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AN INTELLIGENT HUMANOID ROBOT IMITATION BY IMAGE RECOGNITION

Sithara Gopinath
PSN College of Engineering and Technology, Tirunelveli, Tamilnadu, India,
gopinathsithara@gmail.com

ABSTRACT— **In this paper, we present a system for the imitation of human motion on a humanoid robot by means of image recognition. For achieving this imitation, three main processes are to be considered. They are human imitation data acquisition; the data modification; and the ankle angle adjustment on the supporting foot of robot. In the first process that is human imitation data acquisition first we are pasting 13 color marks on a human body at different locations. For acquiring the motion imitation we have to make use of a Logitech webcam C905 to identify these color marks and then the relative positions of the marks for each motion is recorded and calculated into the motion database. In data modification stage, these data are modified with the help of computer simulation to make sure that the zero moment point of the humanoid robot is within the stable region. At last stage that is in ankle angle adjustment stage the ankle angles are adjusted. Thus, in real time the humanoid robot can imitate almost all the human motions with stability.**

I. INTRODUCTION

A successful Interaction depends on various factors like the acceptance of a humanoid robot by society, its capabilities to acting unconstrained human-centered environments and its communication skills. In [1] a glove with some flexion and some pressure sensors are pasted on to obtain the hand gestures of a human for controlling some robots. Especially, human-like motion and gestures of a robot are main contributions to its appearance, which has a strong influence on a user. An arm robot is successfully built to perform some tasks, such as object grasping, by measuring the motions of a human arm, in [2] and [3]. These interactions deal with some parts only. Also this interaction can be extended to a whole humanoid robot. If the humanoid robot human, then we may teach the robot make perform various complex human motions like walking gymnastics, dancing [4], Kong-Fu show [5], etc.

In this paper, to achieve the motion imitation three processes were required: 1) the human imitation data acquisition; 2) the data modification; and 3) the robot‘s ankle angle adjustment. About six cameras and image processing were applied to recognize the 38 marks pasted on the human body in [5] so that the robot could imitate a human practicing gong-Fu ―Tai Chi.‖ [6] performs similar studies. In [7], the various human hand motions in real time is imitated by the humanoid robot using only one camera which helps to recognize the skin color of both the human‘s hands. Thus we have to modify this acquired data of human motion to guarantee the balance of the robot foot to attain stability when it performs the motion imitation. A ―stable motion trajectory‖ is made up as a result of data.

II. BLOCK DIAGRAM AND WORKING OF THE SYSTEM.

The experimental plant of the hardware is described as shown.

Fig.1.Block diagram of Experimental plant

The hardware of the overall system (shown in Fig. 1) includes PC, a webcam, USB2-Dynamixel card, a humanoid robot, and a force sensor module..The webcam was connected to the computer through the universal serial bus (USB) port.

The PC was chosen as the centre of control to acquire the motion performance, stabilize and control the humanoid robot for achieving the human motion imitation. There is a 3D virtual humanoid robot inside the computer to display the human motions using and to obtain the human motion data. The computer sends the commands to all the AX-12 motors inside the humanoid robot using USB2-dynamixel card through the USB port motions were displayed on the monitor with the help of a 3D virtual humanoid model. The human motion imitation is done by Visual Studio C++.

the control. The CPU of the computer is an Intel Core 2 Quad 2.4 GHz with 2GB RAM. In a computer system, all the human motions were displayed on the monitor with the help of a 3D virtual humanoid model.

B. Webcam

A Logitech webcam C905, which helps to capture the image of human motions with various colours pasted on the body, using software Visual Studio C++ with an open source computer version (OpenCV) library. The webcam used here has many advantages such as a) resolution of the captured image was 640 × 320 pixels, b) speed of image capture was 30 frames/s. The captured data in the webcam was connected to the PC through the universal serial bus (USB) port.

C.USB2DynamixelCard

This act as an interface between the PC and robot, which helps in serial transmissions.USB2-Dynamixel is a bridge for the communication between them and the AX-12 motors. From the computer the commands are transmitted to all the AX-12 motors using this USB2-Dynamixel card through the USB port of the computer.

D. Humanoid Robot

The Fig. 2 shows the structure of the humanoid robot. Humanoid robot is a robot with its body shape built to resemble that of the human body. AX-12 is a small and light servo motor, which contains a microcontroller, which helps to receive all the commands sent from the personal computer. The humanoid robot implemented here consists of 16 such AX-12 motors. There are a total of 16 degrees of freedom (DoFs) in the humanoid robot. Bioloid robot kits helps to construct the mechanical structure of the robot, and its main actuator component is the 16 AX-12. AX-12 motor has a maximum torque 16.5 kg·cm and the speed about 306 °/s with a 10 V input. The commands sent from the PC to microcontroller‘s controls the AX-12 motors through a USB2-Dynamixel card , and also it can receive

Fig.2. Humanoid robot.

some feedback data from AX-12 corresponding to those comments through the same card..

