

**INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES  
& MANAGEMENT****DESIGN & CONSTRUCTION OF WALKING BIPEDAL ROBOT**Deepti Malviya<sup>1\*</sup> Suman Sharma<sup>2</sup>Truba college of Engineering & Technology, Indore <sup>1,2</sup>**ABSTRACT**

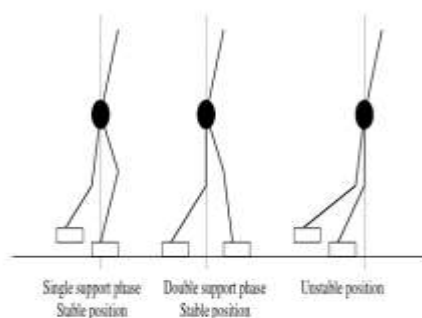
It is easier for bipedal robots to exist in a human oriented environment than for other types of robots. Furthermore, dynamic walking is more efficient than static walking. For a biped robot achieve dynamic balance while walking, a dynamic gait must be developed. Two different approaches to gait generation are presented—an intuitive approach using software for gait animation, and a periodic approach that provides a scalable gait with parameters for controlling step length, step height and step period.

Despite several decades of research, locomotion of bipedal robots is still far from achieving the graceful motions and the dexterity observed in human walking. Most of today's bipeds are controlled by analytical approaches based on multi body dynamics, pre-calculated joint trajectories, and Zero-Moment Point considerations to ensure stability. However, beside their considerable achievements these methods show several drawbacks like strong model dependency, high energetic and computational costs, and vulnerability to unknown disturbances. In contrast to this, human locomotion is elegant, highly robust, fast, and energy efficient. These facts gave rise to the main hypothesis of this thesis, namely that a control system based on insights into human motion control can yield human-like walking capabilities in two-legged robots.

**INTRODUCTION**

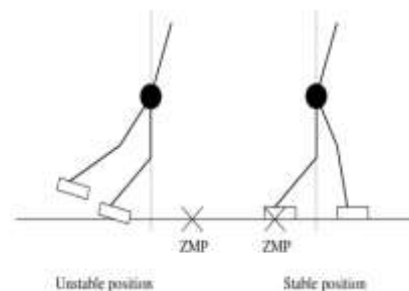
Bipedal robots will operate in a human environment with much greater efficiency than any other type of robot yet devised. It is hoped that eventually bipedal robots can be used to complete tasks which are too difficult or dangerous for humans. This includes applications such as working in extreme environmental conditions (such as in fire rescue operations), with toxic gases or chemicals, with explosives (such as land mines) or as an aide to humans in similar situations. Also, a useful by-product of research into bipedal robotics will be the enhancement of prosthetic devices.

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 [1].



*Figure 1.1 Static walking of bipedal robot*

Dynamic walking is characterised by a small period in the walking cycle where the center of gravity of the robot is not projected vertically onto the area of either foot [2]. This requires there to be a period of controlled instability in the gait cycle, which is difficult to accomplish unless the mechanical system has been designed bearing this in mind.



*Figure 1.2 dynamic walking of bipedal robot*

Attempts at building walking machines can be traced back at least to the 1960s. In addition to research concerning bipedal robots, efforts were also made to develop monopedal (Raibert, 1986) and quadrupedal robots (Furusho et al. 1995). One of the first functioning bipedal robots was developed in the 1970s by Kato (Kato and Tsuiki, 1972). Today, there are many bipedal robot projects in the world, and the number of active projects is growing rapidly. Here, we will briefly review some of the work in bipedal robotics to date. We will mainly focus on motor skills for walking robots. [3]

**LITERATURE REVIEW**

There are several good reasons for developing bipedal walking robots, despite the fact that it is technically more difficult to implement algorithms for reliable locomotion in such robots than in e.g. wheeled robots. First, bipedal robots are able to move in areas that are normally inaccessible to wheeled robots, such as stairs and areas littered with obstacles that make wheeled locomotion impossible. Second, walking robots cause less damage on the ground than wheeled robots. Third, it may be easier for people to interact with walking robots with a humanoid shape rather than robots with a nonhuman shape (Brooks, 1996). It is also easier for a (full-scale) humanoid robot to function in areas designed for people (e.g. houses, factories), since its humanlike shape would allow it to reach shelves etc.

The first biped robot to be successfully created and use dynamic balance was developed by Kato in 1983 [4]. While this robot largely used static walking, it was termed quasi-dynamic due to a small period in the gait where the body was tipped forward to enable the robot to gain forward acceleration and thus achieve a forward velocity. This achievement has largely been cited as the defining moment where the focus of research shifted from static to dynamic walking.

