RoboJackets

FIRST - IGVC - BATTLEBOTS - ROBOCUP

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Rockwell Automation

Georgia Tech College of Computing

Advanced Robotics I
Sept. 9th,2008

Phillip Marks with some pieces from Dr. Dellaert

Outline I

- A Brief History of Robotics
- Robot Architecture
- Locomotion
- Kinematics
- Sensing and Perception
  - Encoders
  - Tactile
  - Accelerometers and Gyros
  - GPS
  - Cameras
  - Sonar/Lidar

Outline II

- Robot Control
  - Reactive
  - Sense – Plan – Act
  - Motor Schema
  - Hierarchical Control
  - Behavior Based
  - Probabilistic
- AI and Planning
  - Path Planning
  - Machine Learning

What is a robot?

- Can make decisions about its environment
- Can change its environment relative to itself
- It moves without human interaction
- Mental vs. Physical Agency

History of Robotics: The Greeks

- First to think about automata
- Hephaestus' servants
- Ctesibes' Automatons
- Heron of Alexandria, **Pneumatica and Automata**

History of Robotics: The Middle Ages

- Al-Jazari's various automata
  - Drink serving waitress
  - Peacock fountain with automated servants
  - Wrote an extensive book on the subject

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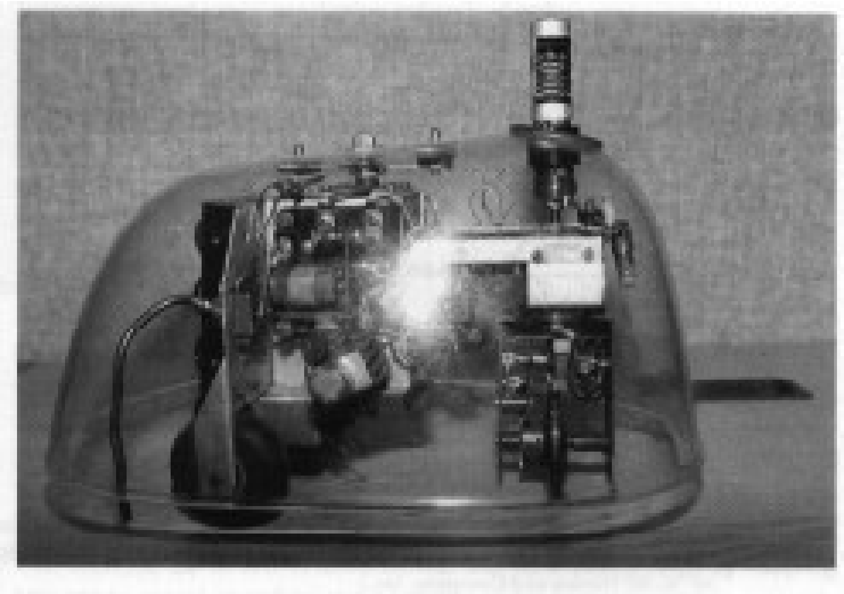
History of Robotics: The Renaissance

- Da Vinci's mechanical suit of amour
  - Could sit up, wave, move its head
- Jaquet-Droz 3 Automata 1773
  - Two small boys that could write or draw
  - A lady who could play piano
  - All used sophisticated cam and gear mechanisms

