Catamaran Identification

Table of Contents

1. Model of the Catamaran

Catamaran vehicle has been modeled by two decoupled dynamics:

- **Longitudinal dynamic**

$$v_{SS} = f_v(u_v)$$
$$v = G_v(s)v_{SS}$$

- **Yaw rate dynamic**

$$\omega_{SS} = f_\omega(u_\omega)$$
$$\omega = G_\omega(s)\omega_{SS}$$

In the previous formulas:

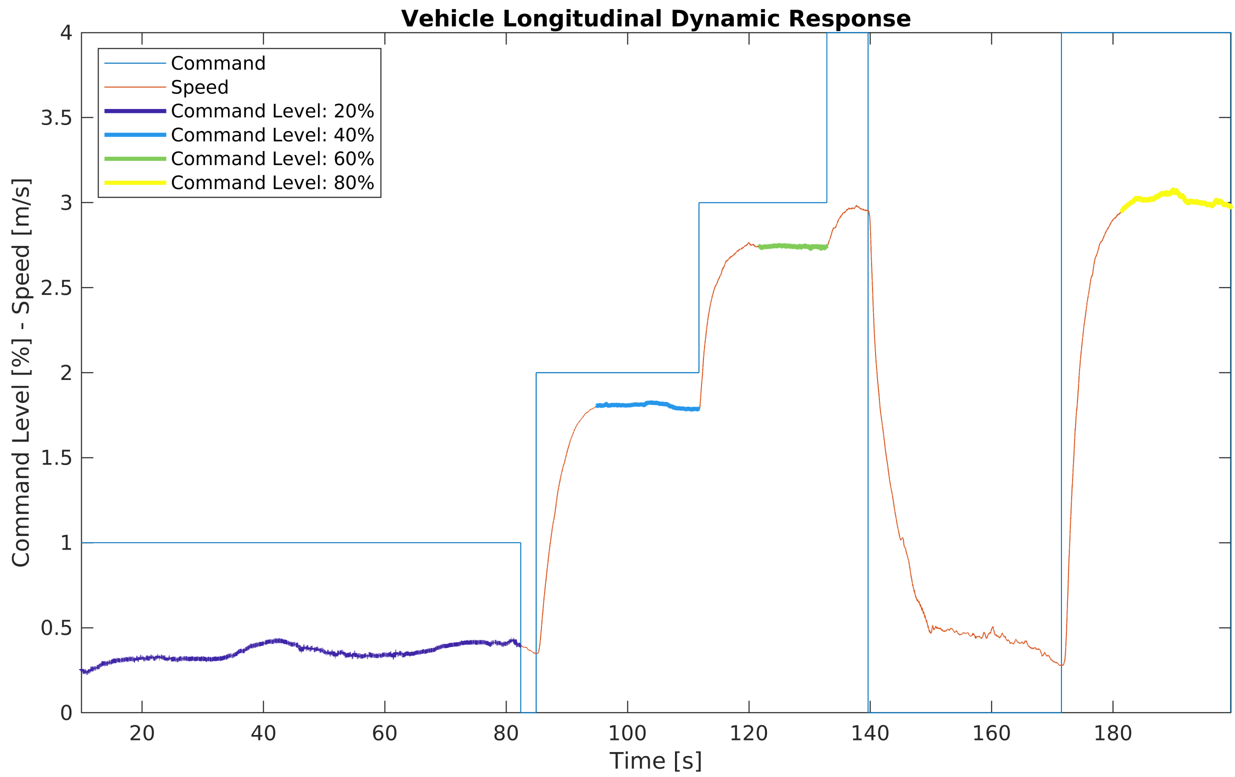
- f_v and f_ω are non-linear functions that map a control action to a steady state speed value
- $G_v(s)$ and $G_\omega(s)$ are first order transfer function with unity static gain: $G_{v/\omega}(s) = \dfrac{1}{1 + \tau_{v/\omega}\, s}$

2. Open loop Test for Longitudinal Dynamic Identification

With the aim to identificate logitudinal dynamic, catamaran has been controlled with several constant speed commands.

