Module 11 : Example study of robots

Lecture 40 : NATARAJ – a case study of a 6-legged robot

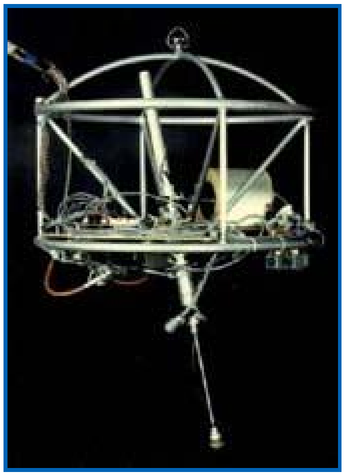
Objectives

In this course you will learn the following

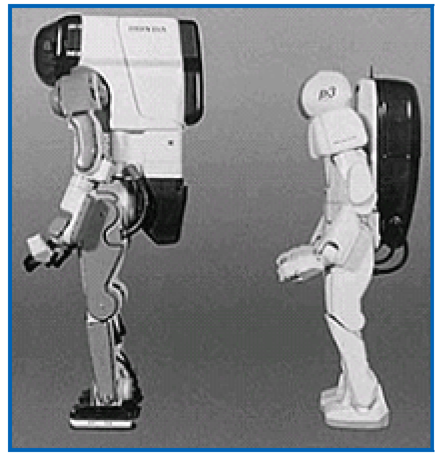
- Mobile Robots
- Legged Robots
- Nataraj Robot
- Nataraj Development : Specifications
- Nataraj Development: Hexapod Configuration
- Leg Design
- Leg workspace and margin of stability
- Foot work volume
- Leg Actuators
- Material Selection
- Leg Actuators Motor Selection
- Implementation and Trials

Mobile Robots

- The focus of the course has been on Industrial robots, which are by and large fixed robots. However, there are many instances when one would like to have a mobile robot.
- A mobile robot is a robot that is capable of going from one place to another.
- Some capabilities required in a mobile robot are:
    - Means of locomotion, i.e., wheels, legs, wings, etc.
    - Navigation, i.e., line following, target seeking, obstacle avoidance, navigation using maps, map building, self localization, etc.



Single leg hopping robot

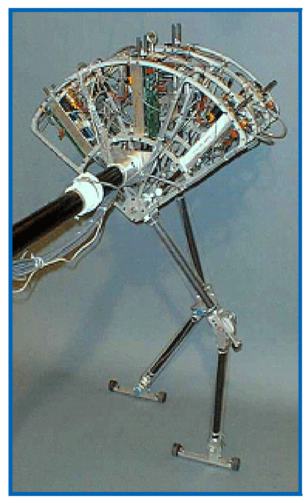


Some early humanoid robots

Legged Robots

Advantages

- Prepared surface not essential
- Continuous surface not essential
- Legged mobile robots can work in environments designed for human beings where wheeled robots cannot be used.
- Active suspension
- Can be made contaminant proof by clothing



Flamingo – a biped using serial elastic actuators Leg Lab MIT

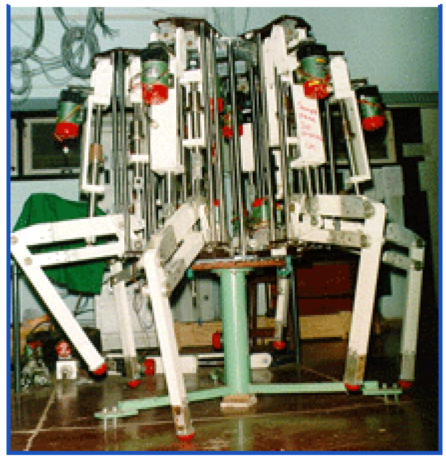
Disadvantages:

- Greater complexity of hardware
- Greater demand on actuator due to self weight
- Greater complexity of control and coordination

Nataraj Robot

Design issues

- Hexapod Configuration
- Leg design
- Interference between legs.

