Automatic Motion Generation from the Posture Template

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Abstract— **This paper presents automatic generation of robot motion using posture template in physical training system. In this system, we define a human-like generic template with two angles, then, we generate robot motion that has used angle data of the created template.**

The angle data is transformed automatically to the most similar motion. This is achieved by suitable expressions for robot specification. The expressions intend to differences of angle measurement on X,Y,Z planes and DOF constraint. We choose several postures and create generic templates for chosen postures. Robot motions are also generated from generic templates by expressions.

Index Terms— **Motion genetate, Motion transform**

I. INTRODUCTION

According to development of robot technology, robot has used in industry and service sphere widely. At the same time, ubiquitous computing that has boundless potential is coming to our life. Being associated with this, robot utilization could be considered as one of the computing device for ubiquitous service. Humanoid robot, that is able to present computing power, human-like contour and human-like motion implementation, could be a good stuff to manage service at various environments and to satisfy the user's sensual requirement, like ubiquitous robotic companion as well known[1][2]. We are interested in the side the above, so we have developed the physical training system using humanoid robot.

The training concept of this system is, if user posture is proper, the system decides to proceed to the next step, but if the posture isn't proper, it informs the state to user and retries the same posture to make the user to perform the right posture.

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Whole system consisted of two parts such as figure 1, creating template and motion generating. About creating template part, it defines human's body by each body part with two angles and width and then creates generic template of posture in order to recognize human's posture. It measures the similar rate between generic template and inputted image via built-in camera. For comparing the similar rate of contour with these two images, we use the Chamfer matching [3][4] technique. After estimating the posture with template, it retries the posture or go on to the next posture. More details about posture measurement and adjusting template are in [5][6].

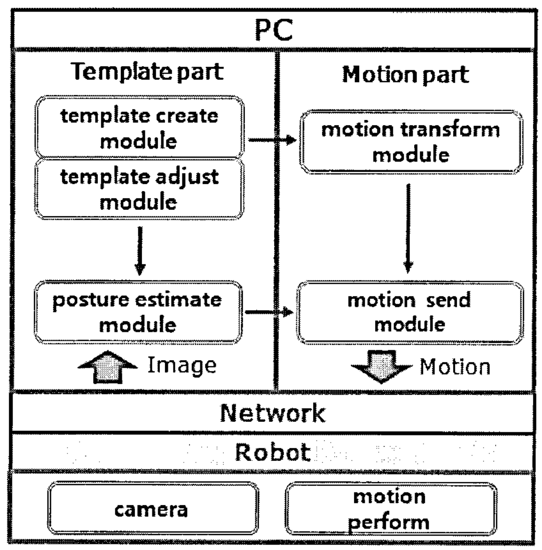


Fig. 1. The architecture of physical training system

This paper presents motion generating part. The template of corresponding posture is created and it also creates the well suited motion for robot by using the angle data of template by motion part. Motion part generates robot motion using template transformation. Template is transformed by the robot feature expressions that mean difference of angle measurement on XYZ planes and DOF constraint. We choose four postures from regular physical training course. Four generic templates are created from chosen postures and four robot motions are also generated from generic templates by expressions. Generated motions are sent to robot through network then performed.

In the next section, we provide the basic template for motion. In section 3, we provide motion feature of the robot that is used in this paper, and in section 4, how to generate robot motion.

II. BASIC TEMPLATE FOR MOTION

Human's clothes and somatotype are too various, there is no standard template for particular posture. Therefore, basic template for motion generating has to be created at first. The basic template is also used in posture recognition of the trainee [5].

Human's posture viewed from plane is represented by 13 major joints of neck, shoulder, elbow, wrist, pelvis, knee and ankle in general. We have excluded some joints for detailed representation like neck, wrist and ankle because those joints do not use to make a posture for physical training. Eight joints can be represented by nine body segments that are being connected with each joint. Each segment is associated with length, width, and angle values. In general, the contour of each segment is cylindrical shape, so this can be represented by two parallel lines in plane. Figure 2 shows description of body segments with several values and image drawing of them. Whole template image has been combined with each drawn body segment.

