Yaw Rate Estimation from Differential Wheel Speeds

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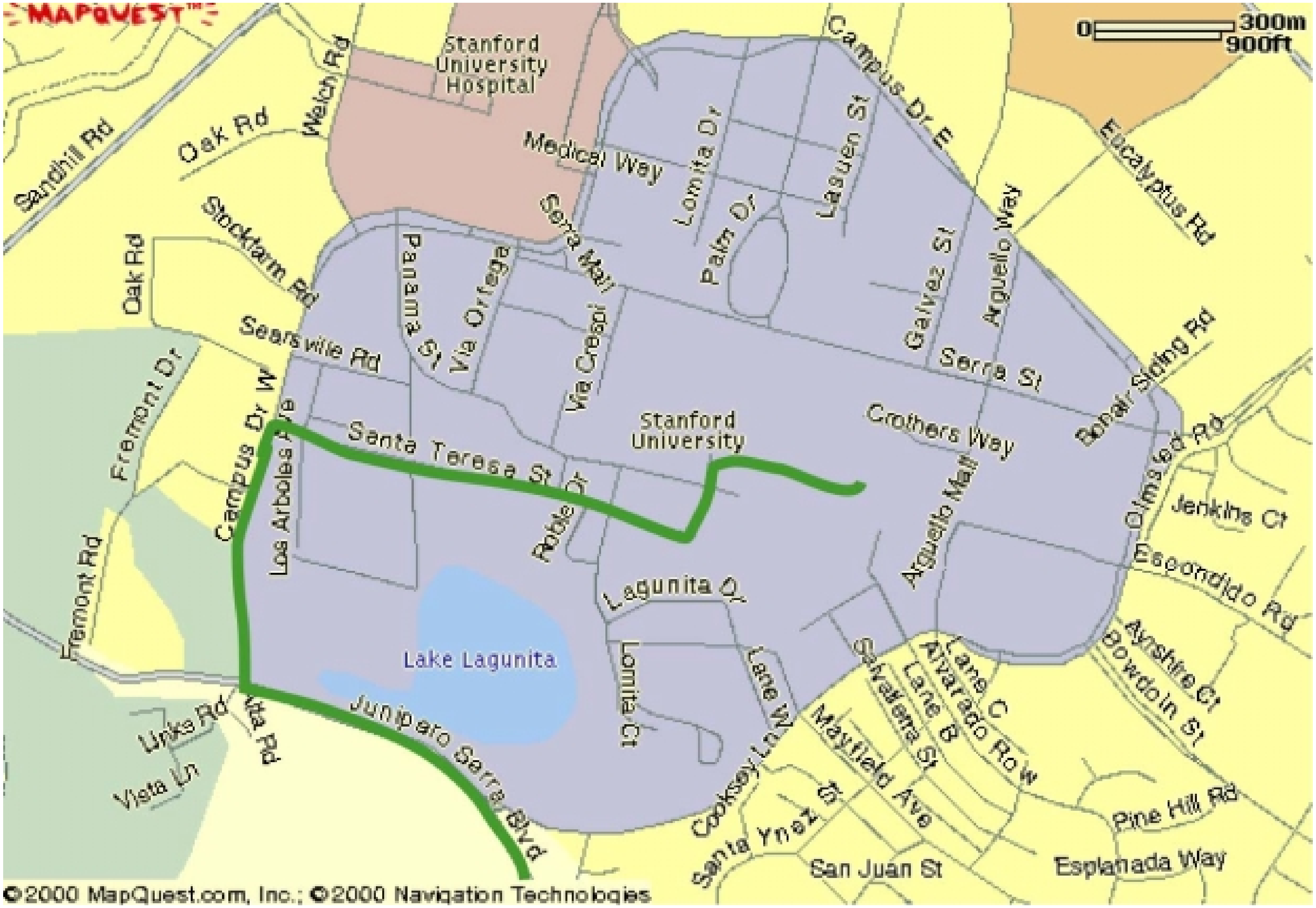
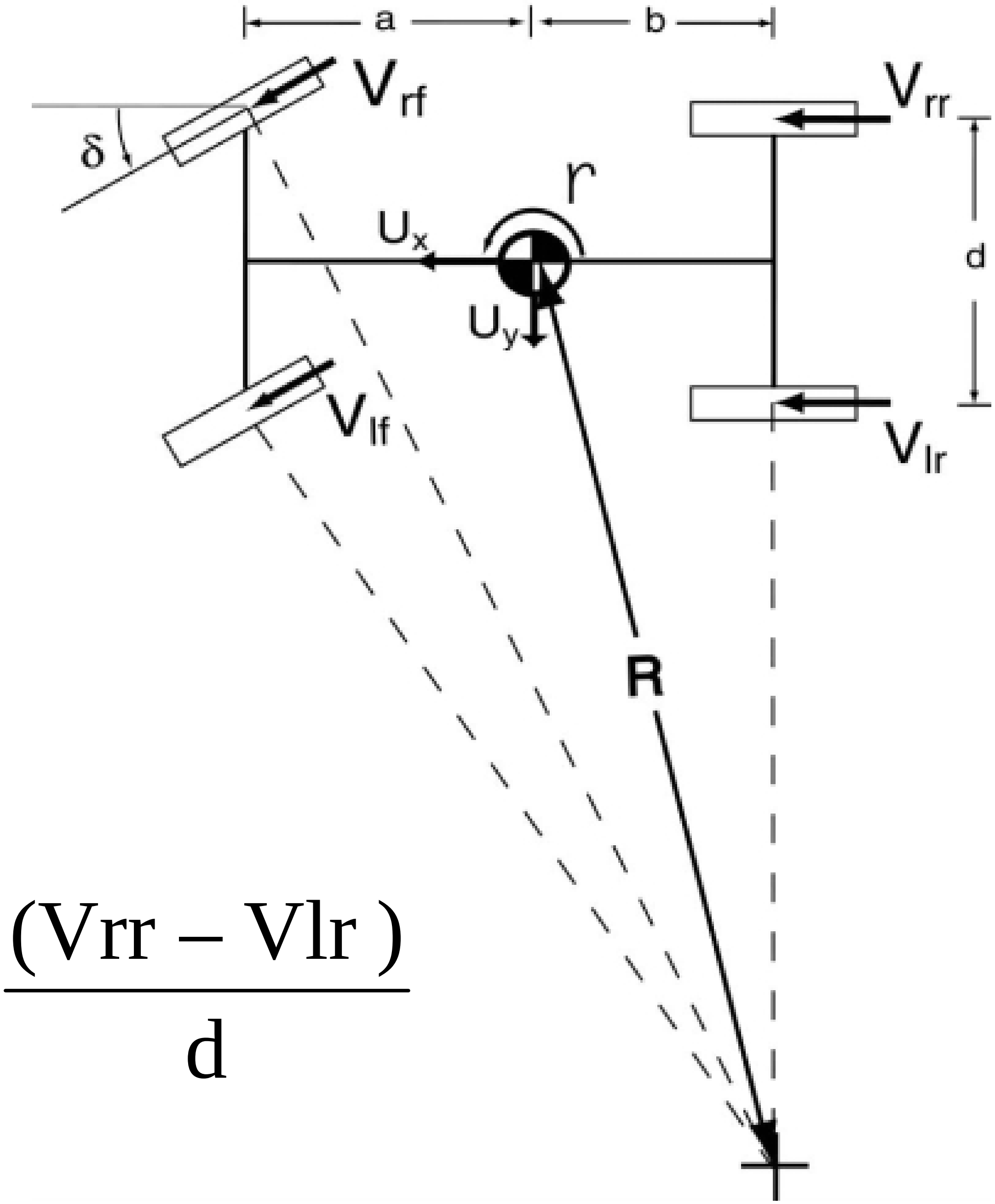
- Questions