Every command level has been kept until vehicle has reached a steady state speed value.

4 breakpoints has been evaluated avaraging along periods of time purged of transients.



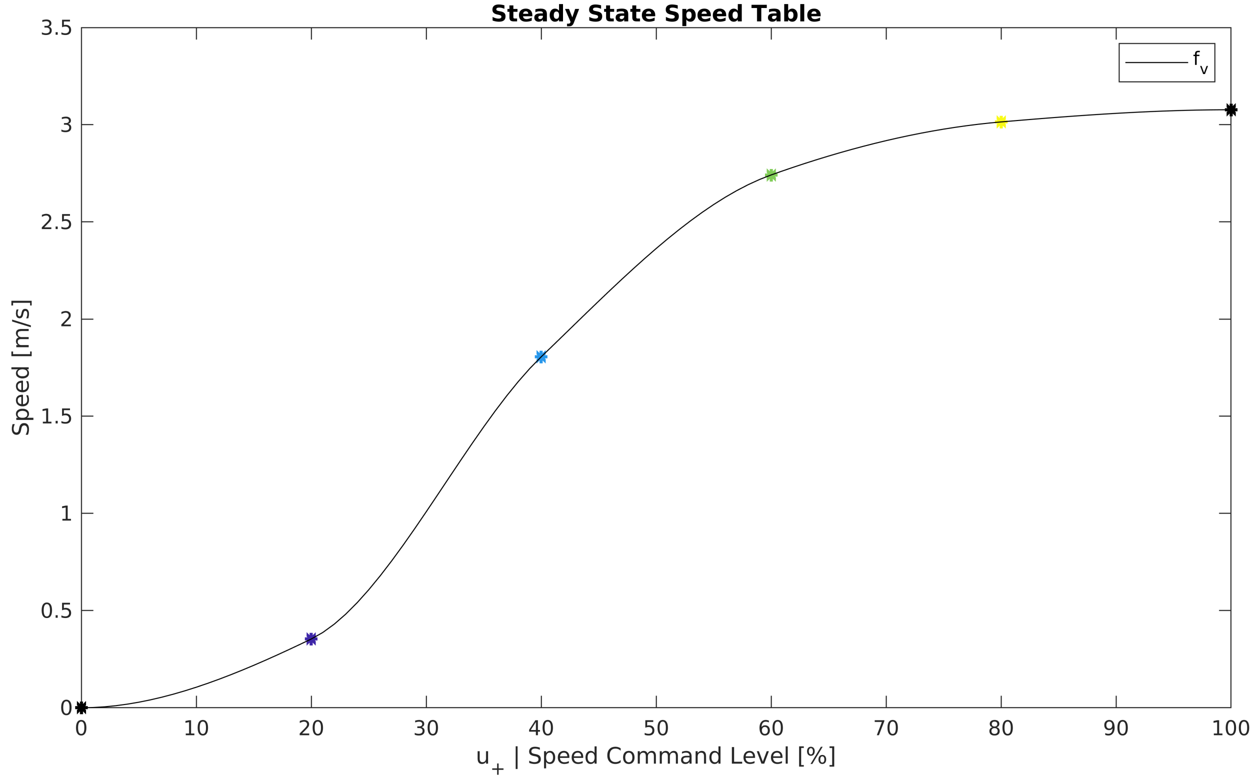

```
Command Level: 20% | Steady Speed: 0.35387m/s
Command Level: 40% | Steady Speed: 1.8059m/s
Command Level: 60% | Steady Speed: 2.7417m/s
Command Level: 80% | Steady Speed: 3.0145m/s
```

2.1 Longitudinal steady-state function

Non-linear function $f_v(u_v)$ can be obtained by interpolating the breakpoint values.

