Robot Patient for Nursing Self-training in Transferring Patient from Bed to Wheel Chair

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Abstract. In this paper, we proposed a robot patient for the nursing training in patient transfer. The robot patient was developed to reproduce the performance of the patients who are suffering from mobility problems. We targeted on the reproduction of movement of the patient's limbs (arms and legs) with the consideration of physical and voice interaction between the patient and nurse. The robot patient had 15 joints including 2 active joints installed with motors, 4 passive joints installed with electric brakes and 9 passive joints without any actuators. To realize the physical interaction, potentiometer type angle sensors was utilized to detect the rotation angle of the joints of shoulders, elbows and knees. In addition, follow-up control approach was applied to the shoulder joint. By this way the robot could react accordingly when the trainees moved its limbs. A voice recognition module was applied to enable the robot to interact with the trainee by voice. An experiment was performed by a nursing teacher for examine the robot's performance. The robot patient successfully reproduced the patient's movement with physical and voice interaction, including embracing, keeping embracing, standing up, keeping standing and sitting down.

Keywords: nursing skills training, robot patient, patient transfer.

1 Introduction

In nursing care, there are many tasks involving moving the patient's body, such as bathing, giving assistance in dressing, and transferring patient from bed to wheelchair[1-3]. For the safety of nurses and patients, it is critically important of the nurses to accurately acquire these skills.

In order to improve the skills for nurses and nursing students in such tasks, the mock patient is generally utilized in simulated training to reproduce the real patient's performance. In traditional nursing education, generally, the mock patients are acted by the stationary manikins [4, 5] or the healthy people [6]. However, such mock

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patients cannot precisely reproduce the real patients. For example, the stationary manikins cannot reproduce the movements of human's joints. In addition, the stationary manikins are unable to respond to the trainees' operation, such as motions or voice commands. On the other hands, for the healthy people, it is difficult to simulate the movements of the patient with decline of muscle strength and paralysis. The healthy people often move their body unconsciously during simulating the patients and the movements often help the trainees to complete the tasks. In view of this, to develop a robot patient which could accurately reproduce the patient's limb movements and interact with the trainee would be great help for the nurses and nursing students to improve their nursing skills.

Former studies developed robots for various medical trainings, such as trainings of dentist's clinic [7], medical examination [8-9] and air way management [10]. However, there are few researches of robots for reproduction of patients' body limbs' movement. In addition, the physical interaction between trainees and patients (e.g. embracing) was not taken into consideration.

The aim of this paper is to solve the problem of reproducing patient's body limbs movement with the consideration of interaction between trainees and patients. The challenging points are how to realize the body limbs movement by minimal actuators and the reproduction of physical and voice interaction.

The prototype robot patient for patient transfer training was proposed in this paper. Using the stationary mannequin as the base, we design arms and the knee joints of the robot. Utilizing the electric brakes and servo motors, the patient's limbs movement was reproduced included passively standing up and sitting down, actively embracing nurse's shoulder and keeping standing posture and embracing posture. Angle sensors were installed on the limb joints to detect the movement of the robot's limb for the purpose of physical interaction with the training. In addition, the speech recognition technique was utilized for voice interaction.

The remainder of the paper is structured as follows. Section 2 describes the robot's specification. Section 3 details the hardware configuration of the robot including joints mechanical structure and sensors. Section 4 details the control methods. Section 5 presents the results of an experiment carried out by an experienced nursing teacher to examine the robot patient's performance. Section 6 concludes the paper.

2 Design Specification

2.1 Procedures of Transferring a Patient from Bed to Wheelchair

When nurses perform transferring a patient form bed to wheelchair, firstly, they should adjust the sitting position of patients and then assist the patients to embrace to their shoulders. Since the patient's arm is weak, nurse need to lift the patients' arm to complete the embracing motion. After that, nurses assist the patient to bend down and then assist the patient to stand up, turn to the wheelchair and sit down. Patient's low limbs were weak and very easy to fall down. Therefore, during such process above, nurses need to hold the patient's waits and support most of the weight of the patients, especially during standing and siting process.

2.2 Design Specification of the Robot Patient

Based on the typical performance of patients who are with mobility problems and need the patient transfer nursing care, the specification of the robot patient for patient transfer training was defined.

The robot height was set as 160 cm and the weight was 25 kg. The robot's arms should have enough degree of freedom to reproduce the embracing motion. While trainee was lifting the robot's arms, the shoulder joints should be able to provide force to embrace the trainee. In addition, the embracing motion should be able to keep while standing up and sitting down.

For the lower limbs, the knee joints should be able to passively rotate during standing and sitting process. The knee joints should provide enough force to keeping standing posture even although the joints did not expand totally. The minimum expanding angle was set as 165 degree.

The robot should be able to understand the trainee's comments. When trainees ask the robot patient to sitting down, the knee joints should loosen automatically for passive rotation.

