CSCI/ECEN 3302
Introduction to Robotics

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Administrivia

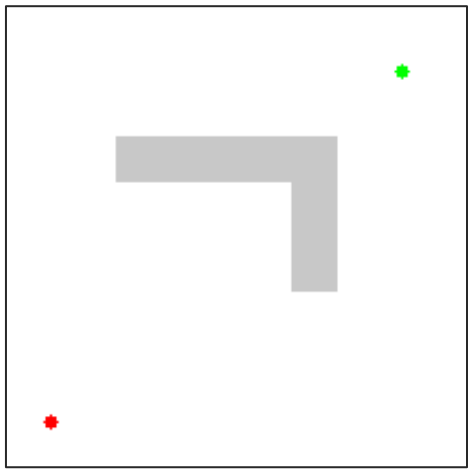
- Lab 3 scores will be released today
- Deadlines:
  - HW2 – tonight at 23.59!
  - Lab 5 – Friday 3/18 at 23.59!
    - Tomorrow is the last day we will work on it
- Spring Break will be a break
  - I will probably send some reading recommendations..

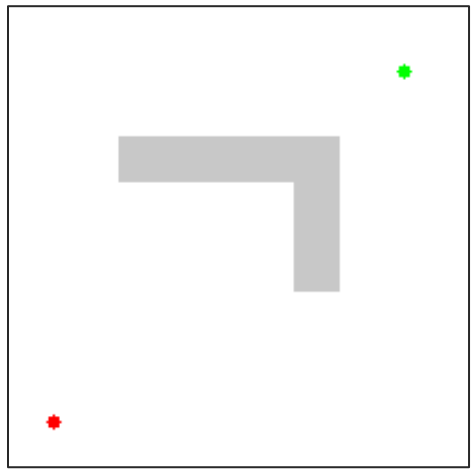
Future Outlook

- Mid-semester review up tonight and open for two weeks
  - Entirely ANONYMOUS
  - If 90% of the enrolled students fill it out, everyone in the class will be awarded an extra 10 points to their final cumulative homework score!!!
- Maja Mataric AMA – April 26th – Last day of lectures!
- Kinova Robotics – Guest lecture – April 19th – 30m
  - I may have another guest lecturer from industry on that day
- Robotics AMA – April 12th
- After Spring Break
  - We will start delving deeper in final project work!
  - Expect 1 or 2 homeworks