MAPQUEST
Stanford University Hospital
Stanford University
Lake Lagunita
Sandhill Rd
Oak Rd
Welch Rd
Stockfarm Rd
Searsville Rd
Fremont Dr
Fremont Rd
Campus Dr W
Los Arboles Ave
Santa Teresa St
Panama St
Via Ortega
Medical Way
Serra Mall
Via Crespi
Roble Dr
Lomita Dr
Palm Dr
Lasuen St
Campus Dr E
Galvez St
Arguello Way
Serra St
Crothers Way
Arguello Mall
Eucalyptus Rd
Bonair Siding Rd
Olmsted Rd
Jenkins Ct
Escondido Rd
Lagunita Dr
Lomita Ct
Lane W
Cooksey Ln
Junipero Serra Blvd
Links Rd
Vista Ln
Mayfield Ave
Salvatierra St
Lane B
Lane C
Alvarado Row
Ayrshire Ct
Bowdoin St
Pine Hill Rd
Esplanada Way
San Juan St
Santa Ynez St
0
300m
900ft
©2000 MapQuest.com, Inc.; ©2000 Navigation Technologies

Motivation

- Vehicle navigation during GPS dropouts
- Yaw gyros add additional expense
- ABS is standard on many vehicles today
- Need high accuracy: signals are integrated

Yaw Rate Estimation



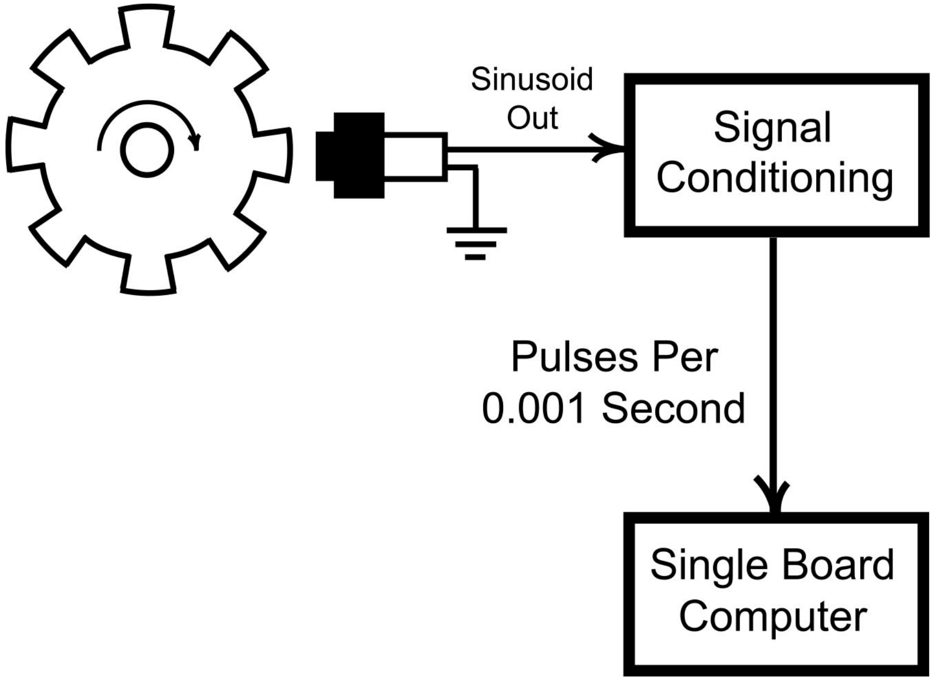
$$r = \frac{(Vrf - Vlf\ )}{d \bullet \cos(\delta)} = \frac{(Vrr - Vlr\ )}{d}$$

Wheel Radius Estimation

$$R = \frac{V}{\omega}$$

```
if (not yawing){
   Compare rev/sec to GPS velocity
}
else{
   Output last non-yaw result
}
```

Wheel Speed Sensor



- Stock ABS
- Variable Reluctance
- 48 [teeth/rev]
- Digital Counter

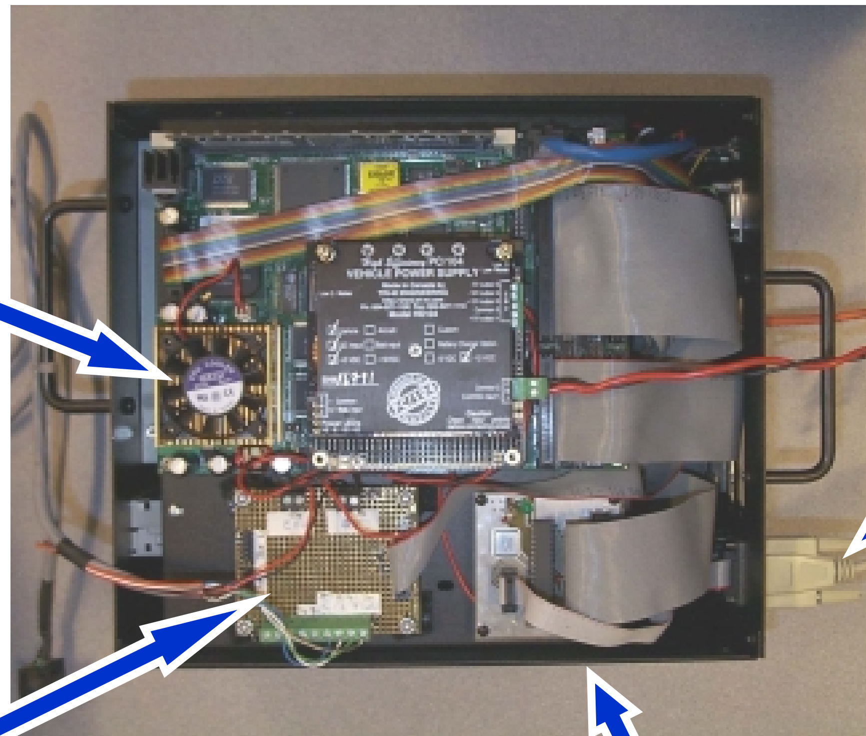
Novatel GPS

- Velocity @ 20 [Hz]
- Accuracy 0.2 [m/s]

Bosch Yaw Rate Sensor

- Range: 100 [deg/s]
- BW: >30 [Hz]

