SMART NEST

Sensor fusion for AIA applications

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Smart Technologies for Transport Safety -
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Secondment arrangements

- October 2013 – February 2014 at UdS

  Inertial orientation and position tracking

- March 2015 – July 2015 at UdS

  Sensor fusion and hybrid motion tracking systems

Information fusion – encompasses theory, techniques and tools conceived and employed for exploiting the synergy in the information acquired from multiple sources (measurements, databases, numerical simulations) such that the resulting decision or action is in some sense better, qualitatively or quantitatively, than would be possible if any of these sources were used individually without such synergy exploitation.

Sensor fusion – combines various sensory data in order to obtain a better information about the measured process then provided by individual sensors. Better quality of information means higher accuracy, reliability, robustness, extended spatial or temporal range and resolution.

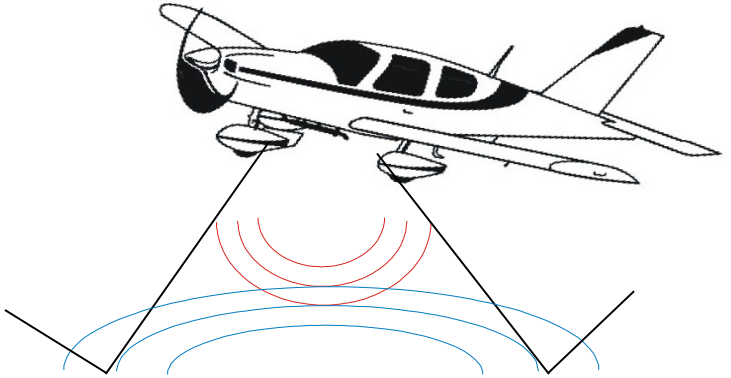
Data fusion – a process of combining information about a system state, which comes from mathematical modelling and multi-sensor measurements.

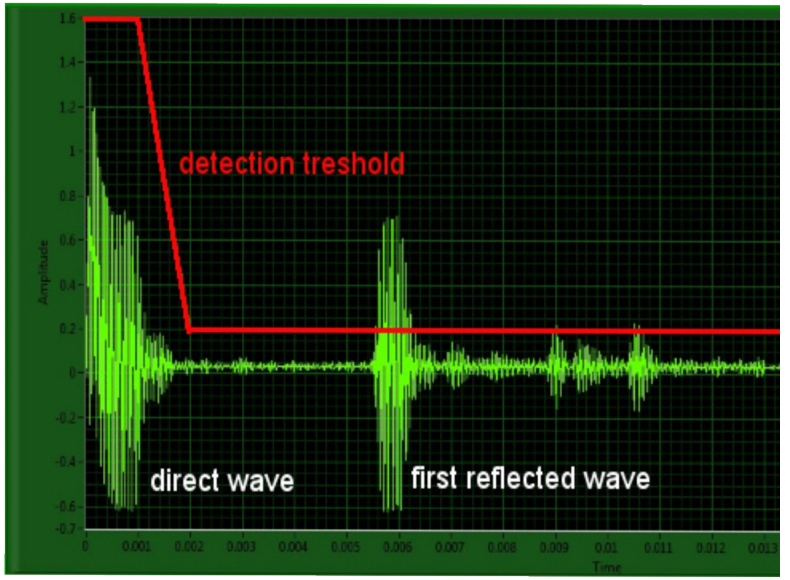
Motion tracking problem using:

- Dynamic or kinematic model of moving body
- Inertial navigation (gyroscopes, accelerometers, inclinometers)
- Distance meters (laser, ultrasonic)
- Other tracking systems (GPS, radar, sonar, lidar, ...)

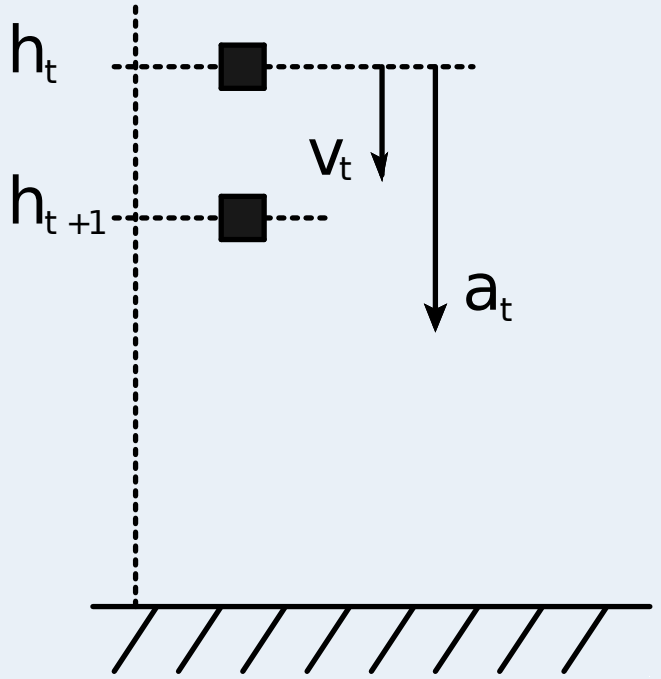
AVI system

Height and velocity estimation for adaptive aircraft landing gear, based on ultrasonic pulse-echo method





Kinematic model



$$h_{t+1} = h_t + \Delta t v_t + \frac{\Delta t^2}{2} a_t$$

Kalman Filter

Process model:

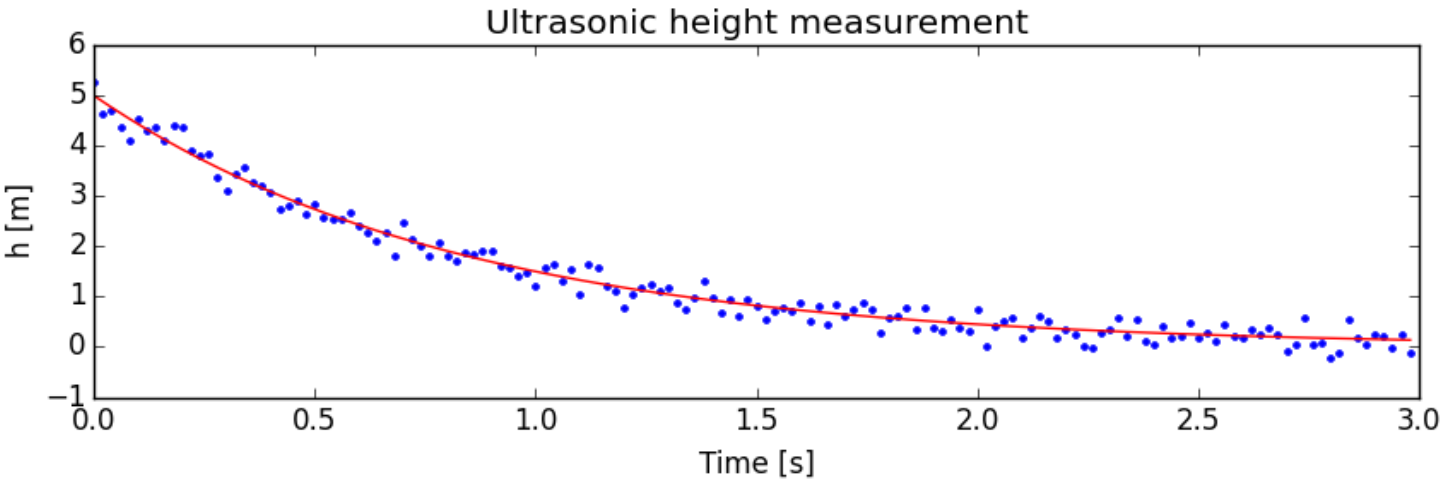
$$\begin{bmatrix} h_{t+1} \\ v_{t+1} \end{bmatrix} = \begin{bmatrix} 1 & \Delta t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} h_t \\ v_t \end{bmatrix} + \begin{bmatrix} 0.5\Delta t^2 \\ \Delta t \end{bmatrix} a_t$$