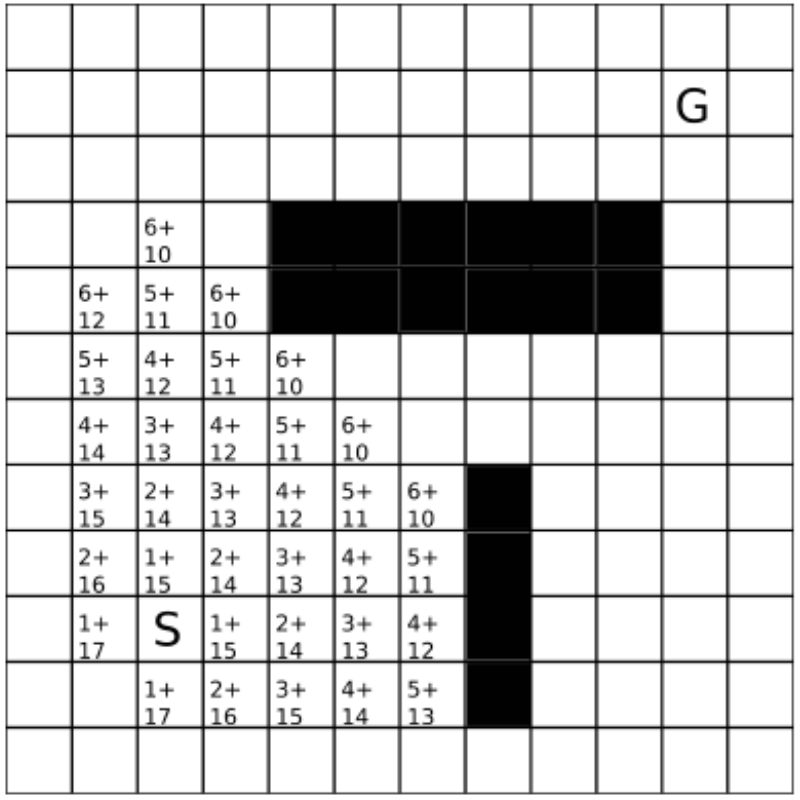
Chapter 13

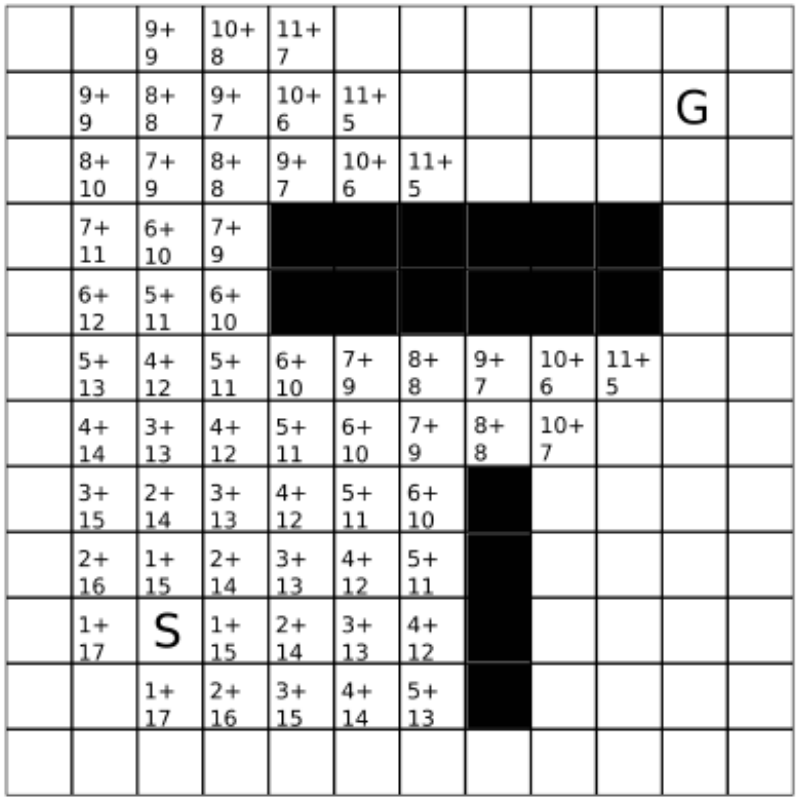
RECAP
Search Algorithms

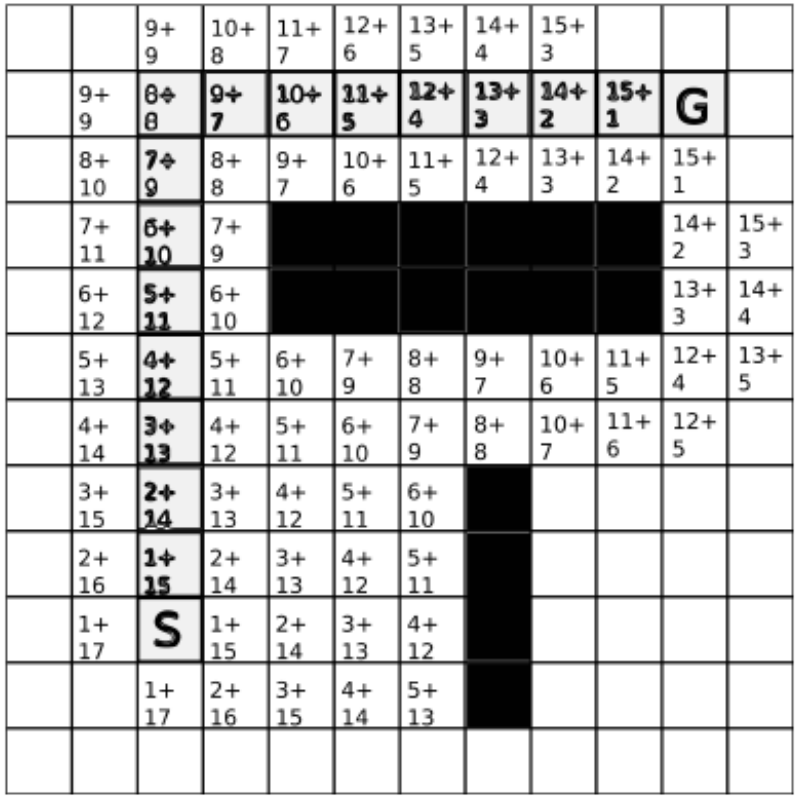




Dijkstra plus directional heuristic: A*







Take-home lessons

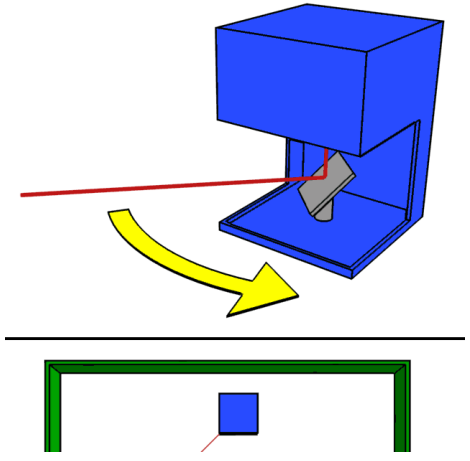
- First step in addressing a planning problem is choosing a suitable map representation
- Reduce robot to a point-mass by inflating obstacles
- Grid-based algorithms are complete, sampling-based ones probabilistically complete, but usually faster
- Most real planning problems require combination of multiple algorithms

