nurse, patient, and environment. However, most of researches focus on only single aspect.

It is useful to view the nursing care task from the viewpoint of interactions among the three aspects, which will give a comprehensive observation to the training system. The nurse-patient interaction includes nurse's action to patient and patient's reaction to the nurse. Nurse's action includes moving patient in bed from side to side, turning over the patient, moving the patient up to bed and etc. Patient's feeling and the body parts to be cared, such as comfortable, uncomfortable, the hands crossed on chest and etc. are as the reaction of the patient.

The nurse-environment interaction includes the environment influence and the nurse's reaction to the environment. For example, the environment influence includes the equipment used, the space, the bed height and etc. the nurse's reaction includes what's needed, whether or not need help, which method should be adopted and etc.

The environment-patient interaction includes environmental influence on patient and the patient's reaction. The environmental influence includes adding equipment, bed height changing and etc. and the patient's reaction includes like, dislike and etc.

In this paper, we proposed a framework based on our analysis domain to observe and interpret the nurse bed care activity. Our approach is distinct from previous approaches, most of which aim at analyzing strict steps for the care task [1], right positions check [3], or body parts posture [4]. We aim at developing a semantic observation scheme for bed care activity, in order to endow the system having the ability to observe a trainee's motion. Therefore, the computer will substitute real human trainer to understand the task activity. Thus, in the intelligent service, based on the understanding, the system will give a trainee specific diagnosis and instruction according to his or her own motion pattern.

2 ACTIVITY ANALYSIS FRAMEWORK FOR BED CARE TASK

According to our analysis domain, bed care analysis framework was proposed as Fig.1 shown, which contains three entities: nurse, patient and environment. However, most of researches focus on one part of this task. Observing the task from the three entities let the system more like a real tutor, who will diagnosis the skill from the main aspects included in the task. Moreover, only training the novices to handle properly the relationships of the three entities, the skill can be really mastered.

Repositioning patient is one of typical bed care tasks to give a patient care in bed. As Fig.2 shows, in order to

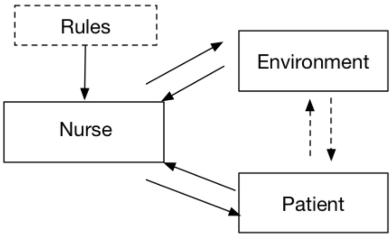

Fig.1 Analysis framework for bed care task

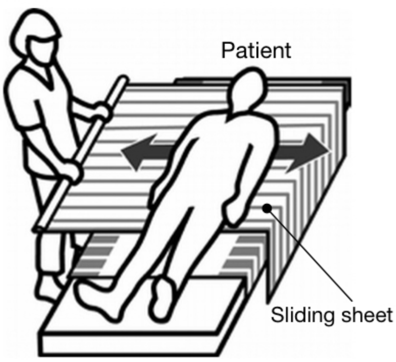

Fig.2 Bed care task- repositioning using sliding sheet

reduce the nurse's load and increase patient's comfort, sliding sheet is used in the task. A Nurse pulls sliding sheet to reposition a patient in bed. Here we take this task for example to give a detail explanation of analysis framework.

During this task, in order to care a patient in bed, a nurse will make actions to a patient, such as changing the patient's position, helping the patient sitting up and etc. The patient will react or affect to the nurse, such as patient's weight, patient's body situation and etc. Or a nurse will make actions to the environment including using sliding sheet to help care the patient, changing the bed height and etc. The environment will also affect the nurse's motion, such as the bed height, how about the tool and etc. Meanwhile, a nurse's motion should follow the rules due to pure manual work, such as no-lift policy, body mechanism and etc. to prevent musculoskeletal disorders, especially low back pain [6].

For the interaction between patient and environment in the bed care task, at most time, is caused by nurse's action and for this reason the interaction lines are shown in dotted line. For example, a nurse change the environment conditions and the changing will affect the patient and patient will also cause effect to environment due to nurse in the task, such as moving or turning compared to the bed.

