Human-like Patient Robot for Injection Training by Chaotic Behavior

Yoshiro Kitagawa[1] Wei Song[1] Mamoru Minami[1] Yasushi Mae[2]
(1 University of Fukui, Japan)
(2 Osaka University, Japan)

Abstract: In this paper, we present a system of patient robot developed aiming at improving abilities of nursing student's medical treatment, such as injection to vein. To let patient robot's motion look like human, we introduce visual servoing into the robot's head motion, simulating human's behavior of looking into the face who is talking with. Evaluating the effectiveness of the robot through the injection, we measure heartbeat rate of student nurses during the injection training, proving the effects of the robot's similarity to human.

Keywords: Patient robot, Chaos, Experimental verification, Nursing application, visual servoing

1 Introduction

Nowadays, some human body models called "phantom" imitating parts of human body are developed, but most of them are used for particular individual technical training. Those partial body phantom do not suit for the nursing training, since the on-line monitoring training through patient robot helps them notice sudden change of patients' conditions, preventing medical malpractices before dropping in worst situation. And this can not be done by phantom.

To offer safe and effective nursing training, the "patient robot" must present its mental expression through face actions and body behaviors since nurses are required to monitor the patients' conditions during nursing procedures. Contrarily the robot has to monitor the nurse students' injection procedure to measure their ability from the view point of patients.

In this paper, we will introduce a new simulator called patient robot. It is important to conduct such a nursing training not only to learn how to secure patient's safety through monitoring the patient's condition with appropriate frequency, but also to let patients feel relieved in nursing. Therefore, development of patient robot that can realize emotional motion reflecting the psychological condition of the patient is essential.

2 Patient Robot

We mounted the robot's head with two CCD cameras as eyes to observe the training nurse and installed some servomotors in the inside head for generating face expression, as shown in Fig.1. By these servomotors, the patient robot can express, normal, smile, angry and painful faces, as shown in Fig.2-5[1]. The moving parts of patient robot's body are shown in Fig.6. Left arm is made by arm model for blood drawing training, and the artificial vein flowing imitation blood is buried in the arm. Moreover, since looking at the state of patient frequently is necessary to avoid danger along with nursing, we detect student's face with these eye cameras to evaluate whether the nurse is paying attentions to the state of patient while injecting[2].

3 Patient Robot System

3.1 Emotional State Space

To engineer that the robot can imitate patient's expressions and behaviors reflecting their mental state, we define patient robot's inside state space representing nurse's injection level as shown in Fig.7. X-axis in it shows the evaluation of the watching skill (Stressed-Relaxed) and Y-axis shows the injection skill (Painful-Tolerable). Psychological condition of the patient robot is expressed by the point of coordinate ($X(t)$, $Y(t)$) in that state space, and patient robot's expression and motion will be decided depending on the value ($X(t)$, $Y(t)$).

In this stage, patient robot can only determine the Stressed-Relaxed axis $X(t)$ because it doesn't have sensor for detecting pain. So $Y(t)$ is always to be zero. According to the detection ratio of trainee's face

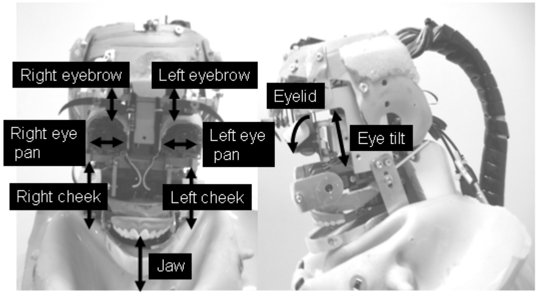

Fig.1 Structure of head

Fig.2 Normal face Fig.3 Smile face Fig.4 Angry face Fig5 Painful face

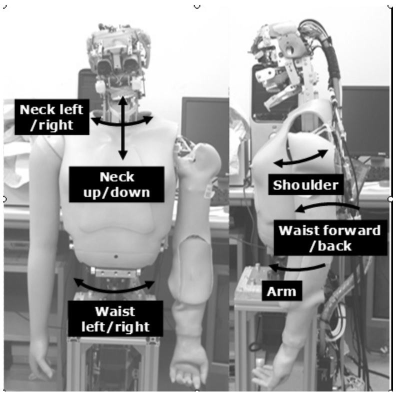

Fig.6 Structure of body

representing how frequently the trainee checks the patient robot face to monitor his/her condition through two cameras set at the robot's two eyes, patient robot can evaluate the injection procedure with how much the trainee makes efforts to get patient's inside information.

The function of normalized detection ratio of trainee's face ${}^{s}E_x(t)$ ($-1<{}^{s}E_x<1$) is determined by real-time face-detecting system in the patient robot.

