ISSN (Online) : 0974-5645
ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 8(S2), 185–188, January 2015*
DOI: 10.17485/ijst/2015/v8iS2/60295

Simulation and Modeling of 6-DOF Biped Mechanism

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Abstract

This is an approach of designing and implementing walking postures for bipedal robot. The project presents efficient mechatronic architecture describing mechanical to software issues related to designing and execution of locomotion. The aim is to simulate and exhibit the robustness and the efficiency of the controller architecture using PD controller in MATLAB. The mission is to develop a biped to walk using Arduino Mega 2560.PRO-E simulation is done to calculate motion parameters. Trajectory planning is accomplished using Matlab.

Keywords: Arduino Mega, Biped, MATLAB, Pro-E

1. Introduction

Mechanical biped locomotion has been subject to rigorous study and research for the last three decades. The available literature lie on a wide range of information, from efficient means of figuring the dynamical equations, model formulation, relations between mechanical limb locomotion and biological limb locomotion, methods of harmonizing gaits, the automated recognition of biped robots, and control as well as manipulation. Human walking is the motivation, furthermore the catalyst for walking robot. In the initial stage of this paper, by the help of motion apprehension of subject's walking on stairs, the scrutinizing of human walking data is achieved. Biped robots can act and change its position more freely than wheeled robots in a candid manner. Empowering a robot to climb stairs or step over snag autonomously, appropriate perception capabilities, together with close coordination between consciousness and locomotion are required. Our exploration focuses on the synergy between mechanized actuation and biped walking in an automated fashion.

1.1 Background Study

The idiosyncratic feature of full-body humanoids is mainly based on bipedal locomotion. On two legs, walking, as well as running may be uncomplicated but at the same time humanoid robots still have deliberate difficulties in it. Among the two conflicting wings approaches to bipedal walking, the first one is based on zero-moment-point theory (ZMP), introduced by Vukobratovic. The ZMP is interpreted the addition of all the moments of all active forces on a particular point in the ground, as equal to zero. A biped robot will be dynamically stable if the zero-moment-point lies within the convex hull (support polygon) of all contact points between the ground and the feet. One of the major use of ZMP is to figure out the stability is a large-scale advance over the center-of-mass projection criterion, that chronicles static stability.

1.2 Past Research Work

The approach of human-like automatons is nothing modern. Leonardo da Vinci (in 1495) designed an armored knight using a mechanical gadget which waves its arms and moves its head via a tensile neck while opening and shutting its jaw. Illustration of humanoid robot appeared in the movies A.I. (Steven Spielberg, 2001),

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and I, robot (Alex Proyas, 2004). Minetti and Alexander[1] recommended a refined structure of limb dynamics which is capable of anticipating functions of walking and running[2]. Alexander used a simple point mass model to spectacle that positive work in walking is unavoidable to build up energy lost during heel strike[3,4]. Mochon and McMahon[5] demonstrated the ballistic motion of the swing leg resembling humans, and McGeer[6] revealed that the entire step cycle can be interpreted by passive dynamics with energy yielded by a slight downhill slope or by active power afforded by a hip torque or an impulse at toe-off[7].

2. Mathematical Modeling

2.1 Forward Kinematics

In Forward kinematics the position and orientation of the end-effector can be determined by configuring the dynamic joints. This study concentrates on the lower part of the biped. Model has 6 DOF namely a 1 DOF thigh, a 1 Degree of freedom knee, a 1 Degree of freedom ankle for each leg. Individual legs can be modeled as a kinematic chain with 3 links connected by three revolute joints.

The local frames (X_i, Y_i, Z_i) are allocate to each joint agreeing to the Denavit-Hartenberg (DH) convention in the Figure 1. Assume the base frame (X_0, Y_0, Z_0) at the middle of the hip as the global reference frame. The kinematic structural arrangement of the left leg of the biped is similar as that of right leg. Hence we assign co-ordinate frames of both the legs same.

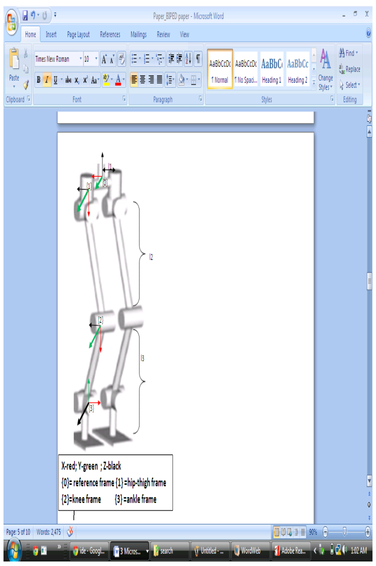

Figure 1. Kinematic description of the biped.