Wrap-up

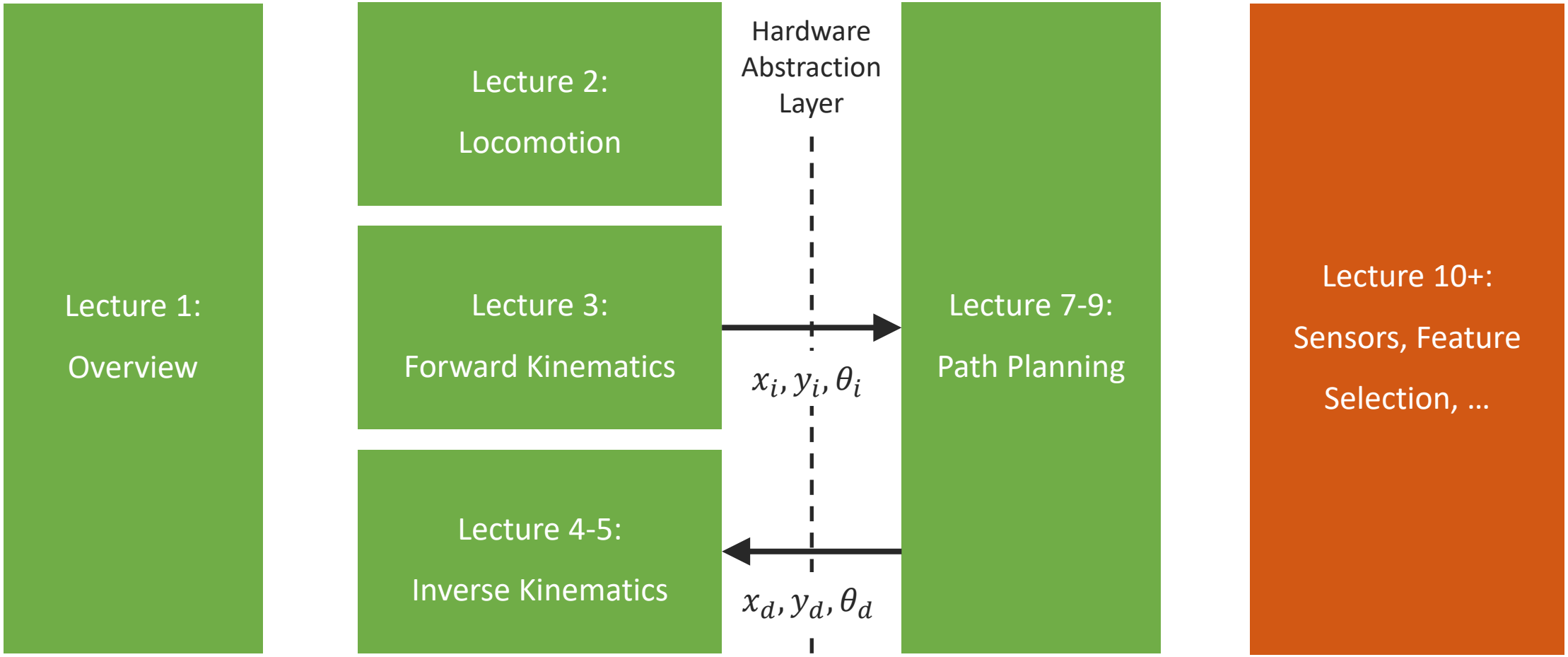
	Completeness	Computational Complexity
Exact Cell Decomposition	Complete	Exponential time
Potential Fields	Not complete	Polynomial time
Discretization and A* search	Resolution complete	Exponential time
Probabilistic RoadMap (PRM)	Probabilistically complete	Hard to characterize!

Chapter 4

RECAP
Sensors

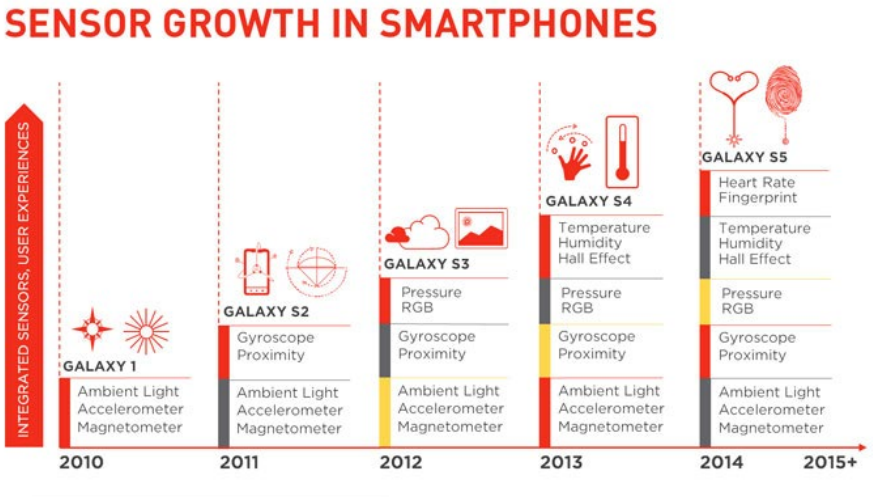


Roadmap


Lecture 1:
Overview
Lecture 2:
Locomotion
Lecture 3:
Forward Kinematics
Lecture 4-5:
Inverse Kinematics
Hardware
Abstraction
Layer
x_i, y_i, θ_i
x_d, y_d, θ_d
Lecture 7-9:
Path Planning
Lecture 10+:
Sensors, Feature
Selection, …

Sample of everyday sensors

Camera



US (ultrasonic)