History of Robotics: Post-War

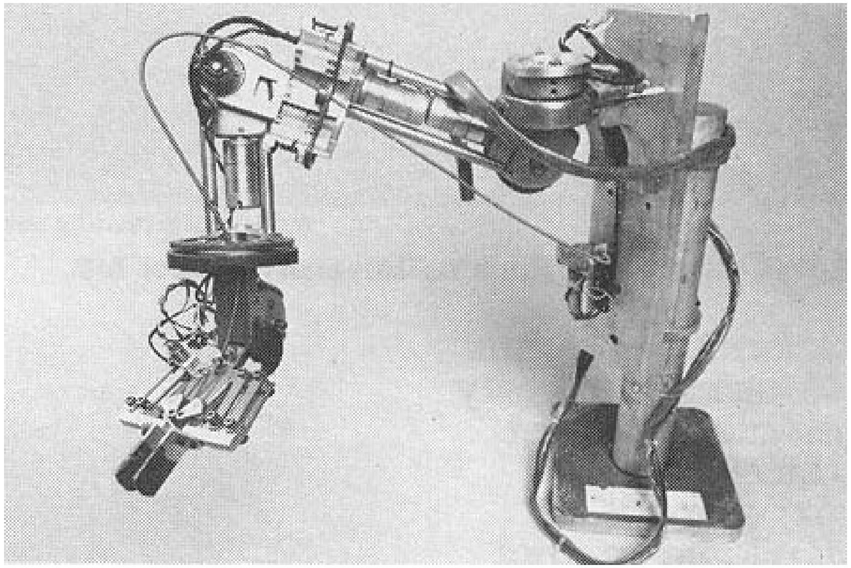
- Electronics make it possible to build autonomous robots
- Before all robots really automatons
- Issac Asimov publishes “I, Robot” in 1950
- He also formulates the “Three Laws”
- Birth of the field of AI at Dartmouth

Elmer, and Elsie, 1948



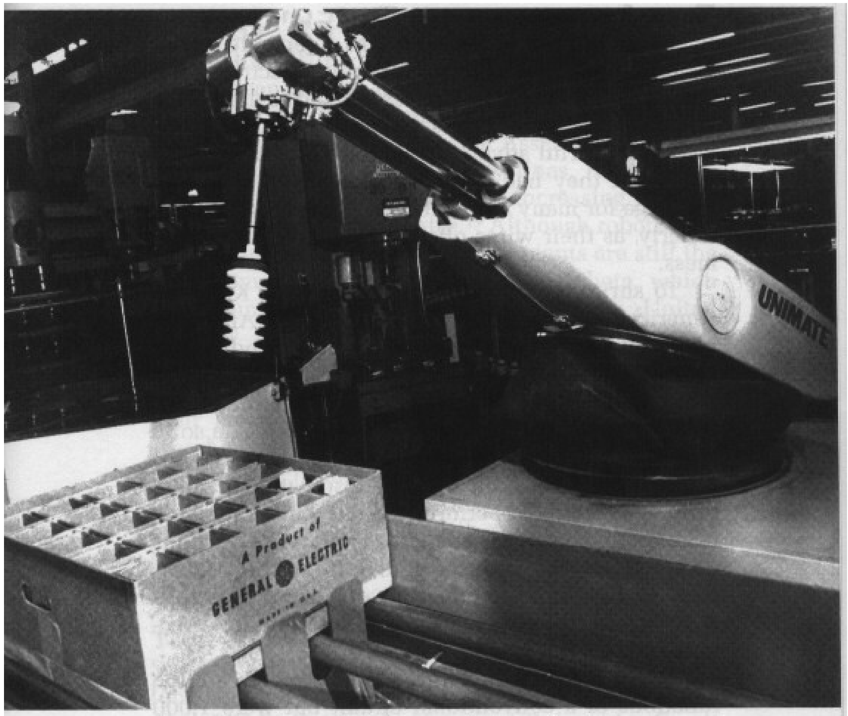
- One of the first, truly mobile and autonomous robots
- Simple, analog circuits
- Phototaxis behavior
- Reactive control
- Most basic mobile robots
- Built by William Grey Walter in 1948

History of Robotics: Age of Automation



- The first robots were mainly industrial
- As such research robotics focused on the problem
- Various arms are studied along with how to actuate them
- Focus on specific problems