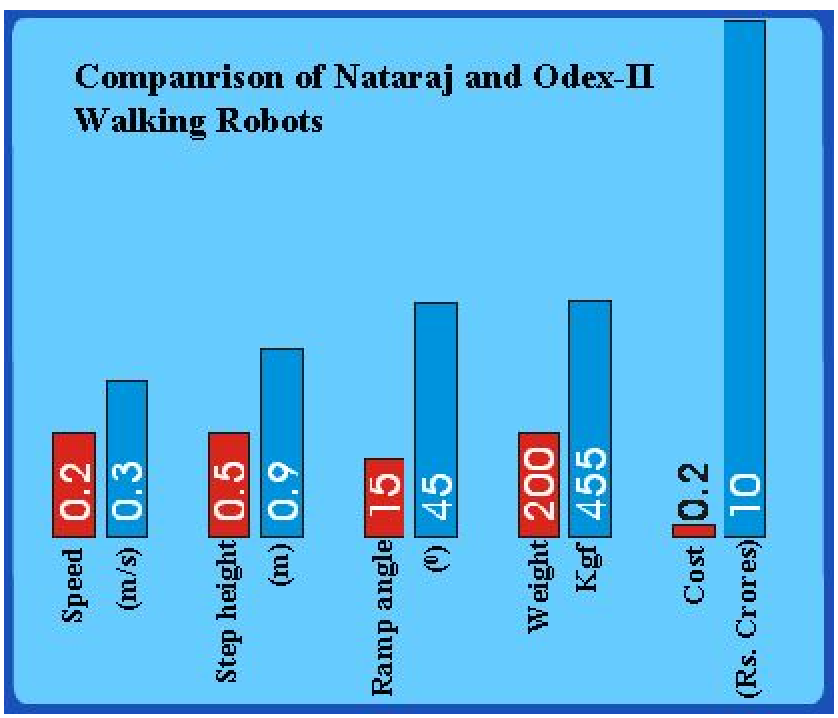


- Multiple gaits
- Stability margins
- Actuation
- Control

Nataraj Development : Specifications

Motivation for developing Nataraj:

- For work in Hazardous unstructured environment (Nuclear power plants)
- Affordable indigenous technology
- Broad specifications for Nataraj:
- Walking speed 0.2 m/s on level ground
- Climb steps of 0.5 m height
- Climb ramps of 15 deg incline
- Weight 200 Kgf with standard payload
- Prototype development in Rs. 2 millions
- In contrast specifications of Odex are:
- Walking speed of 0.3 m/s on level ground,
- Climb steps of 0.9 m height
- Climb ramps of 45 deg incline.