3D

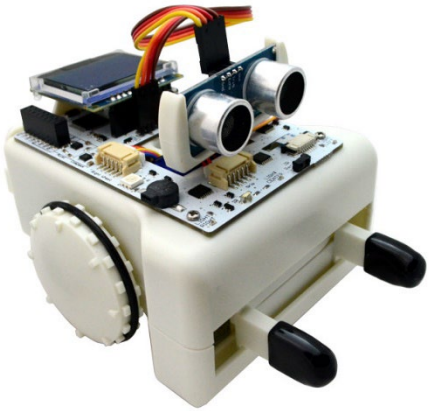
PIR
(passive infrared)

Radar

So far: Robotics always benefits, never drives sensor development

Improving Sparki's Odometry

- Accelerometer:
- Magnetometer:
- Floor sensor:
- Ultrasound sensor:
- IR receiver:
- …



Few (any?) sensors have specific applications, but most problems benefit from as much information as possible.

Classifying sensors

- Type of information
- Physical Principle
- Absolute vs. derivative
- Amount of information (Bandwidth)
- Low and high reading (Dynamic range)
- Accuracy and Precision

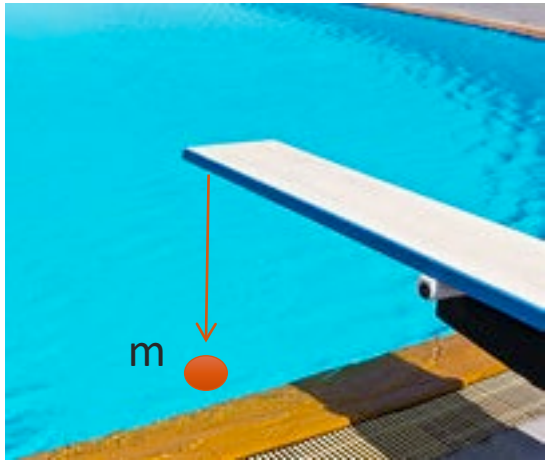
Specification	URG-04LX
Power source	Regulated 5V ±5%
Interface	RS232, USB
Detection Distance	20 to 4000 (mm)
Guaranteed Accuracy (min to 1m)	±10mm
Guaranteed Accuracy (1m to max)	1% of detected distance

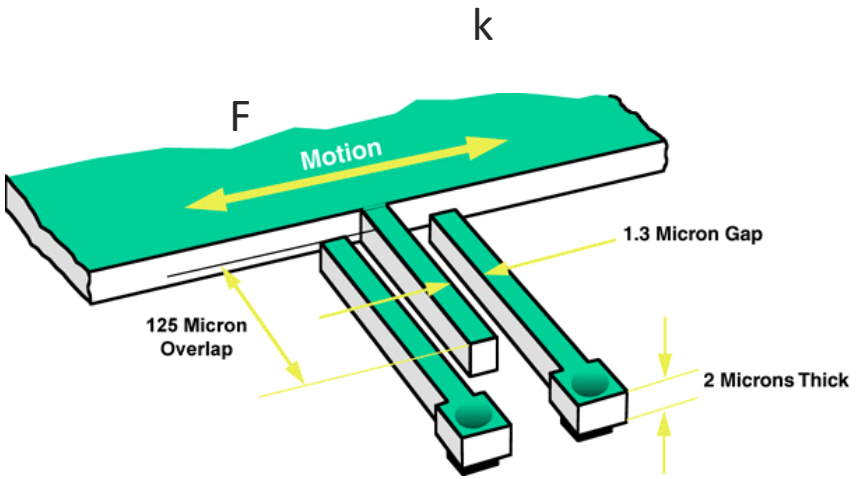
Specifications	
Power source	5V +/-5%
Current consumption	0.5A (Rush current 0.8A)
Detection range	0.02 to approximately 4m
Laser wavelength	785nm, Class 1
Scan angle	240°
Scan time	100msec/scan (10.0Hz)
Resolution	1mm
Angular Resolution	0.36°
Interface	USB 2.0, RS232
Weight	5.0 oz (141 gm)

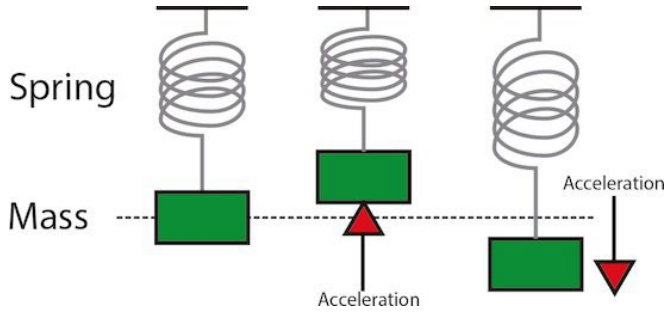
Accelerometer

$$F = kx = ma$$

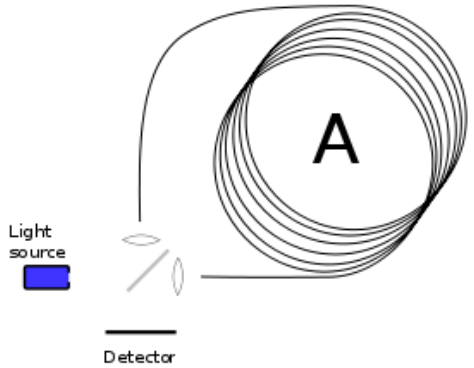
- Very cheap and small
- Measures acceleration
- Integrate for speed and distance
- Applications
  - Tell the pose of an object from the direction of gravity
  - Tell when robot hits an object