Since this time, progress has been somewhat sluggish. The same research group produced the WL-10RD robot which walked once more with quasi-dynamic balance in 1985 [5]. The robot was required to return again to static balance after the dynamic transfer of support to the opposite foot. However Miura and Shimoyama [6] abandoned static balance entirely in 1984 when their stilt biped BIPER-3, which was modelled after a human walking on stilts, showed true active balance. Simple in concept, it contained only three actuators; one to change the angle separating the legs in the direction of motion, and the remaining two which lifted the legs out to the side in the lateral plane. Since the legs could not change length, the side actuators were used to swing the leg through without scuffing the foot on the walking surface. An inverted pendulum was used to plan for foot placement by accounting for the accelerating tipping moments which would be produced. This three degree-of-freedom robot was later extended to the seven degree-of-freedom BIPER-4 robot.

Another approach had been taken by Raibert [7], who developed a planar hopping robot. This robot used a pneumatically driven leg for the hopping

motion and was attached to a tether which restricted the motion to three degrees of freedom (pitch motion, and vertical and horizontal translation) along a radial path inscribed by the tether. A state machine was used to track the current progress of the hopping cycle, triggered by the sensor feedback. The state machine was then used to modify the control algorithm used to ensure the stability of the machine. A relatively simple control system was used which modified three parameters of the hopping gait, namely forward speed, foot placement and body attitude. The success of this research motivated Raibert to extend the robot and control system to hopping in three dimensions, pioneering the area of ballistic flight in legged locomotion.

### EXAMPLES FOR TECHNICALLY CONTROLLED BIPEDS

Since four decades, research institutes throughout the world have been developing bipedal robots. Despite their anthropomorphic appearance, most of the efforts follow a more industrial approach in the design and control of their machines and apply the aforementioned zmp calculation for generating joint trajectories. The most prominent representatives of this kind of robots are described in the following section, two of them in more detail.

The H7 Robot by the JSK Laboratory The Jouhou System Kougaku (jsk) Laboratory of the University of Tokyo has a long tradition of building humanoid robots, some of which are shown in Figure 2.7. The aim of its work is to develop an experimental research platform for walking, autonomous behaviour and human interaction. The design of their latest robot H7 focused on additional degrees of freedom (resulting in 30), extra joint torques, high computing power, real-time support, power autonomy, dynamic walking trajectory generation, full body motions, and three-dimensional vision support. Being 1.5 m tall and weighing 57 kg, the robot features 7 degrees of freedom per leg including an active toe joint. A real-time capable on-board computer, four lead-acid batteries, wireless lan, two ieeel394 high resolution cameras, 6-axis forces sensors and an inertial measurement unit complete the robot's equipment [Kuffner 01, Chestnutt 03, Nishiwaki 06].

The online walking control system of H7 allows to generate walking trajectories satisfying a given robot translation and rotation as well as an arbitrary upper body posture. It is composed of several hierarchical layers as shown in Figure 2.6. Each layer represents a different control cycle and passes its processed

results to the next, lower layer which usually runs at a higher frequency.

The gait decision layer chooses the gait and calculates the footstep locations. The algorithm proposed by the authors determines the next swing leg's foot point relative to the foot of the supporting leg.

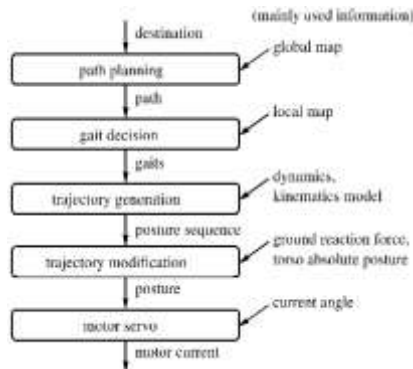


Figure 2.1: dynamic walking control system of the robot H7.

**Methodology**

3.1 Proposed Methodology:

1. Design a gait sequence in joint space.
2. Provide sensors and actuators at joints.

3.2 Designing Gaits:

1. Controlling Balance: when standing, “not required” when walking.
2. Controlling Speed: It is change step size (swing leg must keep up).
3. Controlling Height: It is used to control speed and energy efficiency.
4. Generate intermediate joint angles based on these constraints.

**Mechanical Design**

The design process involves the creation of a specification for the building of a robot upon which the chosen model of dynamic walking will be implemented. The aim is to derive the specifications such that the chosen walking model will succeed. This is not a trivial task—there are many considerations to take account of in order to ensure that the biped robot will be stable while walking. The most important of these are balance, forces, moments, torque, proportions, mass and strength.

The Mechanical design forms the basis for developing this type of walking robots. The mechanical design is divided into four phases:

A - Determining the Mechanical constraints.

B - Conceptual Design

C - Building the Prototype model

D - Specification and Fabrication of the model.

Firstly we make a prototype modal which is made by only aluminum strip after that we made a single leg and done programming to walk it.



Figure 4.1 A Prototype Model of Bipedal Robot

The 3D models are developed using AutoCAD.

