Perception

Robotics and autonomous systems

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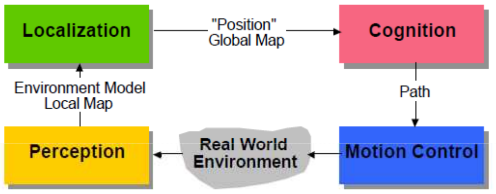
Contents

Introduction

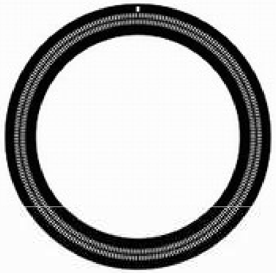


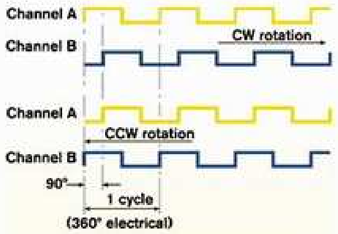
- Perception – More than just Sensing
- Establishes the feedback between robot and external environment

Motor/Wheel Sensor

Overview

- Quadrature incremental encoder
- Up to 160kHz
- Up to 512 x 4 = 2048 ticks/turn
- Need to convert from ticks to rad/s
  - Don't forget the gear ratio

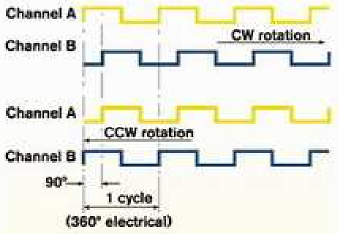




Motor/Wheel Sensor

Counting

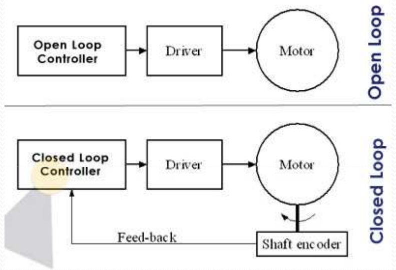
- Decide how to count: CW–UP CCW-DW?
- Each transition is a “tick”
- Keep track of Aq and Bq (previous values of A and B)
- According to the state of A, Aq, B, Bq at each transition, you can see if the rotor is rotating CW or CCW



Motor/Wheel Sensor

What for?

- Closes the motor’s control loop
- You can integrate the wheels’ velocity and get your trajectory according to a robot model – odometry
  - Usually not enough



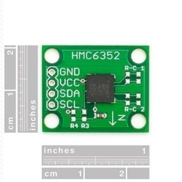
Heading sensors

Determine the robots orientation and inclination

- Proprioceptive (Gyroscope ,inclinometer)
- Exteroceptive (Compass)

Compass

- Hall effect compass(inexpensive, poor resolution, need significant filtering, low bandwidth)
- Flux gate compass(better resolution and accuracy, larger and more expensive)

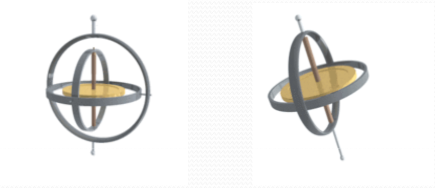


Major drawback in general

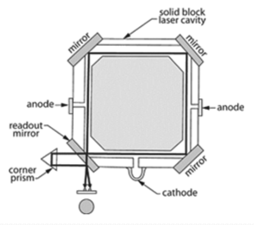
- *weakness of the earth field*
- *easily disturbed by magnetic objects or other sources*
- *not feasible for indoor environments*

Gyroscope

- Mechanical



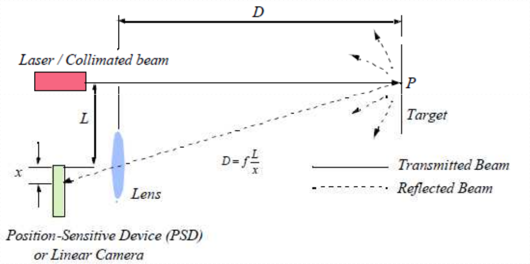
- optical



- Mechanical gyro: The inertia of a spinning wheel provides reference for orientation
- Rate gyro: measures the rotation speed
- Typically drifts with temperature, etc
- Often combined with accelerometers
- low in cost with high performance
- The spinning axis has to be initially selected

