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BI-PEDAL WALKING ROBOT

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Abstract*- This paper describe the mechanical design of a bipedal walking robot, as well as control strategies to be implemented for walking and balance recovery. This bipedal has 10 actuated degrees of freedom (DOF) in the lower body: one at each hip, one at each knee, and two at each ankle. Each degree of freedom is powered by controllable Actuators. These actuators provide high force fidelity and low impedance, allowing for control techniques that exploit the natural dynamics of the robot. The walking and balance recovery controllers will use the concepts of kinematics and the positioning region in order to decide where to step. Positioning Region is a point on the ground in which a biped can step to in order to stop and the kinematics is the locus of such points.*

Keywords: walking robot, 10 degrees of freedom, Lynx motion SSC-32 Servo Controller, Microcontroller, Zero Moment Point (ZMP), ANN, Wight balancing, Kinematics.

1. INTRODUCTION

In recent years there has been much interest stimulated in dynamic walking in bipedal robotics and legged locomotion in general. Part of the reason for this interest is the need for robots which can operate in human oriented environments. Humans present a very elegant model of locomotion to emulate. The state of research into bipedal robotics has progressed to the stage where dynamic walking gaits are being studied. Human beings usually employ a dynamic gait when walking as it is faster and more efficient than static walking. Dynamic legged robots suffer from lack of powerful control techniques. These robots are extremely difficult to control since they are nonlinear and operate throughout the range of their state space; act in a gravity field, interact with a semi-structured, complex environment; are nominally unstable; are Multi Input, Multi Output (MIMO); exhibit time variant and intermittent dynamics; and require both continuous and discrete control (for step-to-step transitions).In addition, the performance measures of such robots are much different from typical notions of performance such as command following and disturbance rejection. Performance for these robots is usually defined in terms of biological similarity, efficiency, locomotion smoothness, top speed, and robustness to rough terrain. Because of these difficulties, the only accept able tools for analyzing such systems are often simulation or experimentation and the only better design tools are often physical intuition, parameter iteration, and hand tweaking .Anyone who wishes to expand the toolbox of analysis and design techniques for such a class of robots will typically either make an advancement in control system design and analysis mathematics, develop automatic techniques or exploit physical intuition. In this paper we present a control technique, called Virtual Model Control and a physical model (appropriate stepping).

2. WALKING STRATEGY OF BI-PEDAL ROBOT

The link mechanism needs to be built to facilitate the bipedal locomotion with enough degree of freedom to perform the walk. How many degrees of freedom are enough to create efficient bipedal motion? This is 14 degrees of freedom (DOF). 10 DOF are the minimum number for the lower extremity to achieve human-like walking, and we know that human gait is the most efficient form of locomotion. Extra four DOF‘s are for body weight balancing in roll and pitch orientation without resorting to the leg DOF’s. But in this robot, there is no such a body and that is why we use only 10 DOF’s. All joints are designed to intersect at a local point to simplify the kinematics computation and control. Upper leg length equals to the lower leg length to simplify the kinematics. The distance between the left and right hips is also important. If the distance is too close, the legs will hit each other during walking. If the distance is too far apart, the ankle’s motors have to work harder in swinging the center of mass from side to side balance during walking.

2.1 Zero Moment Point (ZMP) computations

The resultant force of the inertia and gravity forces acting on a biped robot is expressed by the formula

$$F^{gi} = mg - ma_G$$

Where m the total mass of the robot is, g is the acceleration of the gravity, G is the center of mass and a_G is the acceleration of the center of mass. The Newton–Euler equations of the global motion of the

$$F^c + (mg - ma_G) = 0$$

biped robot can be written as

$$M_X^c + (XG \times mg - XG \times ma_G - \dot{H}_G) = 0$$

Where, $\dot{H}_G$ is the rate of angular momentum at the center of mass. F^c is the resultant of the contact forces at X and M_X^c is the moment related with contact forces about any point X.so it's easier to see that we have

$$F^c + F^{gi} = 0, M_X^c + M_X^{gi} = 0$$

These equations show that the biped robot is dynamically balanced if the contact forces and the inertia and gravity forces are strictly opposite.