$f_v(0) = 0$ and $f_v(u_{v\,\mathrm{MAX}}) = v_{\mathrm{MAX}}$ are assumed to be 2 more breakpoints.

```
Command Level: 0%   | Steady Speed: 0m/s
Command Level: 100%| Steady Speed: 3.0771m/s
```



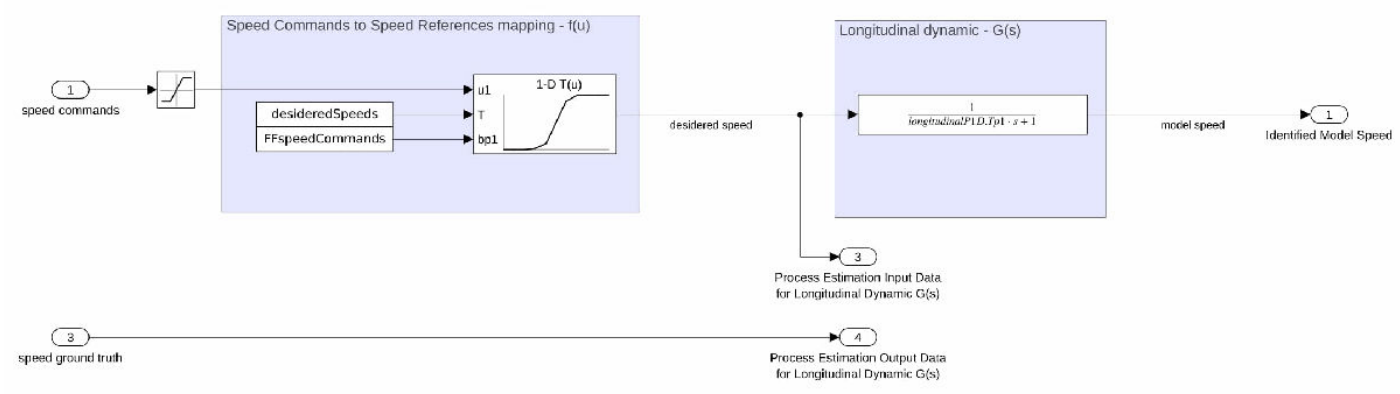
Results of interpolation have been saved in a csv file (FFspeed_USV.csv).

They could be used to fill a lookup table that maps a desired speed to a speed command resulting in a Feed Forward control action.