Ranging Sensors – SHARP IR

How it works

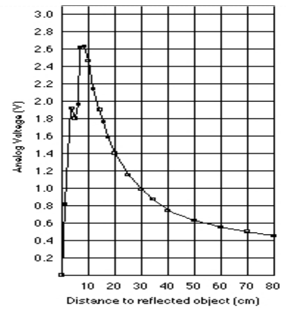


$$D = f\frac{L}{x}$$

Ranging Sensors – SHARP IR

Overview

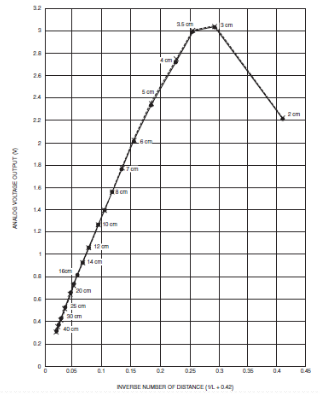
- Some nice features:
  - Low influence on object's color
  - No need for external clock/control
  - Narrow beam
- But not all is good:
  - Nonlinear Output (Voltage-Distance)
  - Low sensitivity at higher distances
  - Minimum distance (care at design)
  - Slow output change (≈40 ms)



Ranging Sensors – SHARP IR

Converting the Output

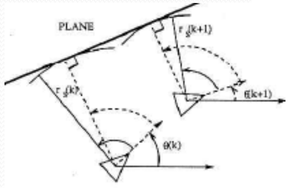
- Many possibilities:
  - Output voltage is "linear" with $\frac{1}{L+c}$
  - Approximate L(V) by a polynomial
  - Build a lookup table (for each sensor) and then interpolate linearly

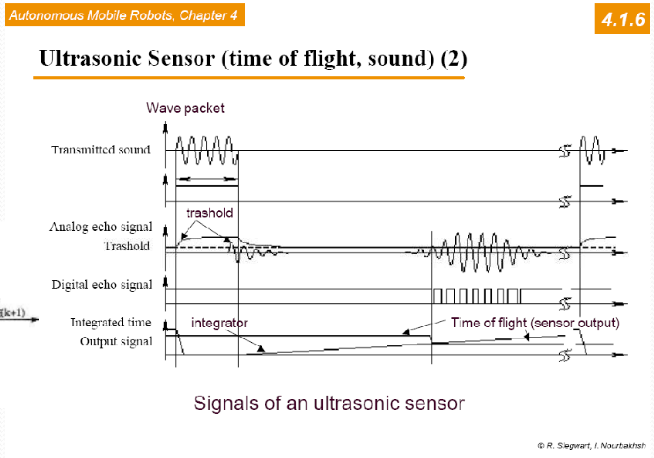


Ranging Sensors – Sonar

How it works

$$d = \frac{c.t}{2}$$





Autonomous Mobile Robots, Chapter 4

4.1.6

Ultrasonic Sensor (time of flight, sound) (2)

Signals of an ultrasonic sensor

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Ranging Sensors – Sonar

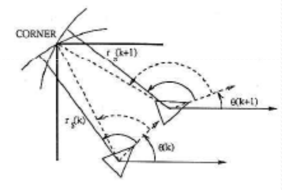
Overview

- Long range (6m "max.")
- Low power consuption
- Several output formats (mm, inch, uS)
- Variable listening time / range
- Adjustable gain (may reduce cross-talk)
- Possible to fire one or all at same time
  - Drawback: fire all may increase cross-talk
- Rather slow for long ranges
- Wide beam – from where does the measure comes?

Ranging Sensors – Sonar

Tunning

- Depending on your maximum range and/or sample time, you may want to change:
  - The gain (“*threshold*”)
  - The range (maximum time of flight)
  - Try and error iterations

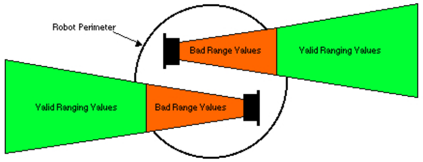


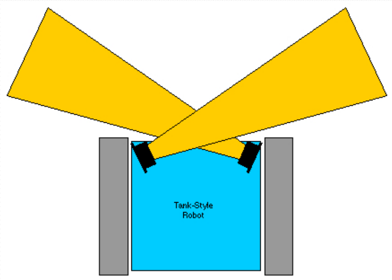
- What about using some other echoes?
  - There can be up to 17 received echoes