Each segment is drawn as follows. At first, we define the start-point of each segment as basis for drawing, then, obtain corresponding point by calculating angle on XY plane and length using trigonometrical function. After assuming the virtual center line that is connected with these two points, we can also obtain the template of each segment through drawing of two parallel lines using translation of 90 degree by fitting on width from the center line.

	angle (XY)	angle (Z)	length (pixel)	Width (%)
torso (center)	270	0	67	100
upper arm (left)	0	0	27	30
forearm (left)	0	0	30	25
upper arm (right)	180	0	27	30
forearm (right)	180	0	30	25
thigh (left)	280	0	55	43
lower leg (left)	280	0	46	35
thigh (right)	260	0	55	43
lower leg (right)	260	0	46	35

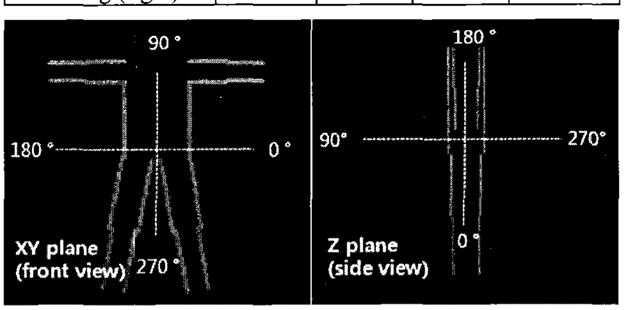


Fig. 2. Representation of basic template

Pre-given values to draw whole template are start-point for template, basic length and width rate of segment, and two kinds of angles. Pre-given start-point is only for torso. Other start-points of each segment are automatically chosen by relative coordinates of other segment that are connected with. For example, start-point of lower arm is end-point of upper arm. To do this, upper level segment must be drawn before lower level segment.

Basic length and width rate of each body segment are set up from the average value that was obtained from measuring three people who have generic somatotype. Basic length describes lengths of each segments when people is standing straight, also means 0 or 180 degree on Z plane. All the basic lengths are needed to pre-define manually. Basic width rate describes relative widths of body segments. In this case, torso has been chosen as the basis for width rate because widths of arms and legs can be expressed as the relative width of torso. If the width of torso is equal to 200 pixels, then the width of upper arm is equal to 60 pixels because the width of upper arm is 30% of the width of torso.

Angles of body segments are given as two kinds. Angle on XY plane is used in representing the posture and angle on Z plane is used in calculating length of segment viewed from XY plane. If body segment moves on direction of Z plane, length of body viewed from XY plane will be changed. We have defined basic lengths of body for standing straight as the above, so calculate changing each length due to angle on Z plane using simple trigonometrical function. For example like figure 2, angle on Z plane of upper arm is 0 degree and length is equal to 27. If angle on Z plane is changing to 45 degree, then length is going to be equal to 19. Two kinds of angles are also used in making robot motion.

III. METHOD OF GENERATING MOTION FROM ROBOT FEATHER

In humanoid robot, there are many servo motors that correspond to human's joints. Each servo motor performs motion by regulating angle of body segments that is connected with the servo motor itself. Thus, it can describe robot motion by angles of servo motors.

Each joint consists of one or two servo motors that are following Degree of Freedom (DOF). For example, joints of shoulder and pelvis need two angle values because they are able to act on two ways of direction on XY and Z planes, and joints of elbow and knee need one angle value in the same way. The value of motion angle uses data that was used to make templates in section 2. Template data has two angles for one body segment. Thus, it can be used to describe robot motion. However, the differences of motion description for each kind of robots make using template data in a raw hardly, so template data have to be transformed. To transform motion for MIRAI SPC-101 humanoid robot that we used in this paper considers to following differences. Specifications of the robot are described in [7].

Seeing as figure 3, starting point and directions between template and robot motion are different on XY plane. Robot represents motion angles at left and right sides within 0° ~ ±180° separately. Therefore, template angle 0° ~ +360° has to be transformed to robot angle upon due to consideration of starting point and directions.

