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# Six Legged Locomotion on Uneven Terrain

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***Abstract** -In this paper current state of many walking robots are compared and advantages of a legged systems against wheeled robots are described. In the subject of our research we have selected a six legged robot which is biologically inspired by insects. We are focusing mainly on locomotion on uneven terrain using opposite gait of locomotion. The six legged robot has been designed to navigate smooth and irregular terrain. The stabilization of legs are inspired by biomimetic stepping leg transferences with an active balance control so as to reduce the propagation of instability while performing rapid stepping actions for a fast walking gait. Robotics has borrowed from nature with varying degrees of abstraction, from physical appearance to observed behaviors. This paper describes the proposed design and construction for the six legged normally called as hexapod robot to navigate on the uneven terrain.*

***Keywords--*****Bio-Robots, Walking Robots, Locomotion and Stability Controlled Gait.**

## I. INTRODUCTION

The hexapod is an insect inspired robot which has six legs that enables to move flexibly on various terrains. The main advantage of this type of robot is its stability. The nature inspired the researchers and new innovative ideas come in mind but sometimes they are simple and effective, sometimes cumbersome and critical[1]. One of the first walking machines was developed in about 1870 by Russian Mathematician Chebyshev. This walking machine had four legs arranged into pairs. Legged machine have been used for at least a hundred years and are superior to wheels in some aspects:

- Legged locomotion should be mechanically superior to wheeled or to tracked locomotion over a variety of soil conditions and certainly superior for crossing obstacles.
- US army investigation reports that about half the earth surface is inaccessible to wheeled tracked vehicles, whereas this terrain is mostly exploited by legged animals.

Wheeled robots are the simplest and cheapest also tracked robots are very good for moving, but not over almost all kinds of terrain. There are different types of legged walking robots. They are roughly divided into groups according to the number of legs they possess. Bipeds have two legs, quadrupeds four, hexapods six and octopods have eight legs. Bipeds' robots are dynamically stable, but statically unstable, such robots are harder to balance, and dynamic balance can only be achieved during walking. Hexapods are six legged robots, on the other hand, have advantages of being statically stable. During walking they can move three legs at a time, thus leaving three other legs always on the ground forming a triangle.

Previous work proved the feasibility of fabricating a crawling insect scale robot capable of forward locomotion on flat ground, and the results motivated multiple improvements in design [3]. The hexapod provides additional degrees of freedom for the robot's censors and on board equipment. Some general purpose robots were tested for this application at the first but now day's specific prototypes developing special features are being built and tested. The Titan VIII walking robot, a four legged robot developed as a general purpose walking robot at the Tokiyo Institute of Technology, Japan.[2]

For some time now, researchers have been aware of the reservoir of insight available from a well guided stud of existing biological systems. The objective of this research is to develop an efficient terrain negotiations and locomotion for hexapod. We'll discuss Mechanical Design in Section II and Embedded Architecture System in Section III and Walking Mechanism in Section IV.

## II. MECHANICAL DESIGN

The performance of robot can benefit greatly than biological principles are incorporated into its mechanical design. The body was design by us using AutoCAD and then CNC machine from a local job shop. We tried to find the lightest material for the body in order to decrease the load of the motors.

Here the six identical legs distributed evenly on the body. Each leg consist the three servo motors for three joints. It contains the required sub system, such as an on board computer, electronic servo motor, actuators, driver boards, PIC micro controllers, censors and batteries. The legs are made of 6061 and 7075 alloys with T6 or T6511 temper designation. These alloys have a high strength to wait ratio and are easily machine and welded.

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Fig. 1 (a): Solid Model of Hexapod

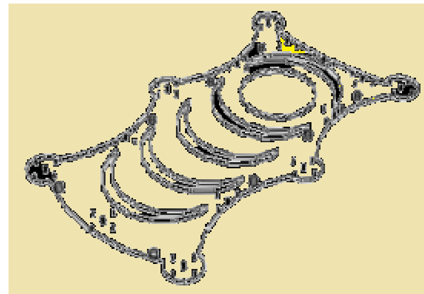

Fig.1 (b): Body Chassis

## III. EMBEDDED ARCHITECTURE SYSTEM

The robot has PIC micro controller which receives servo command packets from the PC using Bluetooth receiver and transmitter module. The controller generates PWM signals for driving servo motors. Also we are using lithium polymer batteries to provide stabilize high current to the servos.