Ranging Sensors

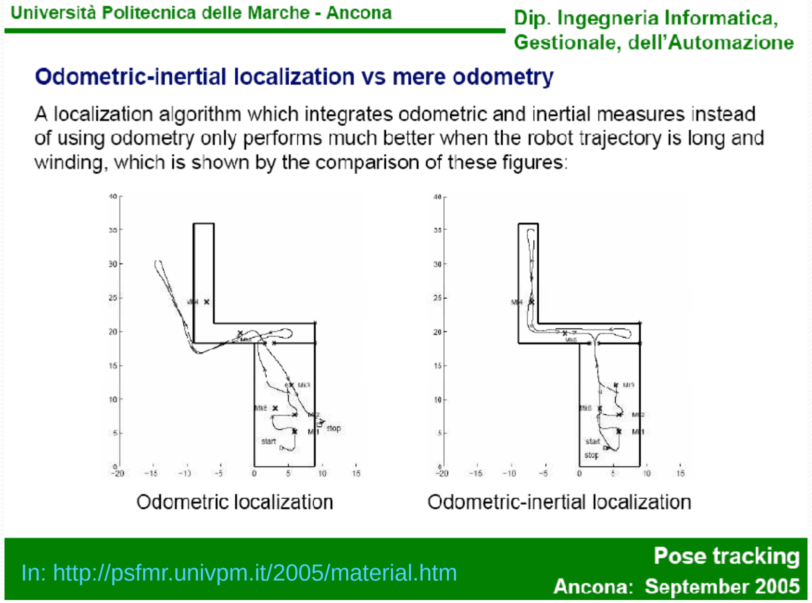
Where to put them

- Avoid cross-talk
- See what you have:
  - 4 SHARP IR 10-80 cm
  - 4 SHARP IR 4-30 cm
  - 2 Sonars 3cm-6m
- Check the environment
  - Long and thin corridors
  - Any idea?





Merging Sensors



Università Politecnica delle Marche - Ancona

Dip. Ingegneria Informatica, Gestionale, dell’Automazione

Odometric-inertial localization vs mere odometry

A localization algorithm which integrates odometric and inertial measures instead of using odometry only performs much better when the robot trajectory is long and winding, which is shown by the comparison of these figures:

Odometric localization

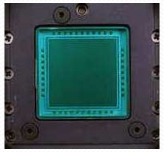
Odometric-inertial localization

In: http://psfmr.univpm.it/2005/material.htm

Pose tracking
Ancona: September 2005

Vision-based sensors

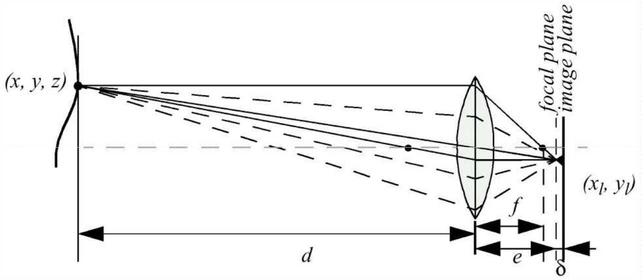
- Vision is powerful sense providing enormous amount of information
- Relatively inexpensive
- Complex sensory processing
- Vision sensors: Hardware
  - CCD- *light-sensitive , discharging capacitors*
  - CMOS -*Complementary Metal Oxide Semiconductor technology*



Visual ranging sensors

- 3 dimensional scene is projected onto a 2dimensional plane thereby losing depth information
- looking at several images of the scene *to* gain more information
- Several ways to get depth from the camera
  - Focus
  - Structured light
  - Stereo vision
  - Time of flight

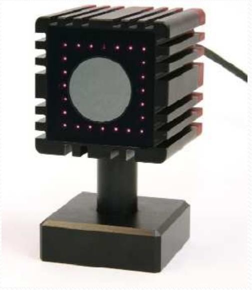
Depth using focus

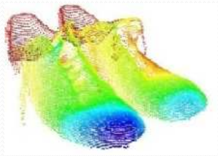


- Basic geometry: $\frac{1}{f} = \frac{1}{d} + \frac{1}{e}$
- The smear is proportional to distance $R = \frac{L\delta}{2e}$