IV .DATA ACQUISITION

In order to make the humanoid robot to imitate the motion of the human, first we have to acquire the entire human motion. In the first process that is human imitation data acquisition first we are pasting 13 color marks on a human body, the person being imitated at different locations

The Fig(3) shows a human with a weight of 50 kg and a height of 150 cm. A Logitech webcam C905 is used to identify these 13 marks on the human body and then their relative for each motion is recorded and calculated into the motion database.

A. Colour Marks Recognition

A webcam is used to capture the image of the human motion with 13 colors, which is composed of a red–green–blue (RGB) color model. Because the RGB are the primary colors and also RGB color model is very sensitive to the luminance change of the environment.

Fig.3. Man with 13 colors

model, which. Thus, by setting all these thresholds values of the *Y*, *U*, and *V* components, all the color marks can be obtained.

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.1 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 128 \\ 128 \end{bmatrix} \quad (1)$$

TABLE I
THRESHOLDS OF DIFFERENT COLOUR MARKS

MARK COLOR	Y VALUE	U VALUE	V VALUE
BLUE	74<Y<94	159<U<176	63<V<83
RED	68<Y<88	98<U<118	191<V<211
YELLOW	174<Y<194	42<U<62	145<V<165
GREEN	107<Y<127	94<U<114	68<V<88

The thresholds values of various color marks are shown in Table I given. The tolerance color region is ±10 for each threshold. Then we are calculating the Cog position of each mark in the image

$$\text{From } (\bar{x}, \bar{y}) = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n} iB(i,j)}{A}, \frac{\sum_{j=1}^{m}\sum_{i=1}^{n} jB(i,j)}{A} \quad (2)$$

Where,

(*x, y*) is the CoG coordinate of the color mark.
(*i, j*) is the exact position of the image's pixel..
m and *n* represents the dimensions of the image.
B(*i, j*) is the weight of a pixel (*i, j*).

B. 3D Angle Calculation

A 3D virtual humanoid model is used to display the human motions and to obtain the human motion data. In Fig 5 Where, *l* is the link between the two adjacent marks. *l* is the projection of link *l* on the *X* –*Z* plane. *θ* is the angle between *l* and *X* -axis.

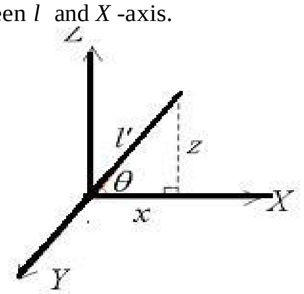


Fig.4. Projection of the link l on the X-Z plane

The 3D angle θ for the humanoid robot can be calculated by equation given below, Where x and *z* are the coordinates of the projection *l* on the *X* –*Z* plane.

$$\theta = \tan^{-1}\frac{z}{x} \quad (3)$$

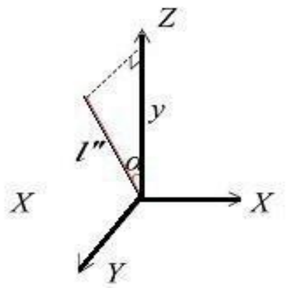


Fig. 5. Projection of the link *l* on the *Y* –*Z* plane.

l is the projection of the link on the *Y* –*Z* plane. It is shown in Fig. 5. In fig. If the 3D virtual humanoid robot performs the human motions such as gymnastics and dancing, they are recorded. Projection of the link *l*, and *α* is the angle between *l* and *Z* -axis shown as

$$\alpha = \cos^{-1}\frac{y}{l''} \quad (4)$$

V.DATA MODIFICATIOIN

In the previous process all the human motion to be imitated are sometimes it may cause the robot may lose balance and fall down. Therefore, we have to modify this acquired data of human motion to guarantee the balance of the robot foot to attain stability.