3 Hardware Configuration

3.1 Joint Configuration of the Robot Patient

The joint configuration of the robot was shown in Fig. 1. The robot has 15 joints, including 2 active joints installed with motor (Futaba Co., Ltd), 4 passive joints installed with electric brakes (Miki Pulley Co., Ltd.) and 9 passive joints without any actuator.

To detect the rotation angle, potentiometer type angle sensors (Alps Electric Co., Ltd) were attached on the joints: shoulder joint S-y, elbow joints and the knee joints. The shoulder joint S-x was installed with a servo motor which had an angle sensor inside.

The patient robot was with the height of 160 cm. The robot's weight is 25kg, which is similar to the mean of real Japanese elderly patients.

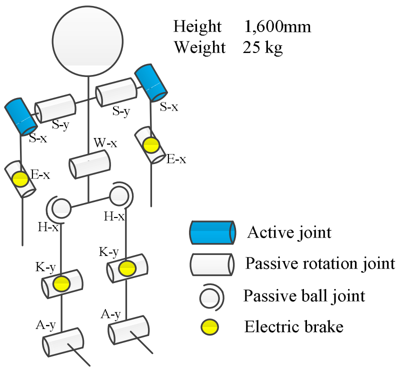


Fig. 1. Joint configuration of the robot patient

3.2 Arms

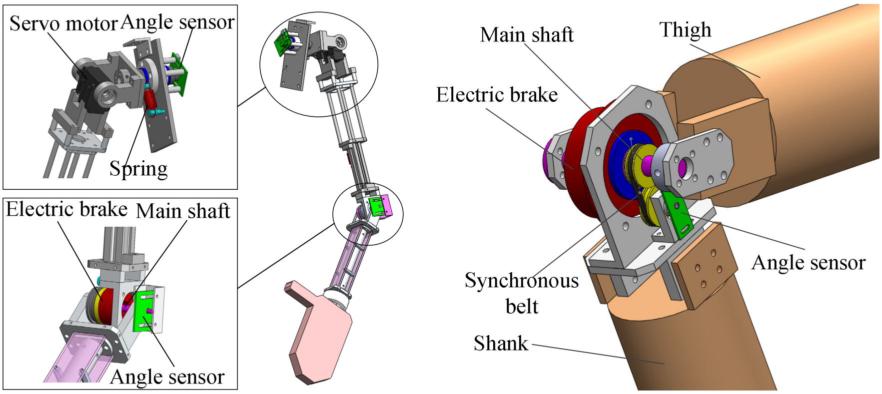
The robot arm had two degrees in the shoulder joints and one degree in the elbow joints (Fig. 2(a)).

The shoulder joint S-x was installed with a servo motor to reproduce the embracing movement of the patient. The motor was working on 7.4 V and the max output toque is 3.2 Nm. The shoulder joint S-y was a passive joint which was installed a potentiometer type angle sensor.

In the elbow joint, an electric brake was installed. The elbow joints would work in two modes, passive rotation and posture maintaining by controlling the brake to be on or off. The electric brake was working on 24V and its output torque is 2.4 Nm.

3.3 Knee Joints

An electric brake was installed on the knee joint to enable the robot patient to keep standing (Fig. 2(b)). The electric brake was working on 24 V and it output torque is 11 Nm. The torque enabled the robot patient to keep standing even if the knee joints' angle was no totally expended. The minimum open angle of the knee joint in the situation of keeping standing was 165 degree. This design enables the robot patient to simulate the patients' performance that their knee joint is unable to expand to 180 degree totally when keeping standing.



(a) Hardware of the robot arm (b) Hardware of the robot knee joint

Fig. 2. Hardware of the robot

4 Control Methods

4.1 Voice Interaction

The voice interaction was realized by the voice recognition module (TIGAL KG Co., Ltd). The robot was trained to recognize two words in Japanese: "Hello." and "Please sit down." When the trainee said hello to the robot, the robot would answer "Hello" to the trainee. This interaction happens before the patient transfer begins. This interaction is a required procedure according to the nursing textbook. When the trainee said "Please sit down" to the robot, the robot would answer "I understand." and then release the knee joints to sit down with the help of the trainee. This command is available only when the step of standing assistance was finished.

4.2 Physical Interaction of Body Limbs

Arm. In order to reproduce embracing movement of the patient, the follow-up control approach was applied on the servo motor of shoulder joint S-x. The servo motor's rotation angle based on the rotation angle of shoulder joint S-y.

During lifting the robot patient's arm, the shoulder joints of the robot would slowly rotate to embrace the nurse. Firstly, while the robot's arms were lower than the level of the shoulder, the shoulder joint was unfolding. Second, while the arm was higher than the shoulder level, the shoulder joint would start to fold. Finally, when the embracing finished, the shoulder joints and elbow joints would provide the torques to keep embracing. The torque would maintain until the transfer process finished.