Measurement model:

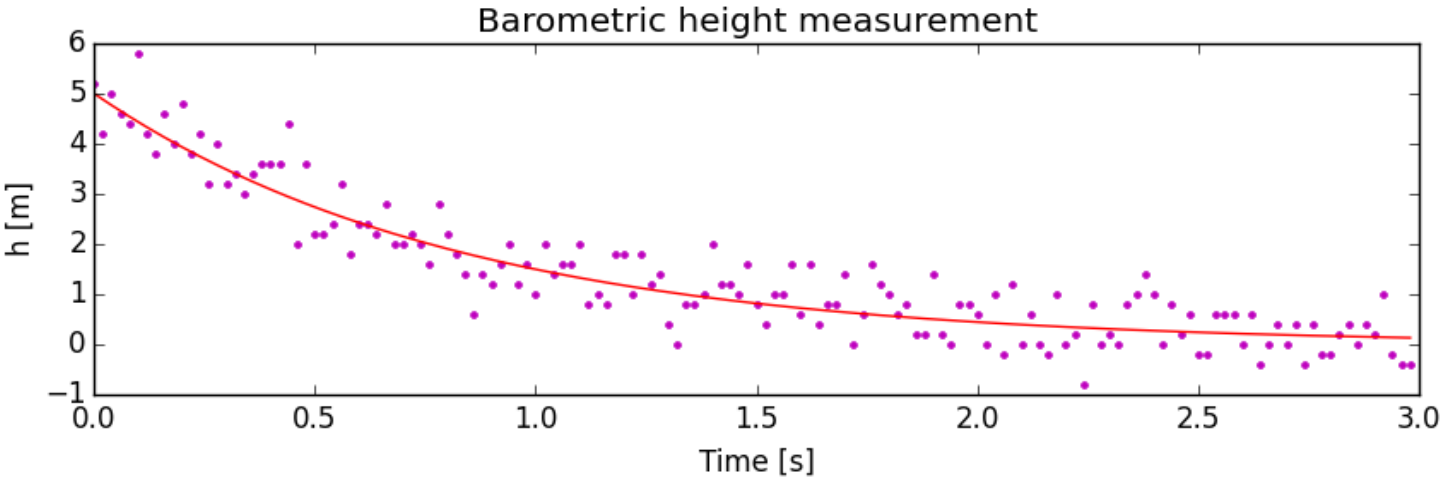
$$\begin{bmatrix} h_t^u \\ h_t^b \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} h_t \\ v_t \end{bmatrix}$$

Sensor features

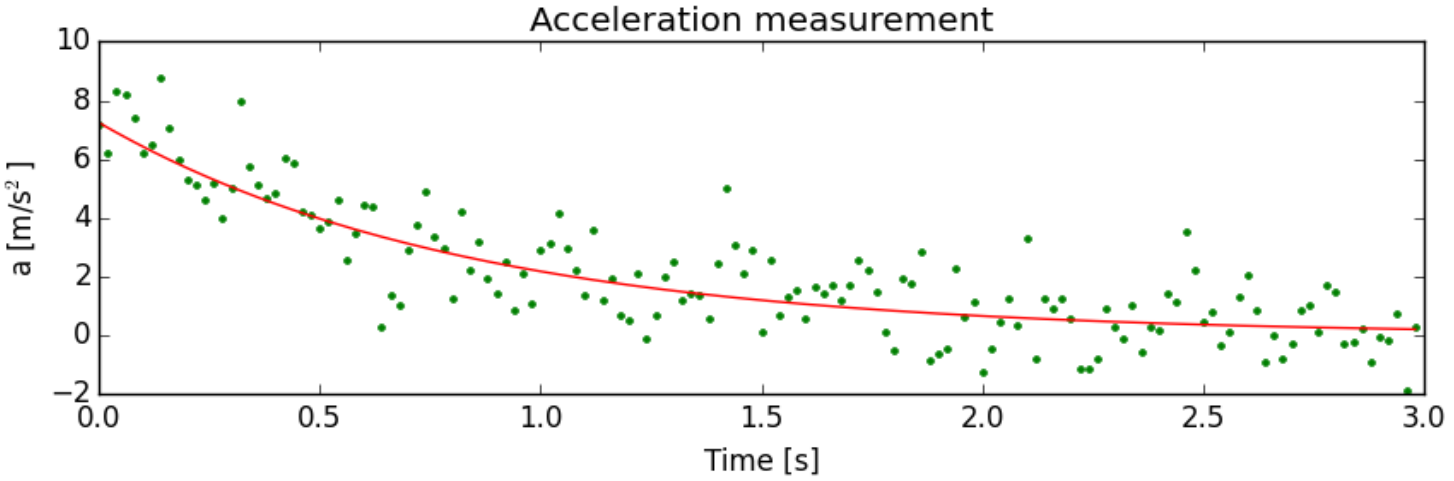
Ultrasonic head	• Intrinsic inaccuracy • Background noise • Limited range (up to 5 meters) • Limited sampling rate
Barometric altimeter	• Very low accuracy (pressure fluctuations, environmental conditions) • Unlimited range
Accelerometer	• Static acceleration induced by gravity • Dynamic components induced by vibrations • High noise • High sampling rate required