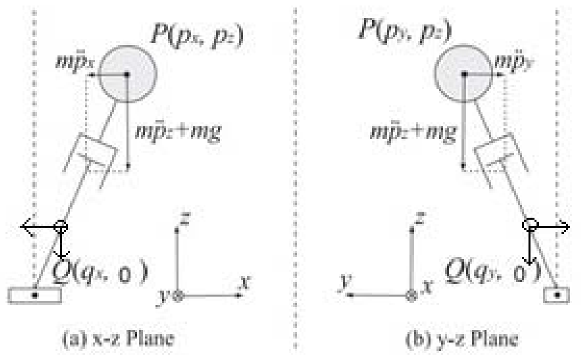

Fig 1. Mass distribution of leg.

If an axis Δ^{gi} is defined, where the moment is parallel to the normal vector n from the surface about every point of the axis, then the Zero Moment Point (ZMP) necessarily belongs to this axis, since it is by definition directed along the vector n. The ZMP will then be the intersection between the axis Δ^{gi} and the ground surface such that

$$M_Z^{gi} = ZG \times mg - ZG \times ma_G - \dot{H}_G$$

$$M_Z^{gi} \times n = 0$$

Where Z represents the ZMP. Because of the opposition between the gravity and inertia forces and the contact forces mentioned before, the Z point (ZMP) can be defined by

$$PZ = \frac{n \times M_P^{gi}}{F^{gi} \cdot n}$$

Where P is a point of the sole where is the normal projection of the ankle.

3. Virtual Model

This is the virtual prototype of the bipedal robot which is made at the solid works software. Some of practical difficulties we can't develop our bipedal as same as designed.

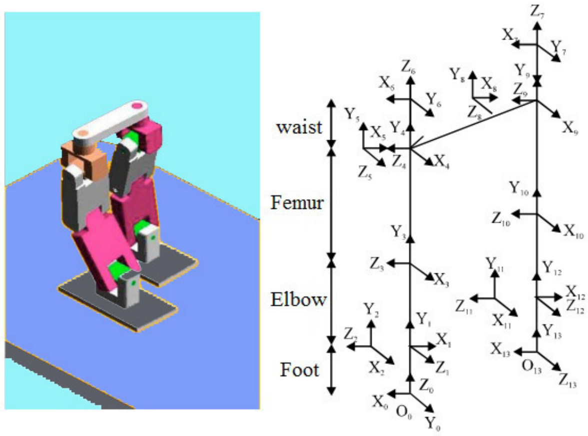

Fig 2.virtual model of leg with vector orientation

4. Design and Fabrication

The design of a bipedal robot needs the shape of human structure. It needs the analysis of human walking style. Replacing the human body parts with different joint and attaching of motor in different positions gives a bipedal robot a human like structure. A typical bipedal robot has four common parts. They are – Motor holder or waist, Femur, Elbow & Foot. *Motor holder*: It is a square box for holding two motors of waist. These two motors can move the legs in left and right direction. It balances the weight of the body when it walks. It moves the right leg on right side and the waist on left side when it walks by right leg and gives opposite motion for walking with left leg. Femur is a joint between waist and knee. It holds a motor to give the motion of knee. It can move the rest of the body in forward and backward direction. It actually creates the step distance for the body. Elbow is the joint between femur and foot. It helps the foot to hold and shift the body at the time of walking. Foot It holds the body weight and shifts the weight to give the body dynamic and static stability at the time of walking. It is the major part of the body.

All the parts of the body are made from plastic sheet of 2mm and 3mm thick plastic sheets.

Structure of a bipedal robot is most important think. If the structure is not correct and suitable for walking, the robot will not walk. The architecture of structure needs great care. Positioning of the structural element should be so accurate.