3.2Emotional Fluctuation by Chaos

Inside state of patient robot that is decided only by sensing result makes the motion of patient robot simple and easy to be predicted by trainee during injection training, resulting in deleting the essential meaning of learning how the caring mind about the patient's condition can avoid malpractices. Therefore we use chaos to change the inside state of patient

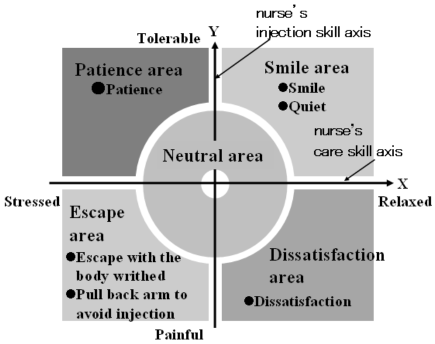

Fig.7 Emotion model of patient robot

robot autonomously, which is existing in real human's inside phenomena what we believe to generate personality by chaos. Here, we use the chaos orbit of a non-linear differential equation called a *Rössler* model.

$$\dot{x} = -y - z$$
$$\dot{y} = x + ay \qquad (a = 0.2; b = 0.2; c = 5.7) \qquad (1)$$
$$\dot{z} = b + z(x - c)$$

X-axis value $X(t)$ in Fig.7 is changed into $X(t)+x(t)$ by adding chaos orbit $x(t)$. Also, Y-axis $Y(t)$ is changed into $Y(t)+y(t)$ and those are denoted by ${}^{c}E_x(t)$, ${}^{c}E_y(t)$ as

$${}^{c}E_x(t) = X(t) + x(t) \qquad (2)$$
$${}^{c}E_y(t) = Y(t) + y(t) \qquad (3)$$

3.3 Motion Generation

The motion of patient robot is decided by value of ${}^{s}E_x(t)$ or ${}^{c}E_x(t)$ which is mentioned in sections 3.1 and 3.2. For example, radius of circle of "Neutral area" in Fig.7, named E_{th}, is the threshold to change patient robot's motion. Patient robot performs smile, normal and painful faces, when Eq.(4) is satisfied.

$$(A)\ {}^{*}E_x(t) > E_{th} \rightarrow \text{smile face}$$
$$(B)\ |{}^{*}E_x(t)| \le E_{th} \rightarrow \text{normal face}$$
$$(C)\ {}^{*}E_x(t) < -E_{th} \rightarrow \text{painful motion} \qquad (4)$$

In Eq.(4), ${}^{*}E_x(t)$ expresses either ${}^{s}E_x(t)$ or ${}^{c}E_x(t)$. The motion being influenced from chaos is hard for trainee to predict the motion of the patient robot, thought to generate human-like atmosphere.

4 Visual Servoing

We perform a 3-D visual servoing experiment of the patient robot by using the recognition result of the 3-D head pose. Here, the position / orientation of the target

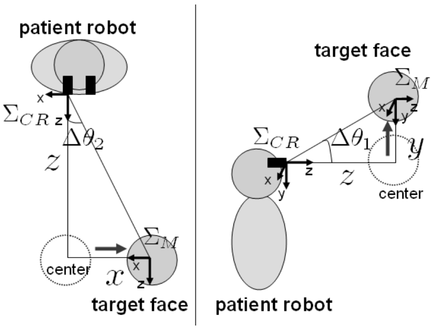

Fig.8 Angle of servoing

head is recognized by two cameras installed in the inside head of the patient robot, and the objective of the visual servoing is to control the patient robot to keep observing the target human's face through the center of the right camera. Patient robot can rotate pan and tilt angles of two eyes (3-DOF), neck (2DOF) and waist (2DOF), and there are totally 7 DOF to perform motion.

Here, we use the model-based recognition method that explained in [3], and get head's position / orientation. From relation between coordinate system of right camera Σ_{CR} and coordinate system of object's head Σ_M as shown in Fig.8, we can calculate the angle deviation $\Delta\theta_1, \Delta\theta_2$ by Eq. (7) and (8), using the recognized face position (x, y, z) with respect to coordinate system Σ_{CR}.

$$\Delta\theta_1 = \mathrm{atan2}(y, z) \quad (7)$$

$$\Delta\theta_2 = \mathrm{atan2}(x, z) \quad (8)$$

The tilt angle of the patient robot is controlled to decrease $\Delta\theta_1$ to zero, and pan is done by $\Delta\theta_2$. We verified that the patient robot can generate the motion that is similar to human by performing visual servoing.

5 Evaluating Experiment

Experiment of using the patient robot to perform drawing-blood training has been conducted. The trainees are the nurse students who have experience to do injection training using arm model.

5.1 Model for Training

We prepared 4 kinds of training models:

"**Arm model**" a commercial injection training model that imitated just the arm part of human.

"**Doll model**" a whole body model, but doesn't move at all.

Fig.9 Blood drawing using patient robot

"**Sensor model**" a patient robot whose motion is based only on the state determined by sensing.

