EkInBot- A Humanoid Platform for Human Robot Interaction using Finger Gesture Identification

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ABSTRACT
This paper discusses about a simple Humanoid platform EkInBot, specifically designed for Human Robot Interaction Using Dynamic Finger gestures. EkInBot stands for Electronically Interactive Robot and has 8 Degrees of Freedom. The paper emphasis on design and realization of a simplified humanoid robot and implementing finger gesture identification using a system analogous to 'Data Glove'. The proposed gesture recognition mechanism has accelerometer sensors, that tracks finger movements and moves the robot with respect to it.

Keywords
Centre of Gravity (CoG), Centre of Mass (CoM), Degrees of Freedom (DoF), Gestures, Humanoid Robot, Human Robot Interaction (HRI),.

1. INTRODUCTION
Many studies has been carried out on conventional robot manipulators over many years. These manipulators are utilized in industry to improve the output of production and reduce the workload imposed on humans. Traditionally, wheeled robots are utilized to perform tasks where robot movement is necessary. Recently, more and more interest has been grown on researches on humanoids or biped robot. Humanoid Robots fundamentally resembles Human Physical Characteristics.

For any robots to co-exist and collaborate with human beings, there should be a strong interaction dynamics between the human and the robot. This interdisciplinary study of interaction dynamics is known as Human-Robot Interaction. Interaction with robot could be satisfied using various conventional mediums like computer, Mobile phones etc. Researches on HRI using natural gestures is a choice of interest, as it makes easy for the humans to demonstrate his or her intentions in a natural way. Due to the complex processes involved in manipulating natural gestures, design of such interaction schemes are much difficult. A number of studies have been carried on various robot manipulators being operated by conveying human intentions using gesture identification. One such study is the telemanupulation of robotic arm using finger gestures[1].

This paper emphasis on developing a simple humanoid platform with lesser number of actuators, specifically designed for HRI and to manipulate the robot locomotion using dynamic finger gesture.

2. SYSTEM DESCRIPTION

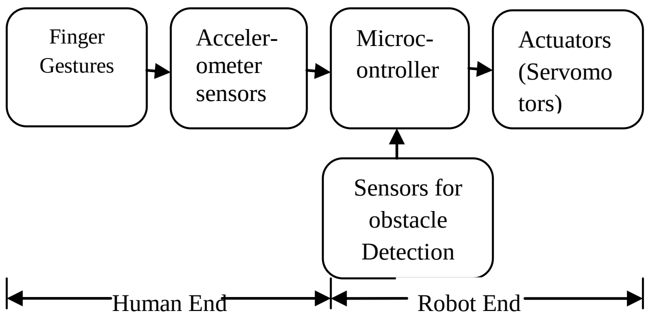

Fig. 1. Block Diagram of EkInBot

Figure 1 shows the Block diagram of EkInBot. The entire system is broadly classified into 2 parts- Human End and Robot End. The finger gestures are picked up using two accelerometer sensors that is attached on to the gloves. As the finger moves, accelerometer converts these movements into various voltage levels and are fed to the Analog to Digital Converter of the PIC 18F452 microcontroller. Microcontroller converts each voltage level into particular actuator movement. Obstacle detection is achieved using Ultrasonic sensor. The application area of the robot platform is not restricted to HRI, which is under consideration for the time being.

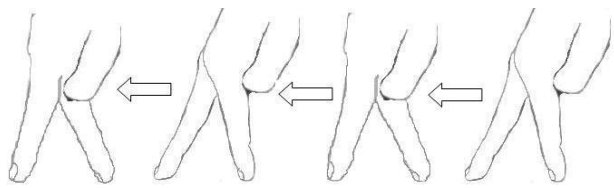

Fig. 2. Gestures under Consideration

The initial phase of the research is to make the robot walk with respect to the human walking like gesture mimicked using index finger and middle finger of the right hand as shown in Figure 2. When middle finger is moved forward, by keeping index finger positioned at a point, the robot lifts its left leg and moves it forward. Now when, index finger is moved forward by keeping middle finger idle, the robot lifts the right leg and moves it forward[2].