5. Trail & Error

We upgrade the performance of our robot by the trial and error method. At the simulation trip we change the length of the leg and actuating motor angle different time. For the different value of angle (θ) and length (l) the robot change its center of gravity as well as the ZMP. The primary result (walk motion) of virtual model at simulation window is very unsatisfactory. After taking some trail taking we found our simulation result satisfactory. But at practical case it is really difficult to apply the full virtual model. For likens of DOF's, It is more difficult to get the expected result. Control system Electrical components are the heart of the equipment's. The bipedal robot needs a different number of electrical components. They are –

- Microcontroller (PIC18F2550)
- SSC-32 servo motor controller
- Servo motor
- Crystal (20 MHz)
- Adaptor

The Lynxmotion SSC-32 Servo Controller is a small preassembled servo controller with some big features. It has high resolution (1uS) for accurate positioning, and extremely smooth moves. The range is 0.50mS to 2.50mS for a range of about 180°. The motion control can be immediate response, speed controlled, timed motion, or a combination. A unique "Group Move" allows any combination of servos to begin and end motion at the same time, even if the servos have to move different distances. This is a very powerful feature for creating complex walking gaits for multi servo walking robots.

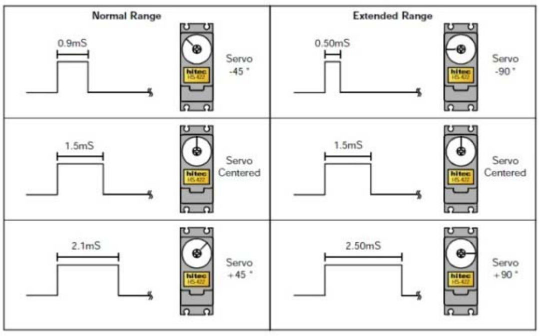

Fig 3. Different position of servo(PWM)

The servo's position or movement can be queried to provide feedback to the host. There is even a 12 servo Hexapod sequencer built in. This allows complete control of all aspects of the alternating tripod gait simply by transferring a few values from the host controller. Any output can be used as a TTL level output. There are 4 digital inputs that are static or latched, so you don't have to worry about missing a short event. They can also be used as analog inputs. There are three terminal blocks for powering options.

6. Positioning

The step positions are fixed after several trails. For a full foot position, it requires 4 different steps. These are some common steps of the bipedal robot. Steps picture flow of the robot are given below,

Limitation of robot:

- In our robot used only 10 DOF. But for smooth running of a humanoid bipedal robot 12 DOF is minimum needed. That is why it does not walk smoothly.
- It is used plastic for the structure of the robot. But it increases the weight of the robot unnecessarily, decreases the strength of the frame.
- The bode height unnecessarily high which causes to make the body stability difficult.