Therefore, in the all interactions the nurse's actions play a lead role in the bed care task. The nurse's action to patient and environment will be mainly discussed. In order to understand the nurse's action, the representation of nurse activity is base on the notion of hierarchy [7]. A nurse's action is made up of multiple body parts gestures such as arm motion, torso motion and leg motion. Each body-part gesture is an elementary event of motion and all these elements construct higher-level motion to accomplish the task. The action target will be patient or environment. The schematic levels of the hierarchy are illustrated as Fig.3 shown. First, Nurse and patient's main joints are obtained by

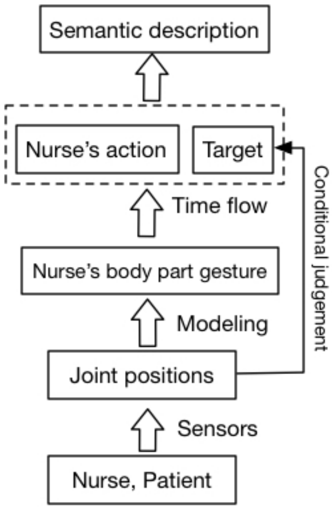

Fig.3 The diagram for semantic level description

sensors and then nurse's body part gestures are obtained by modeling. According to the body part gestures, nurse's action will be formed. In order to determine the action target, conditional judgment will be applied. Therefore, the task activity will be interpreted as nurse's action to target. The system will understand what actions are made during the task process.

3 BED CARE TASK ANALYSIS

In order to get the body part gesture, a body vector model was proposed to represent the body part and each vector represented a body segment. A movement space was proposed to determine the motion direction in a semantic level. The action target will be determined by conditional judgment. For the representation of semantic observation results, we adopt the agent-motion-target type in linguistics [8].

3.1 Body Vector Model

Body vector model was proposed to represent the human body of nurse, as Fig.4 shown. This model represents human motion or posture by nine vectors. Thus, a motion can be analyzed by vector operation. Moreover, a vector including magnitude, direction and origin defines a movement in a simplistic model that can later be analyzed in a semantic way. Human skeleton in a frame consists nine body segment vectors. In the body vector model, vector 1 represents the torso, vectors 2,3,4 and 5 compose arm part and vectors 6,7,8 and 9 compose leg part. The information of human skeleton can be obtained either by RGB-D sensor or motion capture system.

At time *t,* body part vector $\mathbf{b}_t^n = (i_t^n, j_t^n, k_t^n), n = 1,...,9$, and the $\mathbf{b}_t^n$ will represent the posture of the body part. At time *s*, body part vector $\mathbf{b}_s^n = (i_s^n, j_s^n, k_s^n), n = 1,...,9$. The vector value will be the end joint point subtracts the start point. The movement direction of body segment *n* will be

$$\mathbf{d}^n = \mathbf{b}_s^n - \mathbf{b}_t^n \tag{1}$$

The movement direction of a body segment vector is actually the movement direction of vector end joint point compared to vector start point. For example, the movement direction of $\mathbf{d}^2$ will be the movement direction of left elbow joint compared to left shoulder joint.

Although we get the movement direction, it is actually no meaningful for the system to interpret it. In order to determine the semantic meaning of direction, the movement space was proposed to label the direction as our usually see, such as front, left, up-left and etc.