- Weight 455 Kgf with the standard payloads

- Cost US$ 2 millions

Nataraj Development: Hexapod Configuration

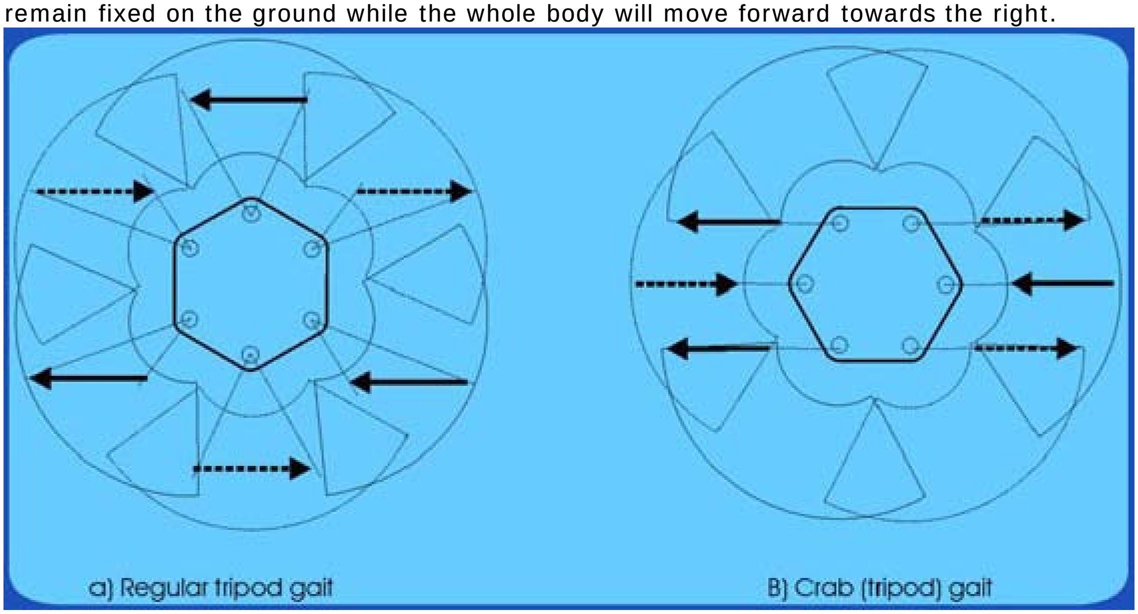
- 3 on a side (cockroach type)

- symmetrically around a circle

Reason: Former has only two equally good directions of locomotion, whereas, the latter has six equally good directions.

Regular and crab tripod gaits

Figure show the typical movement of legs for the two tripod gaits. For the walking machine moving towards the right, the solid arrows represent typical leg movement with respect to the body when these legs are supporting the machine. The dashed arrow, on the other hand, represents movement with respect to the body of the legs in the swing phase. Of course in actual practice, the support feet will remain fixed on the ground while the whole body will move forward towards the right.



Leg Design

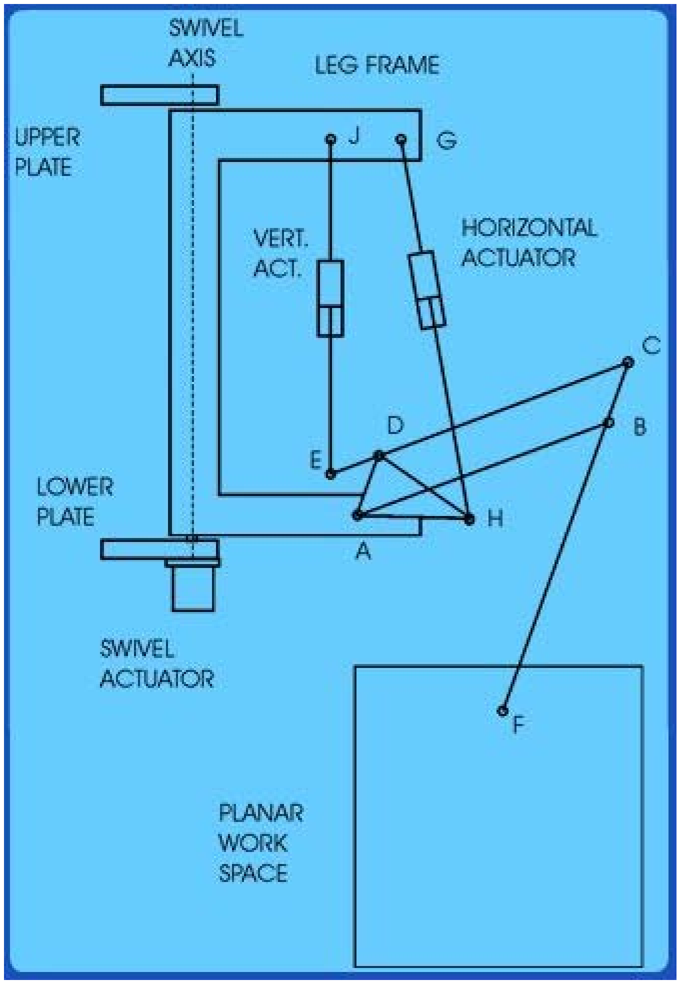
- 3-degrees of freedom legs

- Motion in vertical plane due to two linear actuators and swivel motion of plane due to a rotary actuator

- The pivots A, G and J are on the leg frame that swivels about the swivel axis. ABCD forms a parallelogram five bar with fixed pivots at A. The foot is at point F.