Single Board Computer

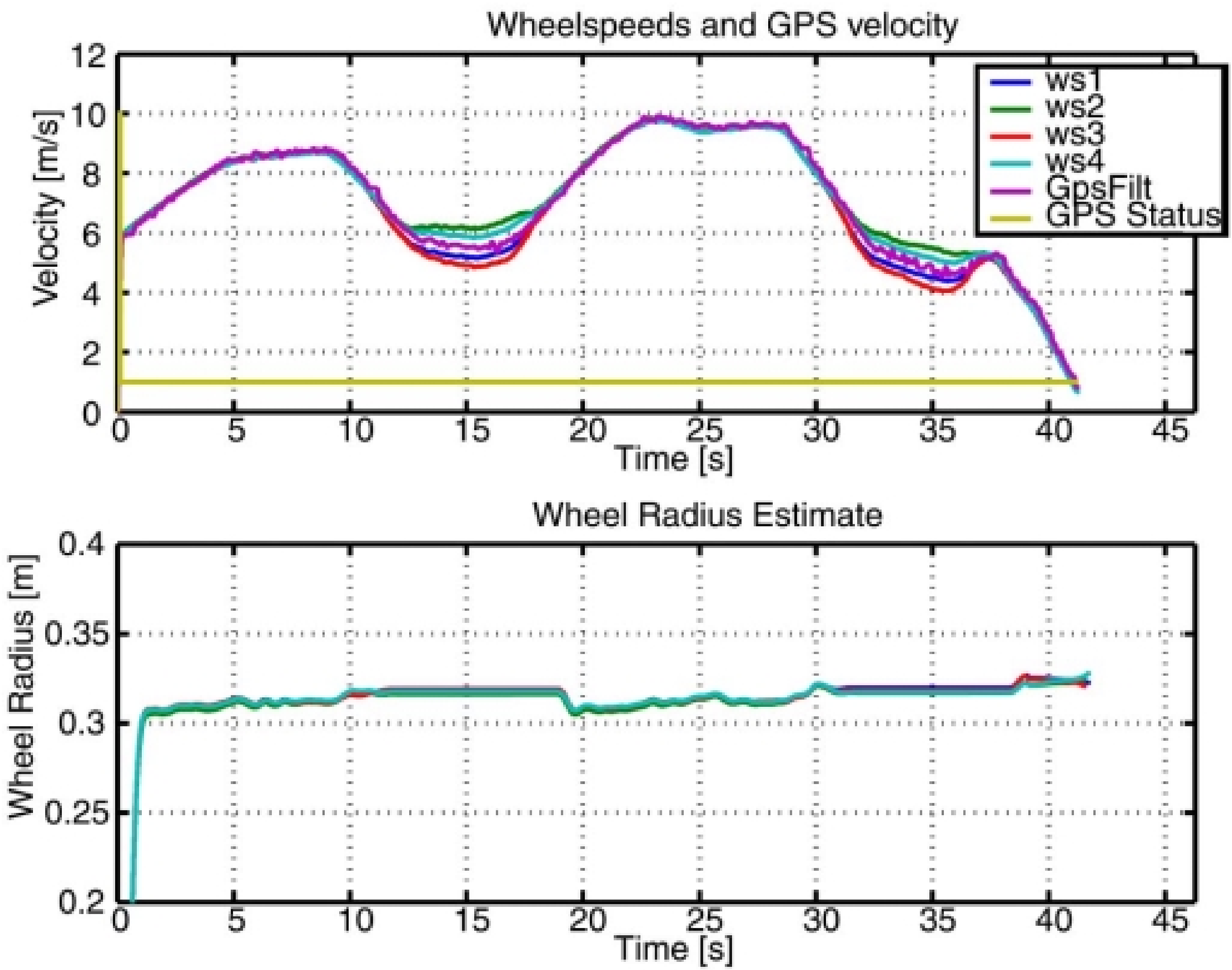


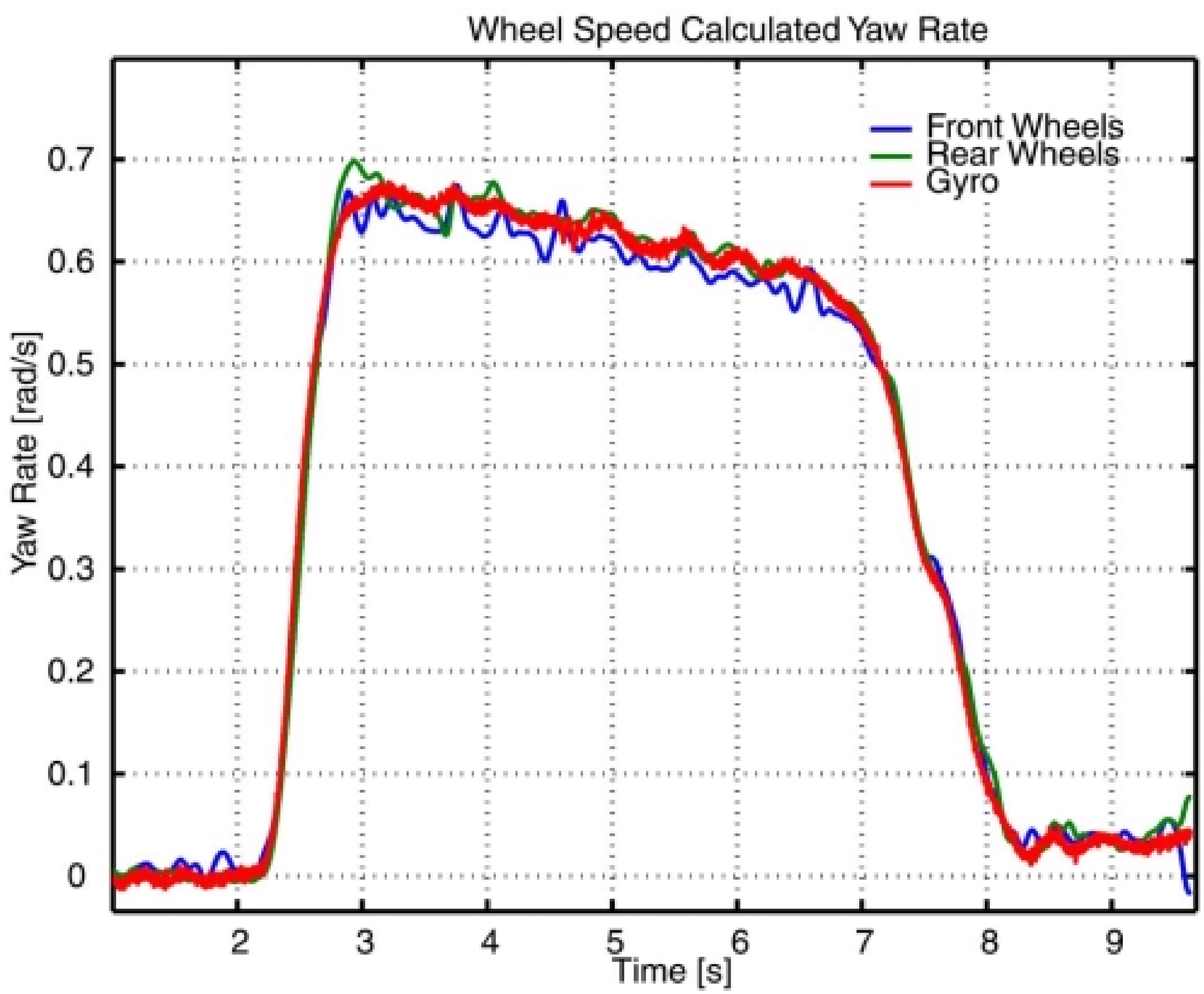
AMD K6 350

GPS
Data
Port

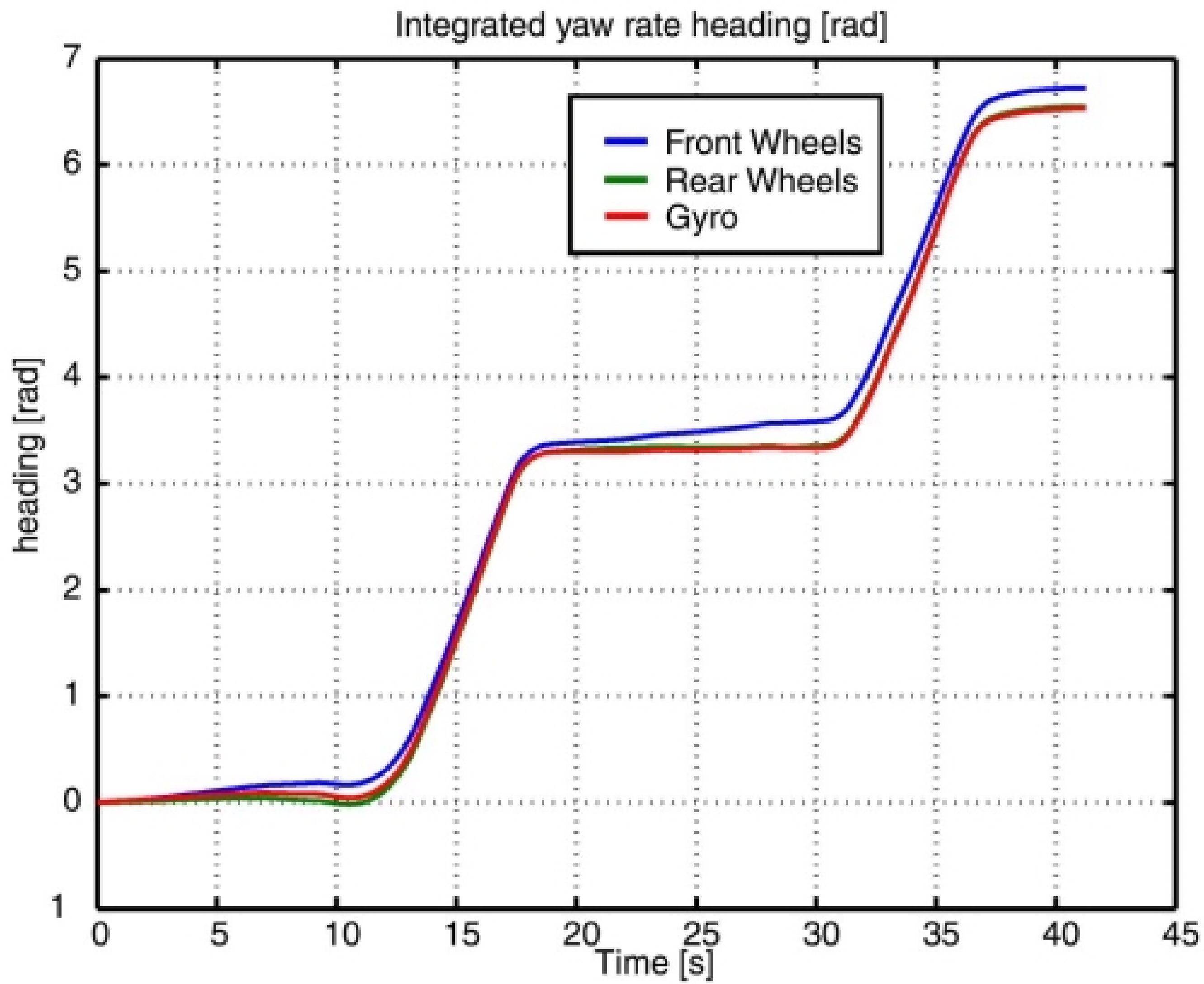
Analog I/O