Considering local co-ordinate frames Li denotes the length of link i and Θ_i is the angle between the X_i-*1* and X_i axes measured about the *Zi-1* axis; d_i is the length from the X_{i-1} to the X_i axis as measured about the Z_i axis; a_i is the distance from the Z_{i-1} to Z_i axis measured along the X_{i-1} axis; and a_i is the angle between the Z_{i-1} and Z_i axes measured along the X_{i-1} axis. Anti-clockwise rotation is assumed positive. DH parameters can be given as:

2.2 Trajectory Planning

For following a desired trajectory it is necessary to control the biped. Hence it is important to generate Joint space trajectory given by the Cartesian space trajectory. Hence walking produces a fixed periodic function which used to calculate rotational angles and torque in the Figure 2.

$$X_0(t) = s/2pi((2pi\ t/P)-sin(2\ pi\ t/P)) \quad (1)$$
$$Y_0(t) = sh/2pi((2\ pi\ t/P)-sin(2\ pi\ t/P)) \quad (2)$$
$$X_1(t) = s/2pi((2\ pi\ t/P)-sin(2\ pi\ t/P)) \quad (3)$$
$$Y_1(t) = sh/2pi((2\ pi\ t/P)-sin(2\ pi\ t/P)) \quad (4)$$
$$X_3(t) = d/2pi((2\ pi\ t/P)-sin(2\ pi\ t/P)) \quad (5)$$
$$Y_3(t) = h \quad (6)$$

Where s = the range covered in one step, sh = the height between the sole of the foot and ground, d = the hip moving distance, h = the height of hip joint, P = the period of single step, and t denotes time.

Table 1. DH table for left leg

DH parameter	Joint		
Θ_i	Θ_1	Θ_2	Θ_3
D_i	-l1	0	l3
A_i	0	l2	0
a_i	Π/2	0	Π

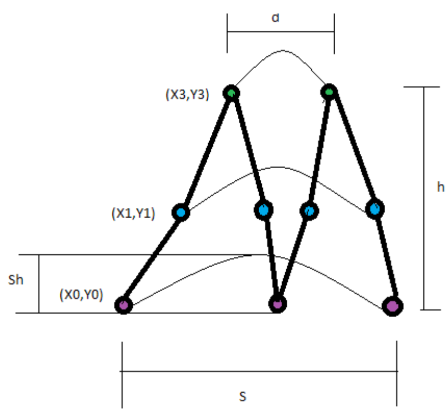

Figure 2. Parameters of trajectory planning.

3. System Architecture

3.1 Specification

3.1.1 Arduino AT mega 2560

Arduino AT mega 2560, with 54 digital pins and 16 analog input pins, is used as a hardware interfacing platform. Operating voltage is maintained at 5 volts at 16 MHz clock frequency. Out of 256KB flash memory 8KB is used by boot loader.

3.1.2 Servo Motors

Nylon gear type Servo Actuators of dimensions 1.6" x 0.8" x 1.4", 41gm with 5.5kg/cm variants is used at 4.8-6.0 Volts Operating voltage. For Pulse Width Modulation 3-5 Volt Peak to Peak Square Wave is required.

3.2 Mechanical Constraints

There are multiple design considerations when designing a Bipedal robot. The main components are Robot's size selection, Degrees of freedom (D.O.F) selection, Stability, Link Design and Foot Pad design.

3.2.1 Robot Size Selection

Miniature size of the robot is elected in this project, so a height of approx 29.5cm is decided followed by the mounting of the controlling circuits, but the substantial robot's size is 26 cm excluding controlling circuits.

3.2.2 Degrees of Freedom

6 DOF.

3.2.3 Link Design

The bracket concludes of two parts. U-shaped bracket A is employed for joints formation and Servo bracket B is used for joint for the motors. Servomotors are hooked inside the bracket A and the bracket B is used to disseminate the output of the servomotor. Dimensions of Bracket A - (51x24.6x49) mm, Bracket B - (66x37.10x24) mm.

3.2.4 Foot Pad Design

The stability of the robot is resolved by the foot pad. Normally over sized and heavy foot pad will have more contact area, causes more stability. But keeping in mind the disadvantage of torque demand and lifting the leg against the gravity, an optimal sized foot pad was used.

4. Block Diagram

Figure 3 explains the basic illustration of the design. Pro-E and Matlab is used for simulating the parameter of the biped while Arduino IDE is used for connecting the logic from the code to hardware level. Using the actuation of motors lifting of leg and walking is set up.