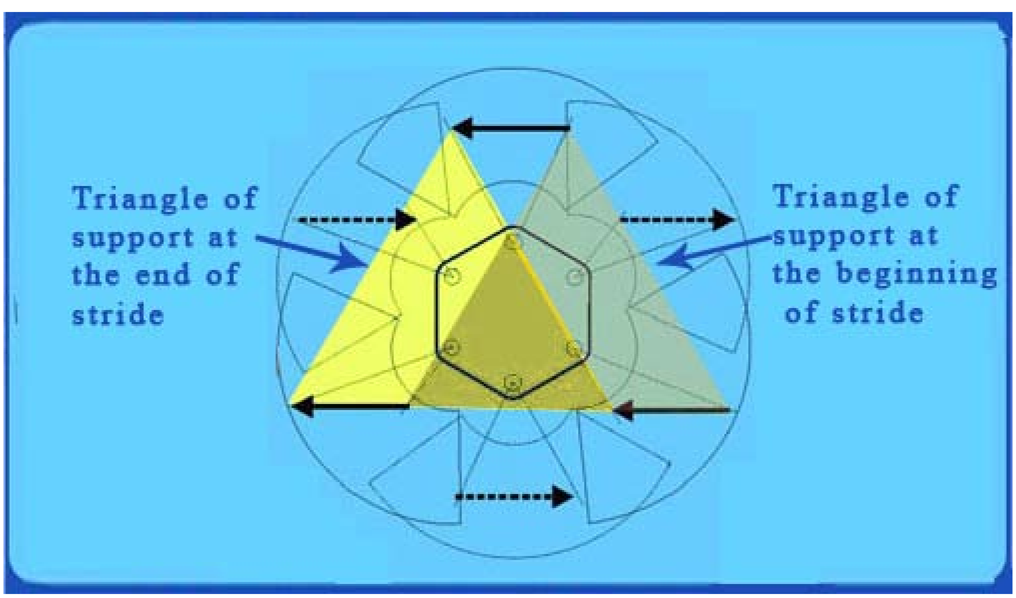
- The workspace of the point F, when swivel is held stationary is defined by the movement of point E. The vertical actuator is designed to remain approximately vertical. With the horizontal actuator held fixed, the foot moves along a line parallel to line EJ with the foot moving in the opposite direction to direction of movement of point E in the ratio 5:1.

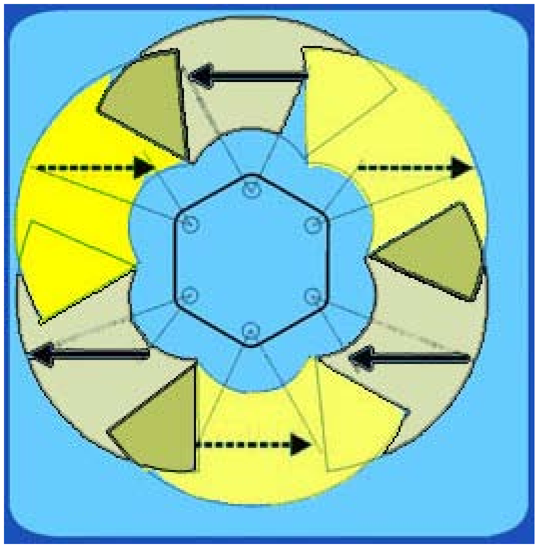
- With the vertical actuator fixed the foot moves along an arc of circle with five times the radius of length of the vertical actuator, i.e., approximate radius of 2m. Therefore, the planar workspace of the foot is approximately rectangular.