Knee. In the beginning of the patient transfer process, the knee joints' brake was put off to enable the joints to passive rotation with the trainees' assistance. The trainee could adjust the legs' posture freely and then to assist the robot patient to stand up. The knee joints would passively expand during standing up. Once both the expanding angle of the knee joints was bigger than 165 degree, the brake would be put on. The torque of friction of the brake supported the robot patient's weight to keep standing. The robot patient was keeping standing until the turning was finished. Then the trainee would give comment to inform the robot patient to relax the knee joints for sitting down by voice interaction.

5 Experiment

5.1 Procedures

In order to examine the proposed robot patient's performance in patient transfer training, we conducted an experiment with a nursing teacher who is an expert in the nursing field. The teacher performed the steps of standing process and the sitting process to evaluate whether the robot patient would well reproduce the patient's performance, including voice interaction and physical interaction of body limbs.

In addition, the teacher was also asked to perform the same steps to an human mock patient who has up to 30 hours experiences in simulating patient for patient transfer training. The height of the mock patient is 160 cm. The height is the same as the robot.

The head trajectories of the robot were compared with the human mock-patients, since the head trajectories would reflect the movement of the mock patient's whole bodies during standing and sitting processes. We used the camera to record the image sequence of the experiment process. The image processing approach which was developed in our previous work [11] was utilized to extract the trajectories of the head of both robot and human mock patient.

5.2 Results and Discussion

Fig. 3 shows the image sequences when the nursing teacher assisted the robot to embrace stand up and sit down. The robot patient successfully reproduced the patient's movement of body limbs, including active rotation of shoulder joints, passive rotation of elbow joints and the knee joints. In addition, the posture keeping (embracing and standing) was also reproduced.

Fig. 4 shows the trajectories of heads of the robot patient and the human mock patient. The axis of x and y were respectively corresponding to the head's movement in vertical and horizontal direction (Fig. 3). The trajectories of the robot patient were similar to that of the human mock patient during the process of sitting down. The slope of the trajectories was slowly increasing as the decrease of the x.

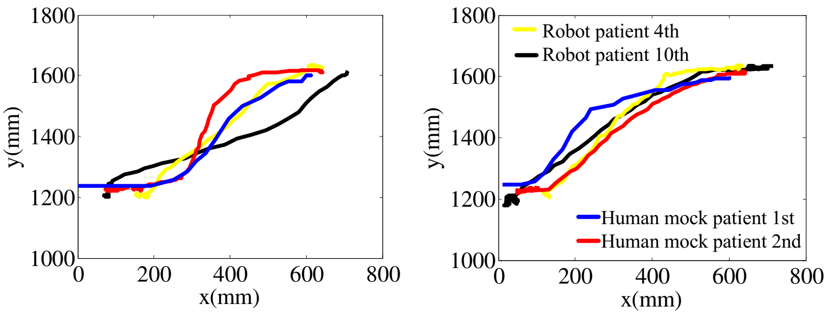
However, for the standing process, trajectories of the robot patient were different from that of the human mock patient. The difference was caused by the rotation range of the waist of the robot patient which was not enough. The human mock patient bended her back forward during standing while the robot patient bended the back backward.

The nursing teacher's subjective evaluation of the robot patient's performance was also conducted. The teacher was satisfied with physical interaction through the movement of the robot patient's arms. The teacher's comments are follows. The follow-up control of the shoulder joint well reproduced the movement of the weak patient's arms. The keeping embracing was also well reproduced by the patient robot. In addition, the teacher was satisfied with the reproduction of movement of the patient's knee joints, especially the movement when the sitting down process. The teacher commented that the electric brake of the robot patient would well reproduce the situation that the patient's knee joints' force suddenly disappears when the siting down assistance begins. This performance was difficult to reproduce even though by the experienced human mock patient.

From the nursing teacher's view point, this robot patient was suited to the simulated training for the trainees who have the patient transfer experience before hand, such as the senior nursing students or the nurses.

The nursing teachers' advises for improvements were the same as head trajectories analysis results. That is, the robot patient's waist should be improved to enable the robot to reproduce the back bending forward during standing up. This improvement will be considered in our future works.

Fig. 3. Image sequences when nursing teacher performed patient transfer using the robot patient: embracing (6s to 10s), standing assistance (11s to 13s), keeping standing (14s to 18s) and sitting assistance (18s to 20s)



(a) Standing process (b) Sitting process

Fig. 4. Comparison of head trajectories

6 Conclusion

In this paper, to assist the nurses and nursing student to improve their skill, a robot patient was developed for patient transferring training. The robot was designed to reproduce the patient's limb's motion, including embracing, keeping embracing, passively standing, sitting and keeping standing. Through the potentiometer type sensors installed in joints and speech recognition module, the robot was able to interact with the training, including physical interaction and voice interaction. The performance of the robot was examined by an experienced nursing teacher. The result revealed that the robot was able to well reproduce the patient's limbs motion while interacting with the nursing teacher.

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