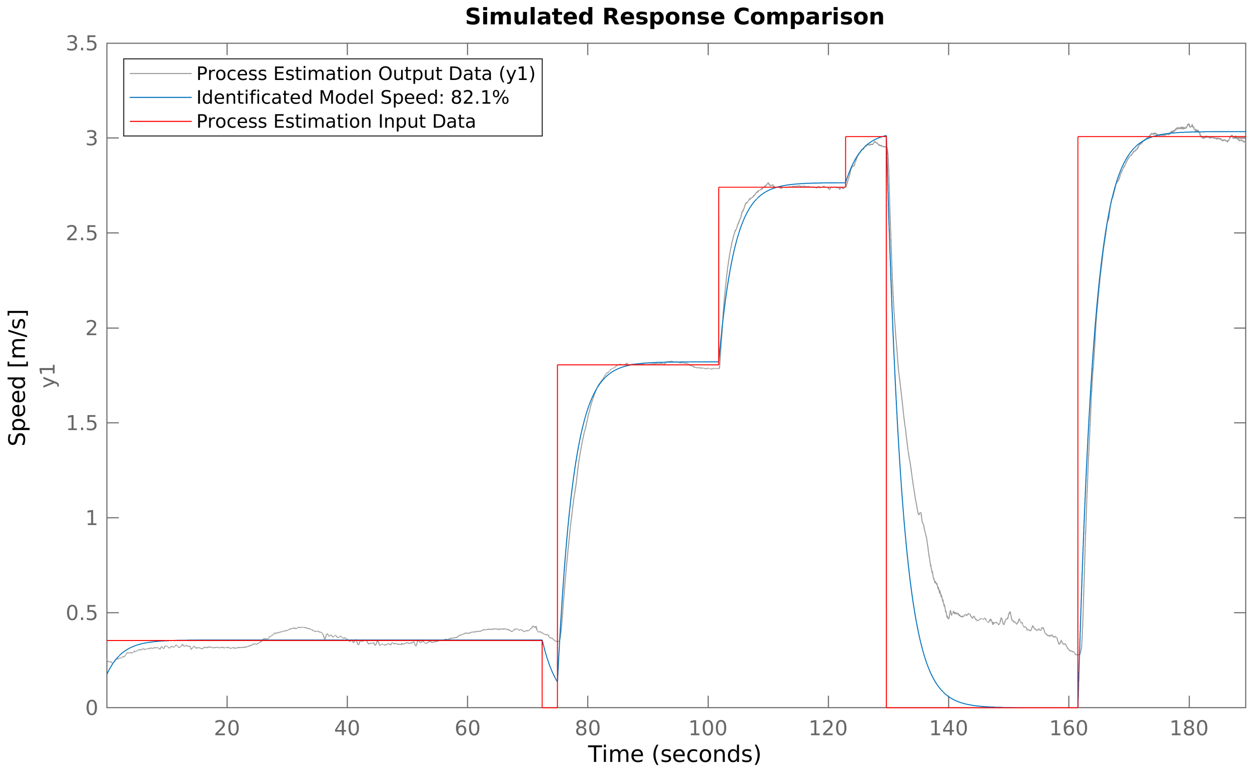
$u_{v\,\mathrm{FF}} = f_v^{-1}(v_{\mathrm{des}})$

2.2 Longitudinal dynamic

In order to estimate a process model $G_v(s)$ with unity static gain, speed commands data are mapped in speed references through the non-linear $f_v(u_v)$.




```
longitudinalP1D.Tp1 = 2.6298s
```



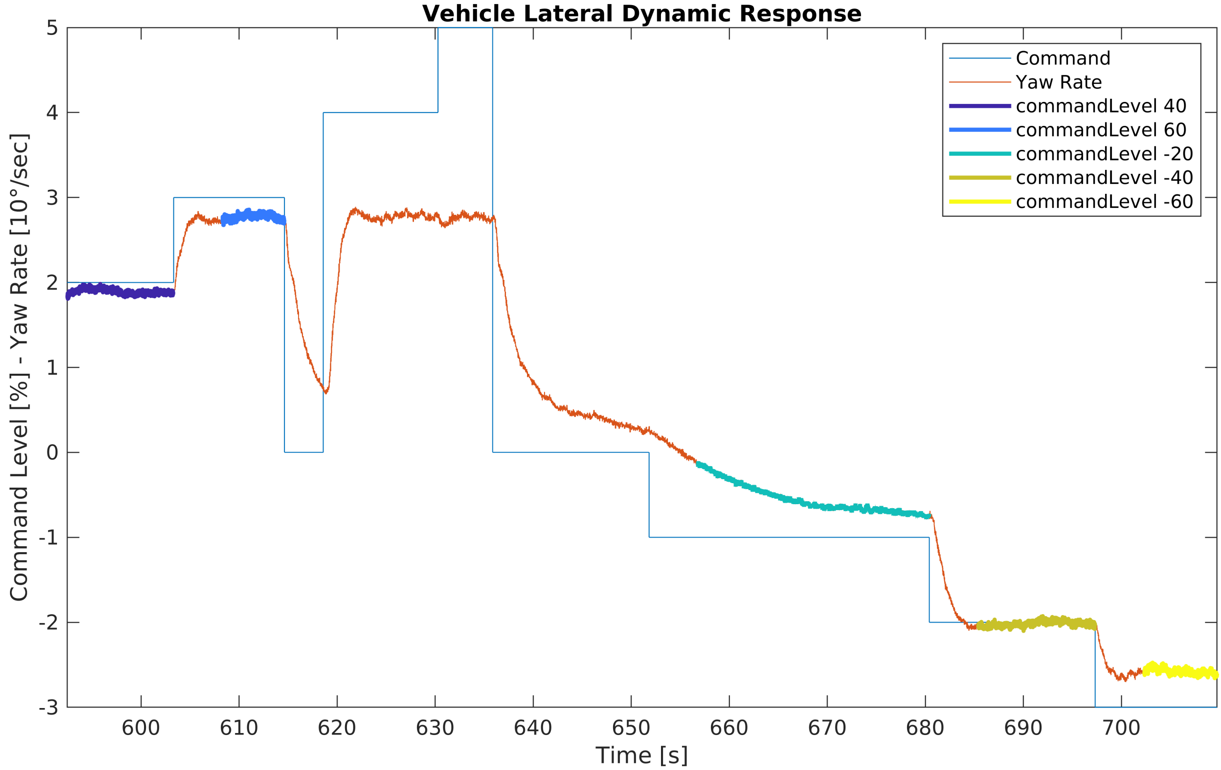
Identificated model output data fits the ground truth speed data according to a NRMSE of 82.1% (Normalized Root Mean Squared Error).