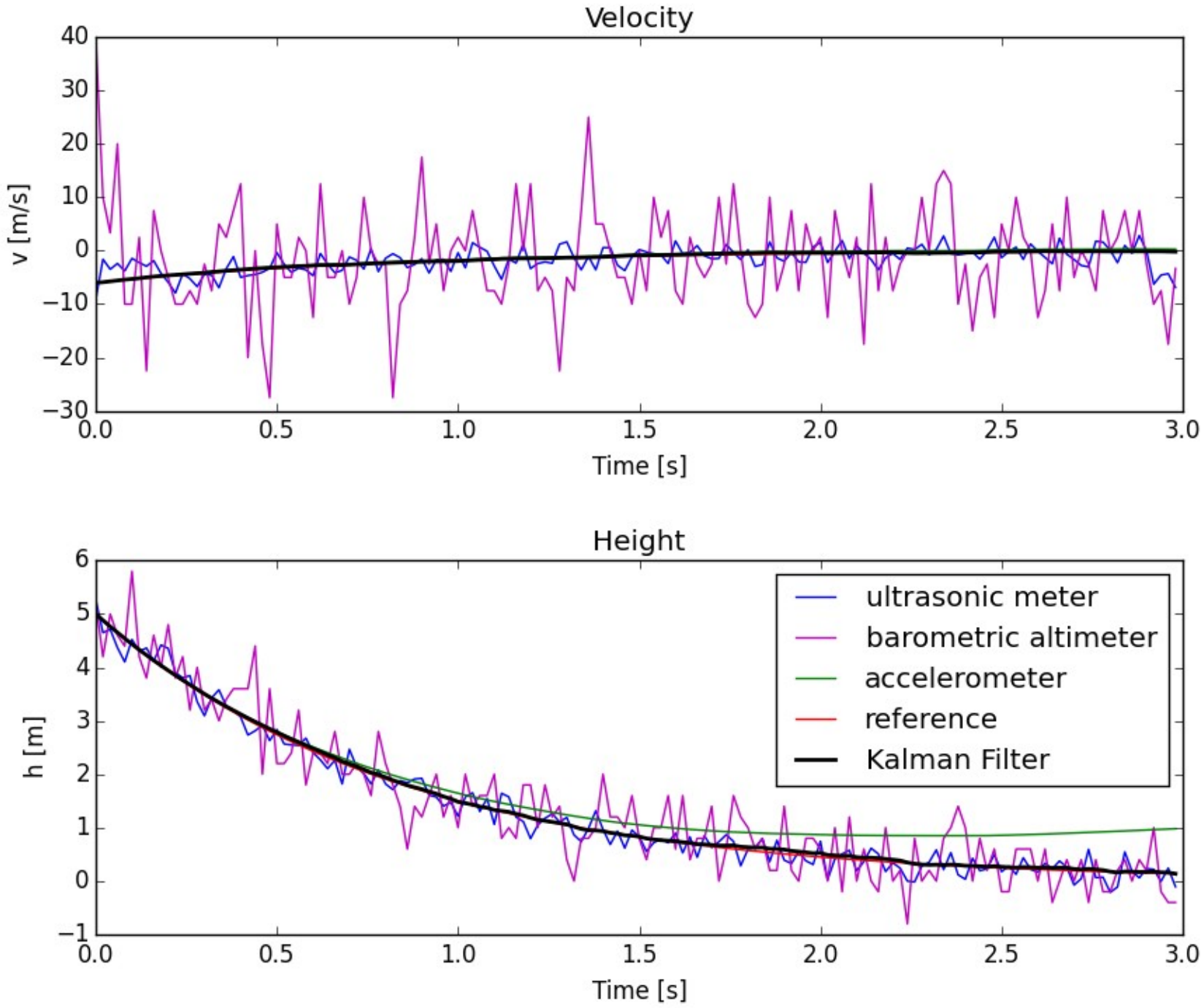
- White noise, σ = 0.2

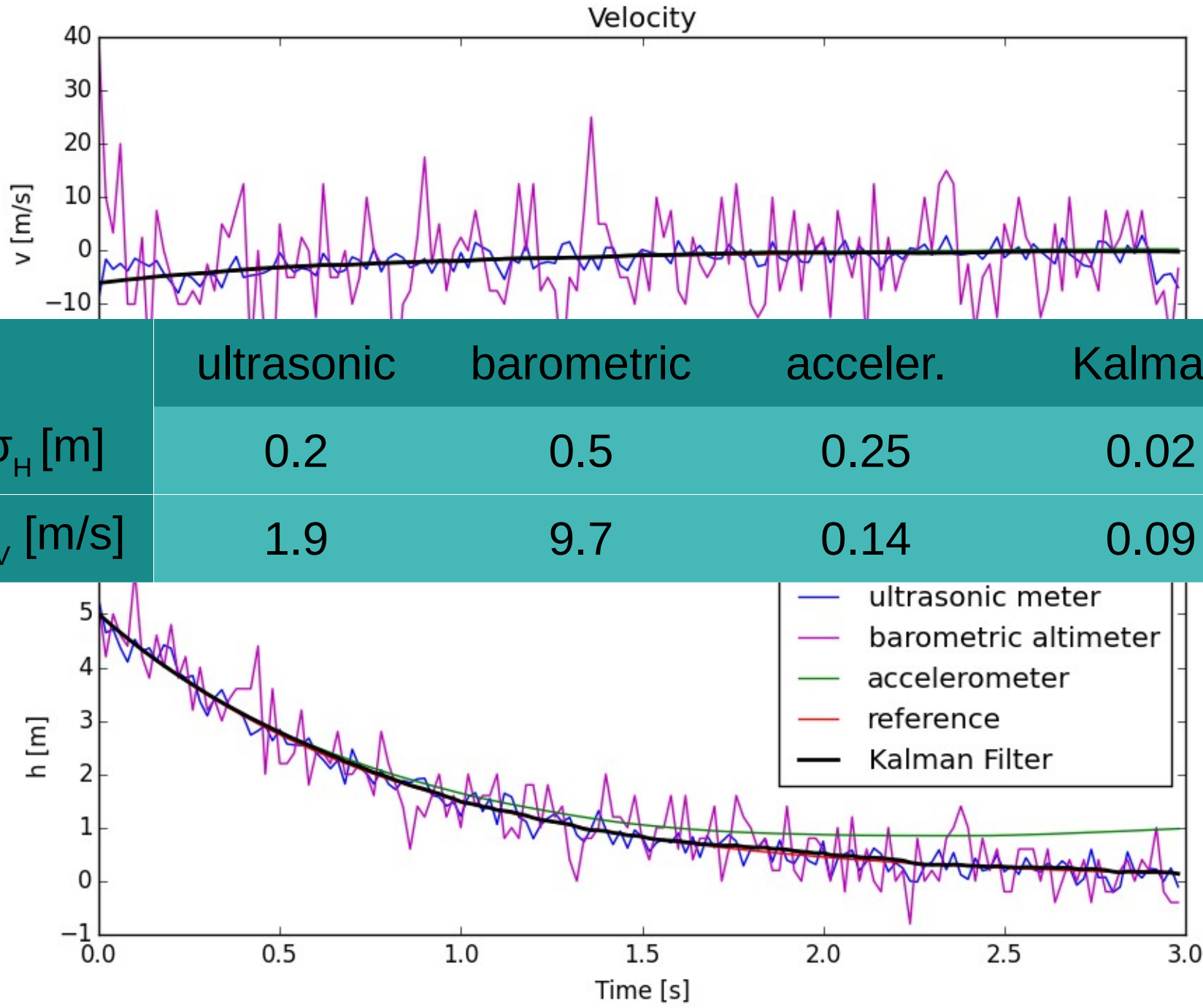


- White noise, σ = 0.5
- Resolution Δh = 0.2



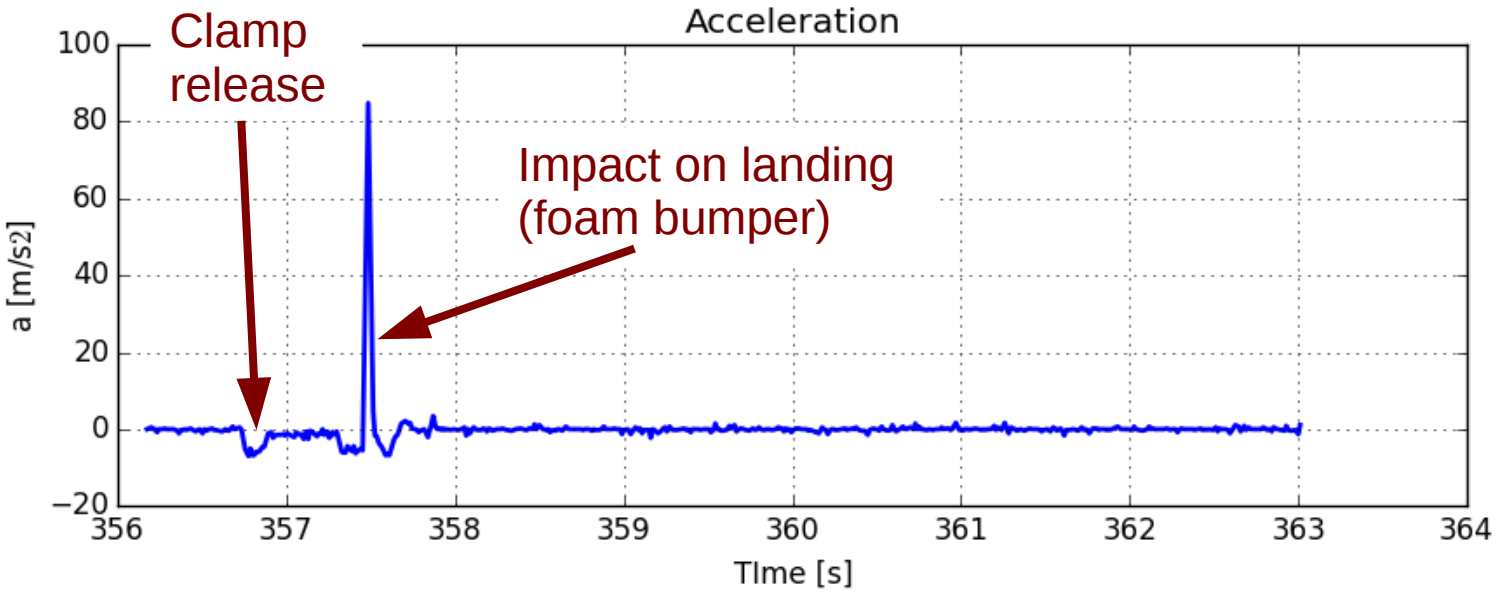
- White noise, σ = 2
- 3Hz and 50Hz harmonic interference
- Bias $\Delta a_c = 0.2$