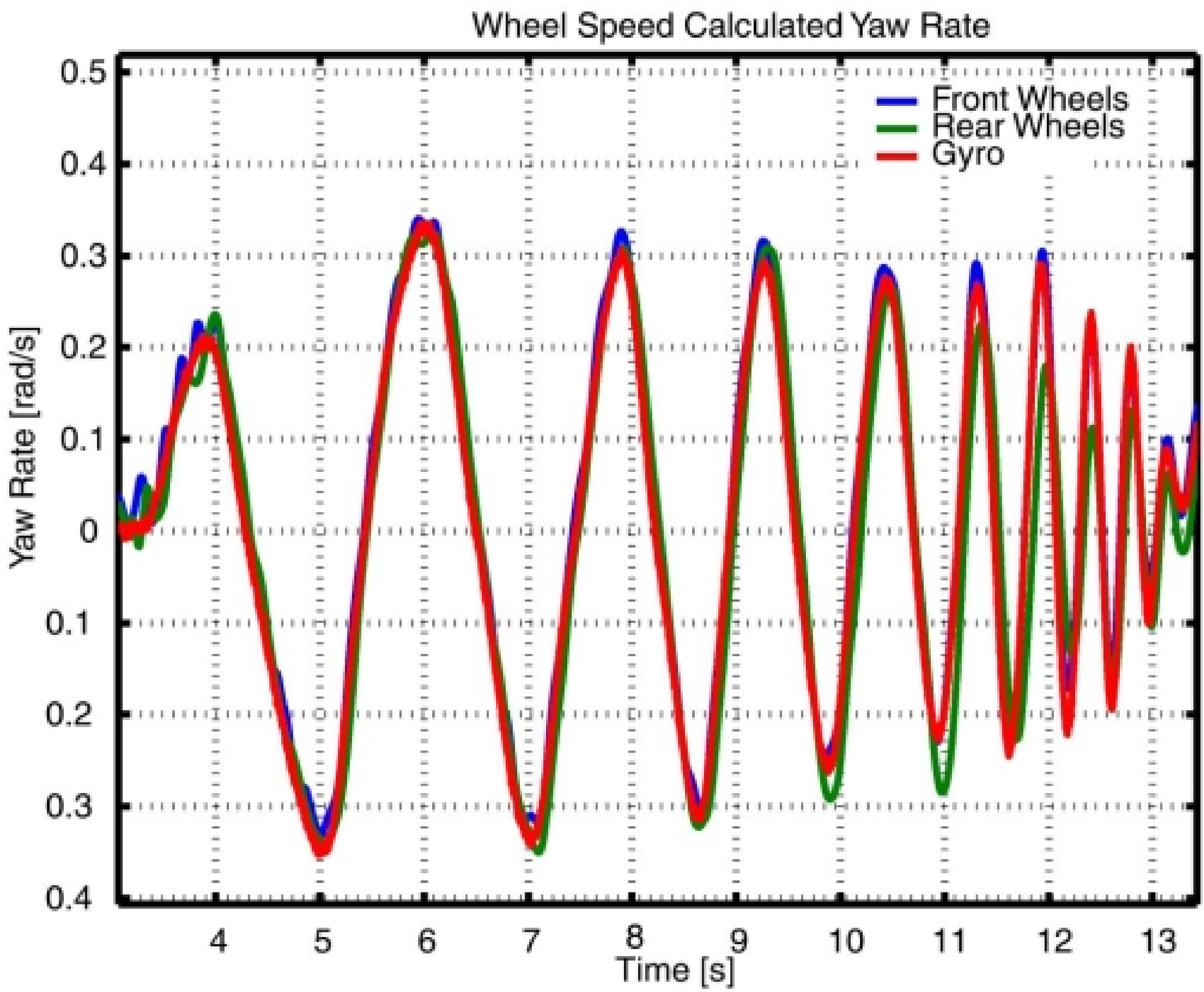
Wheel Speed Interface


Wheelspeeds and GPS velocity
Velocity [m/s]
Time [s]
ws1
ws2
ws3
ws4
GpsFilt
GPS Status
Wheel Radius Estimate
Wheel Radius [m]
Time [s]