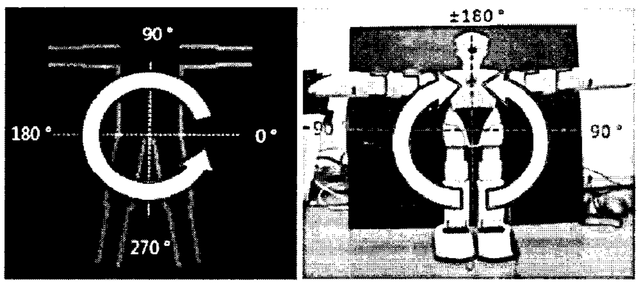


Fig. 3. Difference between angle basis

One more thing that has to be considered is DOF. The range of posture description with template is not limited because there is no concept of DOF on template, but the same thing of robot is not. Table 1 represents DOF on each joint of MIRAI SPC-101 robot.

TABLE I
DOF OF MIRAI SPC-101 ROBOT

	DOF (XY plane °)	DOF (Z plane °)
torso (center)	None	-38 ~ +8
upper arm (left)	0 ~ +142	-27 ~ +92
forearm (left)	None	-87 ~ +87
upper arm(right)	0 ~ -142	-27 ~ +92
forearm (right)	None	-87 ~ +87
thigh (left)	-10 ~ +18	-43 ~ +88
lower leg (left)	None	-143 ~ +3
thigh (right)	-18 ~ +10	-43 ~ +88
lower leg (right)	None	-143 ~ +3

Robot cannot perform the motion over DOF, so all of template angles must be transformed within the range of DOF. According to the above, template angles on XY plane can be transformed to motion angles by following expression.

XY plane (Left side)

$$\text{motion}\theta = \frac{\pi(\text{radian})}{2} + \text{template}\theta$$
$$\text{if}\left(\text{motion}\theta > \pi(\text{radian})\right),$$
$$\text{motion}\theta = \text{motion}\theta - 2\pi(\text{radian}) \quad (1)$$

XY plane (Right side)

$$\text{motion}\theta = \text{template}\theta - \frac{3\pi(\text{radian})}{2} \quad (2)$$

For the next step, template angle on Z plane also have to be transformed. Figure 4 shows the posture of robot knees bent with legs. It shows difference of angle on Z plane between template and motion by the datum plan.

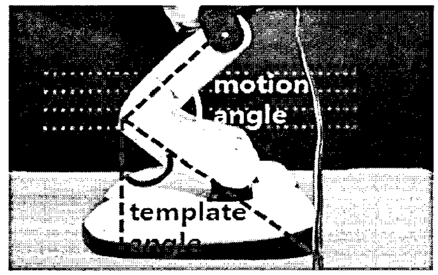


Fig. 4. Angle difference on Z plane

Template angle on Z plane means the angle standard of vertical line as shown in figure 2. However, robot angle fluctuates up to angle of upper level segment. Because robot joint is connected with other segments physically, so it is susceptible to angles of connected segments. There is the expression to transform angle on Z plane to motion as considering above figure.

Z plane

$$\text{motion}\theta = \text{template}\theta - \text{preTemplate}\theta$$
$$\text{if}\left(\text{motion}\theta > \pi(\text{radian})\right),$$
$$\text{motion}\theta = \text{motion}\theta - 2\pi(\text{radian}) \quad (3)$$

The preTemplateθ in expression (3) is the angle of connected segment. For example, if templateθ is the angle of lower leg, then preTemplateθ will be the one of thigh. After obtaining motion angles on XY and Z plane, it must confirm that these angles are out of DOF range or not. The constraint means maxima and minima values of DOF of each joint.