Velocity
v [m/s]
Time [s]
Height
h [m]
Time [s]
ultrasonic meter
barometric altimeter
accelerometer
reference
Kalman Filter

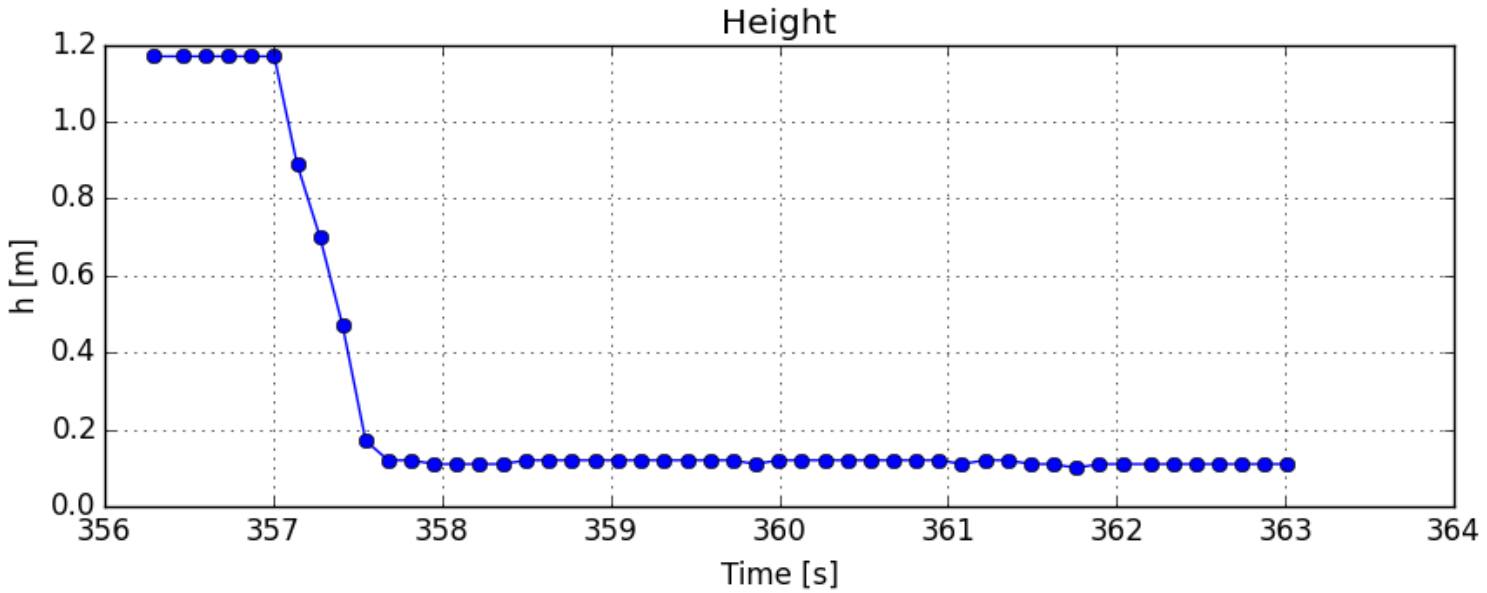


	ultrasonic	barometric	acceler.	Kalman
σ_H [m]	0.2	0.5	0.25	0.02
σ_V [m/s]	1.9	9.7	0.14	0.09