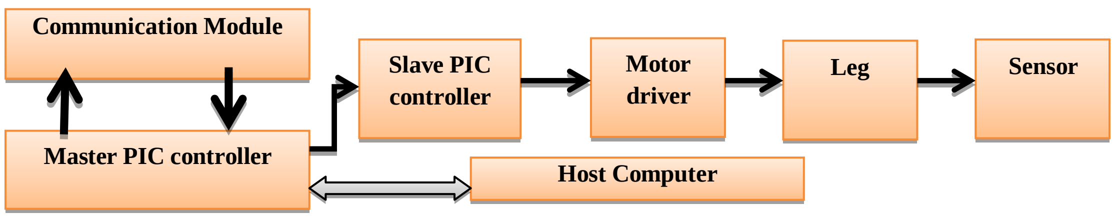


Fig. 1 (c): System Block Diagram

Each of three joint actuators per leg directly drives its associated leg segment. By attaching the leg segment directly to the servo output horns, the mechanical design of the joint is simplified. It is important for the leg control system to know current joint angles (servo position) and joints load (current consumption). The servos internal PCB which is responsible for receiving PWM position commands from a host and converting those commands into servo output positions has been removed. Master PIC is required to operate six slave PIC controllers. Input voltage can range from 7 VDC to 12 VDC. The control boards are capable of operating several modes connected to a PC via Bluetooth transmitter / receiver module. The master PIC is responsible for using its walking parameters for generate, stepping motions, normally these parameters are sent by the Central computer, however, they could also be preprogrammed so that controller can operate without a host. The master PIC executes its leg control software which has been hand programmed in assembler, to optimize performance and maintain absolute control over system timings.

## IV. WALKING MECHANISM

Walking mechanism tend to be heavier than wheeled vehicles mainly because of large numbers of actuators and complex leg structure. In addition energy consumption is larger [4]. A terrain negotiation in a three leg supporting phase basically requires no additional actuating functions, because tripod creates a unique steady posture on any terrain.

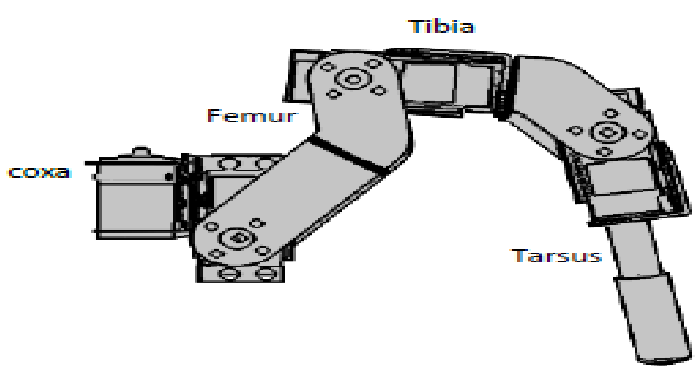


Fig. 1(d): Leg diagram

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The robot generally has a group of program gait sequences used for different purposes. The main types of gait will be used in the robot.

***A. Wave Gait "Metachronical Gait"***

In this gait mode the robot move one leg at a time, it starts by lifting one leg and then lowering it down gradually until the foot touches the ground and then the next leg starts to move, as mentioned before this gait sequence is rather slow but it provides maximum stability for the robot, and it enables the robot to walk on rough terrain. This is illustrated in Fig.(e)