3. Open loop Test for Lateral Dynamic Identification

In the same way in order to identificate lateral dynamic, catamaran has been controlled with several constant yaw rate commands.

Every command level has been kept until vehicle has reached a steady state yaw rate value.

5 breakpoints has been evaluated avaraging along periods of time purged of transients.




```
Command Level: +40% | Steady Yaw Rate: 18.9377deg/sec
```

```
Command Level: +60% | Steady Yaw Rate: 27.7585deg/sec
```

```
Command Level: -20% | Steady Yaw Rate: -5.4723deg/sec
```

```
Command Level: -40% | Steady Yaw Rate: -20.1593deg/sec
```

```
Command Level: -60% | Steady Yaw Rate: -25.7432deg/sec
```

3.1 Lateral steady-state function

Non-linear function $f_v(u_v)$ can be obtained by interpolating the breakpoint values.

Missing of the +20% command has been fixed considering a symmetrical breakpoint.

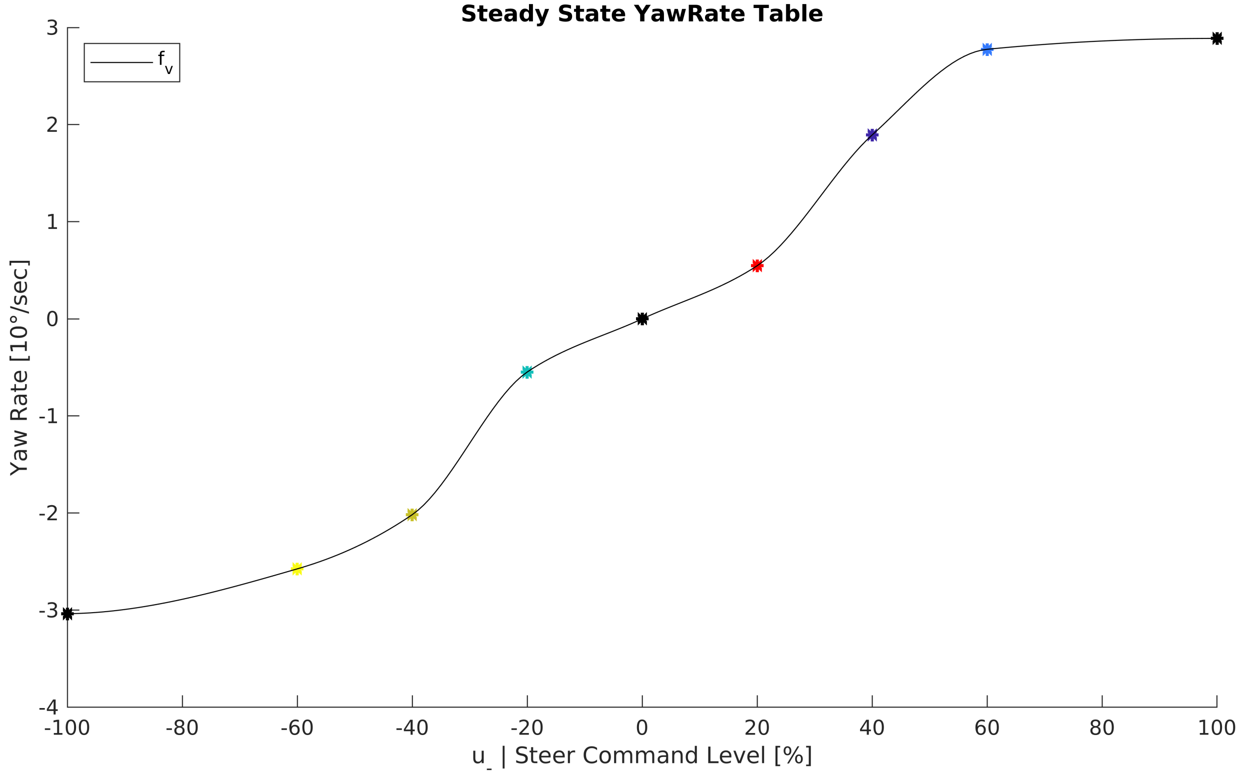
$f_\omega(0) = 0$, $f_\omega(u_{\omega\ \mathrm{MAX}}) = \omega_{\mathrm{MAX}}$ and $f_\omega(u_{\omega\ \mathrm{MIN}}) = \omega_{\mathrm{MIN}}$ are assumed to be 3 more breakpoints.

```
Command Level: +20% | Steady Yaw Rate: 5.4723deg/s
```

```
Command Level:  0%  | Steady Yaw Rate: 0deg/s
```

```
Command Level: +100%| Steady Yaw Rate: 28.8819deg/s
```

```
Command Level: -100%| Steady Yaw Rate: -30.3617deg/s
```



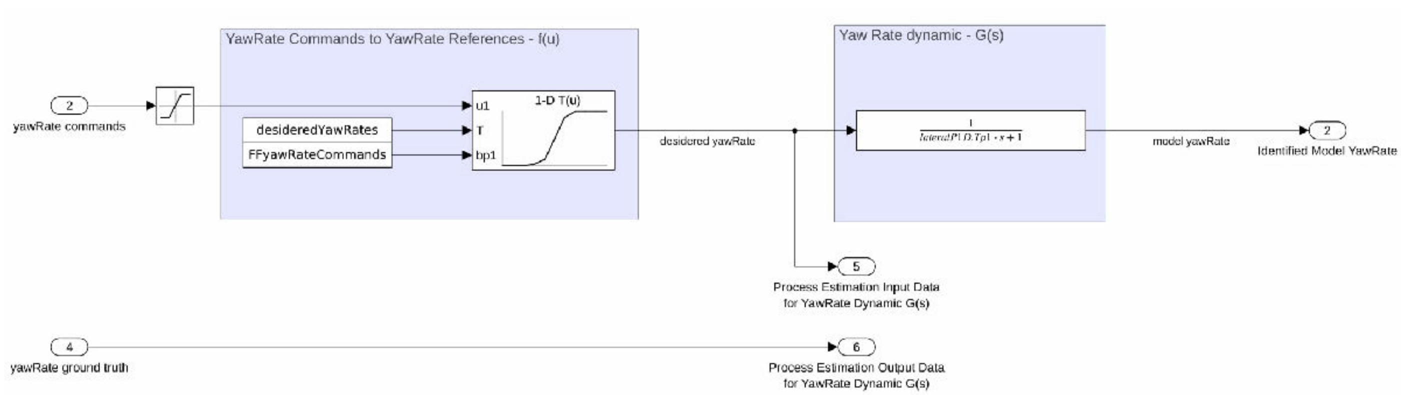
Results of interpolation have been saved in a csv file (FFyawRate_USV.csv).