Live results from drop-test stand

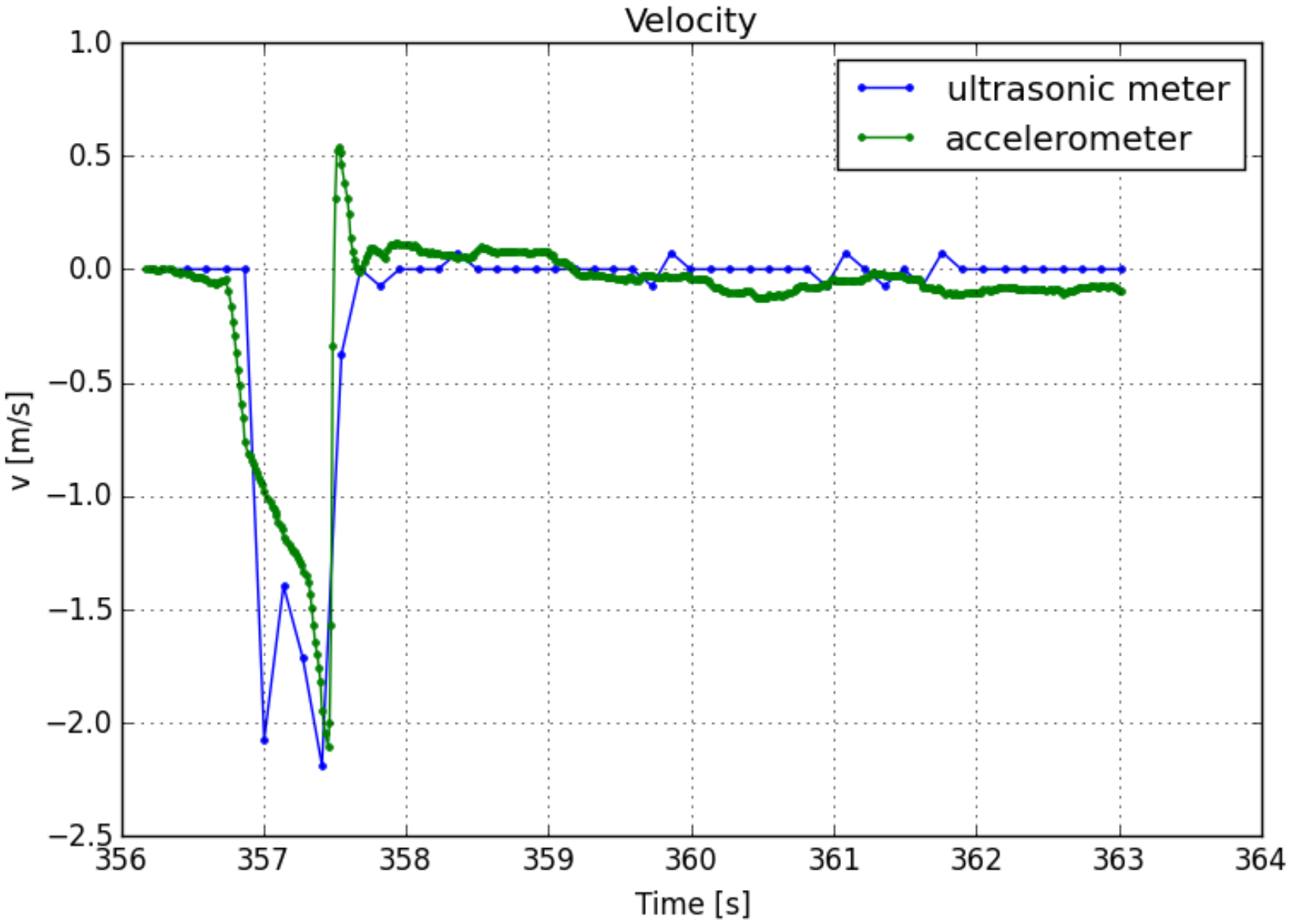


$f_a \approx 80Hz$

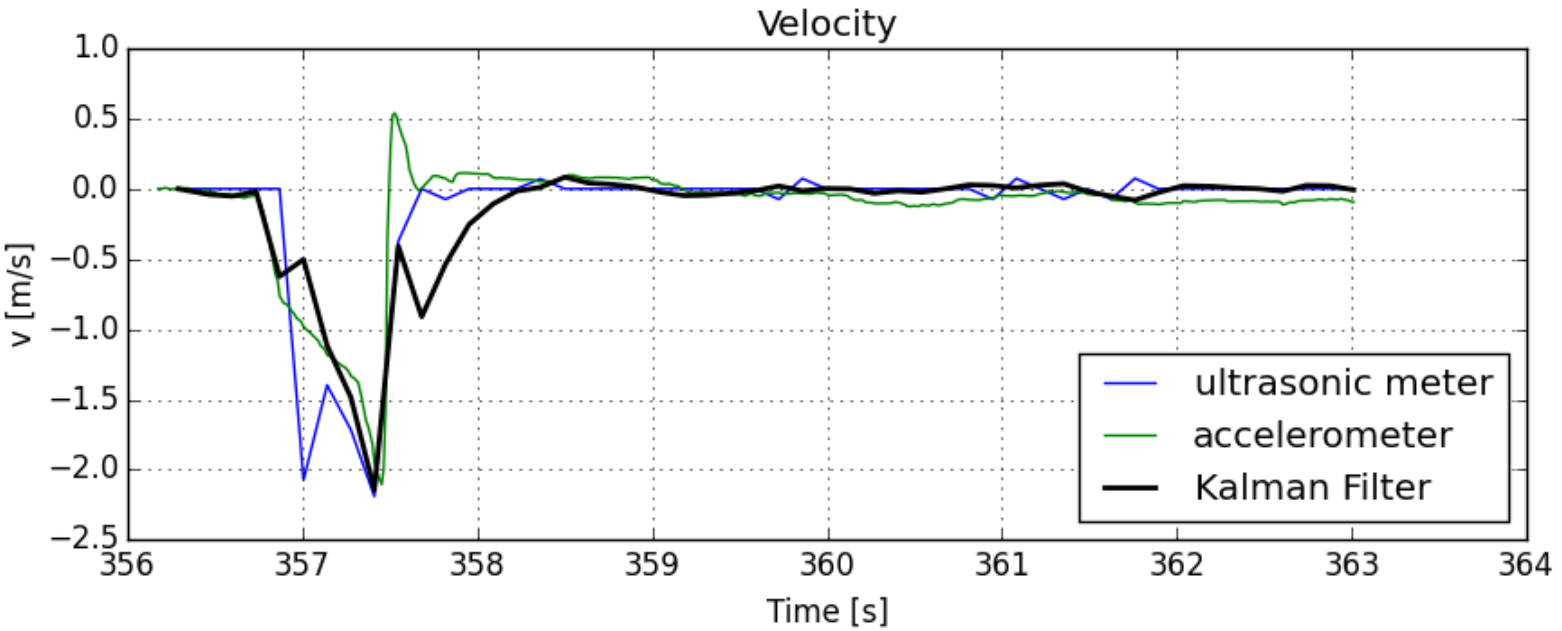


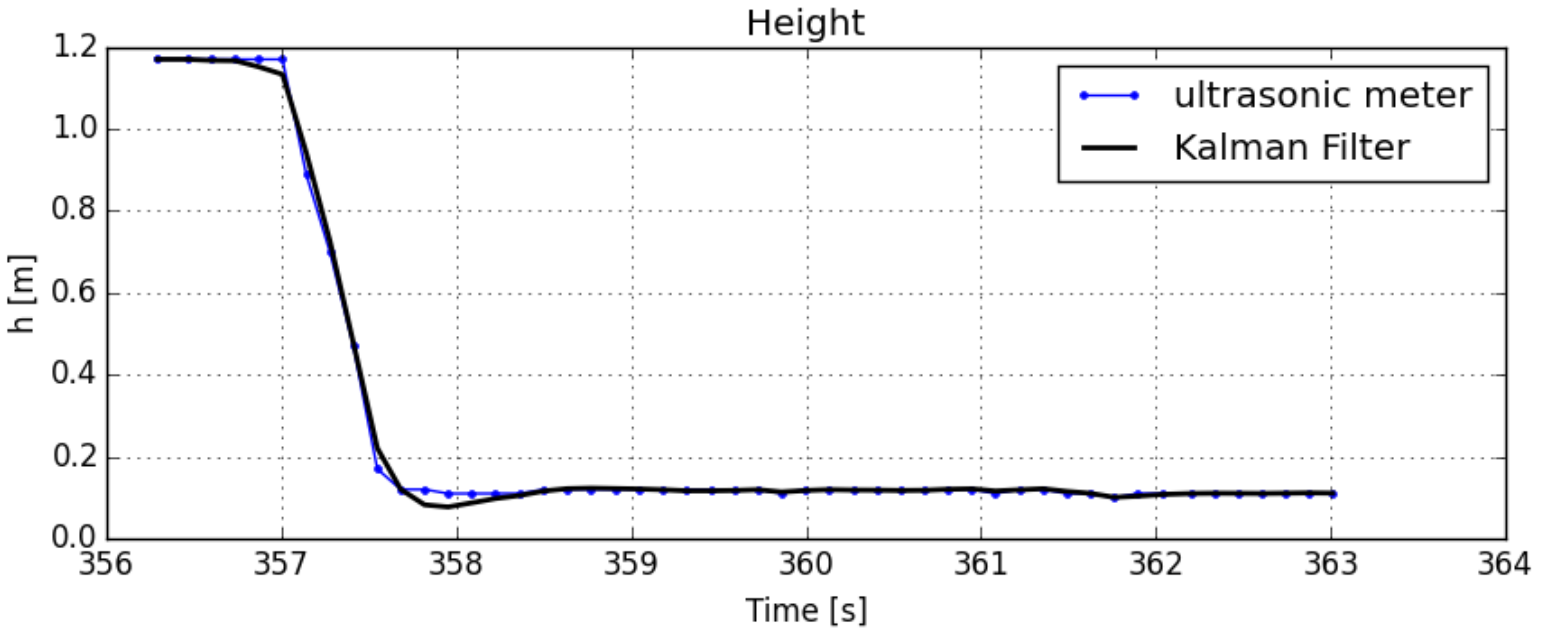
$F_h \approx 7.5Hz$