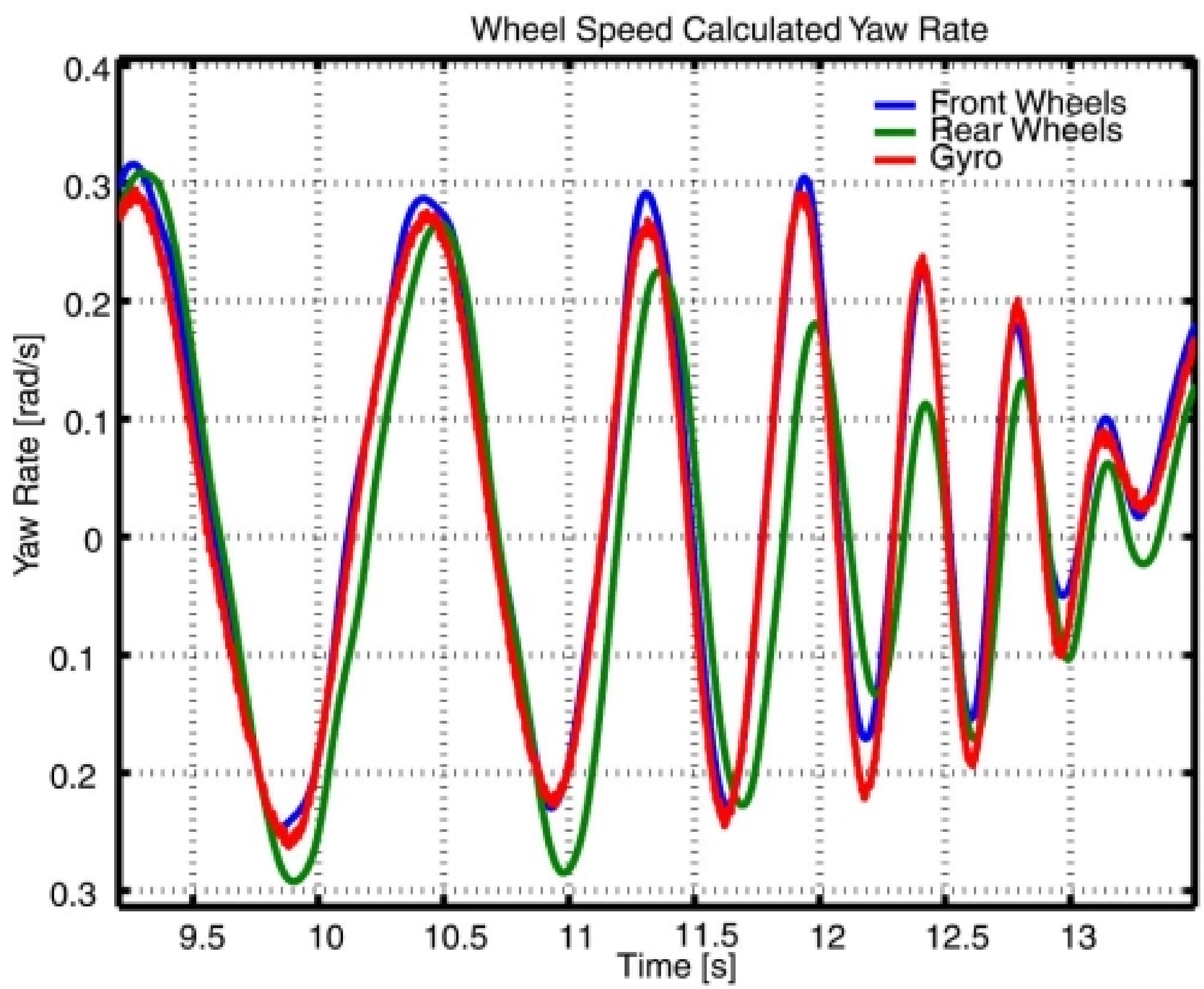


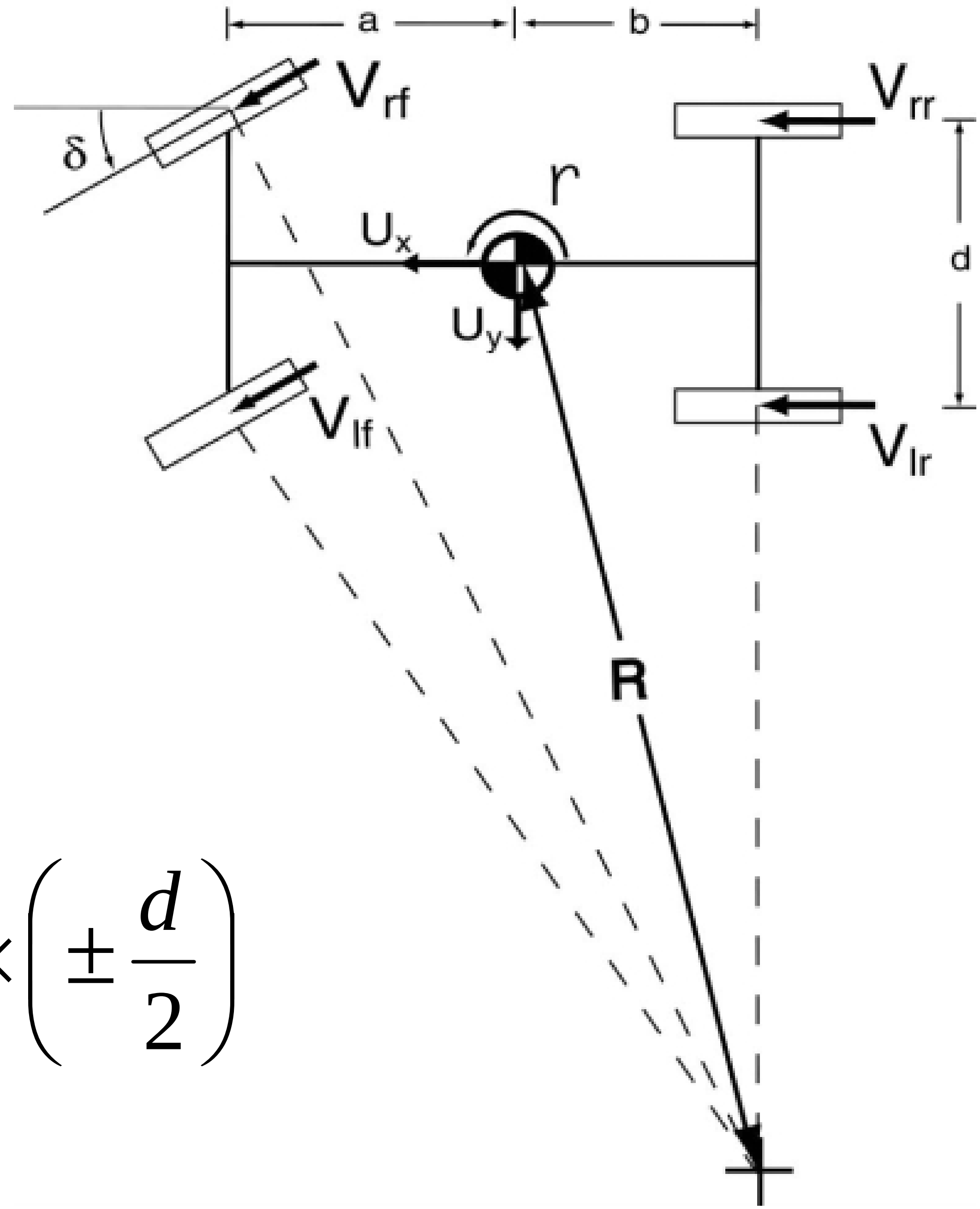
Wheel Speed Calculated Yaw Rate
Front Wheels
Rear Wheels
Gyro
Yaw Rate [rad/s]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
2
3
4
5
6
7
8
9
Time [s]