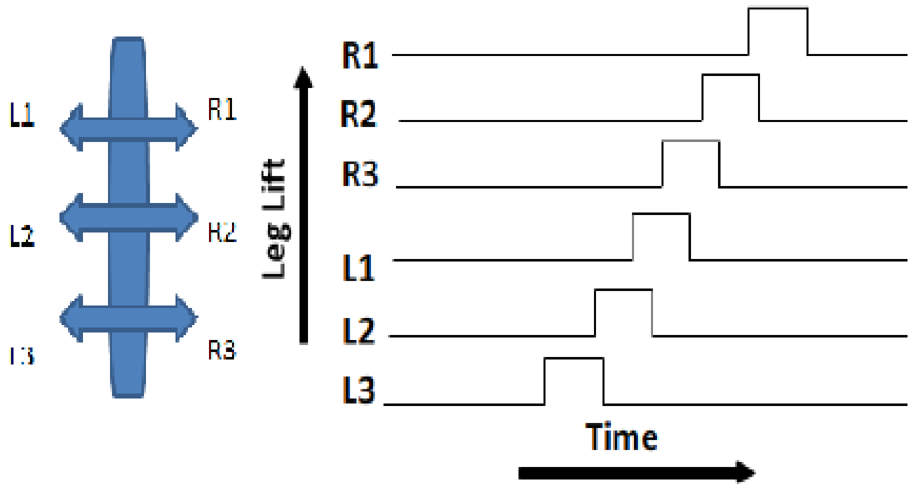


**Fig.1 (e): Single Wave Gait**

***B. Ripple Gait "Two Wave Gait"***

In this gait the two legs at a time, since it has two independent wave gaits. The opposite sides legs are 180 degrees out of phase and it needs 3 beats to complete one cycle.

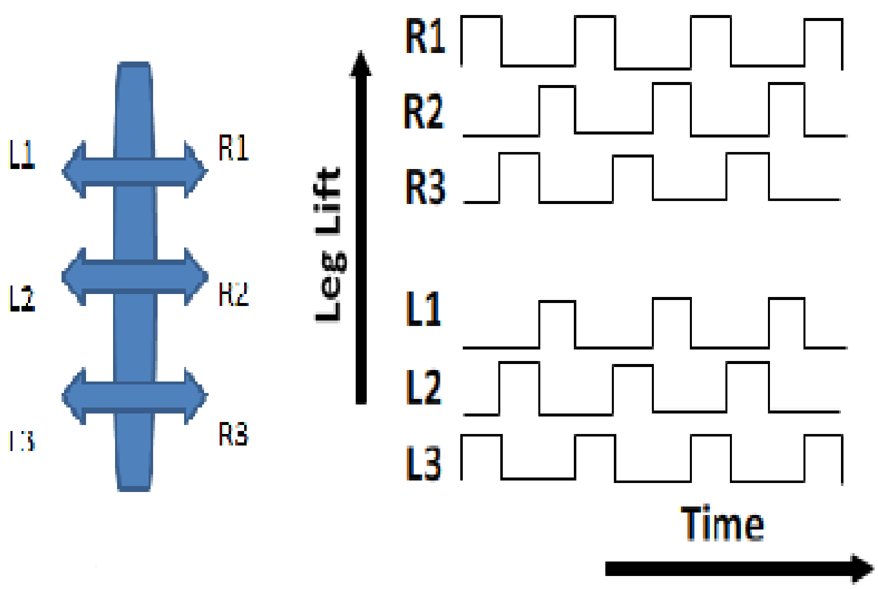


**Fig. 1(f): Ripple Gait**

***C.Tripedal Gait***

This gait is the fast gait for the hexapod; it completes a cycle in two beats. In this gait the robot lift three legs simultaneously while leaving three legs on the ground, which keeps the robot stable.

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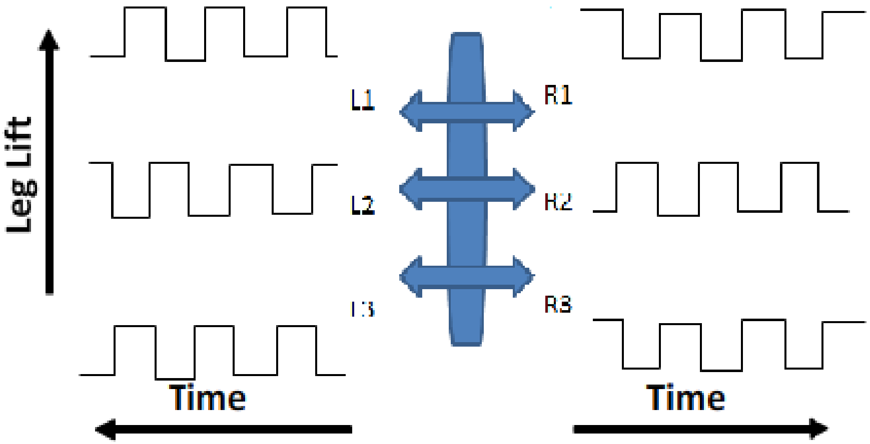
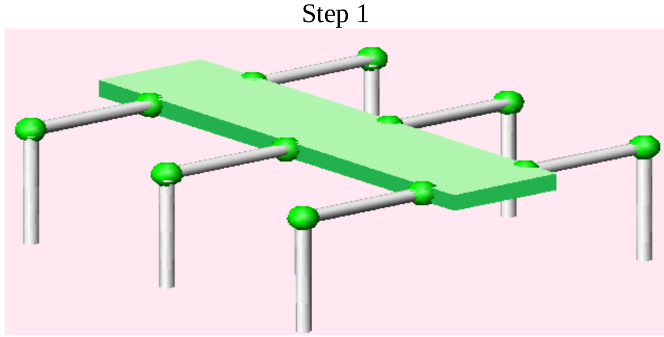