Live results from drop-test stand

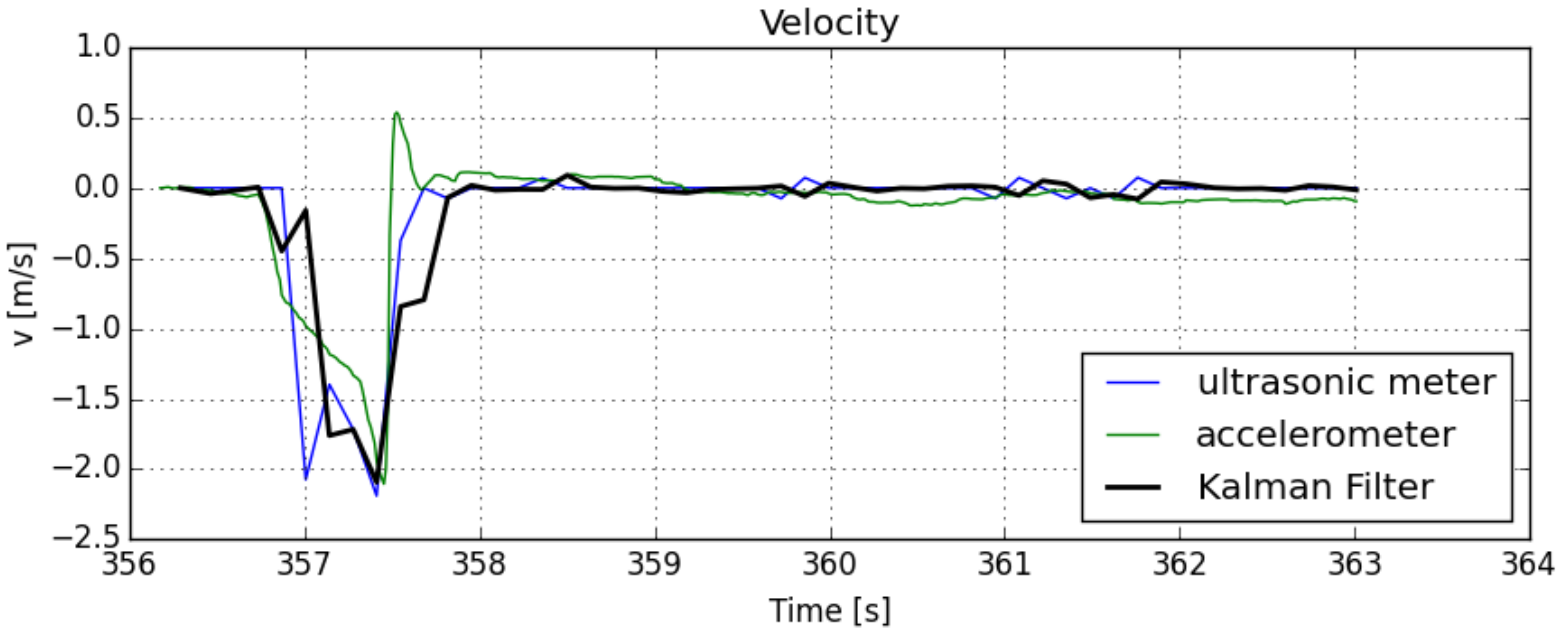


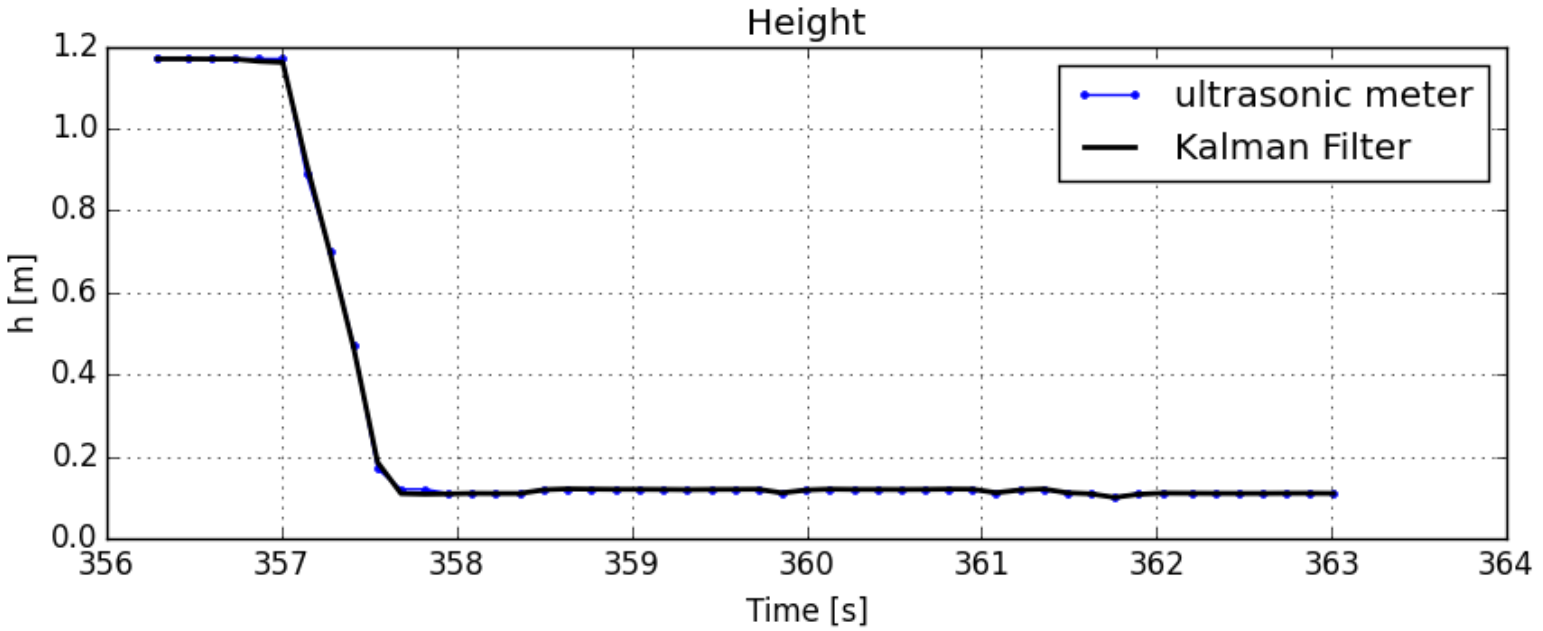
More or less optimal estimation, $\sigma_a = 1$ [m/s^2], $\sigma_h = 0.01$ [m]



