REALIZATION OF TAI-CHI MOTION USING A HUMANOID ROBOT

Physical interactions with humanoid robot

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Abstract: Even though in recent years research and development of humanoid robots has increased, the major topics of research generally focus on how to make a robot perform specific motions such as walking. However, walking is only one of the complicated motions humans can perform. For robots to play an active role in society as our partner, they must be able to simulate precisely various kinds of human actions . We chose tai-chi as an example of complicated human actions and succeeded in programming a robot to perform the 24 fundamental tai-chi actions.

Key words: robot, physical interaction, communication

1. INTRODUCTION

Many companies and universities are currently doing research and development into humanoid robots. These robots are equipped with a certain amount of flexibility at their robotic “joints,” making it possible for them to perform various motions. However, most of these studies investigate little outside of rising or walking actions, ignoring the rest of the actions that humans can perform. As a result, little research has fully investigated and utilized robotic flexibility. Indeed, since walking and rising are good examples of complicated and dynamic actions, it is valuable to study them. At the same time, however, it is expected that in the near future humanoid robots will be introduced into society to become our partner at home and in the workplace. Therefore, robots must not only walk or rise but also do various kinds of human-like operations naturally. Robots must also use these motions to communicate with humans. Based on this basic concept, we tried to reproduce smooth full body actions in a commercially available humanoid robot. We selected the motions of *tai-chi,* a Chinese martial art form, because smooth movements condensed from all human actions for exercising the entire body are essential to it. Therefore, our goal is to design tai-chi actions, install them, and develop a humanoid robot that can perform them.

2. HUMANOID ROBOT

We decided to use a robot developed at the Hajime Laboratory to reproduce the smooth exercises of tai-chi. This humanoid robot was equipped with 22 servomotors, enabling it to simulate the smooth, human-like motions by simultaneously controlling all of these motors. The hardware specifications of the robot are shown in Table 1, and its appearance is shown in Fig. 1.

Table 1. Specification of the humanoid robot used for experiment

Size / Weight	34cm / 1.7kg
Flexibility	22 (leg 12, arm 8, waist 1, head 1)
CPU	SH2/7047F
Motor	KO PDS-2144, FUTABA S3003, FUTABA S3102, FUTABA S3103
Battery	DC6V

3. TAI-CHI

There are five major schools of tai-chi: Chin, Kure, Son, Bu and Yo, which is the most commonly practiced style. Yo's extended version has been officially established by the Chinese government. As an established tai-chi, there are 24 formula, 48 formula, 88 formula, and etc. In creating tai-chi motions, we chose the 24 formula tai-chi because even though it is the simplest form of tai-chi, it still contains the strong points of the other schools.

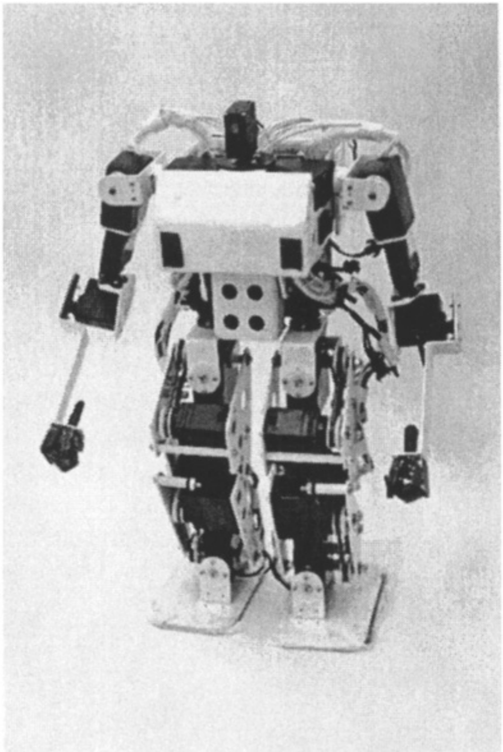

Fig. 1. Appearance of the humanoid robot

4. MOTION EDITOR

A motion editor was used to design the robot's motion as shown in Fig. 2. Fig. 2 also shows the *Front, Right,* and *Top* views for the robot's front, right, and above positions, respectively. In the *Perspective* view, we can rotate the robot image 360 degrees in any direction to gain a panoramic view. The angle of each motor is controlled by the parameter in the upper right part of the figure. The number in the left-hand side shows the data assigned to each motor, and the right-hand side number shows the angle of each motor. The transition time for each motion is decided by the parameter in the lower right part of the figure. Moreover, since we can create and store 32 motions in one file, 24 files were created to store all of the 24 formula tai-chi motions.

5. MOTION DESIGN

Basically, each motion was created manually using a motion editor. By connecting each created motion, a series of smooth actions was generated. The detailed process is described below.

5.1 Creation of motion with the motion editor

As described in section 4, we exhaustively studied each tai-chi motion through magazines and videos. Then we divided each continuous motion into a series of short, key motions; key frames were decided for each motion. Next, a portion of each key motion was decided using the motion editor, which then output the control data for each servomotor. In the process, we had to create each motion, maintaining as much balance as possible.