Leg workspace and margin of stability

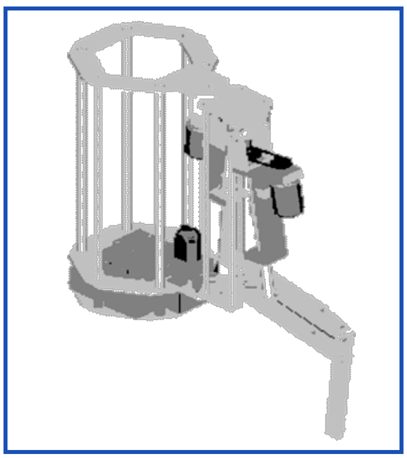
- The regions where possible foothold locations for the six legs could lie are sectored annular regions. These regions are allowed to overlap for the neighbouring legs.
- For tripod gait, The leg stride is limited so as to achieve sufficient stability margin (i.e., measure of how close the CG of the machine comes to the edge of a triangle of support. In the second figure, two triangles of support are shown corresponding to the extreme positions of the support legs. The stability margin is also indicated for the two positions as green and yellow arrows, respectively.

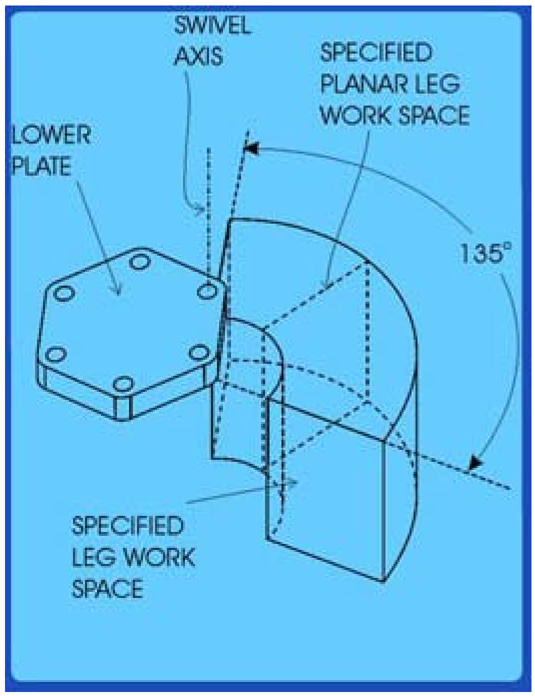




Foot work volume

Work volume of leg tip





Material Selection

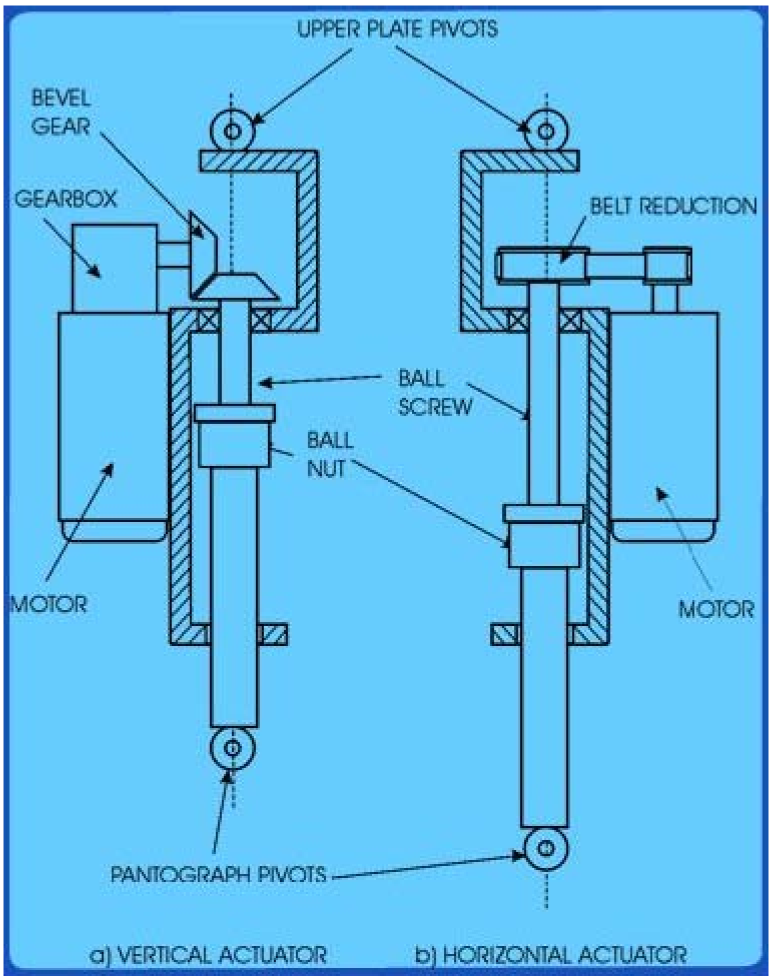
The following materials were considered for leg mechanism of Nataraj. The results of the tests performed are shown in the Table below:

S/N	Material	Density Kg/m 3	Youngs Modulus GPa	UTS MPa
1.	Al alloy (IS 24345)	2700	80	475
2.	Al alloy (IS 63400)	2700	80	200
3.	Titanium (BARC sample)	4500	129	415
4.	Ti alloy (Midhani grade 5)	4500	129	900

Finally the more easily available aluminum alloy (IS 63400) was chosen due to availability in standard sections, unlike titanium alloy, available only in the sheet form.

Leg Actuators

- Actuator operating point changes depending on whether the leg is bearing the weight of the machine or not (i.e., whether the foot is on the ground or in the air).
  - The vertical actuator is required to deliver 8750 N at 0.01 m/sec. and 389 N at 0.04 m/sec.
  - The horizontal actuator is required to deliver 1470 N at 0.05 m/sec. and 62 N at 0.5 m/sec.
  - The performance range demanded is wider than that for the vertical actuator and can be met only by a motor whose field has been weakened for obtaining the higher speed.
  - The swivel actuator is required to deliver 13 Nm at 8 rad/sec.



Leg Actuators Motor Selection

- Both the Horizontal and Vertical actuators make use of ball screws with a pitch of 10 mm and 31 mm nominal diameter.
- The stroke of actuator is 115 mm. The motor is of Rallis make (Model SPM 13, AC/DC motor) with an output of 350 Watts and speed ranging from 2000 to 15000 rpm. The horizontal actuator is also ball-

screw driven by a motor through a gear reduction of 5.3

- The swivel motion is obtained from a Rallis motor (Model SPM 24, AC/DC motor) with an output power of 180 Watts and speed ranging from 1520 to 2800 rpm. The motor drives the output through a 41:1 gear reducer.

- Implementation and Trials

- The final weight of the walking machine is more than to 250 kg instead of the original estimate of 150 kg. This was due to the fact that the actual vertical and horizontal actuators weighed one and a half times the original estimate. This led to a substantial increase in the overall weight of the machine and the forces on the leg bearings. Consequently several parts, like the leg bearing housings, had to be redesigned for greater strength and resulted in further increase in weight.
- The walking machine was run using both external power supply with umbilical cord and on-board batteries. The Robot was moved at one-third the rated speed using crab gait.

Recap

In this course you have learnt the following

- Mobile Robots
- Legged Robots
- Nataraj Robot
- Nataraj Development : Specifications
- Nataraj Development: Hexapod Configuration
- Leg Design
- Leg workspace and margin of stability
- Foot work volume
- Leg Actuators
- Material Selection
- Leg Actuators Motor Selection
- Implementation and Trials

Congratulations, you have finished Lecture 40. To view the next lecture select it from the left hand side menu of the page