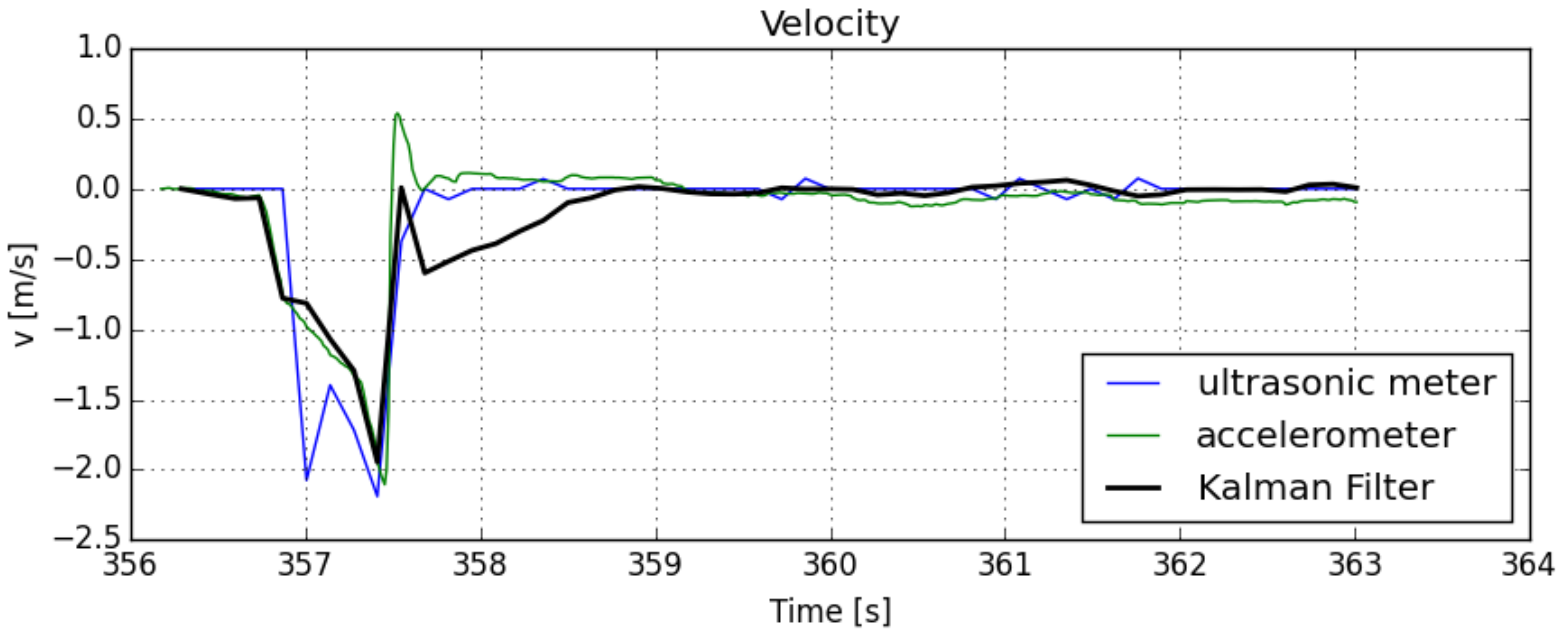


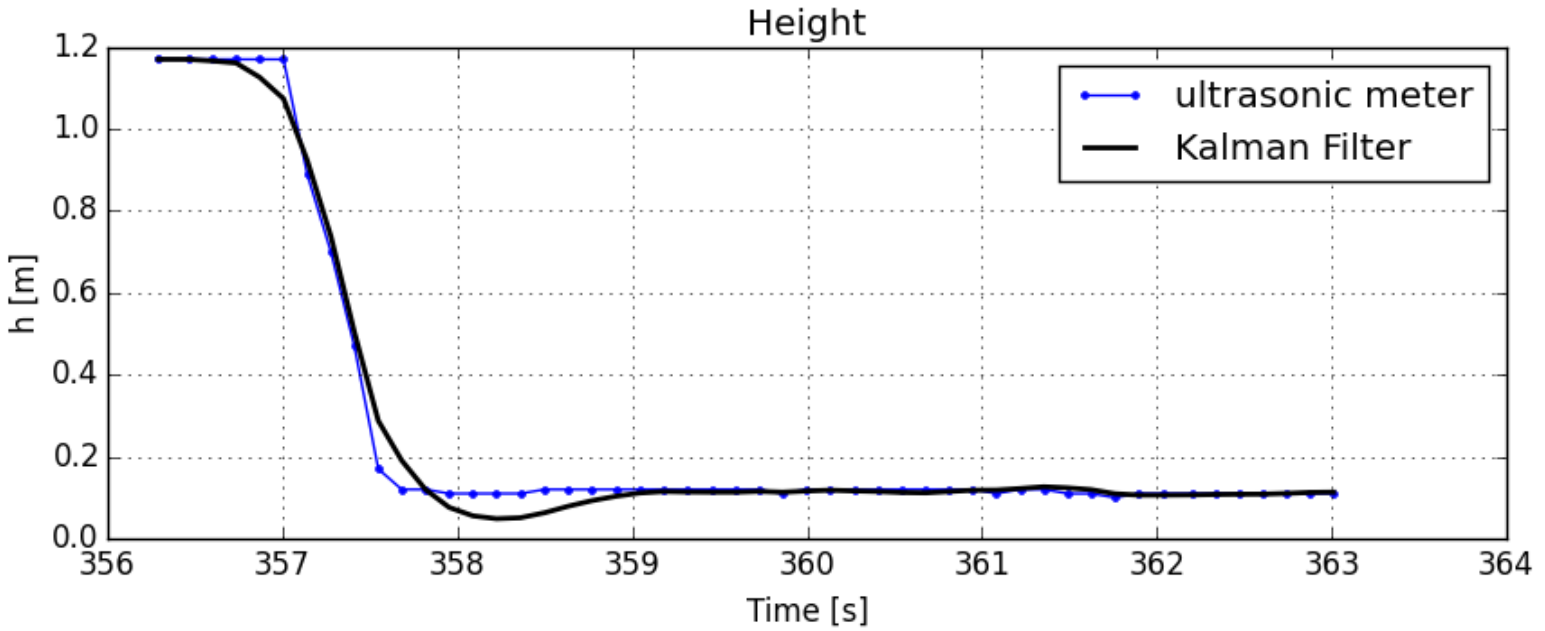
More confidence in distance, $\sigma_a = 2$ [m/s^2], $\sigma_h = 0.005$ [m]



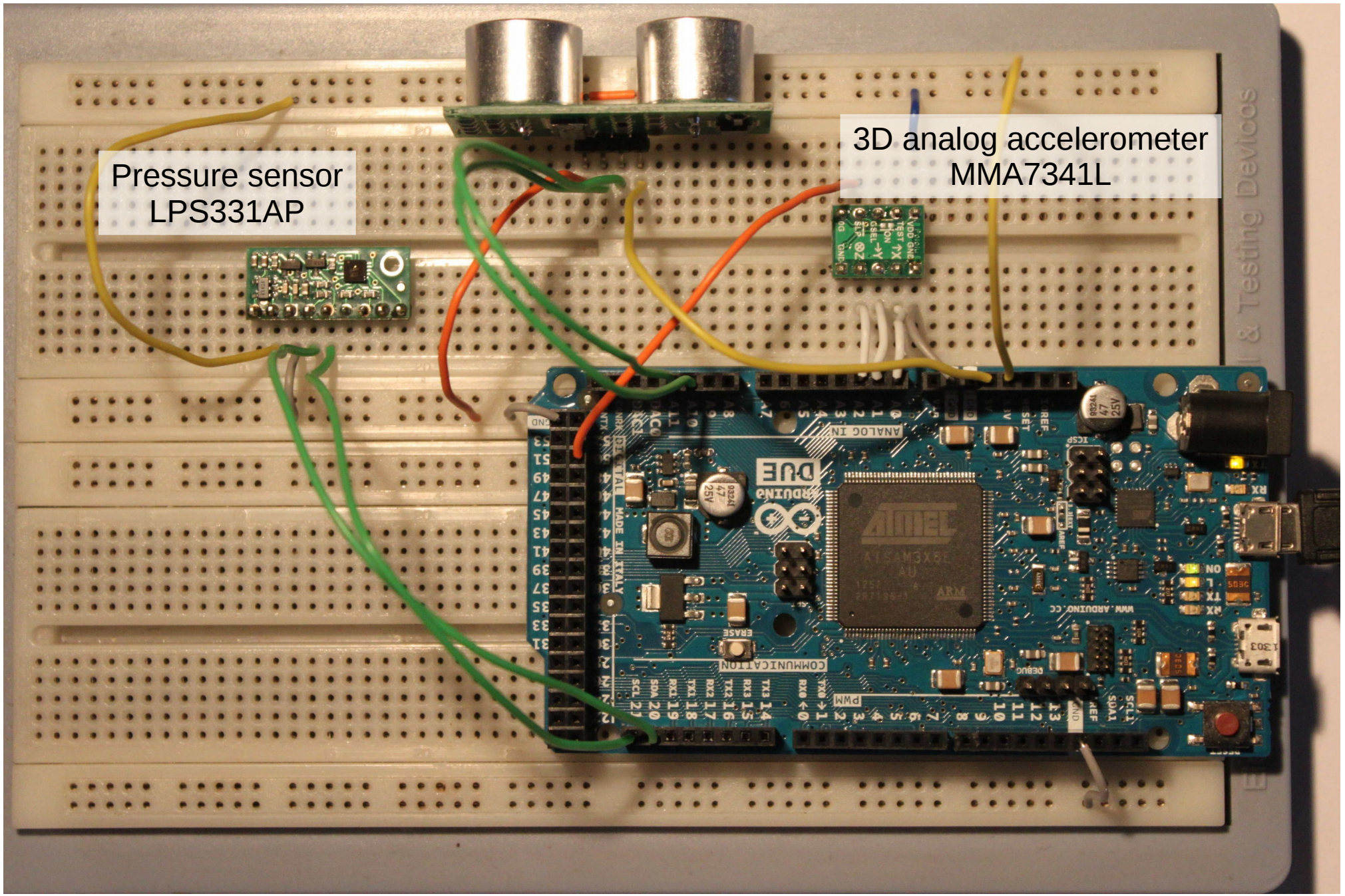


More confidence in acceleration, $\sigma_a = 0.5$ [m/s^2], $\sigma_h = 0.02$ [m]

