



Combined Adaptive Cruise control and Optimal Speed Profile

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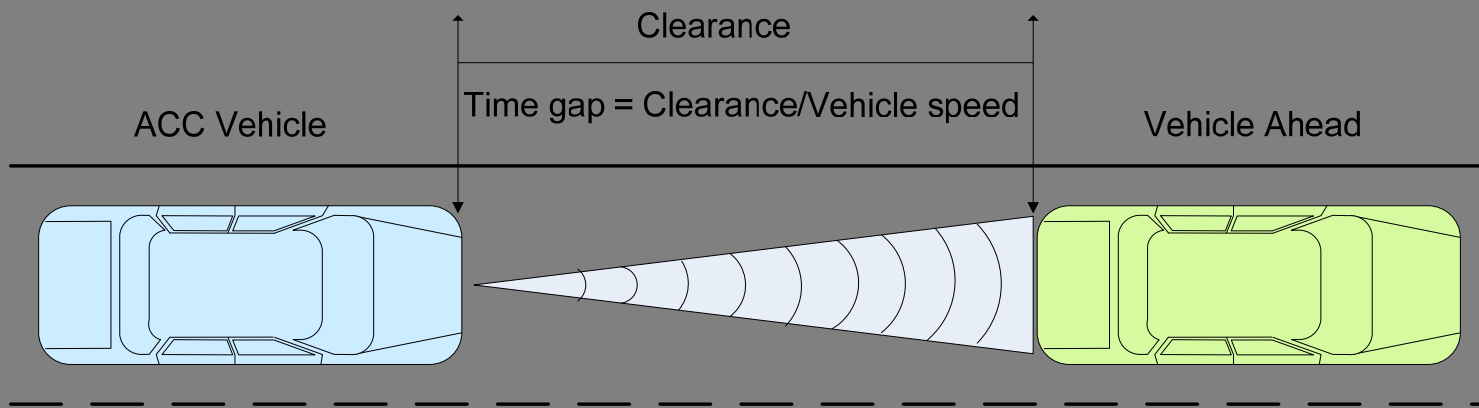
Outline of this presentation

- Adaptive cruise control
- ACC and optimal speed profile
- Optimal problem definition
- Speed calculation in each iteration of optimisation
- Optimizer and ACC model
- Simulation and results
- Stability analysis



Adaptive Cruise Control (ACC)

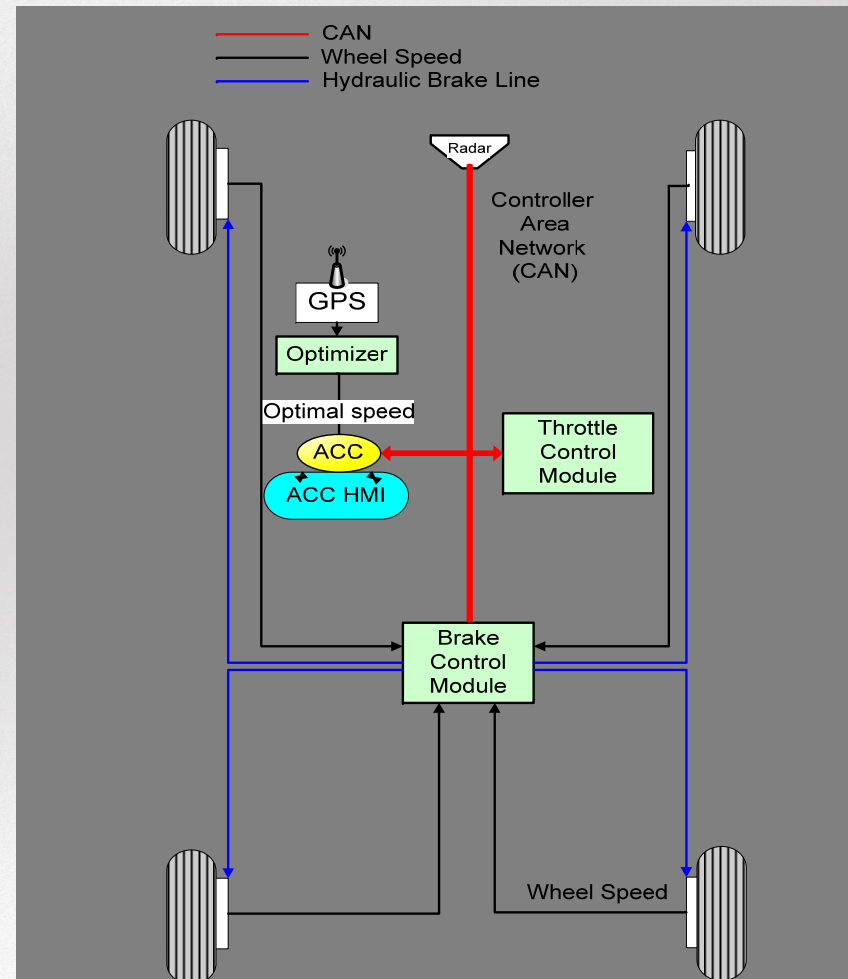
ACC is an extension of the conventional cruise control system, and it allows the host vehicle (ACC vehicle) to follow another vehicle with an appropriate clearance or a predefined time gap.