Unimation UNIMATE

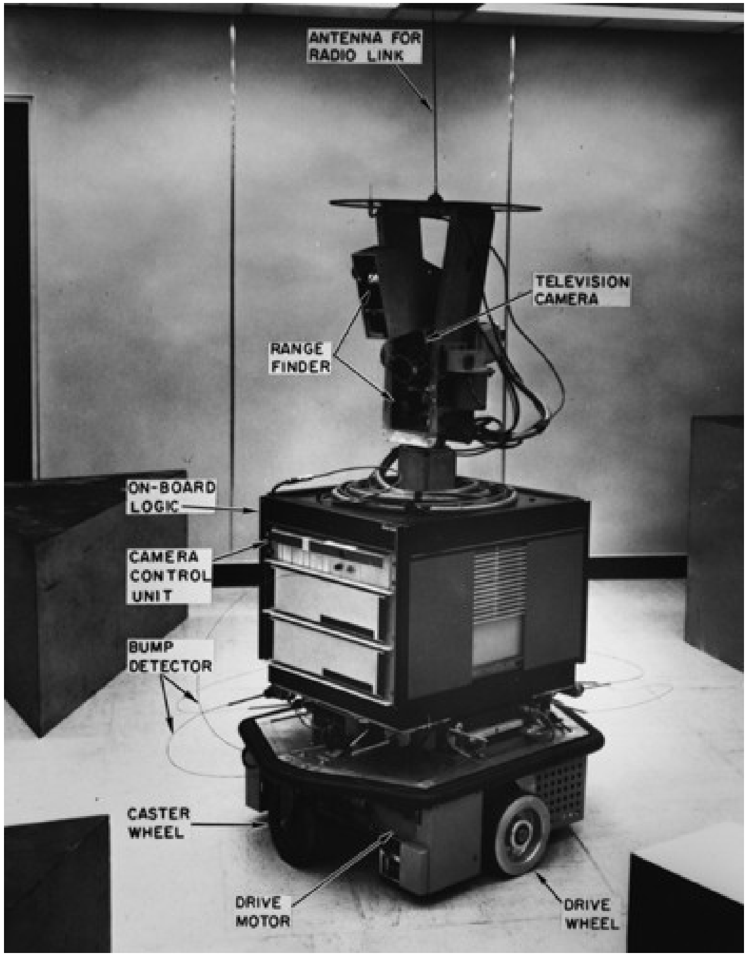


Armed for duty. A Unimate robot—really, just an arm—picks up and puts down parts in a General Electric factory.

- First industrial, programablel robot
- 6 DOF
- Started work for GM in NJ in 1961
- Unimation would later go on to build the PUMA

Shakey 1966-1972

- SRI robot used for AI research
- Got its name from its jerky movements
- Had a tv camera, rangefinder, and bump sensors
- Could create and execute plans, and rearrange its environment
- Could also perceive the world
- Failed to achieve its lofty goals