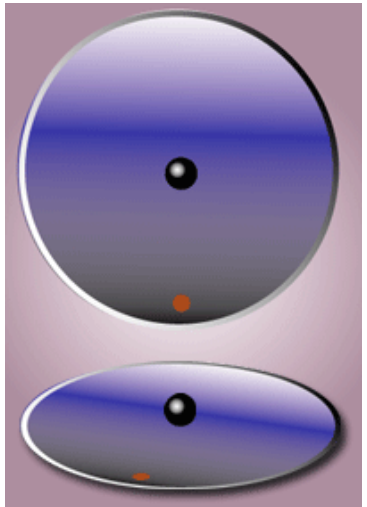




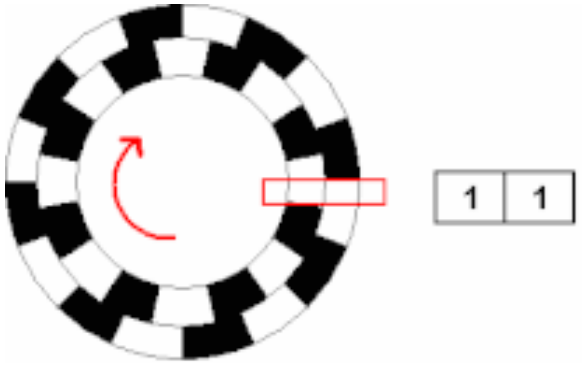
Gyroscopes

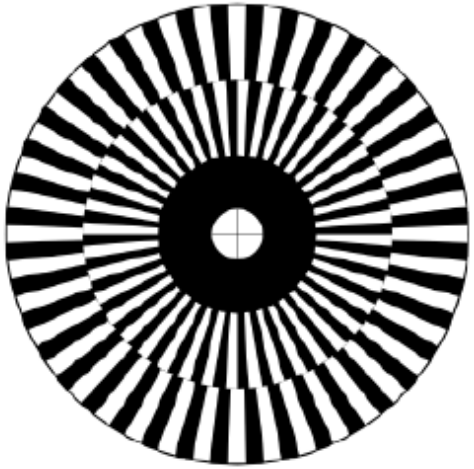


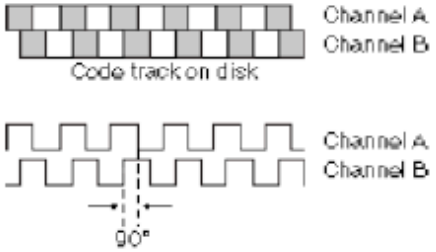
- Measures orientation
- Very expensive, infeasible to miniaturize
- Rate gyroscopes measure rotational speed
- Implemented using MEMS vibration devices, measure Coriolis force on two proof masses vibrating in plane
- Applications
  - Correct heading