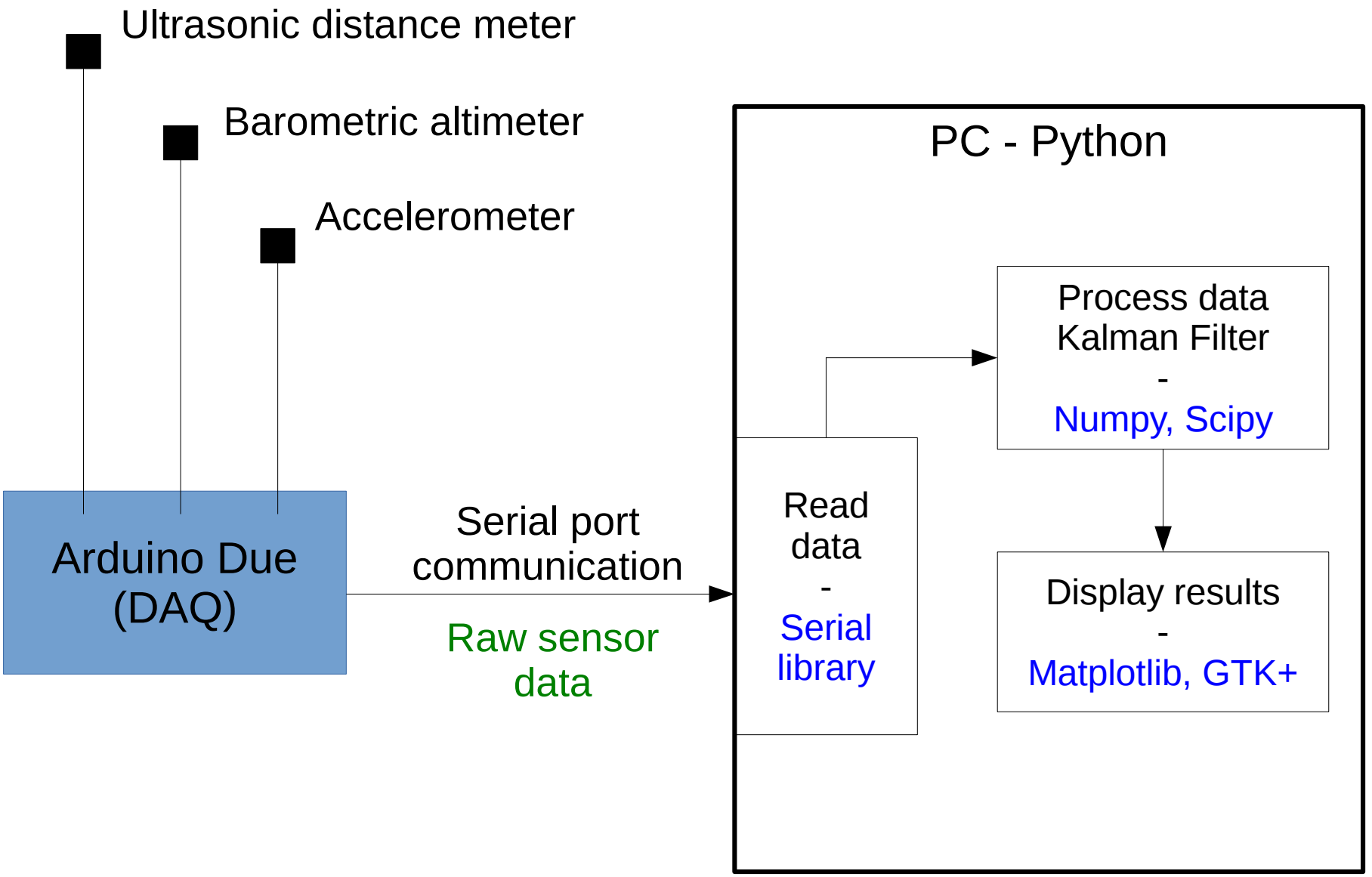




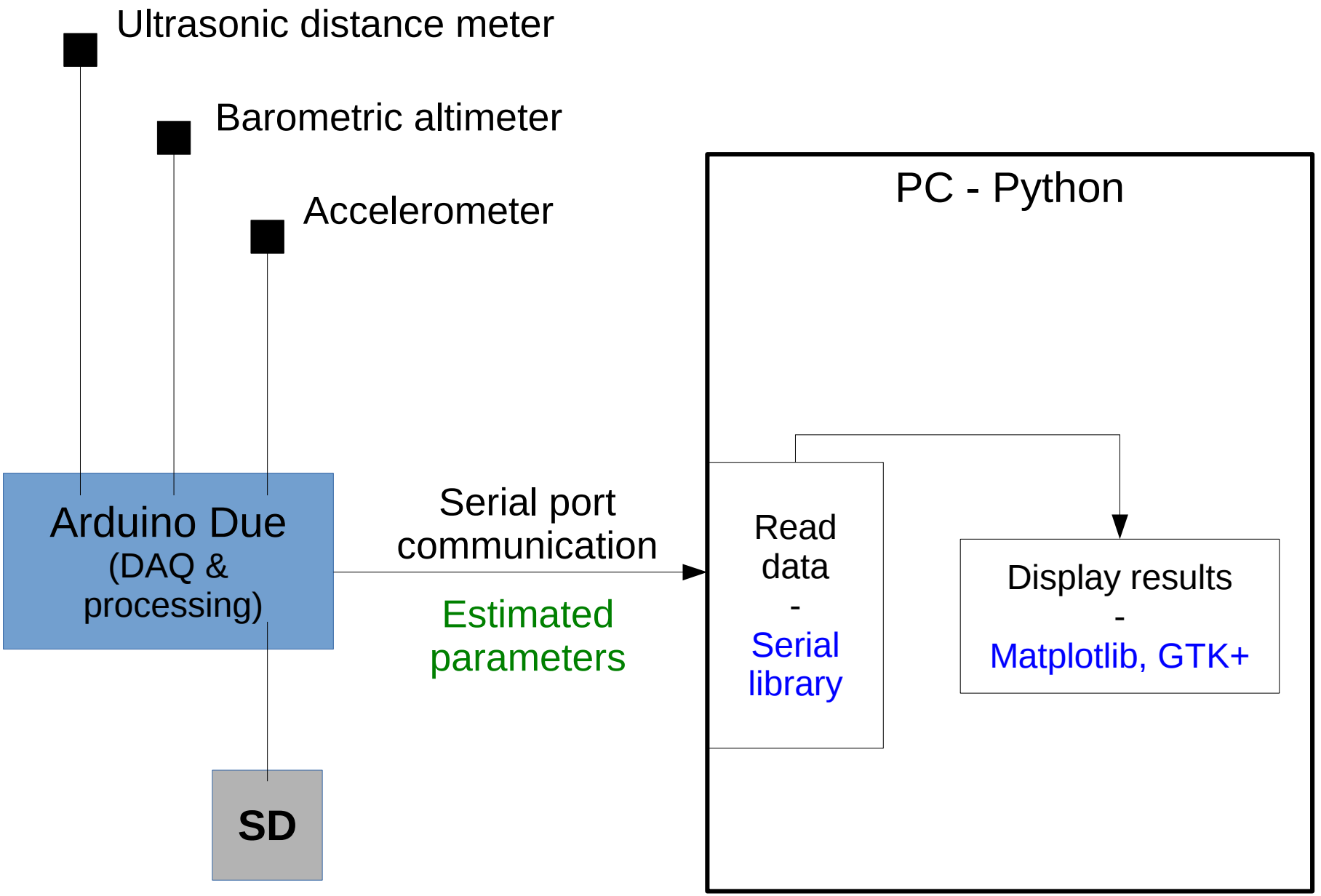
Ultrasonic sensor
US-015



Hardware prototype (ver.1)



Hardware prototype (ver.2)



Summary – what has been done

- Inertial orientation and position tracking
- Gait tracking
- Hybrid motion tracking systems

  off-line and on-line sensor fusion
- AVI system development
  - Velocity estimator for 1D hybrid system
  - Hadware prototype
- 3D position tracking for mobile robots

Summary – what's to be done

- Velocity estimation for 3D AVI system
- 3D position tracking for mobile robots
  - Distance estimation for MAV