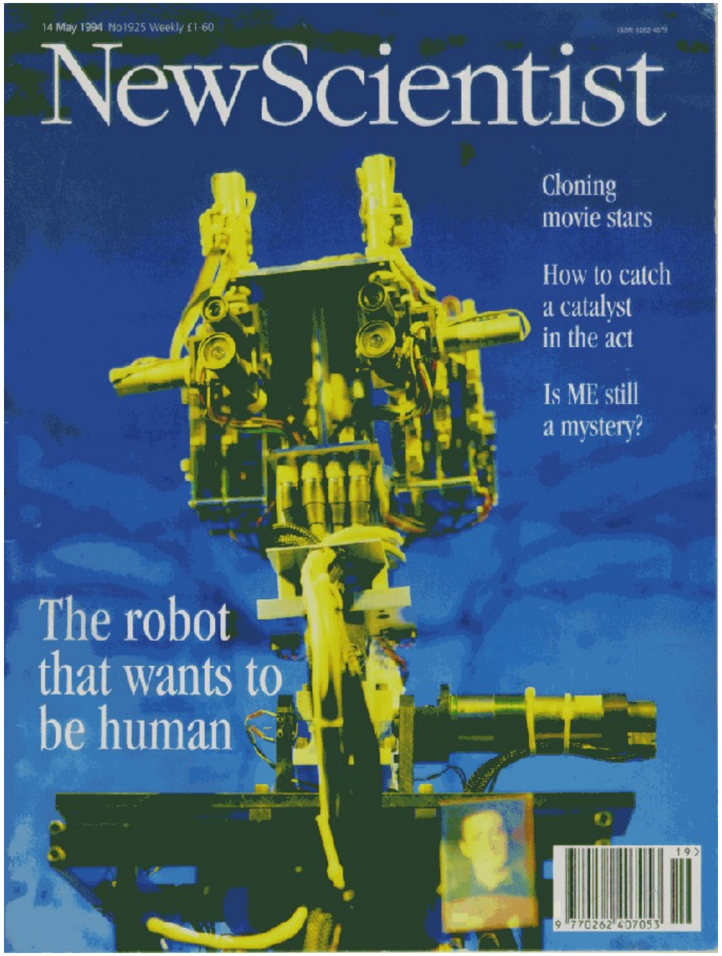


History of Robotics: Personal Robot Craze

- Computers start to become affordable
- Some companies attempt to capitalize by making robots
- Most fail
  - Either robot is not capable enough
  - Too expensive
  - Or both

Cog

- Long-term project to create an intelligent robot
- Started by the original “bad-boy” of robotics, Rodney Brooks
- Project focused on social interaction as a means of learning



History of Robotics: The Modern Era

- Realization that personal servants not around the corner
- Focus on using robots to solve specific problems
- Exponential leap in hardware
- Truly useful consumer robots

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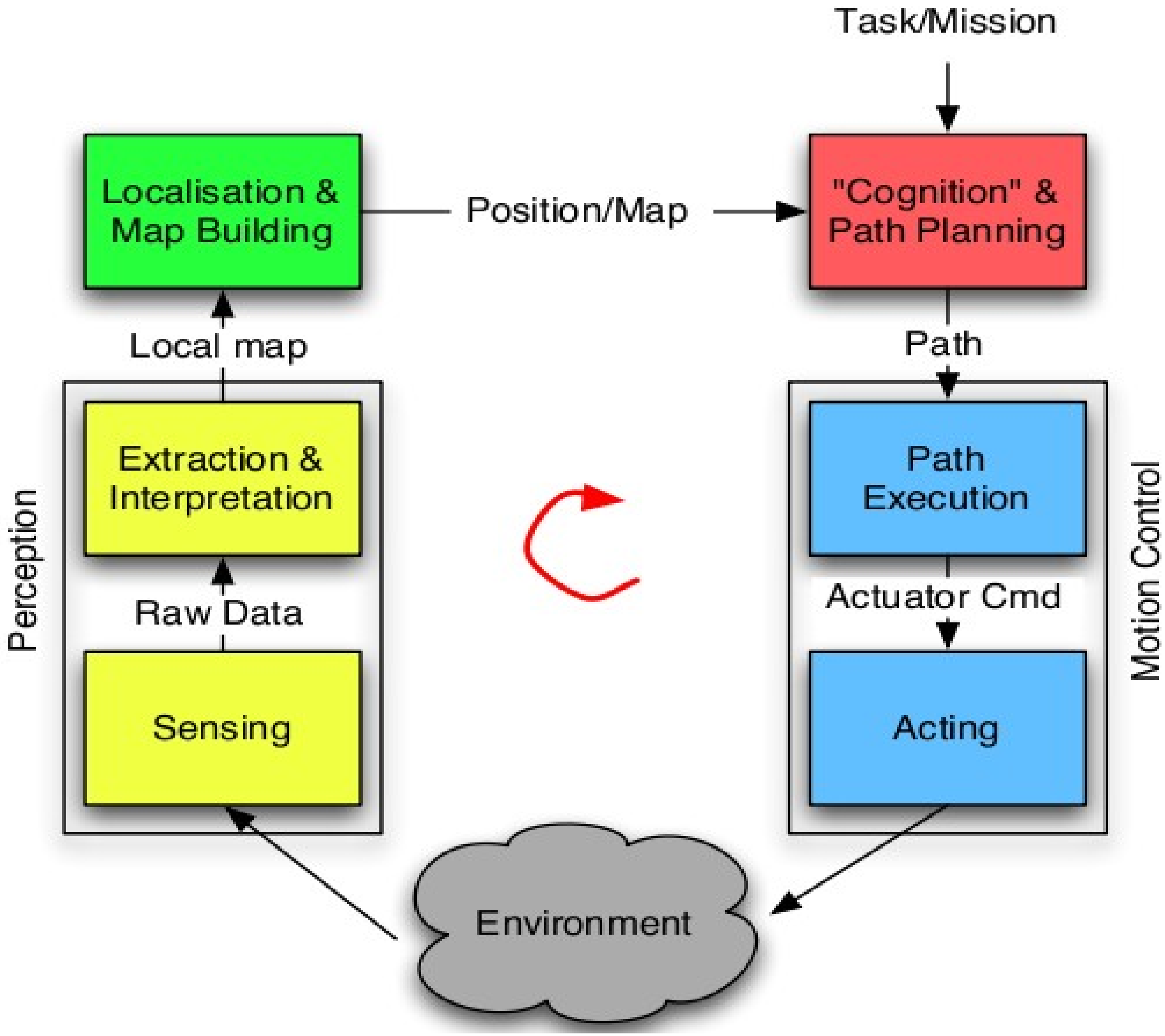
Robot Architecture