Integrated yaw rate heading [rad]
Front Wheels
Rear Wheels
Gyro
heading [rad]
Time [s]

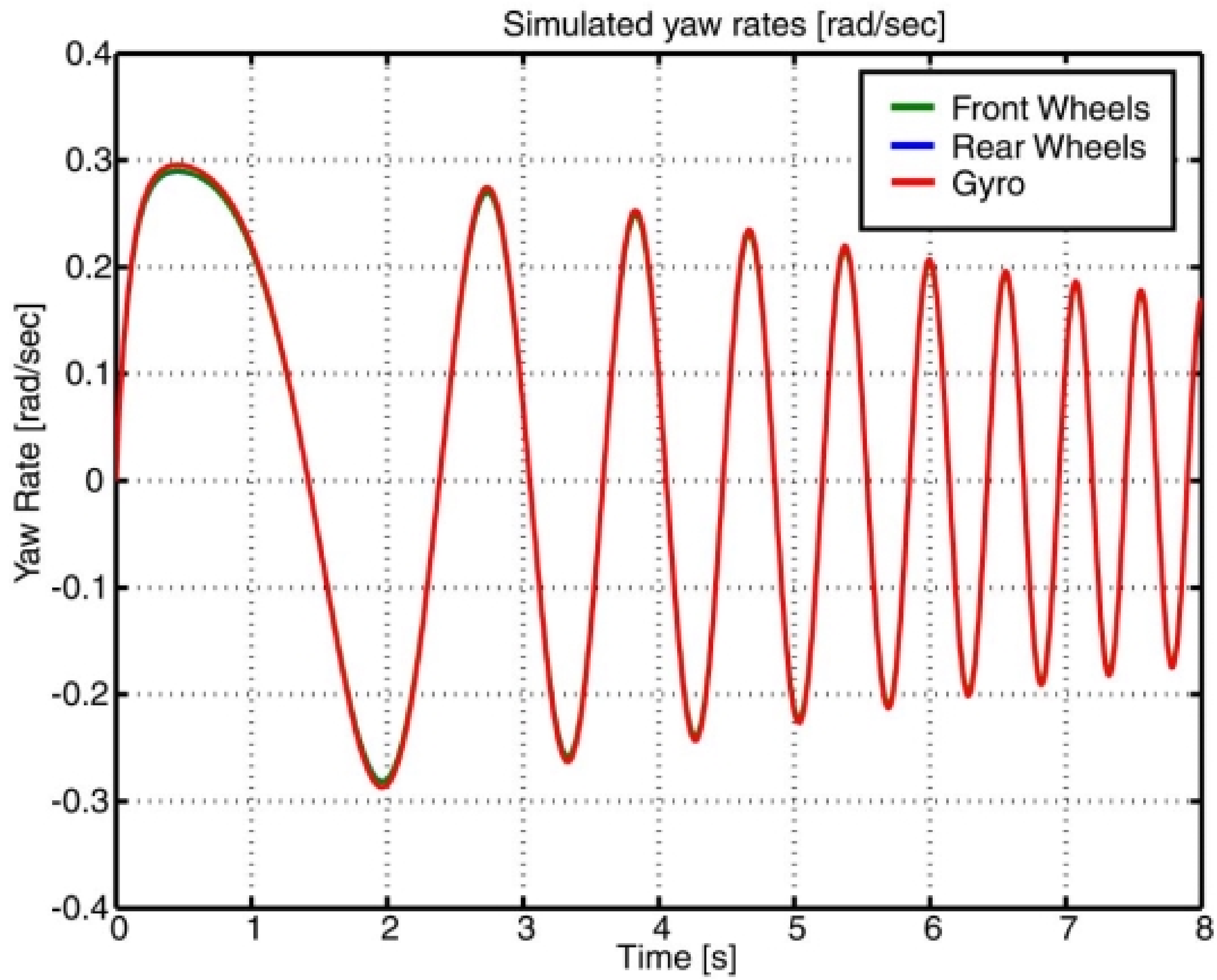


Wheel Speed Calculated Yaw Rate
Front Wheels
Rear Wheels
Gyro
Yaw Rate [rad/s]
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
4
5
6
7
8
9
10
11
12
13
Time [s]


Wheel Speed Calculated Yaw Rate
Front Wheels
Rear Wheels
Gyro
Yaw Rate [rad/s]
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
9.5
10
10.5
11
11.5
12
12.5
13
Time [s]



$$V_{rear} = V_{CG} + r \times \left(\pm \frac{d}{2} \right)$$


Simulated yaw rates [rad/sec]
Front Wheels
Rear Wheels
Gyro
Yaw Rate [rad/sec]
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
1
2
3
4
5
6
7
8
Time [s]