**Fig.1 (g): Tripedal Gait Reaction**

The hexapod will negotiate two different types of terrain: even terrain and uneven terrain. Terrain negotiation always comprises safety aspects on the motion execution in order to protect living creatures as well as robot's hardware. Especially rough terrain capabilities require the robot to distinguish traversable from hostile locations. Obstacles make sense to the hexapod robot about the type of terrain.

Step 1



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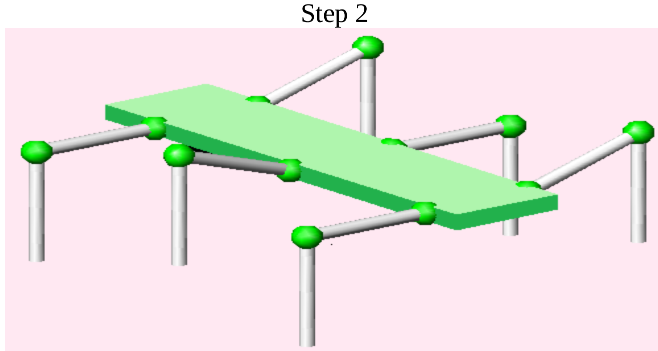

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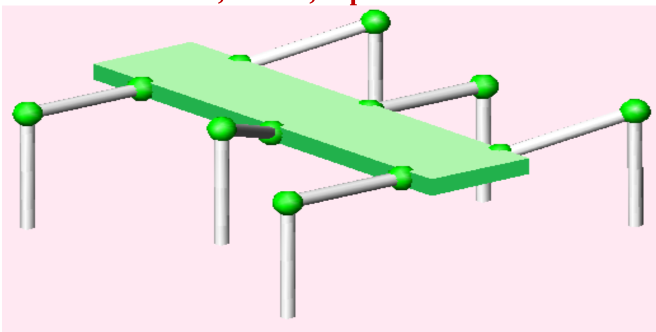
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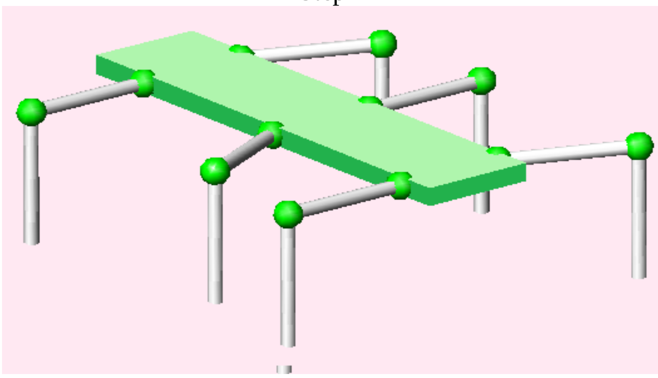
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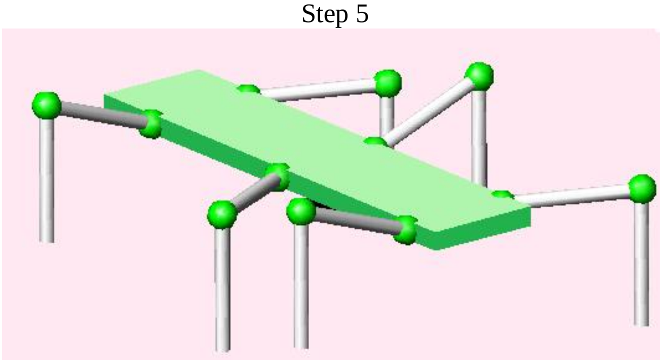
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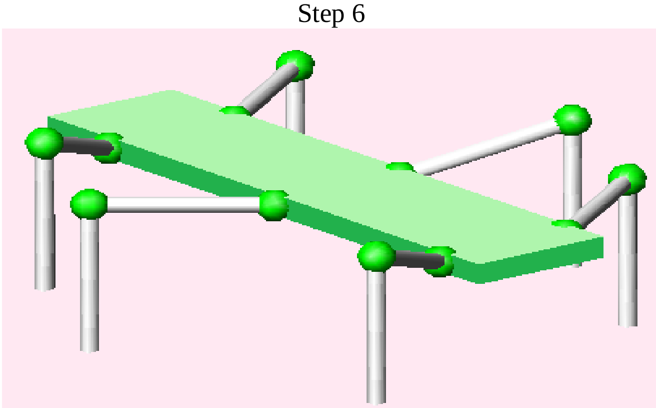
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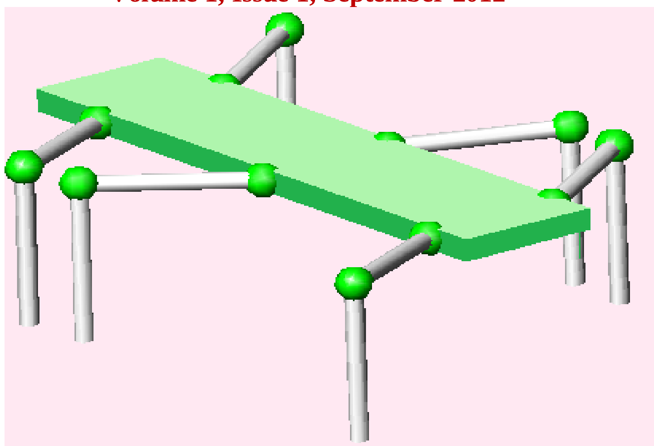