DOF confirm (XY plane, Left side)

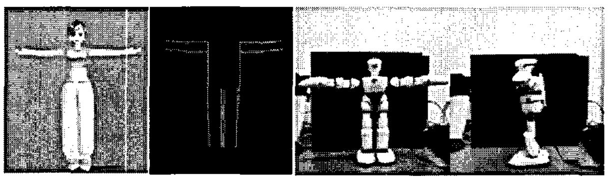
$$\text{if}\,(\text{motion}\theta > \text{constraint}\theta_{max}),$$
$$\text{motion}\theta = \text{constraint}\theta_{max}$$

$$\text{if}\,(\text{motion}\theta < \text{constraint}\theta_{min}),$$
$$\text{if}\left(|\text{motion}\theta| > \frac{\pi(\text{radian})}{2}\right),$$
$$\text{motion}\theta = \text{constraint}\theta_{max}$$
$$\text{else}, \text{motion}\theta = \text{constraint}\theta_{min} \quad (4)$$

The expression (4) is DOF calculating on XY plane (left side). If motion angle is out of DOF, then it will be take maxima or minima of DOF in order to make motion as most similar with template. DOF calculating on XY and Z planes is working on the same way as the above except permutation for absolute value and changing a sign of inequality. The example case of adapted (4) is in figure 6 (d) in next section.

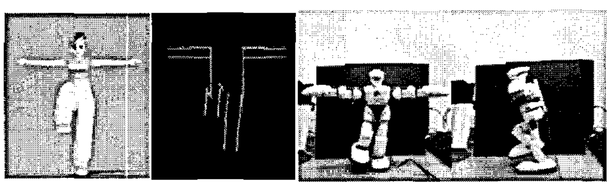
IV. AUTOMATIC MOTION GENERATING

Template data can be transformed to robot motion using the expression in section 3. We have chosen four postures to generate motion automatically. Figure 5 shows it



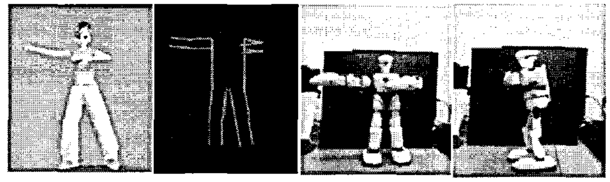
	template		motion description
	angle (XY plane)	angle (Z plane)	
torso (center)	270	0	BDY1+000.0
upper arm (left)	0		LAM1+090.0
		0	LAM2+000.0
forearm (left)	5	0	LAM3+000.0
upper arm(right)	180		RAM1-090.0
		0	RAM2+000.0
forearm (right)	175	0	RAM3+000.0
thigh (left)	269		LLG2-001.0
		0	LLG3+000.0
lower leg (left)	269	0	LLG4+000.0
thigh (right)	271		RLG2+001.0
		0	RLG3+000.0
lower leg (right)	271	0	RLG4+000.0

(a) posture 1



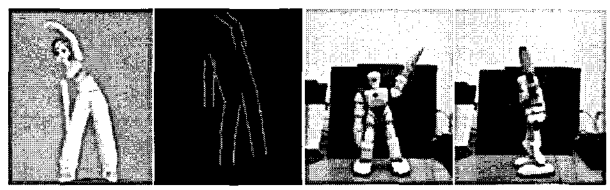
	template		motion description
	angle (XY plane)	angle (Z plane)	
torso (center)	270	0	BDY1+000.0
upper arm (left)	0		LAM1+090.0
		0	LAM2+000.0
forearm (left)	0	0	LAM3+000.0
upper arm(right)	180		RAM1-090.0
		0	RAM2+000.0
forearm (right)	180	0	RAM3+000.0
thigh (left)	265		LLG2-005.0
		0	LLG3+000.0
lower leg (left)	265	0	LLG4+000.0
thigh (right)	130		RLG2-018.0
		105	RLG3+088.0
lower leg (right)	265	0	RLG4-105.0

(b) posture 2



	template		motion description
	angle (XY plane)	angle (Z plane)	
torso (center)	270	0	BDY1+000.0
upper arm (left)	350		LAM1+080.0
		145	LAM2+092.0
forearm (left)	185	0	LAM3+087.0
upper arm(right)	180		RAM1-090.0
		0	RAM2+000.0
forearm (right)	175	0	RAM3+000.0
thigh (left)	280		LLG2+010.0
		0	LLG3+000.0
lower leg (left)	280	0	LLG4+000.0
thigh (right)	265		RLG2-005.0
		15	RLG3+015.0
lower leg (right)	270	0	RLG4-015.0