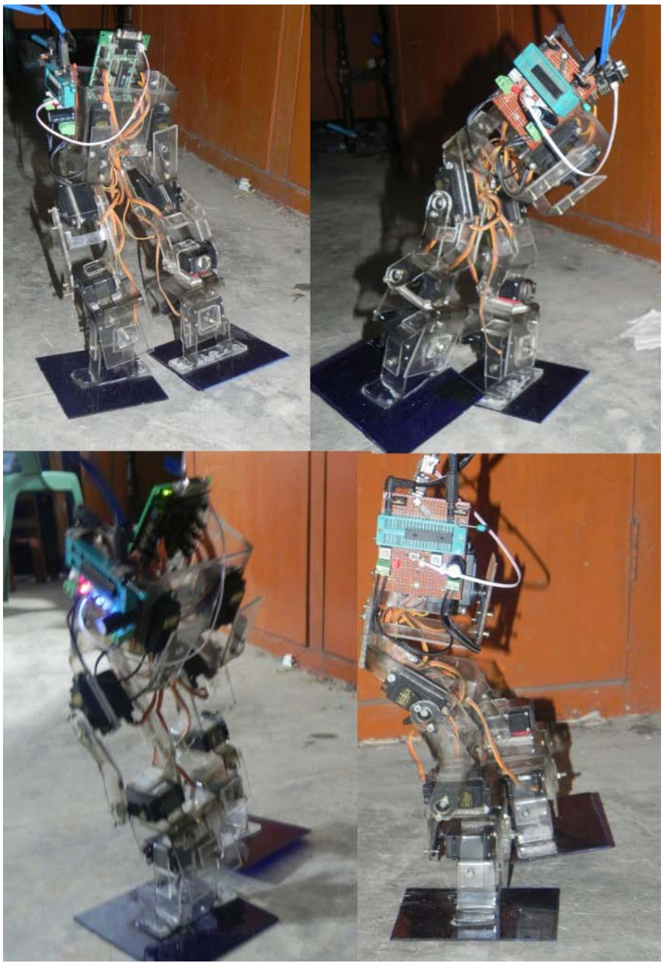

Fig 4.walking steps of bipedal robot

Overcome of the limitation:

- To improve the walking, two more motors are needed to add on the robot at the place of waist.
- To improve stability and to reduce body weight, aluminum will be better for body structure.
- Redesign of the structure is needed. Height and extra part should be minimized.

7. Future work

Future advancement of our Bipedal robot can be carried out for Embedded Processor that can process the control signal faster to the actuators. Complex movements can be achieved by increasing the Degrees of Freedom up to 14. Remote control through wireless mode can also be considered for the future work of our Bipedal walking robot.

8. Conclusion

The Intuition of our work is to study the complex motion of the human body. This is the first step of our work as leg study. With our developed bipedal robot it is fully clear to us that how the complex motion our human body can carry. We think this is the perfect combination of metameric with the real field of engineering as well as the mechatronics. We want to belief, once robot can reduce the physical libber of human work and help the disable people to enjoy their daily life more smooth.

6. ACKOWLEDGEMENT

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7. REFERENCES

[1] Yasuhiko Dote, Servo Motor and Motion Control: Using Digital Signal Processors, Prentice Hall and Texas Instruments Digital Signal Processing Series. 2008.

[2] Andre Senior and Sabri Tosunoglu – “Design of a Biped Robot”, Florida Conference on Recent Advances in Robotics, FCRAR, May25-26, 2006

[3] Design, Fabrication and Analysis of Bipedal Walking Robot Department of Production Technology, Madras Institute of Technology, Anna University, INDIA

[4] Virtual Mo del Control of a Bipedal Walking Robot; Proceedings of the 1997 International Conference on Robotics and Automation (ICRA '97) MIT Leg Laboratory, Cambridge, MA 02139

[5] Design of a bipedal walking robot; Institute of Human and Machine Cognition, USA 32502

[6] H. Miura and I. Shimoyama. Dynamic walk of a bip ed.International Journal of Robotics Research, 3(2):60 (74, 1984)

[7] Development of a Voice Controlled Robotic Arm; Conference on Engineering Research, Innovation and Education 2011,CERIE 2011, 11-13 January 2011, Sylhet, Bangladesh

[8] Welman, C. Inverse kinematics and geometric constraints for articulated figure manipulation. Master’s thesis, Simon Fraser University, Burnaby, BC, 1993

[9] Wang, L.-C., and Chen, C. A combined optimization method for solving the inverse kinematics problem of mechanical manipulators. IEEE Trans. On Robotics and Automation 7, 4 (1991), 489–499

[10] (Ebook - English) Mcgraw-Hil, Pic Robotic -- A Beginner'S Guide To Robotic by John Iovine

[11] Advanced PIC Microcontroller projects in C from USB to RTOS with the PIC18F Series by Dogan Ibrahim

[12] Welman, C. Inverse kinematics and geometric constraints for articulated figure manipulation. Master’s thesis, Simon Fraser University, Burnaby, BC, 1993

[13] Paul Horowitz and Winfield Hill, The Art of Electronics Second Edition, Cambridge University Press, Cambridge MA, 1989, ISBN 0-521-37095-7