Configuration of a robot controller

Introduction

- The controller is the part of a robot that coordinates all movements of the mechanical system.
- It also recieves input from the immediate environment through various sensors.
- The heart of the robot's controller is generally a microprocessor linked to input/output and monitoring devices.

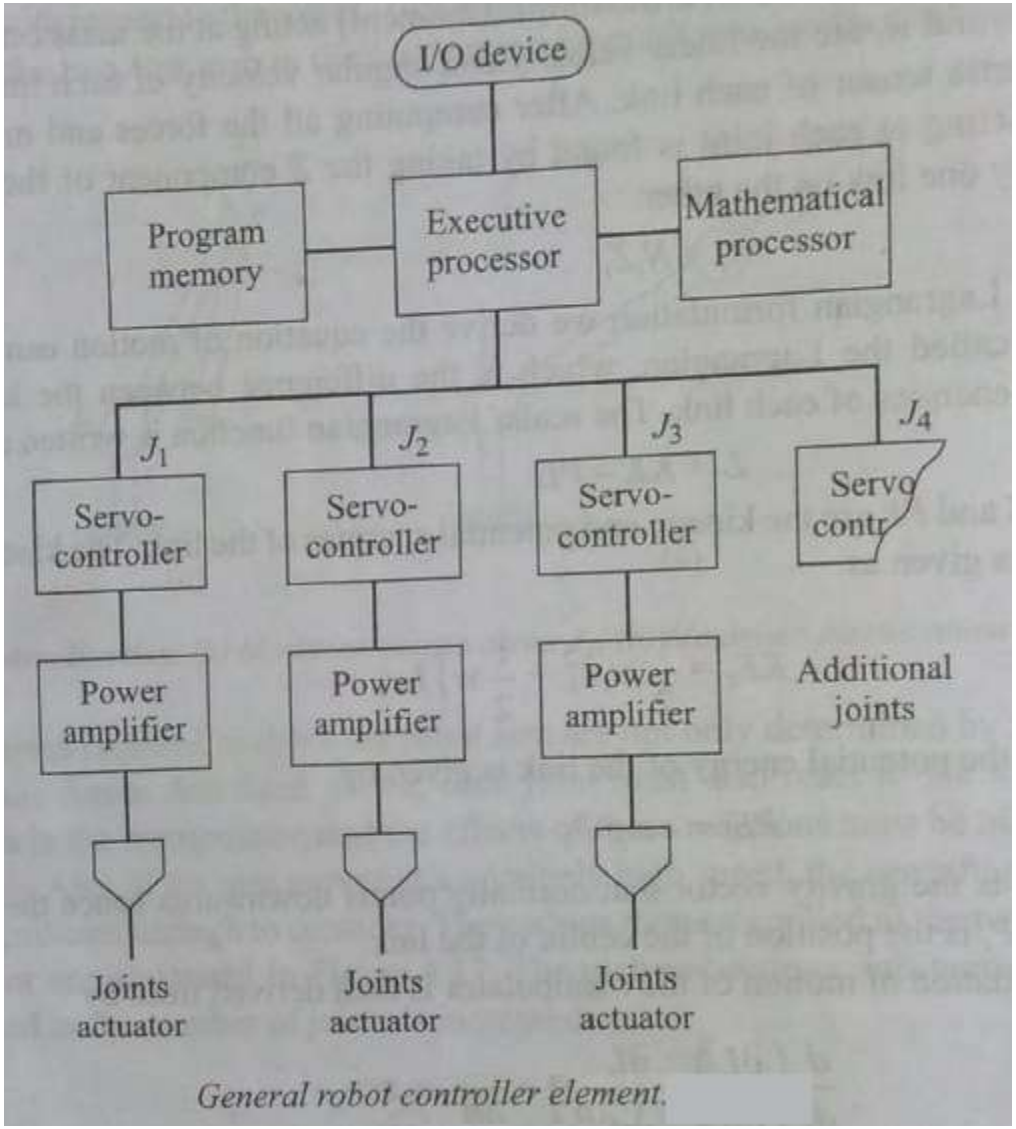
Introduction

- The commands issued by the controller activate the motion control mechanism consisting of various controllers, amplifiers and actuators.

Configuration of a Robot Controller

- The elements needed in the controller include: joint servocontrollers, joint power amplifiers, mathematical processor, program memory, and input device..

Elements for Robot Configuration



General robot controller element.

Locomotion

- Many different kinds of effectors and actuators are used for locomotion:
  - legs (walking, crawling, climbing, jumping, hopping…)
  - wheels (rolling)
  - arms (swinging, crawling, climbing…)
  - flippers (swimming)

Locomotion

It includes:

- Walking
- Running
- Jumping
- Sliding
- Crawling
- Swimming
- Climbing

Stability

- "**Stability** means an equilibrium which can be measured and observed". Stability is especially important in legged robots. There are two kinds of stability – Static and Dynamic

Stability

- *Stability is a necessary property of mobile robots*
- Stability can be
  - static (standing w/o falling over)
  - dynamic (moving w/o falling over)
- Static stability is achieved through the mechanical design of the robot
- Dynamic stability is achieved through control

Static stability

- A statically stable robot is well balanced and does not fall over when standing. This means that the center of gravity of a robot is within its ground contact base. Let us take an example of a robot with three legs arranged in the form of a triangle. This robot does not require any kind of movement to stand stable and can stand balanced as long as the center of mass is within the triangle. This triangle is called the **"support polygon"** which is a horizontal region over which the center of mass lies to achieve static stability.
- The minimum number of ground contact points required for a statically stable robot is three.
- However, achieving static stability with two legs or two wheels is not an easy task. Humans although may seem, are not statically stable. Our muscles and nerves control our balance and make it seem an effortless stability. This is the same reason why a baby takes a year or two to learn how to stand.

