SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

RIAS Robotics & Intelligent Autonomous Systems

Introduction to Mobile Robotics

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What exactly is a robot?

Wikipedia:

A robot is a mechanical intelligent agent which can perform tasks on its own, or with guidance. In practice, a robot is usually an electro-mechanical machine which is guided by computer and electronic programming.

Consensus?

Wikipedia:

There is no consensus on which machines qualify as robots but there is general agreement among experts, and the public, that robots tend to do some or all of the following: move around, operate a mechanical limb, sense and manipulate their environment, and exhibit intelligent behavior especially behavior which mimics humans or other animals.

Definition?

According to the Encyclopaedia Britannica a robot is "any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a humanlike manner".

Note this may include washing machines and CNC mills.

Earliest Reference

In ancient China, a curious account on automata is found in the Lie Zi text, written in the 3rd century BC. Within it there is a description of a much earlier encounter between King Mu of Zhou (1023-957 BC) and a mechanical engineer known as Yan Shi, an 'artificer'. The latter proudly presented the king with a life-size, human-shaped figure of his mechanical handiwork.

Thousand years later ...

The Cosmic Engine, a 10-metre (33 ft) clock tower built by Su Song in Kaifeng, China in 1088, featured mechanical mannequins that chimed the hours, ringing gongs or bells among other devices.[6][7] Al-Jazari (11361206), an Arab Muslim inventor during the Artuqid dynasty, designed and constructed a number of automatic machines, including kitchen appliances, musical automata powered by water, and the first programmable humanoid robot in 1206. Al-Jazari's robot was a boat with four automatic musicians that floated on a lake to entertain guests at royal drinking parties. His mechanism had a programmable drum machine with pegs (cams) that bump into little levers that operate the percussion. The drummer could be made to play different rhythms and different drum patterns by moving the pegs to different locations.[8]

Robotics

- Course in mobile robotics fundamentals
- Robotics combines mechanical, electrical and software systems.
- Goal: Develop background in and survey the subject of mobile autonomous robotics

Topics

- Mathematics
- Mechanics
- Electronics
- Embedded Systems
- Sensors
- Control
- Localization and Navigation

Autonomy

- Where am I?
- Where am I going?
- How do I get there?

- Have a model of the environment
- Perceive and analyze the environment
- Find its position within the environment
- Plan and execute the movement

Contrasts

- Classical robotics (robotic manufacturing)
  - Fixed environment
  - Predetermined tasks
  - Fixed interactions
- Mobile machines (teleoperated)
  - Changing environment
  - Adapting tasks
  - Novel interactions

Components

- Manipulator
- End Effector
- Actuator
- Sensor
- Controller
- Processor
- Software

Attributes

- Degrees of Freedom
  - 3 for a point
  - 6 to add orientation
  - more than 6 is redundant
  - human arm: shoulder, elbow and wrist
- Joints
  - linear
  - rotary
- Coordinates
  - Cartesian
  - Cylindrical
  - Spherical
  - articulated (human arm)

Reference Frames

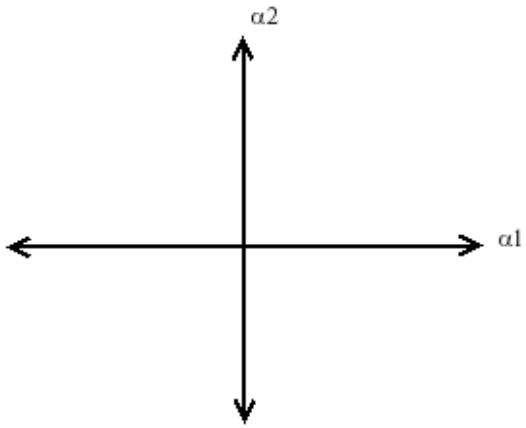
- World Reference
- Joint Reference
- Tool Reference
- Global
- Local

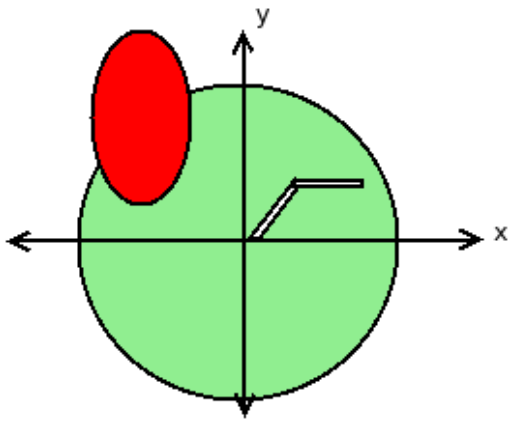
Workspace; physical and configuration

Configuration

- Configuration space - all possible configurations
- Workspace
- Workspace obstacles
- Workspace paths
- Mapping obstacles into configuration space
- Path planning

Configuration





Application Domains

- Manufacturing (welding, painting, inspection, loading, placement)
- Medical
- Hazardous environments (space, underwater, chemical/nuclear, military)

Simulation

- What are we doing?
- Why are we simulating?
- How are we doing this?

Simulation

Russel Smith's take:

- Simulations are quicker to build than robots.
  But realistic simulations are hard to build: need to model actuators (electrical motor dynamics, hydraulics / pneumatics, gear boxes, friction, stiction, flexion and slip), sensors, robot geometry and mass distribution, joint geometries, flexible bodies (vibration effects).
- Simulations let you cheat.
  Easy to make controllers that exploit quirks of the simulated world, that dont work so well in real life.
- Simulated robots do not break.
  The cost of experimentation may be lower.
- The best tradeoff:
  Prototype robot control algorithms on a good-enough simulation, then move to the real hardware.

Simulation

- API primitives: rigid or flexible bodies, joints, contact with friction, collision detection, etc...
- Many techniques, many libraries, lots of research.
- Applications:
  - Game engines
  - Animation software
  - Industrial Design
  - Robotics
- Research tool.

Simulation

1. Equations of Motion
   Lagrangian formulations
2. Integration
   Numerical quadrature
3. Contact and Friction
   Constraints
4. Optimization
   To address constrained optimization problem
5. Collision
   Collision detection required