Understanding Sensors I

Range Finders

CPS 1/296

Ron Parr

Overview

- Sonars
- Laser Range Finders
- IR Range Finders
- Cameras

Sonar

- Very old and common ranging method
- Used by:
  - Bats & Dolphins
  - Early autofocus cameras
  - Submarines and ships
  - Electronic white boards
  - Early robots
  - Medical field

Sonar: Basic Idea

- Send out a "ping"
- Calculate time for ping to return to source
- Compute distance traveled from:
  - Delay
  - Speed of sound (344 m/s)
- Basic sonar devices are simple and inexpensive to fabricate using current technology

Problems with Sonar

- Signal spreads out
- Short range (or spreads energy over wide area)
- Not stealthy
- Sound is (relatively) slow
- Speed of sound is variable
- Can be confounded by:
  - Echoes
  - Ambient sounds
- Low resolution
- Difficult to interpret

Sonar Conundrum

How do some creatures manage to be so successful with it???

Laser Range Finders

- In some interpretations:
  Almost identical to sonar w/different energy source
- In reality:
  - Completely different ball game
  - "Time of flight" becomes an interesting problem (speed of light = $3x10^8$ m/s)
  - Completely different set of pros and cons

Laser Pros and Cons

- Pro:
  - Very accurate (5mm over 10s of meters)
  - Very precise (beam is collimated)
  - High resolution
  - Very resistant to environmental conditions
  - More stealthy than sonar
  - Relatively fast
  - Speed of light arguably more predictable than sound
- Cons:
  - Largish
  - Expensive (thousands to 100s of thousands)
  - Has moving parts (to aim the laser beam)
  - Still active/unstealthy

Examples

http://www.seas.upenn.edu/~taskar/pubs/cvpr05.pdf

http://www.riegl.com/terrestrial_scanners/terrestrial_scanner_literature_/downloads_/URS_Railway_Crossings.pdf

Challenges and Issues

- Managing cons (cost, size, etc.)
- Going from points to shapes
- Mapping color and texture onto shapes
- Registration and alignment in general

But how does it work???

- Measuring time of flight is tricky
- Time to travel 1cm: 0.033 nanoseconds
  (1 nanosecond = 10^{-9}s)
- Solution: Use phase detection
  - Modulate the amplitude of the laser at a high frequency (note: different concept from wavelength of the laser)
  - Combine return signal with output signal
  - Measure phase difference
  - Compute time of travel from phase difference

IR Range Finder

- Note Ambiguity in Terminology: A "laser range finder" typically uses and IR laser. The technology used in IR range finders could also be used with laser.
- "IR Range Finder" typically refers to an inexpensive, short range device that typically uses a linear image sensor and cheap, typically IR, light source

IR Range Finder Ingredients

- Light Source
- Strip of light detectors
- Narrow pass filter to reject ambient light

IR Range Finder Construction

- Place sensor and light source in same plane
- Steps:
  - Calibration (optional)
    - Measure ambient light with reference image
    - Use image subtraction to discover light source
  - Activate Light Source
  - Find light source in linear sensor array
  - Compute depth from geometry
- See in class demo!

IR Range Finder Pros and Cons

- Pro:
  - Relatively inexpensive
  - No moving parts
  - Accurate at short distances
- Con:
  - Accuracy drops off with distance
  - Low resolution
- Similar power/stealth issues to lasers, depending upon light source