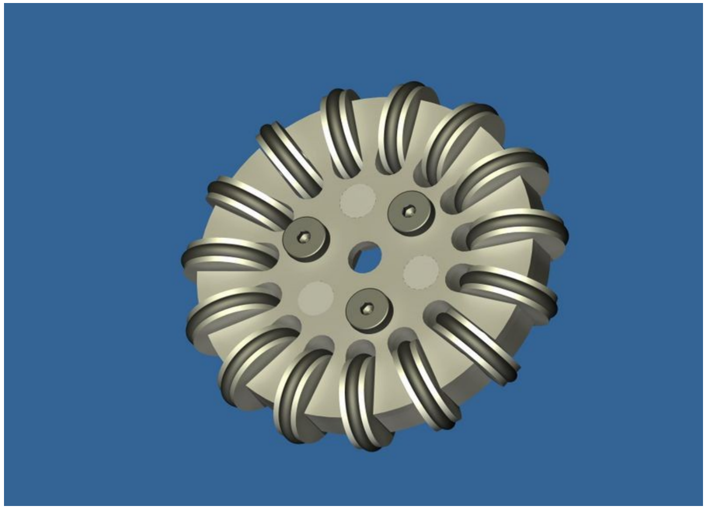
- A robot can be thought of as a mapping between sensors and actuators
- Sensors collect data about the world and store it as a representation
- Some intelligence uses the sensor data to control actuators to achieve some goal
- Actuators carry out commands
- The intelligence must make decisions and not use pre-calculated results in order to be a robot


Task/Mission
Localisation &
Map Building
Position/Map
"Cognition" &
Path Planning
Local map
Path
Perception
Extraction &
Interpretation
Path
Execution
Motion Control
Raw Data
Actuator Cmd
Sensing
Acting
Environment

Locomotion I

- Varied means of motion
- Tank, Crawler, Omni, Aerial,..
- Means of locomotion affects motion control algorithm and robot architecture
- Holonomic/Non-Holonomic
- Energy Constraints
- DoF/Stability/Design Constraints
- Robustness in certain terrain

Locomotion II
Omni



- Holonomic, so robot can be modeled as points
- Control can approximate motion as a single 2D vector
- Individual wheel speeds can be determined using dot product
- Drawbacks
  - Can be hard to control
  - Max speed only when rotating
  - Omni wheels not robust

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Locomotion III
Rescue Crawler

- Goal six legged crawler
- Currently two
- Legs can be controlled by haptic interface or autonomous
- Multiple gait generation strategies
- Uses fluid power

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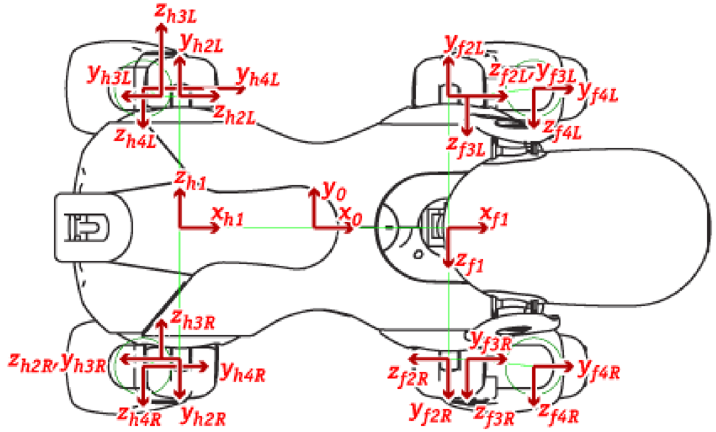
Kinematics I