3.2 Movement space

Movement space will determine the movement direction in our human observation way, such as left, up, front and etc. As Fig.5 shows, X, Y, Z is the world coordinate system, which is determined by our sensor system. The movement space is determined by the human body itself. **f** is the human facing direction and **l** is orthogonal to **f** and **u** is orthogonal to the plane determined by **f** and **l**. For example, for the standing pose motion, **u** will be (0,0,1) to represent up direction, **f** is the front direction and **l** is the left direction. According to three main direction in the movement space, there are detailed 27 movement directions are determined.

$$\mathbf{d}_s = (f, l, u), \forall f, l, u \in \{1, 0, -1\} \qquad (2)$$

In the equation (2), value 1 means that motion changes in this direction, value 0 means that motion has no change in this direction, and value -1 means that motion has opposite changes in this direction. For example, if $\mathbf{d}_s$ =(1,1,0), which means the movement direction is front-left. Thus the motion direction dictionary can be list as Equation (3).

$$\begin{aligned} &motion\_direciton = (md_1, md_2, md_3), \\ &md_1 = \{front, null, back\}, \\ &md_2 = \{left, null, right\}, \\ &md_3 = \{up, null, down\}. \end{aligned} \qquad (3)$$

For the real motion direction, we normalize it to one of direction in the movement space, thus the motion can be understand in human direction. As Fig.5 shown, direction of **d** will choose the direction $\mathbf{d}_s$, which has minimum vector angle with **d**.

For the arm or leg part, its direction is determined by four vectors integrated direction in order to give a semantic description. For the left arm as an example, the two vectors 2 and 3 joint together, always the two vectors' directions are related. The body segment, which has larger movement distance, will be as the dominant body segment part in this time period. For the left arm, the movement direction is $\mathbf{d}_s^l$ and the right arm movement direction is $\mathbf{d}_s^r$.

$$\mathbf{d}_s^l - \mathbf{d}_s^r = (d_1, d_2, d_3) \qquad (4)$$

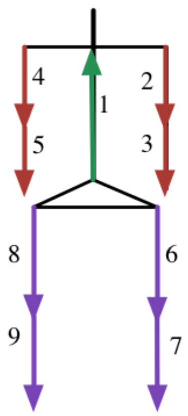

Fig.4 Body vector model

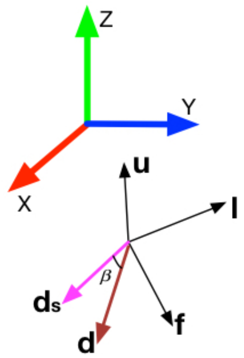

Fig.5 Movement space

if any value of d_1, d_2 or d_3 are equal to 2 or -2 that means two arms move opposite direction, then the arm part movement directions are considered left arm and right arm separately. In other situations, the left arm and right arm almost in the same direction and we choose the common directions as unified arm direction.

3.3 Action target

The bed care task interaction target is patient or environment. First, we should detect the interaction target is patient or environment. In the bed care task. If a nurse makes action directly to a patient, the wrist height should be higher than bed height and meanwhile in certain region, the patient's body joints should be found. Then we design the following steps to detect the interaction target.

Step1: compare the wrist height (*wh*) and the patient's hip height (*h*).

Step2: if *wh* > *h*, and the patient body joint can be found in nurse wrist certain region, then the interaction target is patient. The found patient body joint can determine acted body part of patient.

3.4 Semantic representation

The observation result will represent as triplet = <agent-motion-target> according to the theory of 'verb argument structure' in linguistics [8]. Table 1 illustrates the argument definition.

Table 1 Representation by verb argument structure

Set definition for nurse action
Universe set of interaction: *U*
$U = \{Interaction \mid Interaction = < nurse - motion - patient / environment >\}$
Nurse set: *N*
$N = \{N_h \mid N_h = nurse's\ body\ parts\} = \{arm, torso, leg, null\}$
Patient set: *P*
$P = \{P_j \mid P_j = patient's\ body\ parts\} = \{arm, torso, leg, null\}$
Environment set: *E*
$E = \{E_i \mid E_i = environment\ components\} = \{bed, sliding\ sheet\}$
Motion set : *M*
$M = \{M_l \mid M_l = movement\ of\ body\ part\} = \{motion\_direction\ set\}$

4 EXPERIMENT

Bed care task- repositioning using sliding sheet was analyzed in the experiment. The task scene was set up in the motion capture system and two expert nurses carried out the positioning task.