(c) posture 3



	template		motion description
	angle (XY plane)	angle (Z plane)	
torso (center)	290	0	BDY1+000.0
upper arm (left)	107		LAM1+142.0
		0	LAM2+000.0
forearm (left)	145	0	LAM3+000.0
upper arm(right)	270		RAM1+000.0
		0	RAM2+000.0
forearm (right)	270	0	RAM3+000.0
thigh (left)	280		LLG2+010.0
		0	LLG3+000.0
lower leg (left)	280	0	LLG4+000.0
thigh (right)	260		RLG2-010.0
		20	RLG3+020.0
lower leg (right)	268	340	RLG4-040.0

(d) posture 4

Fig. 5. Generated motion from template

We explain transform steps with posture (d) in figure 5, because posture (d) shows well to how motion angle to be decided by template angle and DOF.

Template angle of upper arm (left side) on XY plane in posture (d) is 107 degree, and this is transformed to -163 motion degree by expression (1). DOF confirms for next step, -163 motion degree is small then constraintθ_{min} , so final motion angle of upper arm is decided on 142 degree by expression (4).

Thigh angle (right side) on XY plane is 260 degree, it is transformed to -10 degree by expression (2), but in this case it satisfy the range of DOF in table 2, so there is no change by expression (4).

Lower leg (right) angle on Z plane is 340 degree, and it is transformed -40 degree by expression (3) because its preTemplateθ is 20 degree of thigh (right side).

The result of transform posture (d) looks like difference with template and motion. However, that is represented by maxima angles as similar as possible, it cannot make motion more similar. Wide range of DOF of robot can make motion freely.

In the case of posture (a) in figure 5, template angles of forearm are each 5 and 175 degree but they have been ignored when transforming to the motion. Forearms and lower legs are acting with one servo motor in this robot, so the angle on XY plane is not used. Posture (b) and (c) are chosen for proving of the motion transforming for high angles with arms and legs. It shows transforming has been completed similarly although angles were fixed to DOF maxima.

This transforming process is only for MIRAI SPC-101 humanoid robot that used in this paper, process must be changed according to kinds of robots. In other words, template data does working as middle level motion description at motion making process. It can be applied to kinds of robot generally through motion transform device that has specific expression of each robot.

There is one more issue that all the motion descriptions treated in this paper are about paused state. Real movement of MIRAI SPC-101 robot is carried out by at least two paused motion descriptions listed sequentially.

In other words, if there are two descriptions about paused state, a servo motor corresponding to each joint will act from the angle of previous description to next description.

V. CONCLUSION

In this paper, we present motion generating on physical training system that is using humanoid robot. To do this, we define human's body with angles and widths to make human's rough contour for recognition in general. And we create the posture template to measure the similar rate between created template edge and inputted image. Then we present the steps that generate motion from template data automatically. About this, several expressions are discussed to describe motion feature of robot. The expressions intend to differences of angle measurement on X,Y,Z planes and DOF constraint in order to adapt motion description to robot feature. Whole system experiments are following after that.

In most case, description of robot motion is directly coded or typed by developer. This needs a lot of time for generating motion, and should be hard to casual users. The way of motion transformation suggested in this paper is based on the template which presents human posture abstractly, so it can be widely applied for various fields with providing feature of robot motion. For example, robot can follow human's movement by generating motion instantly via recognizing process of land marks of human's joints on image.

By the way, we are interested in distributed process system for robot, although there are just a few discussions in this paper. To consider for possibility of the environments as various robot services are running, like ubiquitous robotic companion, it may request robotics framework model of sharing resources with other computing device. We will continue research on side of the way in future.

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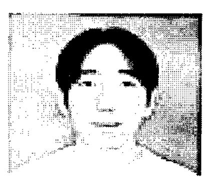

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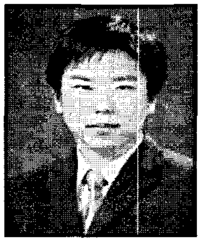

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