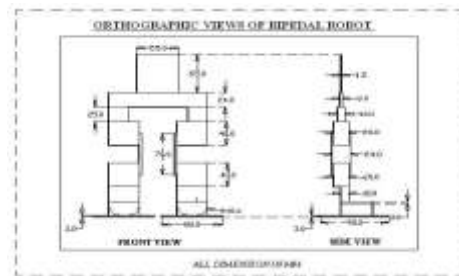


Figure 4.1 A Model of Bipedal Robot

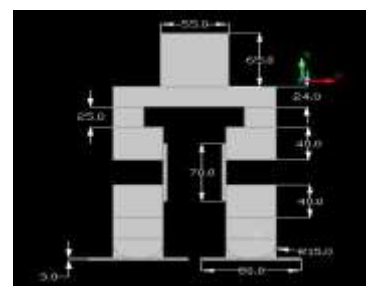


Figure 4.2A Model of Bipedal Robot



Figure 4.3 Final Model of Bipedal Robot

**Specification and Fabrication of the model**

**Degrees of Freedom** –Total of 6 D.O.F (Hip, Knee and Ankle)

S.No.	Name of Component	Length (mm)	Width (mm)	Height (mm)
1	Length of Bipedal model	170	24	275
2	Leg length	40	43	207
3	Foot pad	80	90	3
4	Servo joint upper	40	24	40
5	Servo Clamps lower	40	3	23

Table 4.1 Dimension of Bipedal Model

S.No.	Name of Component	Weight
1	Estimated servo clamp weight	60gms
2	Servo motor weight	55gms
3	Total estimated weight for a link (servomotor + servomotor bracket)	120gms
4	For 6 links (i.e. 2Legeights)	720gms approx
5	Foot pad weight (2 legs)	60gms.
6	Circuits & Batteries	350gms approx
7	Total weight of the robot	1.180Kg approx

Table 4.2 Weight Calculation of all Components

**RESULT**

Stationary walking on the ground plane:

The stability of the robot in the lateral plane can be examined by enabling the robot to walk continuously in the same position on the ground plane. This has the desired effect of reducing tipping moments which are created when the robot translates a foot, which can increase the instability of the robot. Thus the problem of control is simplified, since the parameters of step height and step length are constant, and the motion is effectively restricted to the lateral plane. Through variation of the step period and the magnitude of the trunk motion in this plane, the timing relationship between these parameters can be examined.

Walking with Load and without Load:

We saw during the load position the bipedal is moving proper but it required more power and many times when load is more it was unbalanced. We put load in box which is attached beside the robot and operate it the result is below in table

S. No.	Load / Weight (gm.)	Result
01	10	Walk smoothly
02	20	Walk smoothly
03	50	Walk but slow
04	200	Walk but unbalance
05	250	Fully unbalanced

**Table 5.1: Load/Weight Calculation**

While we run it freely without load, it run smoothly and required low power.

## CONCLUSION

A useful tool for the development of gaits for our bipedal robots has been developed. A more complex control system may be required in order to stabilize the robot sufficiently. This may require an adaptive control system, such as artificial neural networks (ANN), genetic algorithms (GA) or fuzzy logic. However, it is more likely that the method of gait generation will also need improvement, in order to generate the most stable gait before control is implemented, minimizing the control problem.

The importance of gait generation has been established, as well as the significance of control system to stabilize the robot while in motion. Both must be present for dynamic bipedal walking to succeed, and both require more research.

Research in this field is important for developing robots which can operate in normal human environments, and can adapt to disturbances and variations in the environment, enabling them to traverse over uneven terrain. In the future, with the convergence of many widely differing fields of research, this is becoming a reality.

## REFERENCES

- [1] H. Hemami and Y. F. Zheng, "Dynamics and control of motion on the ground and in the air with application to biped robots," *Journal of Robotic Systems*, vol. 1, no. 1, pp. 101–116, 1984.
- [2] R. E. Goddard, F. Zheng, Yuan, and H. Hemami, "Control of the heel-off to toe-off motion of a dynamic biped gait," *IEEE Transactions on Systems,*

*Man, and Cybernetics*, vol. 22, no. 1, pp. 92–102, 1992.

[3] Mattias Wahde and Jimmy Pettersson, A BRIEF REVIEW OF BIPEDAL ROBOTICS RESEARCH, Chalmers University of Technology, Division of Mechatronics, Dept. of Machine and Vehicle Systems.

[4] T. Kato, A. Takanishi, H. Jishikawa, and I. Kato, "The realization of the quasi-dynamic walking by the biped walking machine," in *Fourth Symposium on Theory and Practice of Robots and Manipulators* (A. Morecki, G. Bianchi, and K. Kedzior, eds.), (Warsaw), pp. 341–351, Polish Scientific Publishers, 1983.

[5] A. Takanishi, M. Ishida, Y. Yamazaki, and I. Kato, "The realization of dynamic walking by the biped walking robot WL-10RD," in *ICAR '85*, pp. 459–466, 1985.

[6] H. Miura and I. Shimoyama, "Dynamic walk of a biped," *International Journal of Robotics Research*, vol. 3, pp. 60–74, 1984.

[7] M. H. Raibert, *Legged Robots That Balance*. Cambridge, MA: MIT Press, 1986.