- Study of motion
- As applied to a robotics it is the model of how the robot moves
- We look at robot's model for acceleration, velocity, and position over time
- We will restrict ourselves to 2D
- Generally mapping from point to point
- Two basic operations: translation and rotation
- Can be represented as matrix operations

Kinematics II

- All motion is relative!
- Reference frames are coordinate frames affixed to some real-world point.
  - Example: Five Points
- Generally all motion in inertial reference frame
- Each DoF of robot defines a reference frame
- Going from one reference frame is just a rotation and translation
- This applies to velocity, acceleration, as well as position



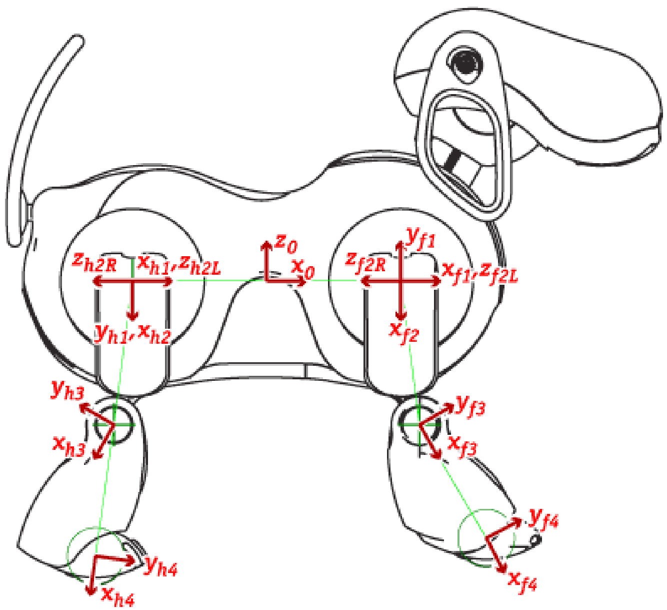
ERS-7 Legs

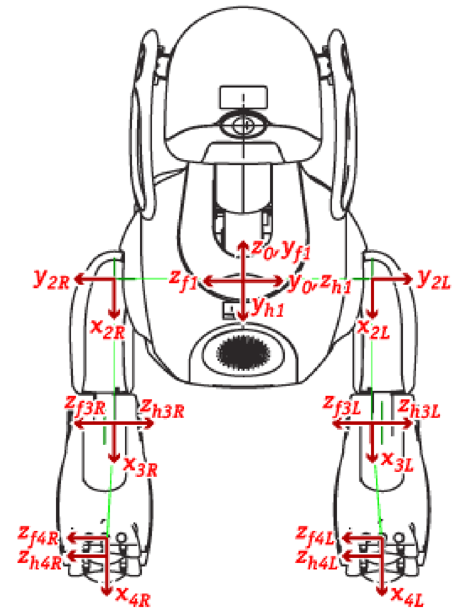
	Δx	Δy	Δz
1. - shoulder	65	0	0
2. - elevator	0	0	62.5
3. - knee	69.5	0	9
f4. - ball	*69.987*	*-4.993*	4.7
h4. - ball	*67.681*	*-18.503*	4.7

Diameter of ball of foot is *23.433*mm

Each link offset is relative to previous link

The shins shown in this diagram appear to be slightly distorted compared to a real robot. Corresponding measurements have been taken from actual models.