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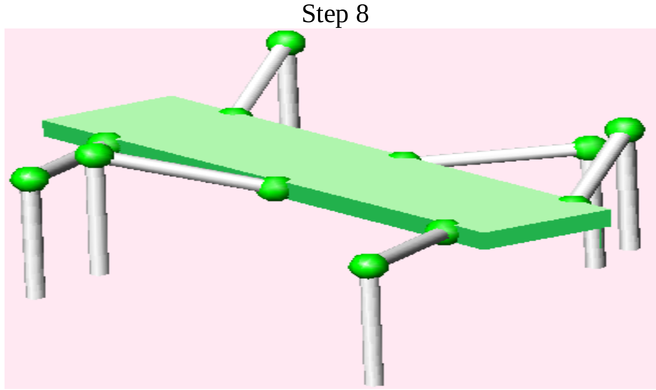

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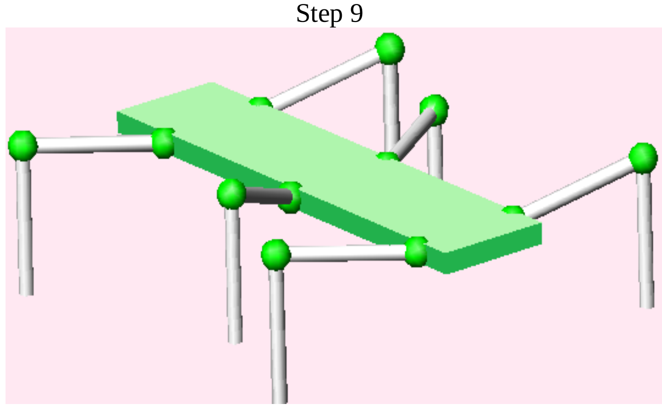

**Fig. 1 (h): Six Legged Locomotion**

## V. CONCLUSION AND FUTURE WORK

The work presented here describes strategy of six legged locomotion which is inspired by neurobiological aspect of the insect. It has been design to implement the leg control method as identified in the insect and gait generation method based on insect observations. We hope to scale it to a full version of six legged robot and its ability to move over several kinds of terrain. Upcoming tests will quantify the performance of the robot during these tasks.

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