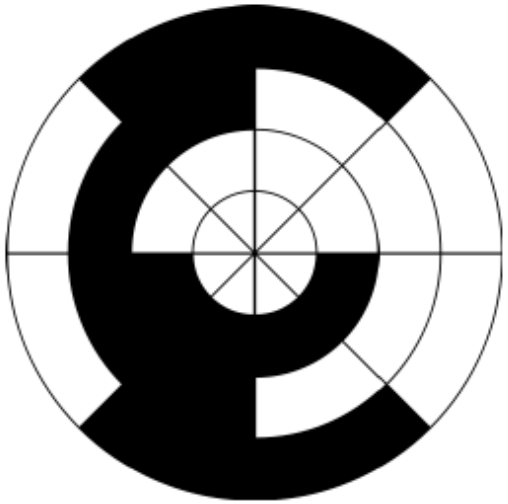


Wheel/Joint encoder



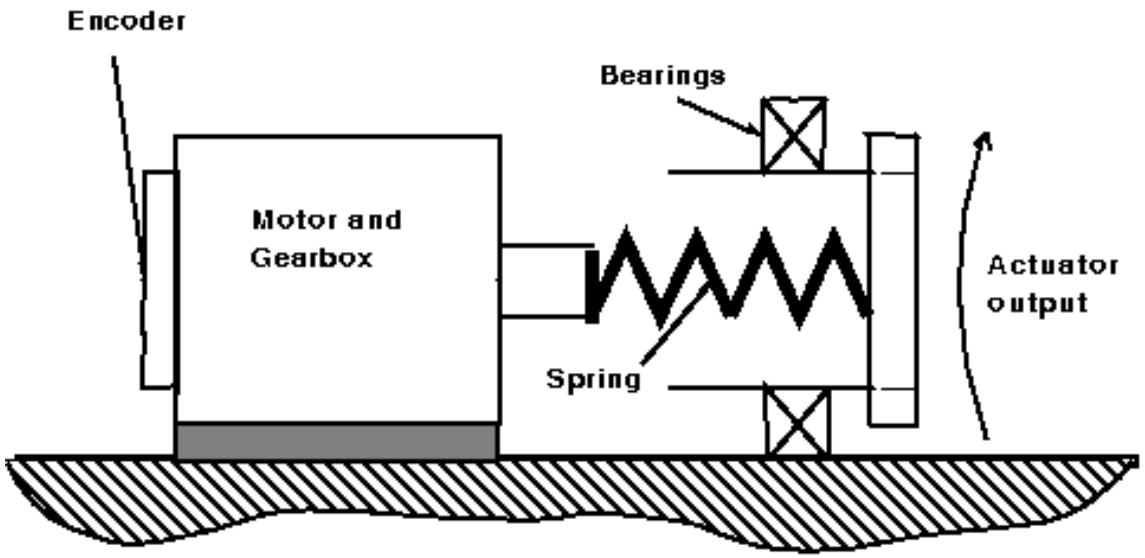


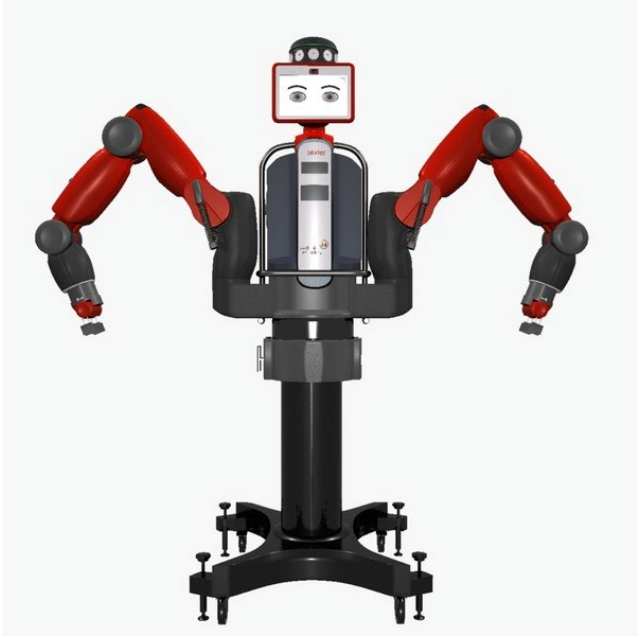




Can also be implemented magnetically or electrically (same principle). Main stream technology: CNC machines and RC servos.

Series Elastic Actuator



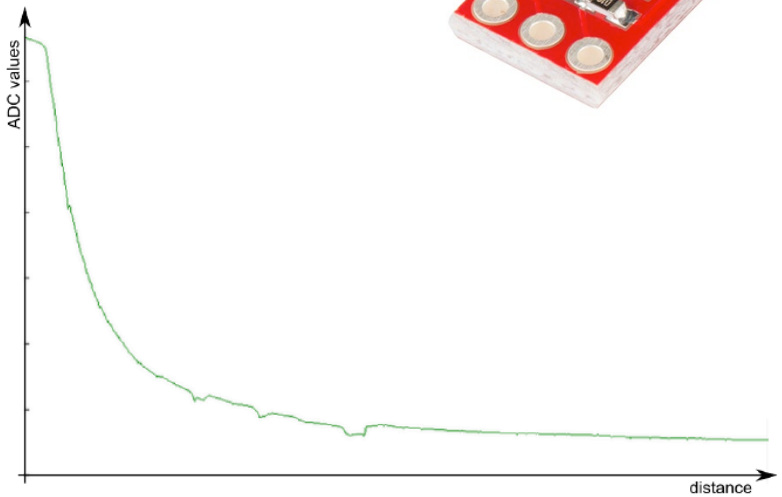


F=kx (Hooke's law)

Measure distance using potentiometer

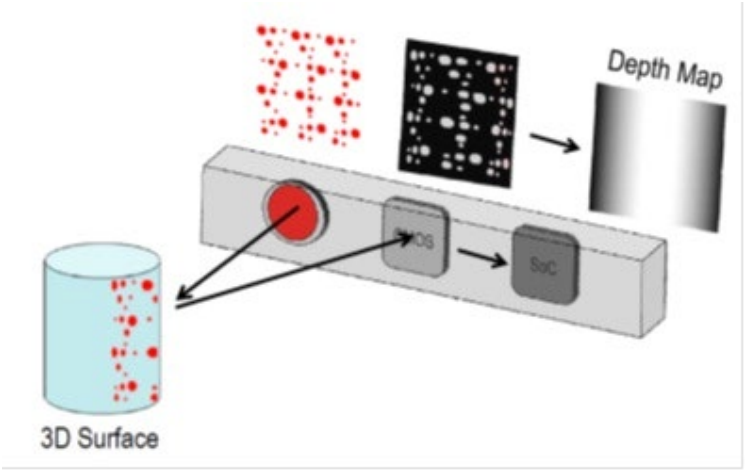
Distance from light intensity

- Emitter/receiver pair
- Highly non-linear
- Depends on surface color
- Confuses emissions from other sensors
- Requires a lot of energy



Distance from structure

Zhang et al. (2002)