Kinematics IV

- Kinematics help us determine how to move our robot
- Also contain constraints that restrict motion (Diff robot can't strafe)
- We can use kinematics to predict how robot responds to inputs (Fwd Kinematics)
- Or we can derive set of inputs needed to reach a point (Inverse Kinematics)
- Unfortunately no kinematic model is perfect
- Controls help this issue

Kinematics III: Differential Drive Model

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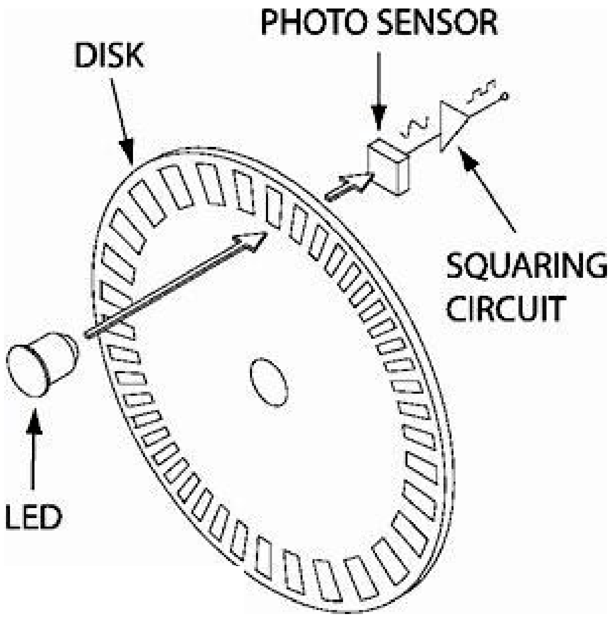
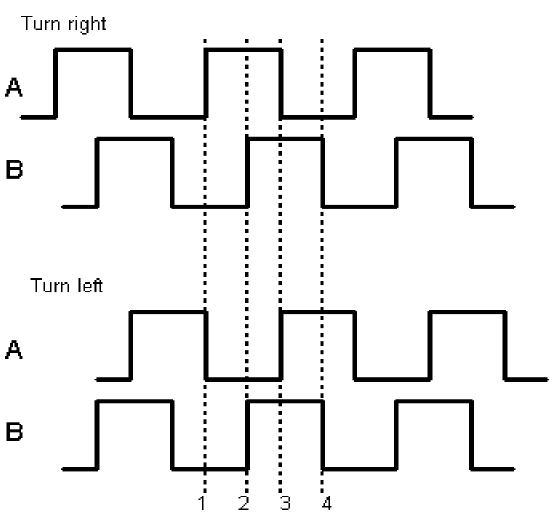
Sensing and Perception: Encoder

- Measures rotational speed and/or position
- Two types: absolute and relative
- Generally output quadrature signal
- Can be used to report how far a wheeled robot has moved or speed





Sensing and Perception: Tactile

- Everything from basic switch behavior to pressure and strain
- Robot bumper
- Limit switch on arm
- Strain gauges on contact surfaces

Sensing and Perception: GPS/Magneto

- Several flavors of GPS
  - Regular
  - DGPS
  - Corrected GPS
- GPS is relatively accurate, depends on # satellites
- Magneto works best outdoors
- Any magnetic field disturbances must be stationary

Sensing and Perception: Accelerometers/Gyros

- Used to determine pose
- Accelerometers allow us to recover the change in velocity of the robot
- Gyros give the rate of angular motion
- Accelerometers can be configured to behave like gyros
- Current devices use MEMs technology

Sensing and Perception: Cameras

- Can give us rich information about the world
- Can also introduce noise and require significant processing
- Examples:
  - Stereo
  - Pose Estimation
  - Finding obstacles

Sensing and Perception: Sonar/LiDAR

- Range finding
- Can also help determine object features
- Pulses of sound or light sent and reflections measured
- Information not as rich as cameras but also easier to process
- LiDAR is best but very expensive

Robot Control: Overview

- Highest level of control makes decisions using sensors and then sends commands to actuators
- Inside this level of control can be other levels of control
- Robot control is a problem of proper abstraction of the problem
- Goal is to build complex behavior using simpler behavior
- Emphasis on modularity

Robot Control: Reactive

- The original
- React to events

Robot Control:
Bug Algorithm

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