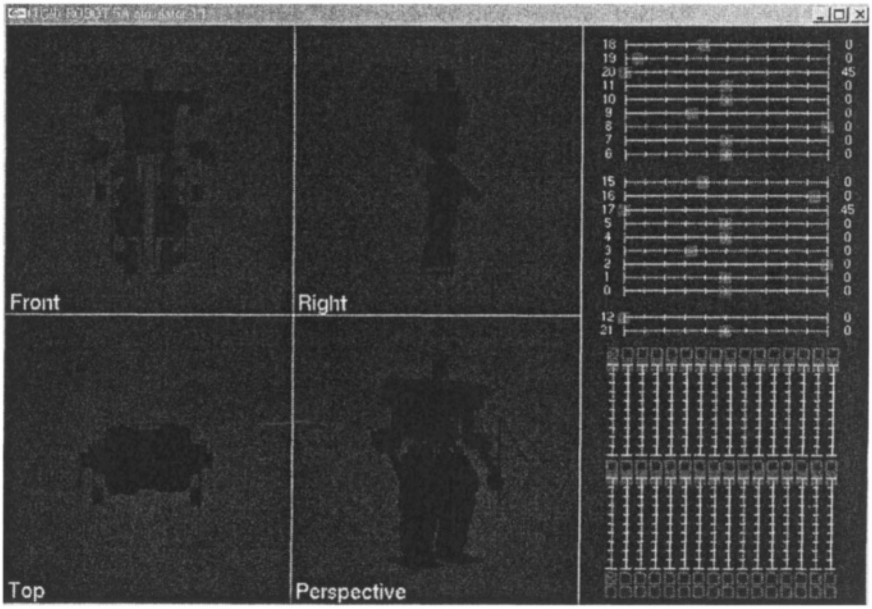

Fig. 2. User interface screen of the motion editor

5.2 Check of continuous action

Before connecting the motion created in section 5.1 to a series of motions, it was necessary to investigate any incongruities by comparing the motion with that of human tai-chi motion from magazines and videos. Tai-chi, essentially, is comprised of a series of continuous actions that do not stop from beginning to end. When the robot does tai-chi, however, there is a short pause when the motion is connected because of the specifications of the motion editor that we used. However, if we concentrate on watching the tai-chi motion of the robot, however, there is no little sense of incongruity.

5.3 Motion adjustment on an actual robot

Each tai-chi motion created in section 5.2 was then installed into the robot and checked. Since the robot's center-of-gravity could only be checked during simulations with the actual physical robot, this whole process was the most important and time consuming. Sometimes small differences in the center-of-gravity between the computer graphics robot and the physical robot couldn't be recognized on the motion editor. If the robot fell down during a tai-chi motion, the motor angle had to be adjusted. A key frame between two key frames had to be carried out. In this way, we investigated for incongruity in the series of robot motions, eventually obtaining complete motion data.

6. DEMONSTRATION OF TAI-CHI MOTION BASED ON HUMAN ROBOT INTERACTION

We extended our study and added a speech recognition tool called *Julian* to the robot, enabling it to perform a tai-chi demonstration based on communication with humans. When a user utters a command sentence, the key words are extracted by the speech recognition tool, converted into the control command for the robot, and sent to it (Fig. 3). The control data for each motion itself is loaded in the robot's microcomputer. Corresponding to the control command sent from the Server PC, the microcomputer reads out suitable control data to control the robot movement.

At various exhibitions we demonstrated our robot having easy conversations with the audience and showing them various tai-chi motions. In the future, various applications are possible based on such interaction between humans and this type of humanoid robot. For example, a robot can talk or chat with humans and act as their partner. It can also entertain humans by showing them tai-chi or dancing with them. Moreover, such forms of entertainment that currently use computer characters as fighting games and role-playing games could be performed with humanoid robots. In the near future there could be a growing market for such interactive games.

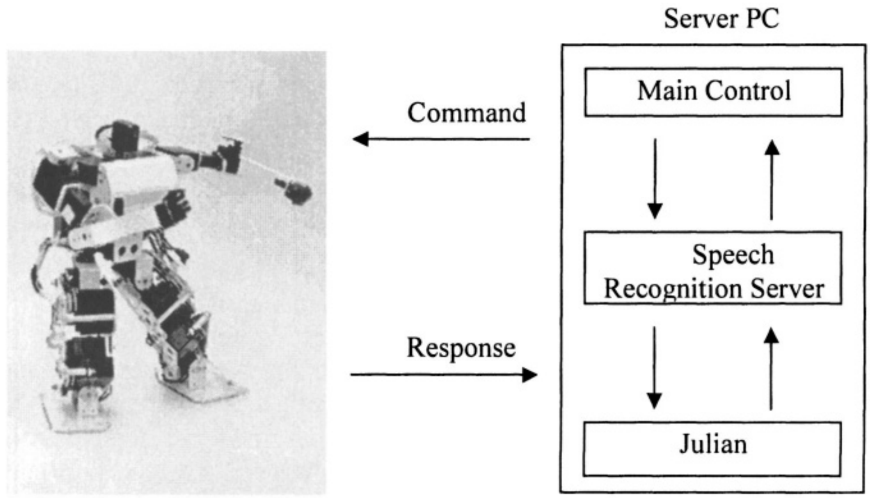

Fig. 3. Composition of the conversation system using the robot

7. CONCLUSION

In this paper we investigated the realization of tai-chi motions for a humanoid robot and created a control data base of human-like tai-chi motions. However, tai-chi is only one of the complicated motions and actions of humans. A humanoid robot must be able to perform various human-like motions, so a robot needs to be capable of autonomous motion, action, and behavior.

For the autonomy of a robot, there are many research issues. We want to prepare a database containing various kinds of fundamental motions and achieve any desired motions and actions by combining these basic motion units. For the preparation of such a database, it is necessary for the motion editor to grasp the center-of-gravity balance and make it easy for the user to design robot motions. In addition, it is necessary to introduce new technologies for the humanoid robot. For example, if a robot encounters stairs, it must use image processing to recognize their height and inclination. Thus, research of image processing is also required. Research on accurate speech recognition is also needed.

At present the functions of humanoid robots are very limited. However, we believe that someday such autonomous robots as science fiction *Androids* from movies will emerge and be introduced into society.