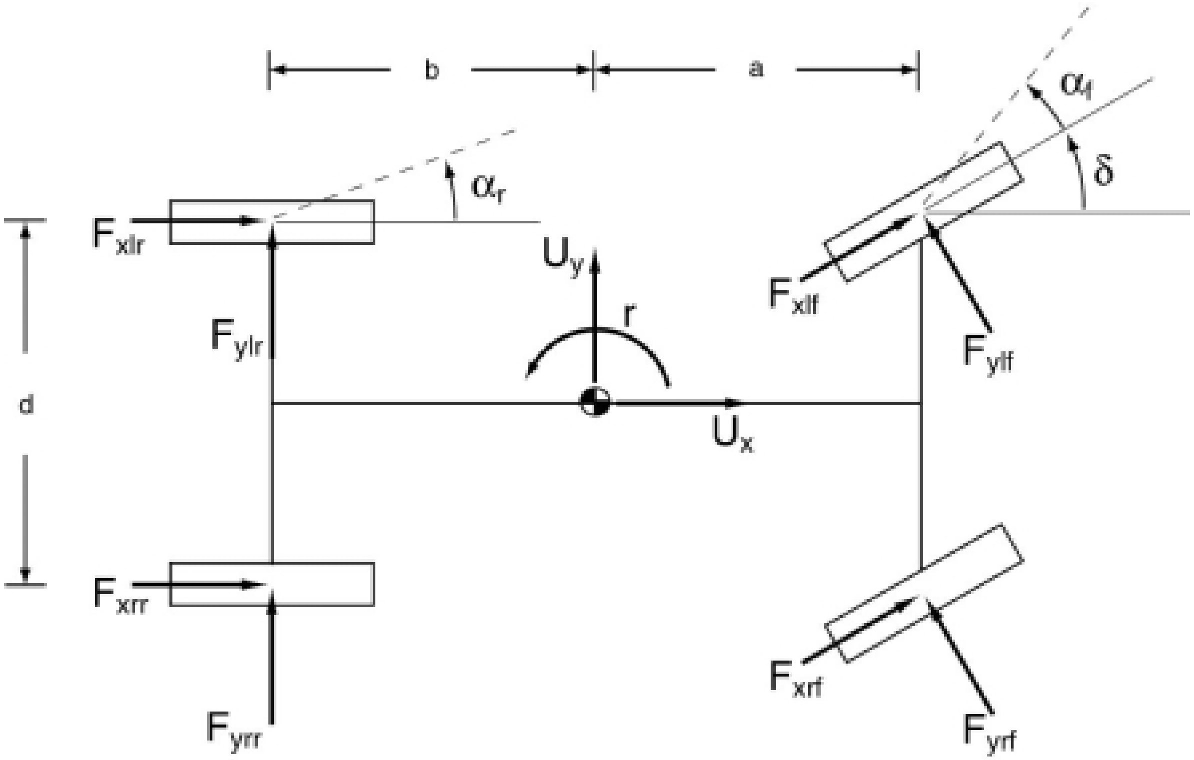
Future Directions

- Look at a dynamic model to compensate for lag in rear wheel yaw rate estimate
  - First order slip model
  - Side Slip?
- Model Reduction
  - How can we know quantitatively when our model is good enough?

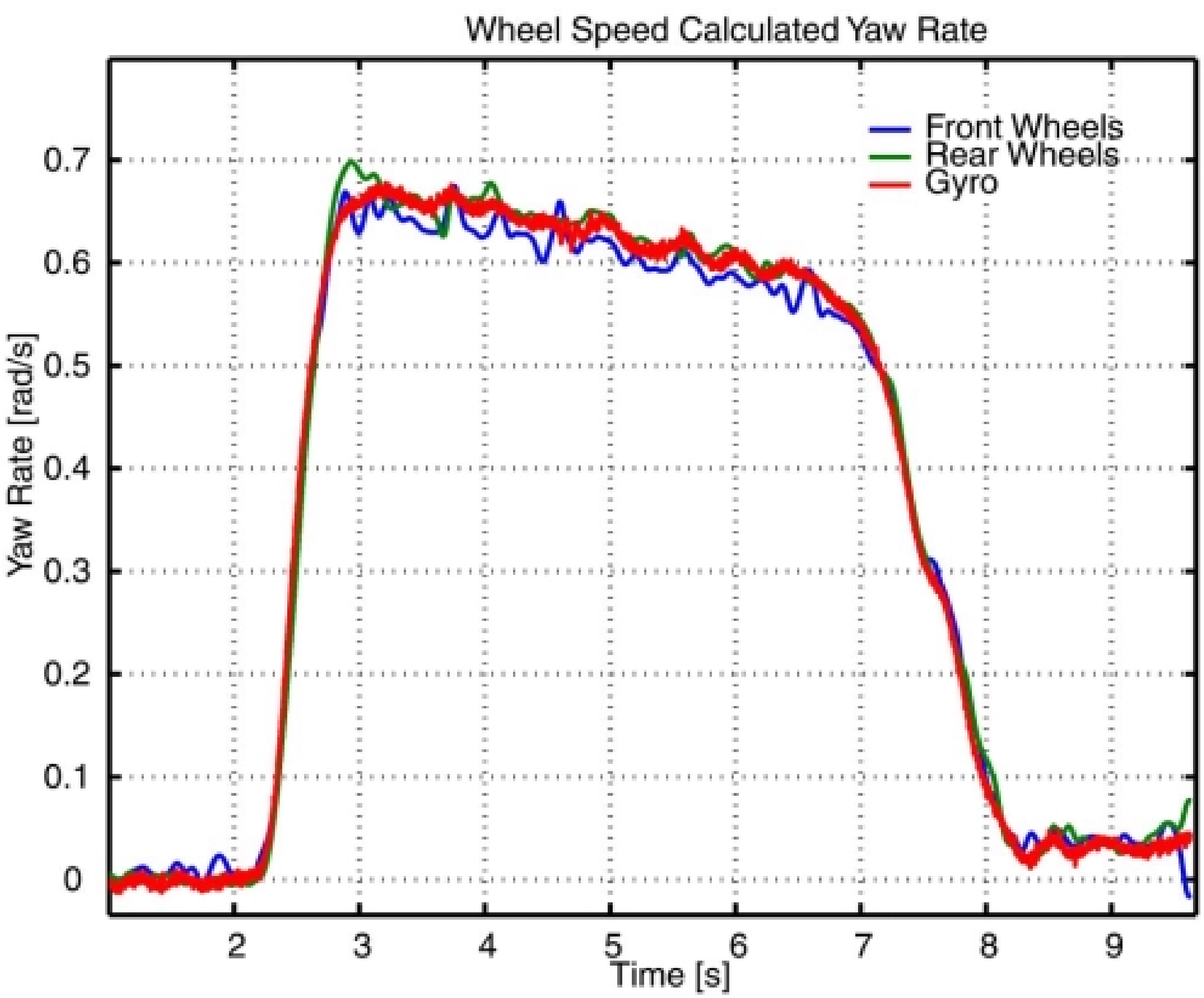
Conclusion

- First pass system shows promise
- The smaller the error, the longer we can keep a good estimate of attitude
- Need to increase model sophistication