3D Range Camera

- Can combine ideas from cameras and lasers range finders
- Based on the time-of-flight (TOF) principle
- Ex: Swiss Ranger gives 176x144 images with range information

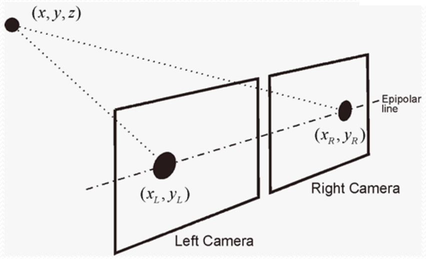


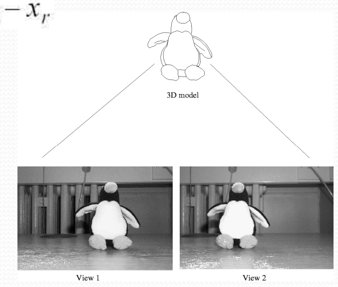


Stereo vision

- Obtain distance estimates of a point in the world using the pixel offset in two images
- Distance is inversely proportional to disparity

$$z = b\frac{f}{x_l - x_r}$$



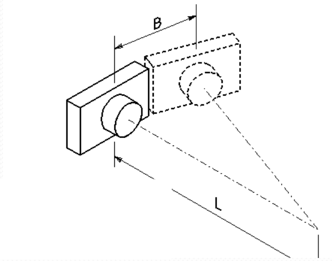


Stereo vision - Applications

- Localization and Mapping
  - Finding the robot position from reference points
  - Measuring environment relative to robot
- Detecting obstacles in mobile robotics
- Object recognition
  - Table detection

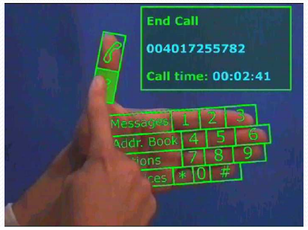
Single moving camera

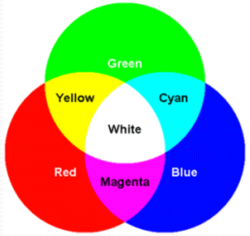
- A Single moving camera can also be used to obtain distance information
- Successive photos are taken of the environment
- Disparity information from consecutive photos is used for distance estimation



Detecting and Tracking color

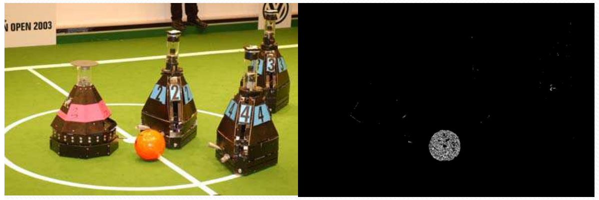
- Skin detection
  - Face Detection and Face Tracking
  - Hand Tracking for ,Gesture Recognition, Robotic Control, Other Human Computer Interaction
- Motion estimation of ball and robot for soccer playing using color tracking

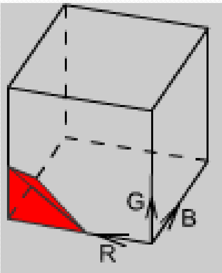




Detecting color

- In color images each pixel is characterized by three RGB values.
- Histograms plotted for each of the color values and threshold points are found
- Color Segmentation





DCS-900

- Single JPEG image from the camera
  - 0.25-0.5 seconds to respond to a request for an image
  - 2-4 images per second
- Stream of current images in MJPEG stream format
  - Initial delay
  - 30 frames a second

Representing uncertainty

Sensors are imperfect devices with errors

- Systematic noise (deterministic errors),that could be modeled, e.g. through calibration e.g. optical distortion in camera lens
- Random noise (non-deterministic errors) errors that cannot be predicted, Typically modeled in probabilistic fashion

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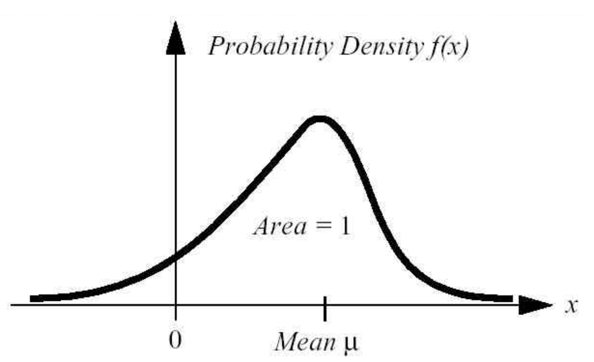
Density function identifies a probability density f(x) for each possible value x of X