4.1 Repositioning task set up

Repositioning task using sliding sheet was set up in optimal motion capture system (MAC3D) with eight cameras (HMK-200RT; Motion Analysis Corp.). The capture frame is 200Hz.

Nurse's activity was carried out around the bed region. The domain was built as Fig.6 shows. In this task, the patient lay on the bed and there was sliding sheet (the blue material) between patient and bed to reduce the friction. The nurse repositioned the patient using this tool. The patient could not move by herself. In order to prevent tissue breakdown of patient, nurse should reposition the patient about every two hours. In this experiment, two expert nurses carried out the task with the same patient. In this task analysis, the goal is to detect how nurse make action to the patient and environment.

As Fig.7 illustrates, the 12 main joints of body are measured. And they are labeled by R/L_position format. For example, the joint of right shoulder was labeled as R_shoulder, the same for others. Therefore, the shoulder joints, elbow joints, wrist joints, hip joints, knee joints and ankle joints were measured. In the task, both nurse and patient were measured in this way and these joints 3D coordinates were measured to record the movements of nurse and the postures of patient.

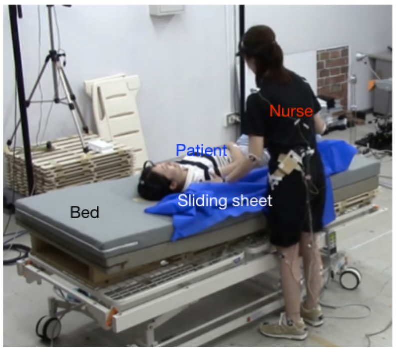

Fig.6 Repositioning task

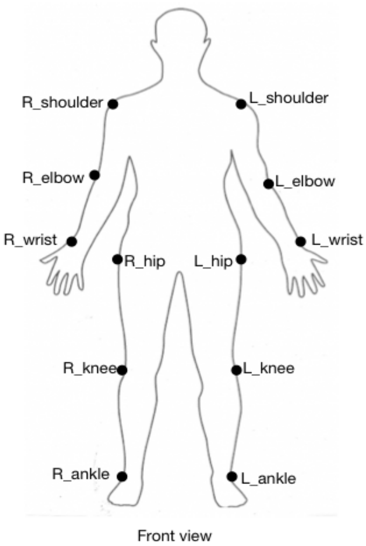

Fig.7 Measured markers

4.2 Exemplar tasks

In this paper, we concentrated on the exemplar activity nurse bed care task. The characteristics of the test actions are summarized in Table 2. The nurse action is depicted in Fig.8. In pulling repositioning, nurse draws sliding sheet to move up the patient. This motion mainly uses nurse's body to reposition the patient. The arm motion mainly move backward and left to accomplish the task, meanwhile, the torso and leg will coordinate with arm motion to make this activity. In the pushing motion, nurse directly pushes patient's leg to move up the patient. Accordingly, arm and torso motion will be forward and down to give a force to move up the patient. While the legs are almost no motion in this task.

Table 2 Activity descriptions

Repositioning	Description
Pulling	Arm left-backward sliding sheet, torso down-back, leg left
Pushing	Arm forward patient's leg, torso forward, leg natural