A ―stable motion trajectory‖ is made up as a result of data. To achieve this purpose, some concepts, like multilink system and ZMP (zero moment point), are applied to analyze the stability of the human motion data in the computer simulation. .In fact, in ―real experiment‖ the stability obtained by stable motion trajectory can still not be guaranteed the stable motion when the modified data is directly applied to the ―real‖ humanoid robot due to the limitations of hardware and environment, such as the friction of the floor and motors backlash mechanism. So there arises the need of considering ―CoP. The flowchart of the motion data modification is shown in Fig. 6. The multilink system is constructed using the motion data obtained. To ensure the balance the ZMP of each motion is then calculated. A fuzzy ZMP adjuster is used to reduce the ZMP error. If the motion is unstable, then the supporting foot's ankle angle can be adjusted by a fuzzy ZMP adjuster to reduce the ZMP error to fix the stability.

sum of all the moments is zero. Thus it is calculated as stability index in robotics for humanoid robots. To measure the exact position of the ZMP, the centre of mass of each link must be needed. , which is already be calculated by (6).With the help of these multilink system concept, the position of the ZMP (*xzmp* , *yzmp*) for the humanoid robot can be calculated from the following equation

$$x_{zmp} = \frac{\sum_{i=1}^{n} m_i(\ddot{p}_{iz}+g)\ddot{p}_{ix} + \sum_{i=1}^{n} m_i \ddot{p}_{ix} p_{iz}}{\sum_{i=1}^{n} m_i(\ddot{p}_{iz}+g)} \quad (7a)$$

$$y_{zmp} = \frac{\sum_{i=1}^{n} m_i(\ddot{p}_{iz}+g)\ddot{p}_{iy} + \sum_{i=1}^{n} m_i \ddot{p}_{iiy} p_{iz}}{\sum_{i=1}^{n} m_i(\ddot{p}_{iz}+g)} \quad (7b)$$

A. Multilink System.

Let the rotation matrices *Rix* and *Riy* be defined as

$$R_{ix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha_i & \sin\alpha_i \\ 0 & -\sin\alpha_i & \cos\alpha_i \end{bmatrix} \quad (5a)$$

$$R_{iy} = \begin{bmatrix} \cos\theta_i & 0 & -\sin\theta_i \\ 0 & 1 & 0 \\ \sin\theta_i & 0 & \cos\theta_i \end{bmatrix} \quad (5b)$$

Fig.6.Flow chart of motion modification

Where, i=1, 2, 3

mi is the mass of link *Li* .

n is the total links of the robot.

g is the gravitational acceleration.

pix , *piy* , and *piz* are the positions of mass centre of link *Li* with respect to the *X* , *Y* , and *Z* coordinates. $\ddot{p}_{ix}$, $\ddot{p}_{iy}$, and $\ddot{p}_{iz}$ are the double derivatives of *pix* , *piy* , and *piz* .

C. Fuzzy ZMP adjuster

In computer simulation all the motion data recorded in the database is checked to confirm whether the value of ZMP of the humanoid robot for each motion is inside the safe region or not. The recorded motions change from the standing posture to the left leg lifting forward postures, then a series of ZMP positions are obtained corresponding to the series of motion data which are calculated from (7). Let then ZMP error is given as ($e(s, t)$) and then differential value of the ZMP error ($\Delta e(s, t)$) can be defined as

$$e(s, t) = ZMP_{ideal} - ZMP_{current}(s, t) \quad (8a)$$

$$\Delta e(s, t) = e(s, t) - e(s, t-1) \quad (8b)$$

Where, *ZMPideal* is the ideal location of the ZMP, that is the exact centre of the safe region. *ZM*

Where, *Rix* is the rotation matrix around the *X* –axis.
Riy is the rotation matrix around the *Y* –axis

Thus, from Fig.8. If P1, P2, P3 are the positions of various links in above figures, then

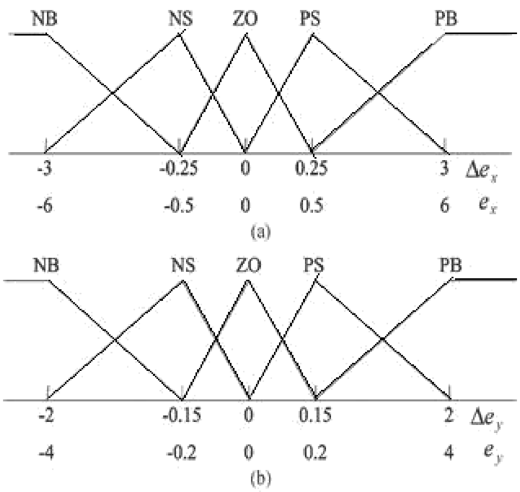
$P1 = R1y\, L1$ (6a)

. $P2 = R1y\, L1 + R1y\, R2y\, L2$ (6b)

$P3 = R1y\, L1 + R1y\, R2y\, L2 + R1y\, R2y\, R3x\, L3$ (6c)

B. Concept of ZMP

The term ZMP stands for Zero Moment Point. At this point



Pcurrent (*s*, *t*) denotes the current location of the ZMP. *s* = 1, 2, 3, . . . , *N* are the series of recorded motion data. *t* is the iteration time for a fixed *s*.