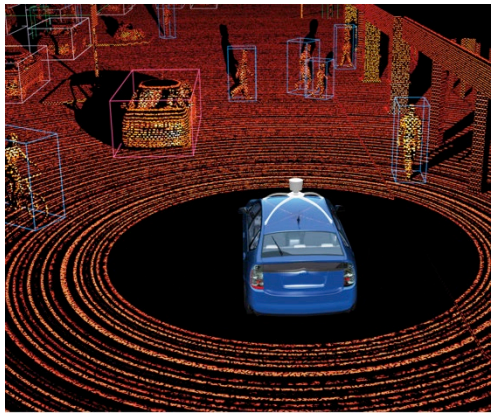


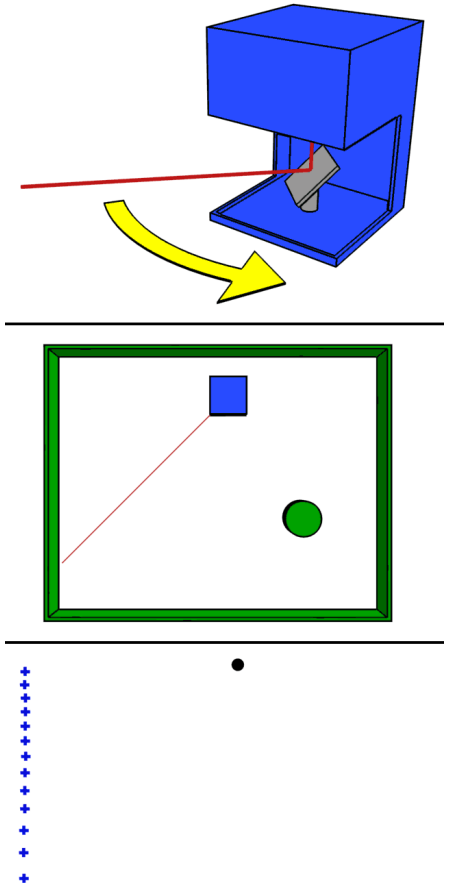
http://www.depthbiomechanics.co.uk/?p=100

Distance from Sound

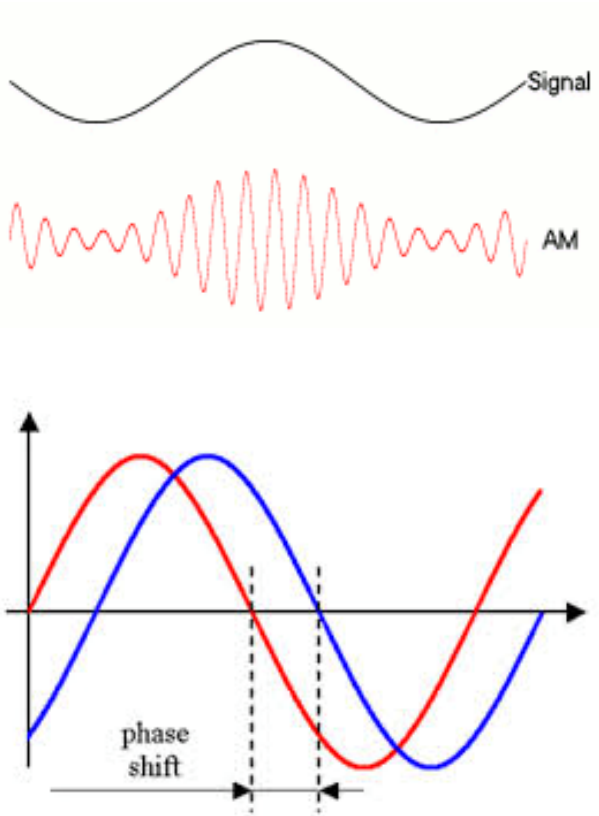
- Emitter/receiver pair
- Algorithm
  - Emit ping
  - Measure time until it returns
  - Calculate distance based on speed of sound
- Requires large objects
- Quality of result depends on object size

Distance from phase shift



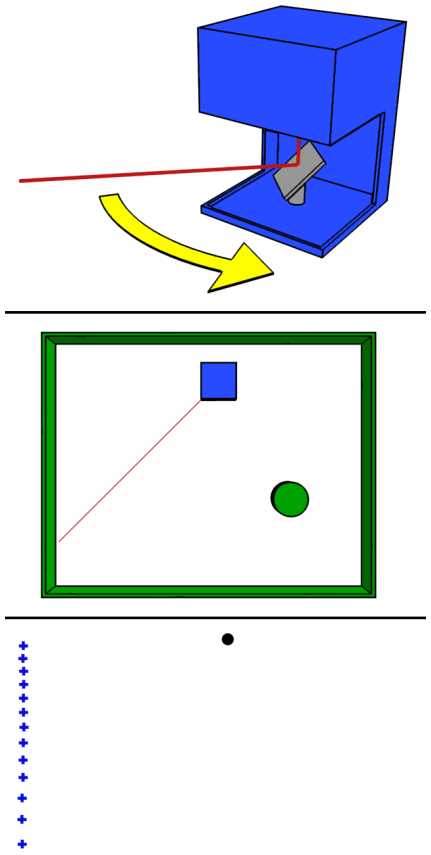


5 Mhz ~ 60m



https://en.wikipedia.org/wiki/Lidar (LIght Detection And Ranging)

How much data does a laser scanner produce?