3. AN OVERVIEW ON ROBOT DESIGN
The proposed humanoid platform, EkInBot has 8 DOFs. 4 DOFs in upper body and 4 DOFs on lower body. Figure 3 shows design model and configuration of links and joints of the proposed robot. The shoulders of left and right arm of the

robot has 1 DOF each and exhibits pitch orientation. The elbows of both the arms are also of 1 DOF and exhibits roll orientation. In lower body, Hips exhibits yaw orientation and are of 1 DOF each on both legs. Orientation of the ankles are in roll axis[3.4].

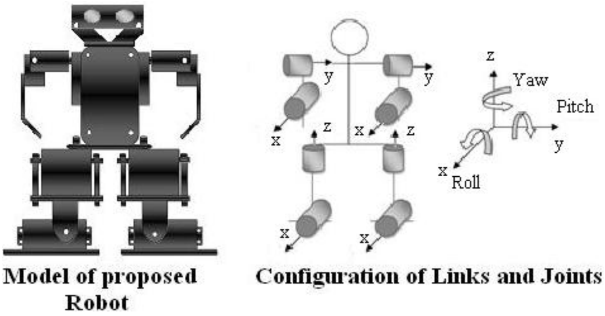

Fig. 3. Design Model and Configuration of Links and Joints

3.1. Kinematic Model of lower limbs

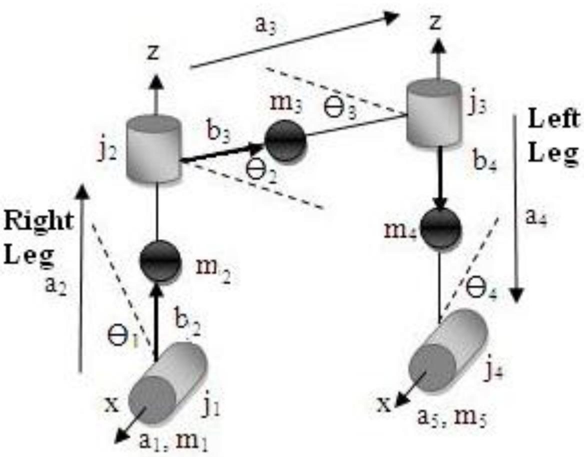

Fig. 4. Joint angles and link parameters

Calculating the position and orientation of the end effectors of the robot is called Forward kinematic analysis. Here the end effectors are the foot of the robot that enables locomotion. Kinematic modeling is the computation of Joint space from Cartesian space. This computation is necessary, as it determines orientation of the foot and position of COM of the links. Figure 4 shows Joint angles and link parameters of a 4 DOF lower limb.

The robot basically has 5 links and 4 joints at its lower body. To reduce the mathematical complexity, the foot links, a_1 and a_5 are virtual links with zero mass and zero length [3,4,5]. Thus the structure reduces to a 3 links, 4 joints biped model. From figure 4,

J_i represents joint associated with link i and are revolute joints,

a_i is the link vector connecting the joints j_{i-1} to j_i,

b_i is the COM vector specifying the COM of link i ,

m_i is the Mass of link i and

Θ_i represents angle of rotation of each joints.

The orientation of the third link frame of the biped structure shown in Figure 4, can be found using equation 1.

$$ {}^{0}_{3}R(\Theta_1,\Theta_2,\Theta_3) = {}^{0}_{1}R_x(\Theta_1)\, {}^{1}_{2}R_z(\Theta_2)\, {}^{2}_{3}R_z(\Theta_3) \quad (1)$$

Solving equation 1, gives the result as in equation 2

$$ {}^{0}_{3}R(\Theta_1,\Theta_2,\Theta_3) = \begin{bmatrix} C_2C_3 - S_2S_3 & -C_2S_3 - S_2C_3 & 0 \\ C_1S_2C_3 + C_1C_2S_3 & -C_1S_2S_3 + C_1C_2C_3 & -S_1 \\ S_1S_2C_3 + S_1C_2S_3 & -S_1S_2S_3 + S_1C_2C_3 & C_1 \end{bmatrix} \quad (2)$$

The iterative equation for position of COM of link i+1 is

$$ P_{i+1} = \begin{bmatrix} x_{i+1} \\ y_{i+1} \\ z_{i+1} \end{bmatrix} = {}^{0}_{i}Rb_i + P_{j_i} \quad (3)$$

where

P_{j_i} is the position of joint i defined as

$$ P_{j_i} = \begin{bmatrix} x_{j_i} \\ y_{j_i} \\ z_{j_i} \end{bmatrix} = {}^{0}_{i-1}Ra_i + P_{j_{i-1}} \quad (4)$$

3.2. Biped Logic Gait Phases

Gait is defined as pattern of movement. A biped has seven logic gait phases.