Complete chance of X having some value

$$\int_{-\infty}^{\infty} f(x)dx = 1$$

The probability of the value of X falling between two a and b

$$P[a < X \leq b] = \int_a^b f(x)dx$$

mean value

$$\mu = E[X] = \int_{-\infty}^{\infty} xf(x)dx$$

mean square value

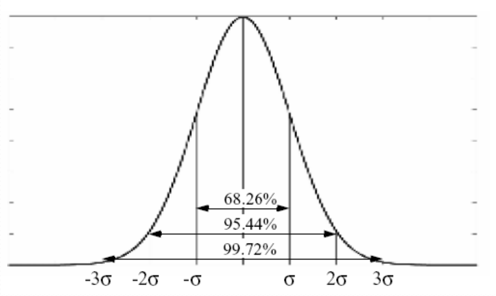
$$E[X^2] = \int_{-\infty}^{\infty} x^2 f(x)dx$$

variance

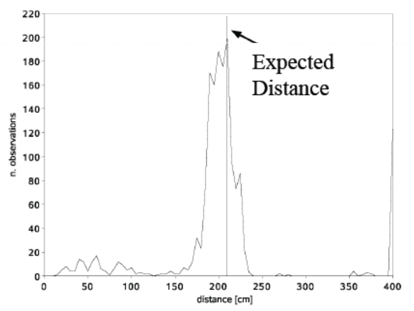
$$Var(X) = \sigma^2 = \int_{-\infty}^{\infty} (x-\mu)^2 f(x)dx$$

Gaussian distribution

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

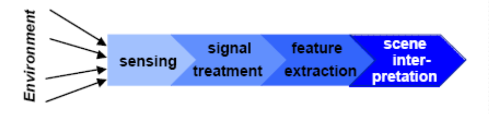


- 2000 images in different positions in the field



Feature Extraction

- Autonomous mobile robots; able to determine their relationship to the environment.
  - by using raw sensors
  - by using feature extraction



The perceptual pipeline: from sensor readings to knowledge models.

Feature extraction

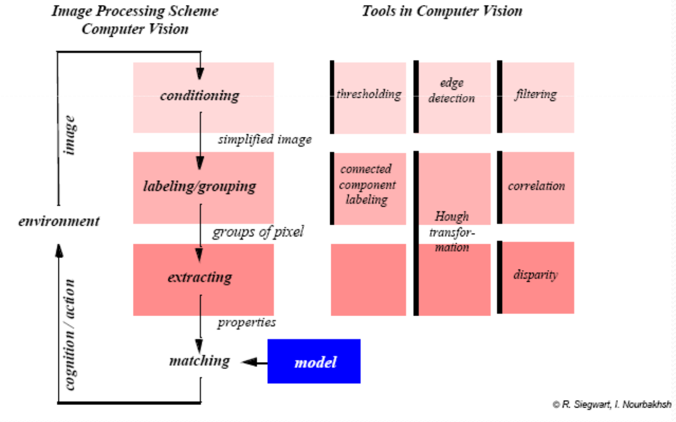
- Feature definition
- Target environment
- Available sensors
- Computational power
- Environment representation

Feature Extraction

- Feature extraction base on range images
  - Geometric primitives like line segments, circles, corners, edges
  - Most other geometric primitives the parametric description of the features becomes already to complex and no closed form solutions exist.
  - However, lines segments are very often sufficient to model the environment especially for indoor applications.

Feature Extraction

- Visual appearance base feature extraction- vision



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Feature extraction

- Choose the right feature to make correct perception about environment, e.g. Line feature
  - Useful for indoor – office building- environment
  - Useless for Mars navigation

- Choose the right sensor
- Take into account the computational power/time

Feature Extraction

- Some of the applications:
  - Obstacle avoidance – range based sensors
  - Pattern matching
  - Data reduction
  - Color classification
  - Non-speech audio for outdoor navigation system

The Bremen Autonomous Wheelchair „Rolland“

References

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End

- Thanks
- Questions?