"**Chaos model**" a patient robot whose motion is based on the inside state determined by sensing and chaos.

The photographs of the experiments are shown in Fig.9.

5.2 Action Pattern of Patient Robot

In the evaluation experiment, we divided the blood drawing performance into four processes, as shown in Fig. 10. These four processes are

[Process I] From the time of the action start to the time when the nurse student takes an injector.

[Process II] From the end time of process I to the time when nurse student sticks injector into the vein of the patient robot.

[Process III] From the end time of process II to the time when nurse student pulls the injector out.

[Process IV] From the end time of process III to the time when the injection procedure completes.

These periods from I to IV are shown in Fig.10. The motion of the robot in case of using a sensor model and using a chaos model obeys the motion pattern that is chosen by operator as shown in Fig.10. Patient robot performs given action pattern based on its inside state during each process. During this training process, the patient robot keep detecting the front face of the nurse student to estimate whether the trainee pays attention to the patient's situation during the blood drawing. In process II, the operator of the experiment indicates when the trainee took the injector by keying in one of two motions, "A" or "B", where A represents a motion to hate and scare the injection without face expression (with normal expression), and B does no motion and no expression, are determined by

$$E_x(t) \le E_{th} \rightarrow \text{motion A} \quad (4)$$

$$E_x(t) > E_{th} \rightarrow \text{motion B} \quad (5)$$

At the end of process II, when the operator chooses the motion on the operation form is "C" (no motion with normal face) or "D" (motion like hating injection with painful face) in the case of using the sensor model. In this experiment, we used D at all of the eight times. The motion in case of using the chaos model is given by

$${}^{c}E_{x}(t) \text{ î } E_{th} \text{ Ä! } \text{motion D} \quad (6)$$

$${}^{c}E_{x}(t) > E_{th} \text{ Ä! } \text{motion C} \quad (7)$$

5.3 Experiment Method

Letting a nursing student train the drawing-blood procedure four times using each model introduced in 5.1, we examined whether student still feels nervous even when draws blood repeatedly four times. We attached a pulsimeter to wrist of the nurse student to measure a pulse rate during the injecting action.

5.4 Experiment Result

We evaluate the effectiveness of the motion of the patient robot based on the student's heartbeat rate.

We define the period of Process I defined at 5.2 as T_1, the period of Process II and III as T_2, and the period of Process IV as T_3, which are shown in Fig.10. Table 1 shows average and the inclination of the pulse rate during each term by using 4 kinds of model separately mentioned at 5.1.

In drawing-blood procedure, the most important process is in term T_2, and we pay attention to this term. If the inclination of the pulse rate is a positive number, it means the nurse student keeps feeling of nervous in T_2. When using chaos in patient robot's motion, the inclination of the pulse rate becomes positive number in T_2 as shown in Table 1. We can say that the nurse student kept nervous while injecting practice by chaos. Therefore, it is effective to use chaos in the training of the drawing-blood.

6 Conclusion

In this research, we installed the motion generated by chaos in a patient robot's motion. The effectiveness of the psychological motion of the patient robot has been verified by measuring of the heartbeat rate of the nurse students in the training of the injecting. From the training experimental data, we can say that such a patient robot has a meaning on improving the ability to inject correctly while caring patient states.

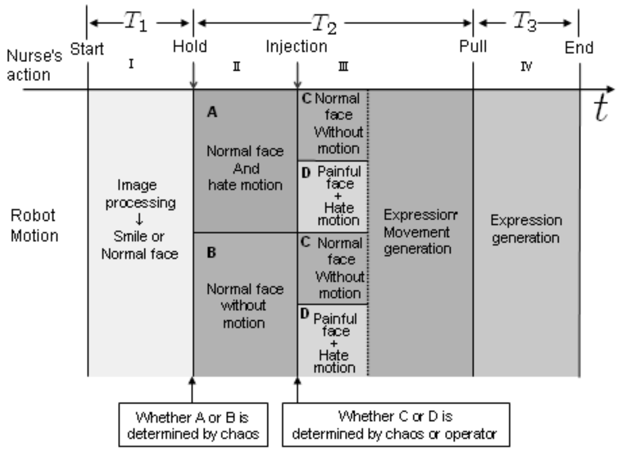

Fig10. Action pattern of patient robot

Table 1 Inclination of heartbeat (all average)

	Arm	Doll	Sensor	Chaos
Start → Hold (T_1)	0.1370	0.0794	0.2220	0.0383
Hold → Pull (T_2)	-0.4675	-0.0875	-0.0896	0.0382

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Author Biographies

Yoshiro Kitagawa: Master Course Student in University of Fukui, Japan.

Wei Song: Doctoral Course Student in University of Fukui, Japan.

Mamoru Minami: Professor, Department of Human and Artificial Intelligence Systems, University of Fukui, Japan.

Yasushi Mae: Associate Professor, Department of Systems Innovation, Osaka University, Japan.