5. Preliminary Results

5.1 Pro-E Simulation

Pro-E design is a simple tool for animation design of sequence mechanism. Following fig.4 are the sequential results for Pro-E simulation of biped.

5.2 Matlab-Simulink Simulation

Simulation has been done in MATLAB implementing the Simulink model for PID control.

Figure 5 explains the GUI modeling of the Simulink block of the biped for 10 seconds of motion. Simulation for different speed and distance is observed and biped parameters are computed.

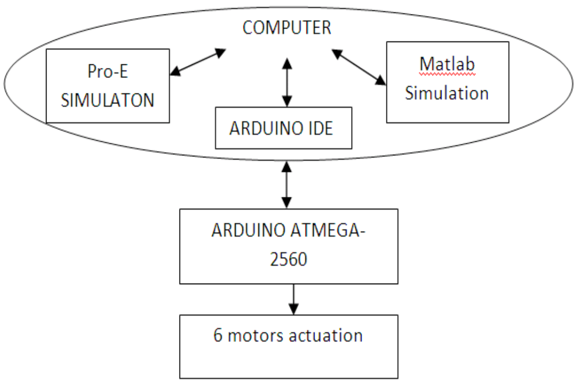

Figure 3. Block diagram of the model.

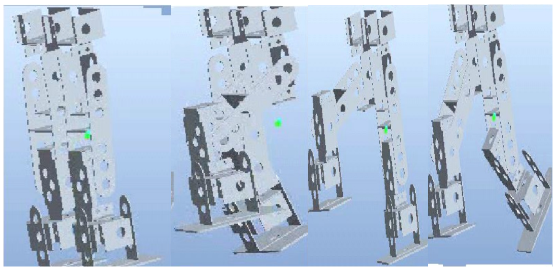

Figure 4. Pro-E Animation.

5.3 Arduino Hardware

Depending in the result of Matlab simulation and Pro-E design parameters for hardware implementation is designed for motor actuation.

Arduino IDE is used for dumping code into Arduino Mega microcontroller. Figure 6 depicts the hardware implementation of biped robot to achieve 6-DOF.

Figure 6: Hardware Implementation

6. Conclusion

In this project we integrated results of Matlab, Pro-E and C coding in Arduino IDE to improve modeling capabilities of biped. Howsoever, ease with which human works are still not reflected in Humanoid robots. The step time was over 10 seconds per step in Matlab simulation and the harmony control strategy was achieved through the application of COG (Center Of Gravity).

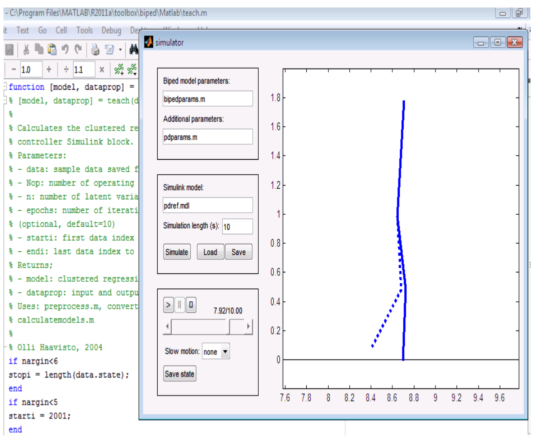

Figure 5. Matlab GUI model.

7. References

1. Minetti AE, Alexander RM. A theory of metabolic costs for bipedal gaits. J Theor Biol. 1997; 186:467–76.
2. Alexander RM. A model of bipedal locomotion on compliant legs. Philos. Trans. R Soc London Ser. B. 1992; 38:189–98.
3. Alexander. Mechanics of bipedal locomotion. Perspectives in Experimental Biology 1. In: Davies PS, editor. Oxford: Pergamon; 1976. p. 493–504.
4. Alexander. Simple models of human motion. Appl Mech Rev. 1995; 48:461–9.
5. Mochon S, et al. Ballistic walking: an improved model. Math Biosci. 1980; 52:241–60.
6. McGeer T. Passive dynamic walking. Int J Robot Res. 1990; 9:68–82.
7. Alexander RM. Optimization and gaits in the locomotion of vertebrates. Physiol Rev. 1989; 69:1199–227.
8. Garcia M, Chatterjee A, Ruina A, Coleman M. The simplest walking model: stability, complexity, and scaling. Asme J Biomech Eng. 1998; 120:281–8.
9. Garcia M, et al. Efficiency, speed, and scaling of passive dynamic walking. Dyn. and Stab. Syst. 2000; 15:75–99.