Specifications	
Power source	5V +/-5%
Current consumption	0.5A (Rush current 0.8A)
Detection range	0.02 to approximately 4m
Laser wavelength	785nm, Class 1
Scan angle	240°
Scan time	100msec/scan (10.0Hz)
Resolution	1mm
Angular Resolution	0.36°
Interface	USB 2.0, RS232
Weight	5.0 oz (141 gm)

Specification	URG-04LX
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Detection Distance	20 to 4000 (mm)
Guaranteed Accuracy (min to 1m)	±10mm
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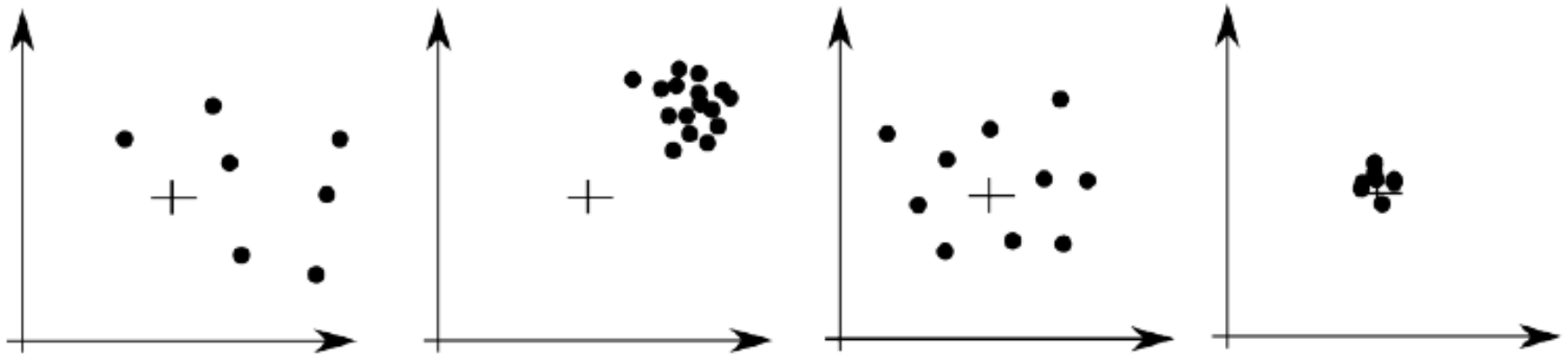
Hokuyo URG

What to do with so much data? (Cameras are even worse!)

Sensor characteristics

- Active and passive
- Resolution
- Accuracy
- Precision
- Bandwidth
- Range
- Dynamic Range
- Cross-sensitivity

Precision vs. Accuracy



Neither precise nor accurate, precise and not accurate, accurate and not precise, precise and accurate

Performance of a laser scanner

- Range: difference between highest and lowest reading
- Dynamic range: ratio of lowest and highest reading
- Resolution: minimum difference between values
- Linearity: variation of output as function of input
- Bandwidth: speed with which measurements are delivered
- Cross-Sensitivity: sensitivity to environment
- Accuracy: difference between measured and true value
- Precision: reproducibility of results

Hokuyo URG

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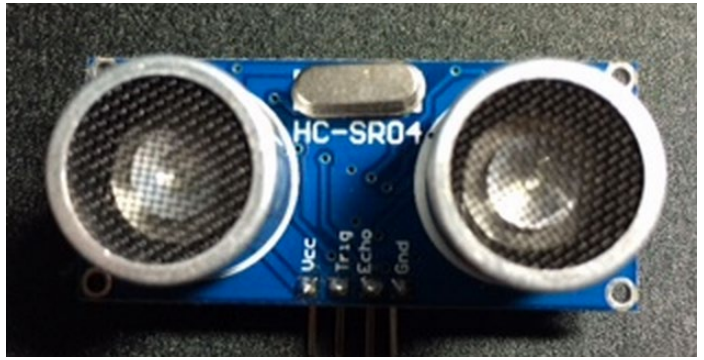
Interface	USB 2.0, RS232
Weight	5.0 oz (141 gm)

Performance of an ultrasonic sensor

- Range: difference between highest and lowest reading
- Dynamic range: ratio of lowest and highest reading
- Resolution: minimum difference between values
- Linearity: variation of output as function of input
- Bandwidth: speed with which measurements are delivered
- Cross-Sensitivity: sensitivity to environment
- Accuracy: difference between measured and true value
- Precision: reproducibility of results



- Power Supply :+5V DC
- Quiescent Current : <2mA
- Working Currnt: 15mA
- Effectual Angle: <15°
- Ranging Distance : 2cm – 400 cm/1" - 13ft
- Resolution : 0.3 cm
- Measuring Angle: 30 degree
- Trigger Input Pulse width: 10uS
- Dimension: 45mm x 20mm x 15mm

Summary

- Sensors do not serve specific applications and no sensor solves a problem completely
- Many sensors observe the same phenomenon using different physical principles
- Different sensors have different trade-offs qualified in their different precision, accuracy, bandwidth, dynamic range and resolution
- There are smart ways to extract the desired information from a set of sensors and fuse them [Sensor Fusion]