CS 378 - Autonomous Vehicles in Traffic I

Week 2b - Hardware Overview
Today

• We'll take a look at the different hardware systems, sensors and actuators on Marvin
  ○ You'll be able to see these in person when you go out to the car
  ○ We will have our first visit to the car on 2/13
Marvin

- 1999 Isuzu VehiCROSS Ironman edition (4 wheel drive)
- A decently rugged vehicle + many solid enhancements
It's pretty rugged

- Feb 2011 Incident - Problem in wheel encoder

- However it is not something we would like to repeat!
Marvin - Basic Hardware

**Processing**
- Multi Core System with NVIDIA GPU's

**Sensors**
- Camera Array
- Velodyne Lidar
- Sick Lasers
- Applanix POS LV (D-GPS, INS, RPS)

**Actuators**
- Steering
- Throttle
- Brake
- Shift-by-wire
Processing

- We have a rack in the back of the car to hold 3 machines
  - We currently use only one of them (*mobile-1*), and keep another for backup (*mobile-2*)
  - We can switch between these machines when necessary

- Configuration on *mobile-1*
  - 2x 6-core Xeon processors
  - 24GB RAM
  - 320GB SATA
  - 2x 1394b cards
Cameras
Camera Details

- **Sony XCD-SX90CR**
  - IEEE 1394b Digital Interface (Firewire)
  - Up to 30 fps at SXGA Resolution
  - Various Frame Rates for High Speed Capturing
    - We run at 15 fps
  - Compact and Lightweight
  - High Shock and Vibration Resistance
Benefits/Drawbacks of Cameras

• Benefits:
  ○ No explicit maximum range
  ○ Passive sensor
  ○ Relatively inexpensive

• Drawbacks:
  ○ Noisy across multiple frames
  ○ Sensitive to illumination changes / dynamic range
    ■ Color constancy
    ■ Dark illumination yields little information
    ■ Too bright illumination saturates pixels: causing white images or blooming (bleeding into adjacent pixels)
  ○ 3D information is lost in 2D projection

• It is a difficult sensor to use. We currently under-use the cameras
CCDs

- CCD stand for Charged Couple Device.
- A CCD chip is essentially an array of capacitors (around 5-25 microns) that are light sensitive.
- On exposure, a photon hits a pixel and releases energy which is transported across the chip to one corner of the array where the values are read.
- Usually give high quality images at a high frame rate.
Color CCDs

- In normal, inexpensive color cameras, CCD array are divided into 2x2 regions of green, red, and blue receptors.
  - Human vision is more responsive to green than red or blue
- Half the pixels in the CCD are allocated to green, a quarter to red and a quarter to blue
- Color is generated for the whole CCD by interpolating neighbor values
- The image we get has already undergone a `lossy compression`
Color CCDs

- In more expensive cameras, there are 3 CCD chips, one that measures wavelengths of blue light, one for red, and one for green.
  - Three images are taken and combined into a single color image
CMOS sensor

- CMOS stands for Complimentary Metal Oxide Semiconductor.
- CMOS is a general process for producing chips (hence the name CMOS sensor). As a result these can be manufactured at most chip manufacturing production lines.
- Several transistors at each pixel amplify the charge which is transported more "traditionally"

CCD v CMOS

- CCD sensors create high-quality, low-noise images. CMOS sensors traditionally are more susceptible to noise.
- Light sensitivity of a CMOS chip tends to be lower. Many of the photons hitting the chip hit the transistors instead of the photodiode.
- CMOS traditionally consumes little power. CCDs use a process that consumes lots of power. CCDs consume as much as 100 times more power than an equivalent CMOS sensor.
- CMOS chips are cheaper because of easier manufacturing - but this typically means reduced quality of the chip as well.

Applanix POS LV Sensor
Applanix POS LV Sensor

The Applanix system provides:

- Continuous position, heading, and speed information for navigation and control
- Generates continuous and accurate *position* and *orientation* information under the most difficult GPS conditions
- We conducted some informal tests of this sensor. We found that sub-meter accuracy is maintained over an extended driving time
  - Error is still <1 m after 3 min of driving with the GPS turned off
  - This included U-Turns and various other maneuvers
- Error on the Applanix is typically around 0.2-0.3 meters. The accuracy of a commercial GPS is typically around 5 meters.
How GPS Works

- The Global Positioning System (GPS) is actually a constellation of 27 Earth-orbiting satellites (24 in operation and 3 for backup)
- Originally developed by the US Military, GPS is now available to the public
- The orbits are arranged so that at any time, anywhere on Earth, there are at least four satellites "visible" in the sky.
- A GPS receiver's job is to locate four or more of these satellites, figure out the distance to each, and use this information to deduce its own location. This is called **trilateration**
- Trilateration is similar to triangulation except it only uses distances but no angles

Trilateration and Triangulation in 2D

Trilateration

Triangulation

[triangulation image from wikipedia: http://en.wikipedia.org/wiki/Triangulation]
The applanix system contains:

- **GPS Receivers**: Embedded GPS receivers provide heading aiding to supplement the inertial data.
- **GPS Antennas**: Two GPS antennas generate raw observables data.
- **IMU**: Inertial Measurement Unit generates a true representation of vehicle motion in all three axes, producing continuous, accurate position and orientation information.
- **PCS**: POS Computer System enables raw GPS data from as few as one satellite to be processed directly into the system, to compute accurate positional information in areas of intermittent, or no GPS reception.
- **DMI**: Distance Measurement Indicator computes wheel rotation information to aid vehicle positioning.
CarTool - Map
Velodyne (HDL-64E)
Velodyne (HD-Lidar)

- LIDAR (Light Detection And Ranging)
- 64 lasers
- 360 degree field of view
- 300 - 900 RPM (5-15 Hz)
- 26.5 degree field of view (elevation)
- +2.0 up to -24 down degrees with 64 equally spaced angular subdivisions
- 5 cm resolution (distance)
3D Laser Scanning: Phase vs TOF

- *Time of Flight (TOF)* is one method of estimating distance of an object.
- distance = speed-of-light * TOF / 2

- *Phase* uses a continuous beam and calculates distance based on phase shift. Because of this reason it is inherently short ranged.

- Time of flight is more noise prone, has less accuracy and can produce less points than phase based laser sensing. However it can be used for longer distances.

- The Velodyne HDL and SICK Laser Rangefinder are TOF

Velodyne LIDAR disassembled

Other Uses

Ultrahigh-resolution mapping image of an urban environment.
SICK Lidar

- 2D Laser Scanner
- 180 degree field of view
- Around 6000 points a second
- 10 Hz

Generating 3D Data using the SICK

[https://www.youtube.com/watch?v=AzhXqAG0tAk]
Review

● Today we saw a brief overview of the hardware on the car
  ○ 2 distance sensors - SICK and Velodyne
  ○ Camera Array
  ○ Applanix POS-LV - Highly accurate differential GPS system with an excellent Inertial Measurement Unit (IMU)
  ○ Excellent processing capabilities

● We'll see some of the more intricate hardware details on our visit to the car.
Programming Assignment 1

- **Programming Assignment 1** is now officially available
  - Due on 2/8
  - We will go over some of the material you will need to work on it next week (for Section 2)
  - Section 1 can be done in C++ or Python
  - Section 2 is in C++ only
  - Section 1 is independent of the material from next week

- In the meantime, here are some C++ tutorials
  - [http://www.learncpp.com](http://www.learncpp.com)