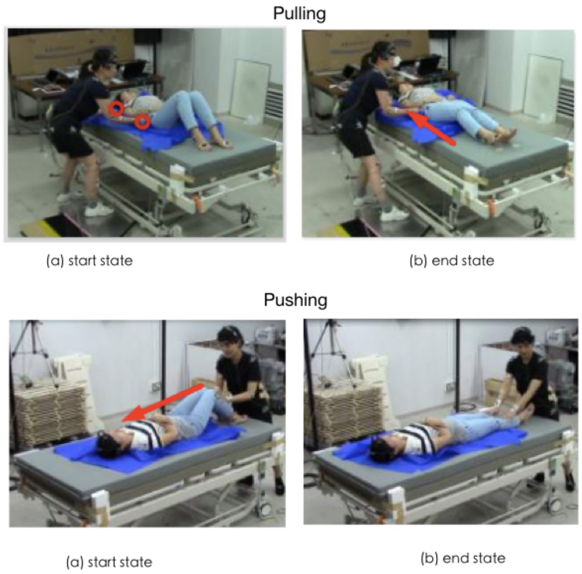

Fig.8 Exemplar tasks

5 RESULTS

All the tasks were captured in motion capture system as we mentioned before. All the captured data had been post-processed in the software EVaRT 4.2 to denoise, smooth and patch the missed data. After the post-process, the captured data can represent the fluency human motion. First, the body part motion was estimated using proposed method to check the effectiveness of the method.

5.1 Body part gesture

For nurse's left direction,

$$\mathbf{l} = \frac{(LR\_shoulder\_x, LR\_shoulder\_y, 0)}{\| LR\_shoulder\_x, R\_shoulder\_y \|},$$
$$LR\_shoulder\_x = L\_shoulder\_x - R\_shoulder\_x,$$
$$LR\_shoulder\_y = L\_shoulder\_y - R\_shoulder\_y \qquad (4)$$

$\mathbf{f} \perp \mathbf{l}$, and **u** = (1,0,0).

For the torso vector, the center of right shoulder and left shoulder will be the end of torso vector and the center of right hip and left hip will be the start of torso vector.

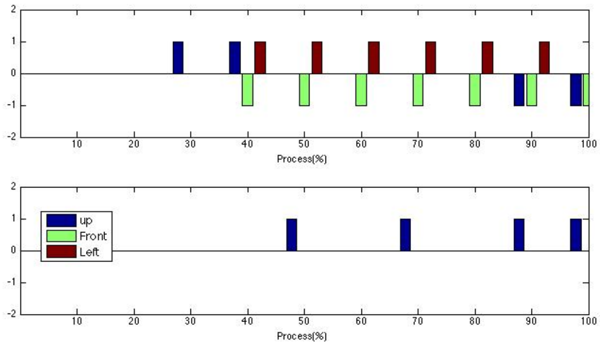

Fig.9 Arm motion in pulling task

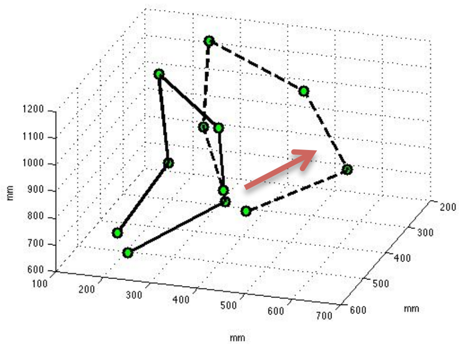

Fig.10 Real arm motion

In Fig.9, top image indicates the left arm motion and the down image indicates the difference between left arm and right arm. There is no 2 or -2 difference, which means there are no opposite movement directions of two arms and two arms having coordination to accomplish the task. According to our method, we choose the common movement direction as arm direction. The main movement direction for the arm motion is left-back direction.

As Fig.10 shown, the solid line is the start posture of arm motion and the dotted line is the end posture of arm motion. This motion direction is mainly up, left and back. Thus by our method, the rough movement direction is estimated. There are two reasons to choose movement direction to describe the motion. First, human cannot produce identical motion for the second time even for the same person. Thus the direction can give a fuzzy description of the motion. Second, for a skill, thousand people will have thousand expressions. Meanwhile, to achieve a skill, movement direction always as the first step for us to learn the skill.