They could be used to fill a lookup table that maps a desired yaw rate to a yaw rate command resulting in a Feed Forward control action.

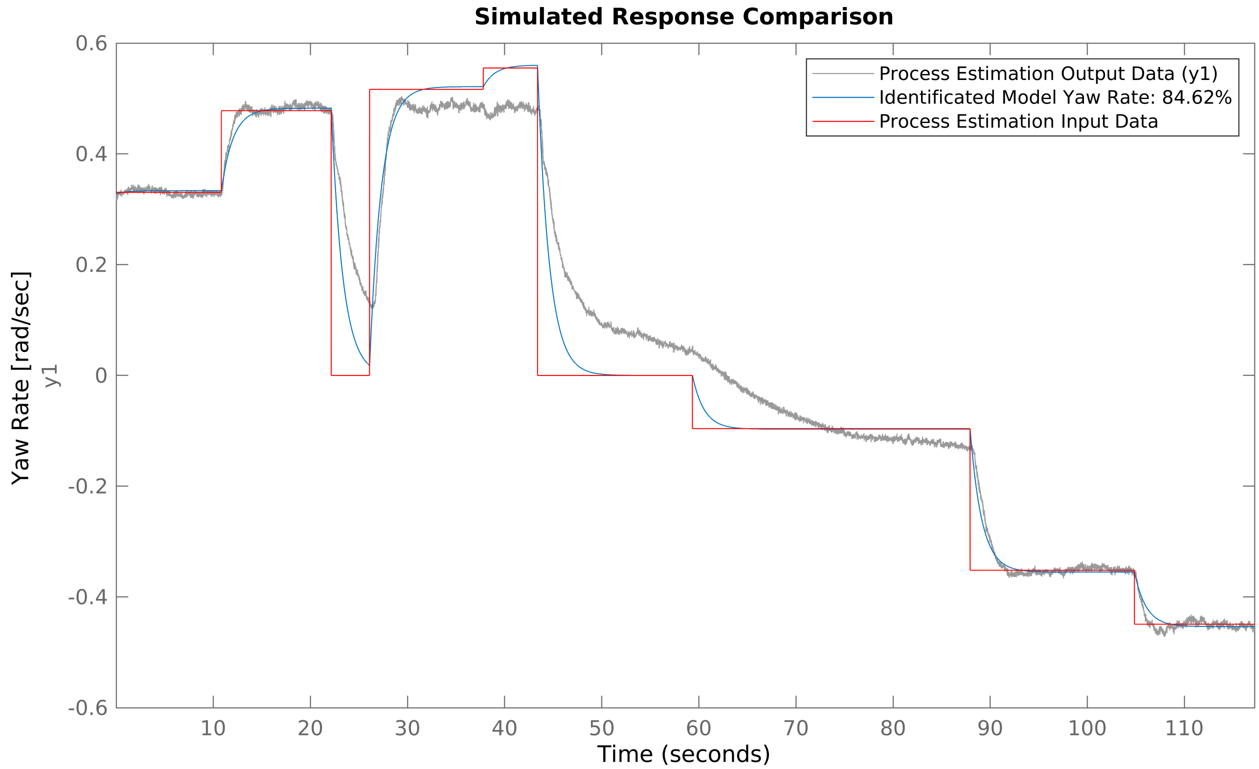
$u_{\omega\ \mathrm{FF}} = f_{\omega}^{-1}(\omega_{\ \mathrm{des}})$

3.2 Lateral dynamic

In order to estimate a process model $G_{\omega}(s)$ with unity static gain, yaw rate commands data are mapped in yaw rate references through the non-linear $f_{\omega}(u_{\omega})$.




```
lateralP1D.Tp1 = 1.201s
```



Identificated model output data fits the ground truth speed data according to a NRMSE of 84.62% (Normalized Root Mean Squared Error).