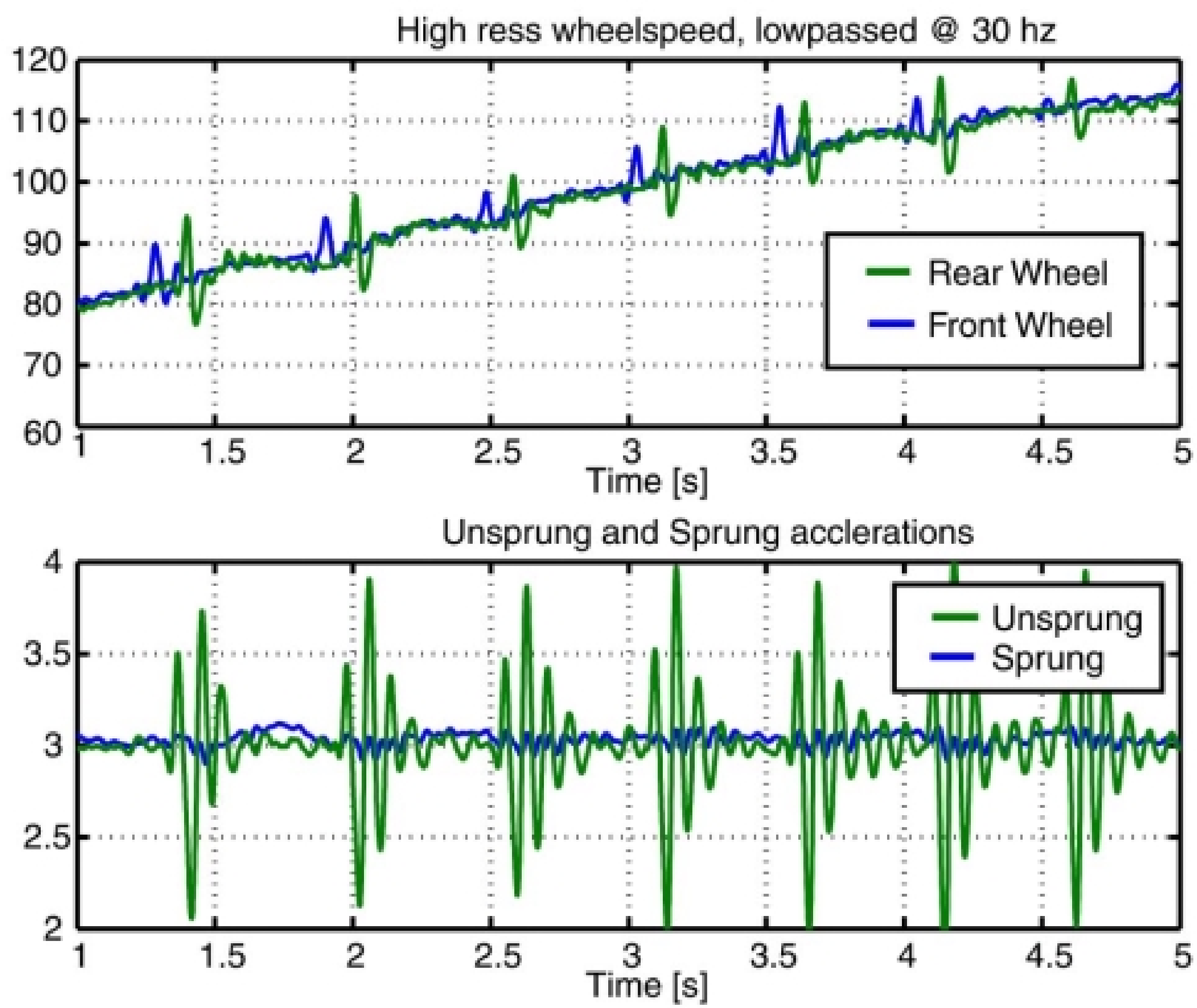
Questions

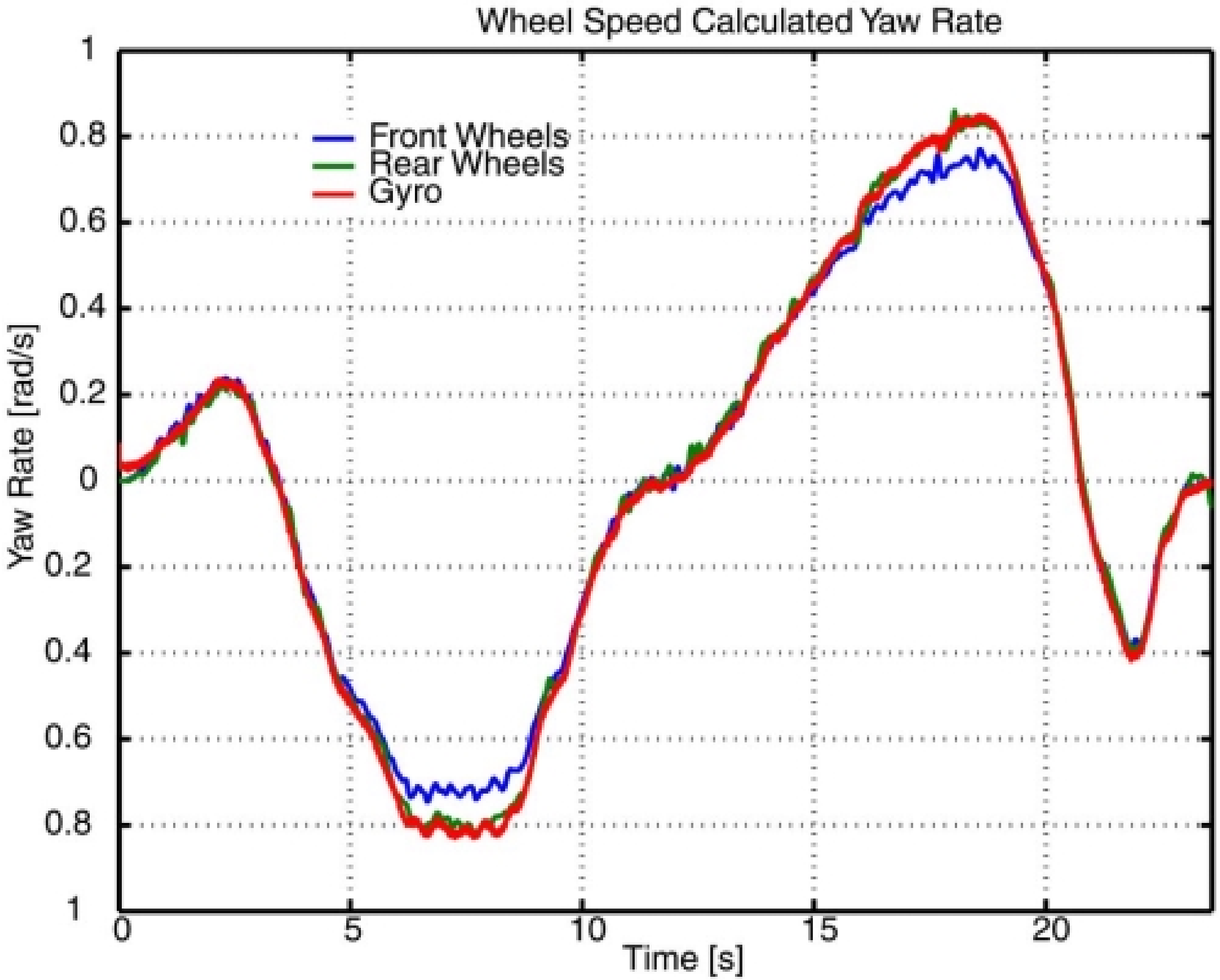


$$
\begin{aligned}
\dot{U}_x &= \frac{F_{xr} + F_{xf}\cos(\delta) - F_{yf}\sin(\delta)}{m} + U_y\dot{\psi} \\
\dot{U}_y &= \frac{F_{yr} + F_{yf}\cos(\delta) + F_{xf}\sin(\delta)}{m} - U_x\dot{\psi} \\
\ddot{\psi} &= \frac{a\left\{F_{yf}\cos(\delta) + F_{xf}\sin(\delta)\right\} - bF_{yr}}{I_{CG}}
\end{aligned}
$$



Wheel Speed Calculated Yaw Rate
Front Wheels
Rear Wheels
Gyro
Yaw Rate [rad/s]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
2
3
4
5
6
7
8
9
Time [s]


High ress wheelspeed, lowpassed @ 30 hz
Rear Wheel
Front Wheel
Time [s]
Unsprung and Sprung acclerations
Unsprung
Sprung
Time [s]



Wheel Speed Calculated Yaw Rate
Front Wheels
Rear Wheels
Gyro
Yaw Rate [rad/s]
Time [s]
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20