5.2 Action target

In the pulling and pushing repositioning task, patient's hip height was constant value h = 887mm. During the task process, nurse's wrist height (*wh*) was compared to the *h*. For patient's body parameters, the largest distance of two neighboring joints is 500mm; therefore, we choose 250mm as the certain region of the wrist. If the $wh > h$ and there are patients joints in 250mm region the interaction target will be patient body part. As Fig.11 shows, the blue lines (left wrist) or red lines (right wrist) are the different value of *wh* subtracts *h*. During the pulling task, *wh* is always lower than *h*, the different value is always minus. During the pushing task, *wh* is always higher than *h* and the different value is always positive. Meanwhile there are joints in the wrist region shown as light color dotted line. According to our judgment method, the pulling task target is sliding sheet and the pushing task target is patient and we can also find the nearest joint to inference the body part.

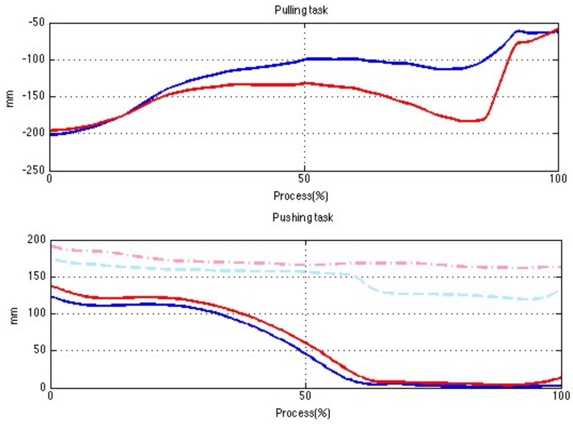

Fig.11 Action target judgment

5.3 Semantic description

Low-level description can be efficiently summarized and represented by the operation triplets. And the interaction target can also be judged by proposed method. All these body part description and target determination can form semantic description of the task. The semantic representation of bed care activity is shown in Fig.12 and Fig.13 for the pulling repositioning task and pushing repositioning task. Same color on the axis is the same description. No description means that there is no motion on this phase.

The semantic description is almost the same as we observe the motion that descripted in Table 2. It means that the system can observe the movement direction similarly as real human tutor who can observe a trainee how the relations of body part motion. The reasults have some suble differences as we descirpted due to complicated human motion. This requires to improve algorithm to improve the rubustness and accuracy. Moreover, for a human motion, motion direction is only one of features. For a intelligent training system will have ability to judge the coordination according to the body part semantic description, which is also we will further focus on.

6 CONCLUSION

In this paper, we have shown a framework for nurse bed care activity analysis. Our framework includes three aspects: nurse, patient and environment. Therefore, the activity can represent by the interaction between nurse and patient or nurse and environment. This framework provides a more comprehensive way to understand the bed care activity for the intelligent training system. We also proposed the body vector method to determine the motion direction from human body's aspect, which defined a simplistic model for semantic analysis. However, for a multi-task activity, task-to-task should be recognized. Meanwhile, this semantic understanding of the activity should be used for automatic evaluation and diagnosis in an intelligent training system. After the evaluation, the system will give specific diagnosis to the trainee including the errors, how to improve and sometimes guidance when a trainee doesn't know what to do. Meanwhile, not only the motion in the skill is analyzed but also power, velocity, acceleration and etc. in the effort domain should be analyzed.

ACKNOWLEGMENT

This work was in part supported by JST RISTEX Service Science, Solutions and Foundation Integrated Research Program, the MEXT KAKENHI, Grant-in-Aid for Scientific Research (B) 24300198