The premise fuzzy sets of the fuzzy rule are (ex , ex) and (ey , ey) in the *X* - and *Y* -directions, respectively, as shown in Fig. 7(a) and the variation of the ankle angle θ^a_y (or θ^a) is the consequent value of the fuzzy rule, and its fuzzy sets in the *X* - and *Y* -directions are shown in Fig. 8.

Fig. 7. Premise fuzzy sets *e*(*s*, *t*) and *e*(*s*, *t*)

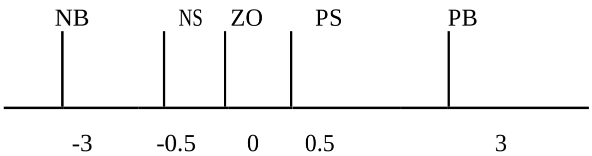


Fig. 8. Consequent fuzzy sets θax and $\theta a\, y$ in the *X*- and *Y* - directions.

The rule table of the fuzzy ZMP adjuster is shown in Table II.

TABLE II
Rule table

e \ Δe	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	NS
NS	***NB***	NS	NS	ZO	ZO
ZO	NB	NS	ZO	PS	PB
PS	ZO	ZO	PS	PS	PB
PB	PS	PS	PB	PB	PB

Now, consider the chosen rule (the one with the bold and italic type) in Table II to explain this. If *e* is NB and *e* is NS, then the output is NB It means that if the ZMP error is large and negative, also the ZMP error difference is small and direction, and also the angle degree is large.

VI. ANKLE ANGLE ADJUSTMENT

When the humanoid robot try to imitate the human motions some disturbances, like hardware limitations, a rough floor etc, may increase the risk of instability, and the humanoid robot may fall down. Therefore, instead of the ZMP, the CoP is measured from the four force sensors located on the soles of the robot. CoP plays helps to check the stability of the humanoid robot while the robot is performing the motions by imitations

A. CoP Calculation

After motion data modification, the humanoid robot tries to imitate all the human motions. From the four force sensors the CoP position of the robot can be found. During the SFSP, the CoP position is calculated.

$$CoP_{current} = \frac{\sum_{i=1}^{n} F_i\, j_i}{\sum_{i=1}^{n} F_i} \qquad (10)$$

Where, *Fi is* the pressure value measured from the *i*th sensor, *ji* is the vector from the *CoP*ideal to the *i*th sensor.

B. Fuzzy CoP *Compensator*

During the SFSP, the ideal CoP is denoted by *CoP*ideal, is set. CoP_{ideal}

*CoP*current is not near the value of *CoP*ideal , then the robot cant balance stability and it may fall down. Otherwise, the robot will not fall down. Therefore to control stability, the error difference between the *CoP*ideal and the *CoP*current can be a factor when controlling the stability factor of the foot.

$$e_c(s) = CoP_{ideal} - CoP_{current}(s) \quad (12a)$$

$$\Delta e_c(s) = e_c(s) - e_c(s-1) \quad (12b)$$

Where ―*s*‖ is 1, 2, 3…N in equation (8) are the series of motion data. The same sampling time is 0.125 s. Here we use fuzzy compensator in fig.12 to reduce the CoP error instead of the previously used ankle joint adjuster .

VII. RESULTS

The fig.9. shows the sample imitation by the robot. The color marks are pasted on the hands and legs only. A real humanoid robot can effectively present the human motion imitation with effectiveness of the proposed processes. But some special motions, such as stooping, hands lifting forward (90°), and also such motions which cover some marks by the limbs of the human. When the human lifts his hands forward (90°), the yellow color mark is overlapped by the green color mark.

Fig. 9.The sample hand and leg imitation of the robot

The recognized motion will be incorrect, if any of the colored mark is missing a strategy is d esigned to replace the mark disappeared color marks by considering the position of the color mark disappears at time ‗t' last appeared at and position at ‗t-1' .Corresponding to the imitated gymnastics motions, a series motion picture of the humanoid robot is shown in Fig. 10.

Fig. 10.pictures for the robot to imitate gymnastics motion

VIII. CONCLUSION AND FUTURE WORK

In this paper, we and implements motion imitation interaction between the robot and human. To achieve these three main processes required. The first is the human motion data acquisition; the second is the motion data modification; and the last is the ankle angle adjustment on the supporting foot (or feet) of the humanoid robot. In these three processes Fuzzy compensator and image processing techniques are used. The major drawback is the humanoid robot can't imitate the human motion, if any of the color mark is disappeared and also all the imitation by the human should have to be performed in front of the webcam. So in future, avoiding these we have make use of accelerometer. Using for accelerometer, there is no need the human to imitate in front of camera and also no problem regarding the color marks will occur.

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