Dynamic Stability

- Dynamic stability is where stability is achieved on movement. Imagine a robot with only one leg which hops from one place to another and is stable unless it keeps moving, but falls over if it stops moving.
- Although dynamically stable robots are harder to control, they are more energy efficient and move faster than statically stable robots.
- Let us take an example of a robot with 4 legs – Tetrapod. Since there are 4 contact points to ground, the robot is stable while standing.
- On movement, the robot can lift one leg at a time and move forward which makes it a slow walking robot. Now imagine if it can move by lifting two legs at a time and hop from one place to another. Since there are only two contact points to ground, the robot is dynamically stable while moving and also energy efficient.

Legs

- A small percentage of amateur robots are designed with legs, and such robots can be conversation pieces all of their own.
- Many difficulties must be overcome in designing and constructing a legged robot.
- First, there is the question of the number of legs, and how the legs provide stability when the robot is in motion.
- Legged robots are a challenge to design and build, but they provide an extra level of mobility that wheeled robots cannot. Wheel-based robots may have a difficult time navigating through rough terrain, but a properly designed leg-based robot can easily walk right over small ditches and obstacles.

Moving and Gaits

A *gait* is the particular way a robot (or a legged animal) moves, including the order in which it lifts and lowers its legs and places its feet on the ground.

Desirable robot gaits have the following properties:

- Stability: the robot does not fall over
- Speed: the robot can move quickly
- Energy efficiency: the robot does not use a great deal of energy to move
- Robustness: the gait can recover from some types of failures
- Simplicity: the controller for generating the gait is not unwieldy.

Moving Gaits: Four Legged robot

- Walking with four legs is common for most animals and there is a good reason to replicate this in robots.
- Four legged robots are statically stable.
- The walking pattern of a four legged robot can be designed in different ways:
  - One leg at a time: At any point there are three contact points to surface and the robot maintains static stability while standing or moving. Moving one leg at a time makes your robot slower and expensive on the resources, but keeps it stable.
  - Alternating Pair: In this approach, alternate legs are moved as if two biped robots are connected together. At any time the robot has two surface contact points creating a dynamically stable robot. Faster and efficient, but less stable compared to the first approach.

Moving Gaits: 6 legged robot

- More number of legs provides greater stability.
- Hexapods (robots with 6 legs) possess greater static stability while moving and while standing.
- These robots are also biologically inspired as there are many insects with 6 legs. If you have observed carefully, most 6 legged robots mimic spiders.
- Hexapods can either mimic Wave gait (wave pattern) or follow Tripod gait.

Moving Gaits: Wave gait

- In this approach, front two legs are moved first followed by the middle two legs, and then the last two legs.
- Once all the three pairs of legs are moved, the body is moved forward to complete one movement.
- At any point of time, there are four legs touching the ground (or surface).

Moving Gaits: Tripod gait

- At any point of time there are three legs touching the ground.
- Alternate legs move forward on either side; i.e. the front and rear leg on one side and the middle leg on the other side are moved first.
- Next the remaining three legs are moved.
- Body is moved forward and the entire process requires only three steps and is clearly much faster than wave gait.
- However, tripod gait requires more leg coordination increasing complexity.

Wheels

- Wheels are the most popular method of providing robot mobility. Robot wheels can be just about any size, dictated only by the dimensions of the robot and your outlandish imagination.
- Robots can have just about any number of wheels, although two is the most common.

Wheels

- Wheels can make your robot move faster, are easier to design and build.
- Legged robots on the other hand are excellent on uneven surfaces and rough terrain.
- Robots with wheels are usually designed to be statically stable, which simplifies control.
- Having multiple wheels means there are multiple ways in which those wheels can be controlled.
- Basically, multiple wheels can move either together or independently

Wheels

- The ability to drive wheels separately and independently, through the use of separate motors, is called a differential drive.
- . If the two wheels are driven at the same speed, the robot moves in a straight line.
- If one wheel (say the left) is driven faster than the other, the robot turns (in this case to the right).
- Finally, if the wheels are driven in the opposite directions of each other but at the same speed, the robot turns in place

Wheels

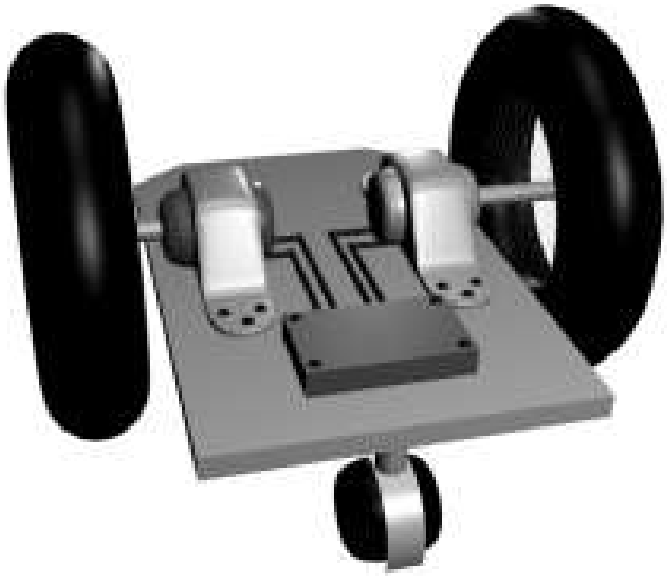


Figure 5.4 A popular drive mechanism for simple robots, consisting of two differentially steerable driven wheels and a passive caster for balance.