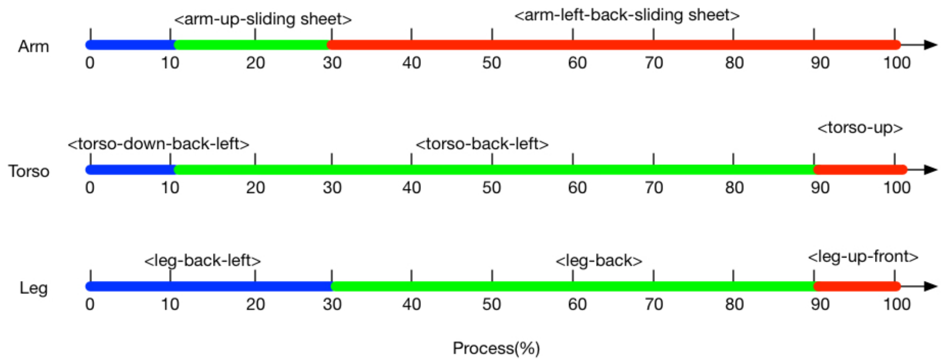

Fig.12 Pulling task

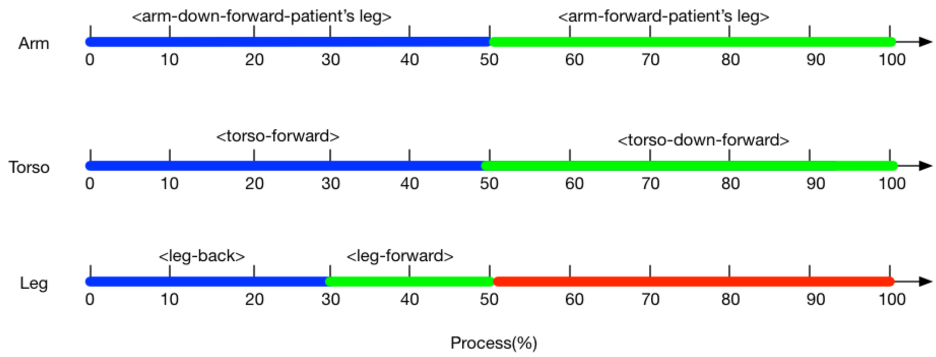

Fig.13 Pushing task

REFERENCE

[1] Huang, Z., Nagata, A., Kanai-Pak, M., Maeda, J., Kitajima, Y., Nakamura, M., Aida, K., Kuwahara, N., Ogata, T., Ota, J., 2014, Self-Help Training System for Nursing Students to Learn Patient Transfer Skills. Learning Technologies, IEEE Transactions on 7, 319–332.

[2] Stalmeijer, R.E., Dolmans, D.H.J.M., Wolfhagen, I.H.A.P., Scherpbier, A.J.J.A., 2009. Cognitive apprenticeship in clinical practice: can it stimulate learning in the opinion of students? Adv Health Sci Educ Theory Pract 14, 535–546.

[3] Wu, P.H., Hwang, G.J., Su, L.H., Huang, Y.M., 2012. A Context-Aware Mobile Learning System for Supporting Cognitive Apprenticeships in Nursing Skills Training. Educational Technology & Society,15,1, 223-236.

[4] Nakagawa, J., An, Q. Ishikawa, Y.,Yanai, K., Wen, W., Yamakawa, H.,Yasuda, J.,Yamashita, A., Asama, H.,2014, Extraction and Evaluation of Proficiency in Bed Care Motion for Education Service of Nursing Skill, ICserv, 064 ,1–6.

[5] Aguirre, A., Lozano-Rodero, A., Matey, L.M., Villamane, M., Ferrero, B., 2014. A Novel Approach to Diagnosing Motor Skills. Learning Technologies, IEEE Transactions on 7, 304–318.

[6] Nelson, A., Baptiste, A., 2004. Evidence-based practices for safe patient handling and movement. Online Journal of Issues in Nursing.

[7] Park, S., Aggarwal, J.K., 2004. Semantic-level Understanding of Human Actions and Interactions using Event Hierarchy. Computer Vision and Pattern Recognition Workshops, 1–9.

[8] Sarkar,A., and Tripasai, W., 2002, Learning verb argument structure from minimally annotated corpora. In proceeding of COLING, Taiwan.