- **Initial Double Support Phase**:- This is the phase 1, in which the robot is in neutral condition. The upper body weight is shared among the two legs. Thus Centre of Gravity (COG) is maintained between the legs.
- **Extending Left Leg Phase**:- The biped leans from left to right by extending left leg in order to take weight off the left foot. This is the Phase 2 of biped gait. The COG is concentrated on right foot region.
- **Lift Left Foot Phase:-** Phase 3 of biped logic gait phases. The right foot is left under the upper body and left foot is moved forward.
- **Lower Left Foot Phase:-** In phase 4, once the left foot reaches the highest point of its trajectory, it is lowered back to ground. The COG is now between the two legs.
- **Extending Right leg Phase:-** The biped leans from right to left by extending right leg in order to take weight off the right foot. This is phase 5.
- **Lift Right Foot Phase:-** The Phase 6. Right foot is moved forward, keeping left feet under the upper body.
- **Lower Right Foot Phase:-** The final phase in which, the right foot is lowered back to ground.

For successful walking these phases are executed repeatedly one after the other. [3,4,6,7,8,9]

3.3. Lower Body Structural Design
The lower limbs of the robot has 4 angular motions. Servo motors with double ball bearing and metal gears having stall Torque of 14 Kg/cm are used in the proposed design to provide these angular motions. Large plastic foot pads of 9x6.5 cm, provides more stability, when the robot stands in one foot during walking. The ankle motors are fixed on to these foot pads. Plastic brackets are employed to join the hip motor and the ankle motor . The servomotors at the hips hangs on shaft to the plastic link, that connects the two legs. Optimal distance has been maintained between the two legs, in order to avoid hitting each other.[3]

3.4. Upper Body Structural Design
The upper body consists of arms and torso that include 4 DOFs in total. Space for installing the controller board and electronics has been considered in the torso. The size of the torso is 9x5 cm and is made of plastic. Servo motors with double ball bearing and plastic gears, having stall torque of 5.5 Kg/cm are used in shoulders. At the elbows, micro Servos of lesser size and stall Torque of about 1.8 Kg/cm are employed. Aluminum brackets connects shoulder servo and elbow servo. The elbow motors are designed to hang on to the bracket, which is connected to the shoulder motor. The arm part of the robot is also made of Aluminum. Figure 5 shows, the fabricated model of EkInBot [3].

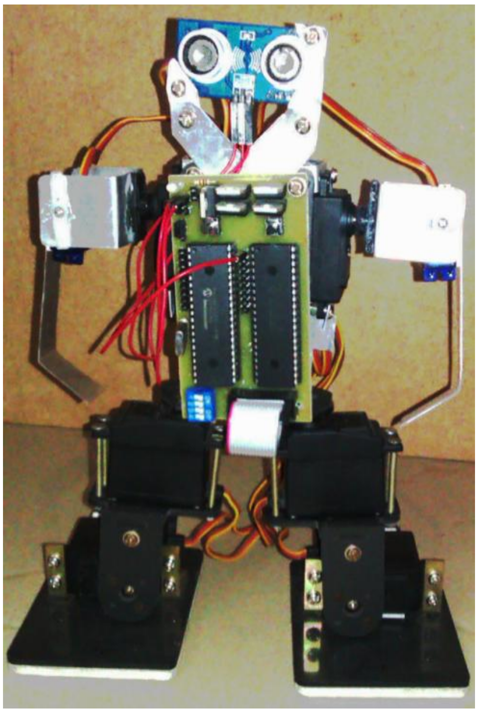

Fig. 5. Fabricated Model of EkInBot

3.5. Electrical Design
The main controller board of the robot consists of two processing elements. Microcontroller PIC 18F452 acts as the processing elements. Only one microcontroller will be active at same time. Jumpers are provided to select the required microcontroller. Microcontrollers could be programmed to perform more than one applications. A 4 pin DIP switch is employed to select a particular application embedded in each controller. A separate servo extension board provides power and signals for the servomotors. This extension board is connected to main controller board via FRC.

At the human side, a glove fitted with two accelerometers are used. The accelerometer used is based on Freescale's MMA7361L. It is a simple three axis accelerometer, which provides analog output at each axis. The operational voltage of the module is 5 volts and is highly sensitive. Accelerometers are connected to the analog inputs of the PIC 18F452 microcontroller[2,3].

4. IMPLEMENTATION OF HRI
Consider that there are three stages for achieving walking like gestures using fingers. Biped logic gait phases are classified into seven, as discussed in section 3.2. The microcontroller is programmed in such a way that, each gesturing stages are assigned to attain certain biped gait phases for successful walking. Stability is the major problem that arises during robot walking. To attain stability, when only one leg is on ground, the concept of 'Dead Weight' is utilized. According to this concept the weight of the upper body is moved so as to bring the COG on the axis of footing leg [2,3,4,6].

Various stages of gesturing and biped logic gait phases assigned to each is illustrated in figure 6 and is explained as follows:

- **Stage 1**:- Both Middle finger and Index finger are aligned in same line. Now the robot should execute initial double Support phase. The Dead Weight is denoted by W_M and will be shared among the two legs .

- **Stage 2**:- The index finger is moved forward, while keeping middle finger positioned at a point. This executes, Extending left leg phase, Lift left foot phase and lower left foot phase. During extending left leg phase, the upper body weight is moved towards right leg, concentrating COG over right foot region. In Lift left foot phase, left leg is made to swing in air at an angle Θ_R, keeping right feet under the upper body.

- **Stage 3**:- The Middle finger is moved forward, while keeping the index finger positioned at a point. Extending right leg phase, Lift right foot phase and lower right foot phase of biped logic gait phases are executed at this time [2,3,4,6].

5. FIRMWARE DEVELOPMENT
A 3 axis Accelerometer has 3 outputs, i.e. X, Y and Z. The output of Y axis is considered for time being. During a legitimate gesturing, a particular voltage range will be available at the Y axis which is fed into the analog input pins of the microcontroller. The microcontroller is programmed in such a way that, the voltage ranges fed are compared with a set of predetermined, voltage ranges within the controller. Each predetermined voltage ranges are assigned with programs to generate PWM signals for servo motors, to achieve various walking phases associated with each gesturing stages. It should be noted that, once one stage is gestured, then the same should not be gestured the very next time. In other words, same voltage levels shouldn't come consecutively. This leads to execution of same phases one after the other causing the robot to fall. To avoid this, if same stage of gesturing is detected, then the robot is programmed to

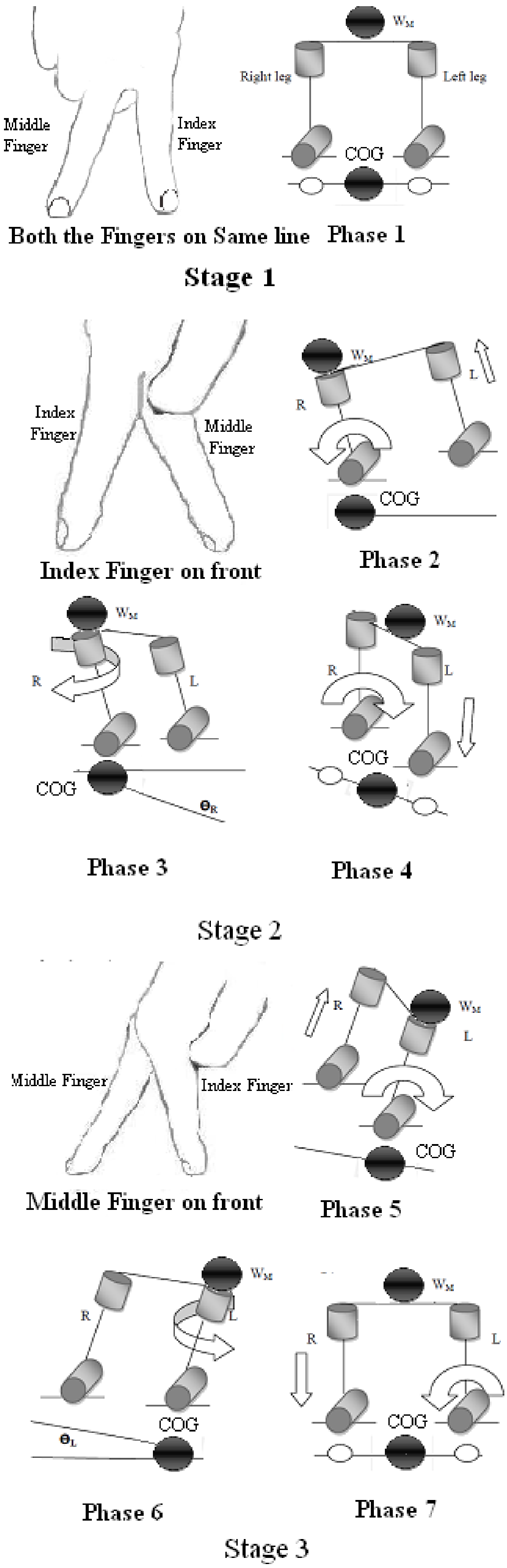

Fig. 6. Various Stages of gesturing and phases assigned to it

execute, phase 1, i.e. the robot will stand in neutral attention posture. Table 1 shows various voltage values available at the Y axis of the accelerometers during various stages of gesturing. Figure 7 shows the flowchart of the firmware logic.

Table 1. Stages and corresponding Voltage values

Stages Of Gesturing	Voltage output at Y axis Middle Finger	Voltage output at Y axis Index Finger
Stage 1	<= 0.999V	<= 0.999 V
Stage 2	>= 1.450 V	<= 1.200 V
Stage 3	<= 1.400 V	>= 1.500 V

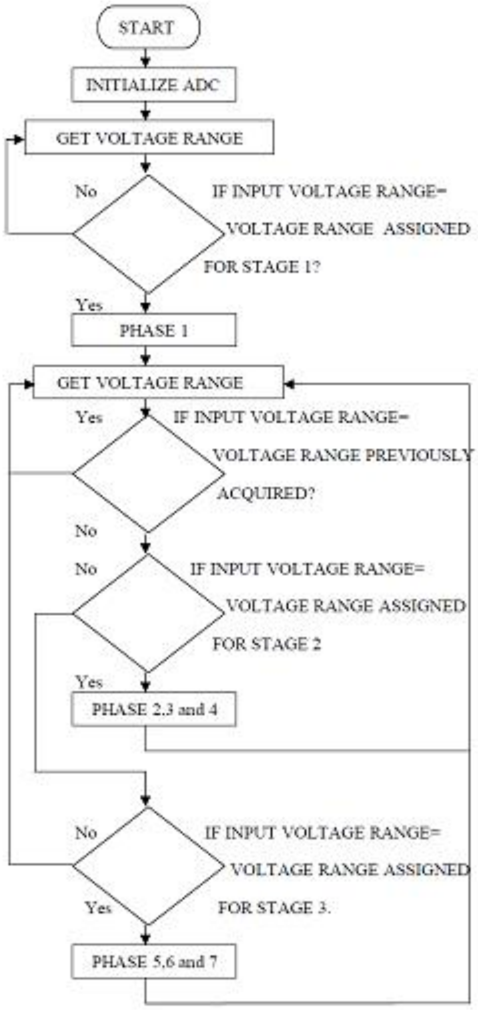

Fig. 7. Flow Chart for HRI

6. CONCLUSION

This paper introduces EkInBot, a low cost, simple humanoid robot specially designed for HRI using finger gesture identification. Even though, humanoid locomotion is only discussed, same methodology can be utilized so as to perform a productive task. For the time being, HRI is achieved by a wired interconnection between the glove and the robot. This could be converted into a wireless system employing ZigBee or Bluetooth technologies in future. Figure 8, shows implemented results of achieving HRI. EkInBot, not only provides a platform for HRI, but also for many other common robot applications like obstacle detection, pick and place etc. By further research and modifications, more useful and advance applications can be incorporated on to this platform.

Fig. 8. Implemented Results

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