ACC and optimal speed profile

- Interface switches as in conventional cruise control
- Input from setting the time gap between the ACC vehicle and forward vehicle
- HMI to set the destination address (the information can be uploaded from GPS or digital map)
- Optimizer block





Optimal problem definition

$$F_{tr} = M\dot{v} + C_{rr}Mg\cos\alpha + Mg\sin\alpha + \frac{1}{2}C_D A\rho(v + v_w)^2$$

$$T_t = \frac{r_w}{f_r} \frac{1}{g_r} \frac{1}{\eta_f \eta} F_{tr}$$

$$\omega = \frac{f_r}{r_w} g_r v$$

$$T_t = T_e + T_m$$

$$T_e = \eta_{ice} \frac{P_{ch}}{\omega}$$

$$T_m = \eta_e \frac{P_{em}}{\omega}$$

$$P_{tr}(k) = \eta_{ice}(k)P_e(k) + \eta_e(k)P_m(k) \quad \text{for } k=1,2, \dots, n$$

$$\dot{m} [T_m(k), \omega(k)] Q_{lhv} = \frac{P_e(k) + \eta_e(k)P_m(k)}{\eta_{ice}(k)}$$

$$\min_v J = \sum_{k=1}^n \dot{m} [T_m(k), \omega(k)] Q_{lhv}$$

subject to:

$$v \in [v_{min} \ v_{max}]$$

$$\omega \in [\omega_{min} \ \omega_{max}]$$

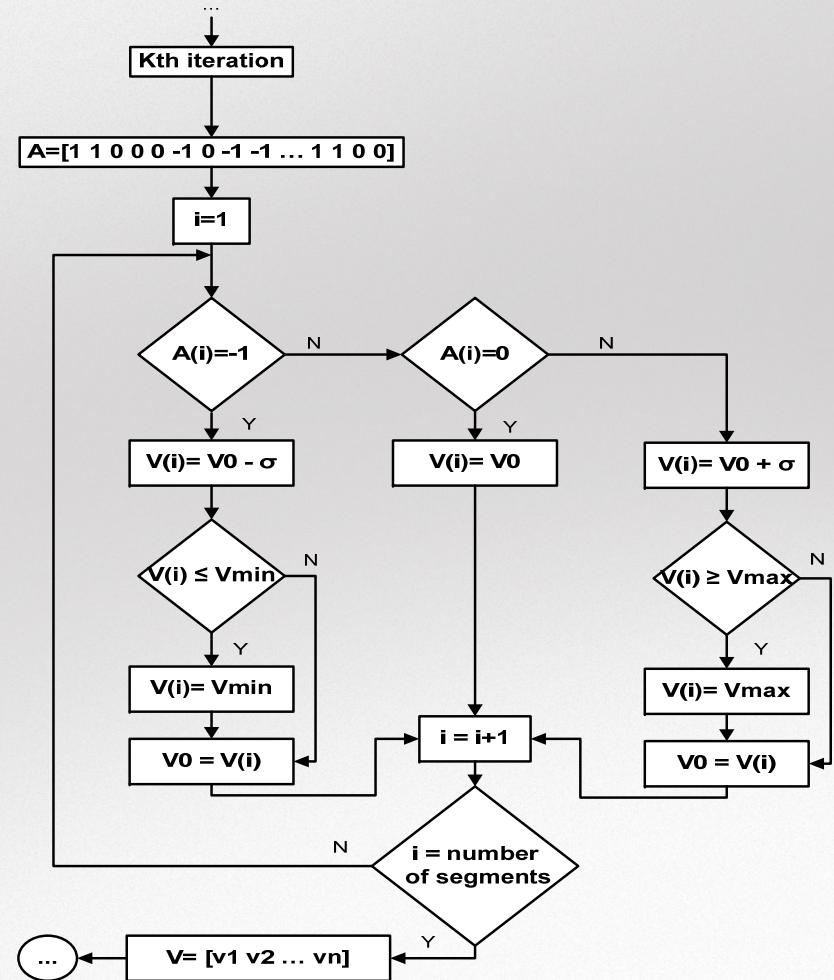
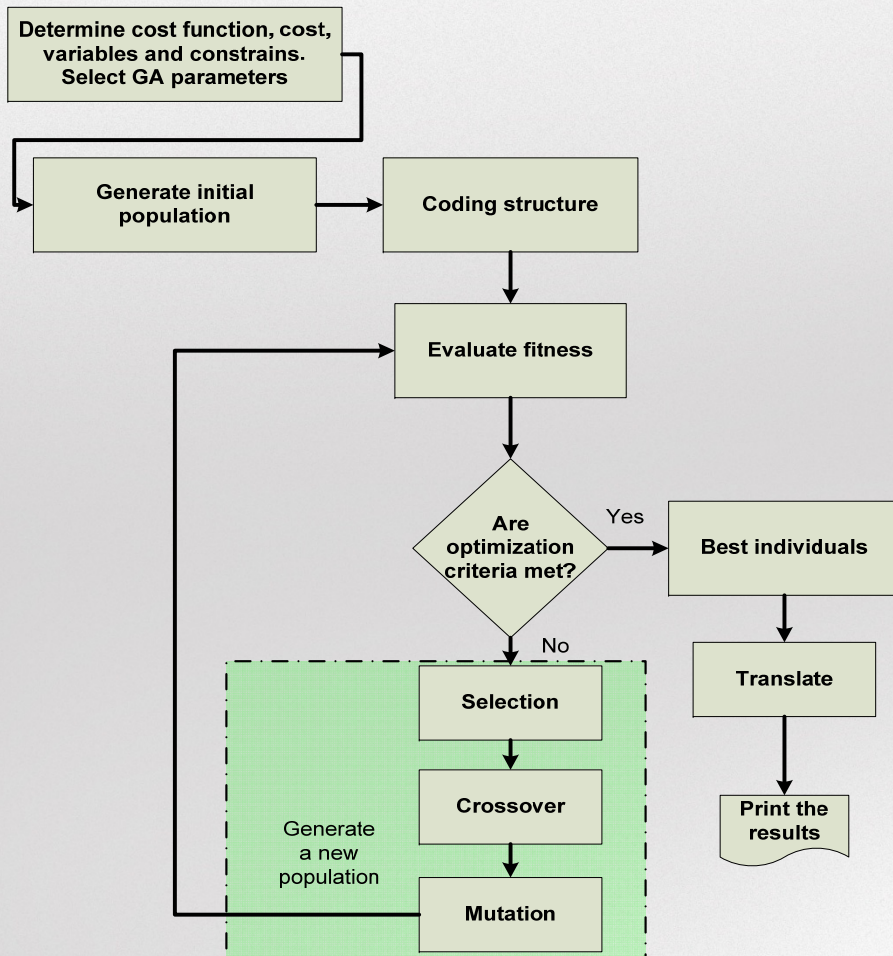
$$P_e \in [P_{e_{min}} \ P_{e_{max}}]$$

$$P_m \in [-P_{e_{max}} \ P_{e_{max}}]$$



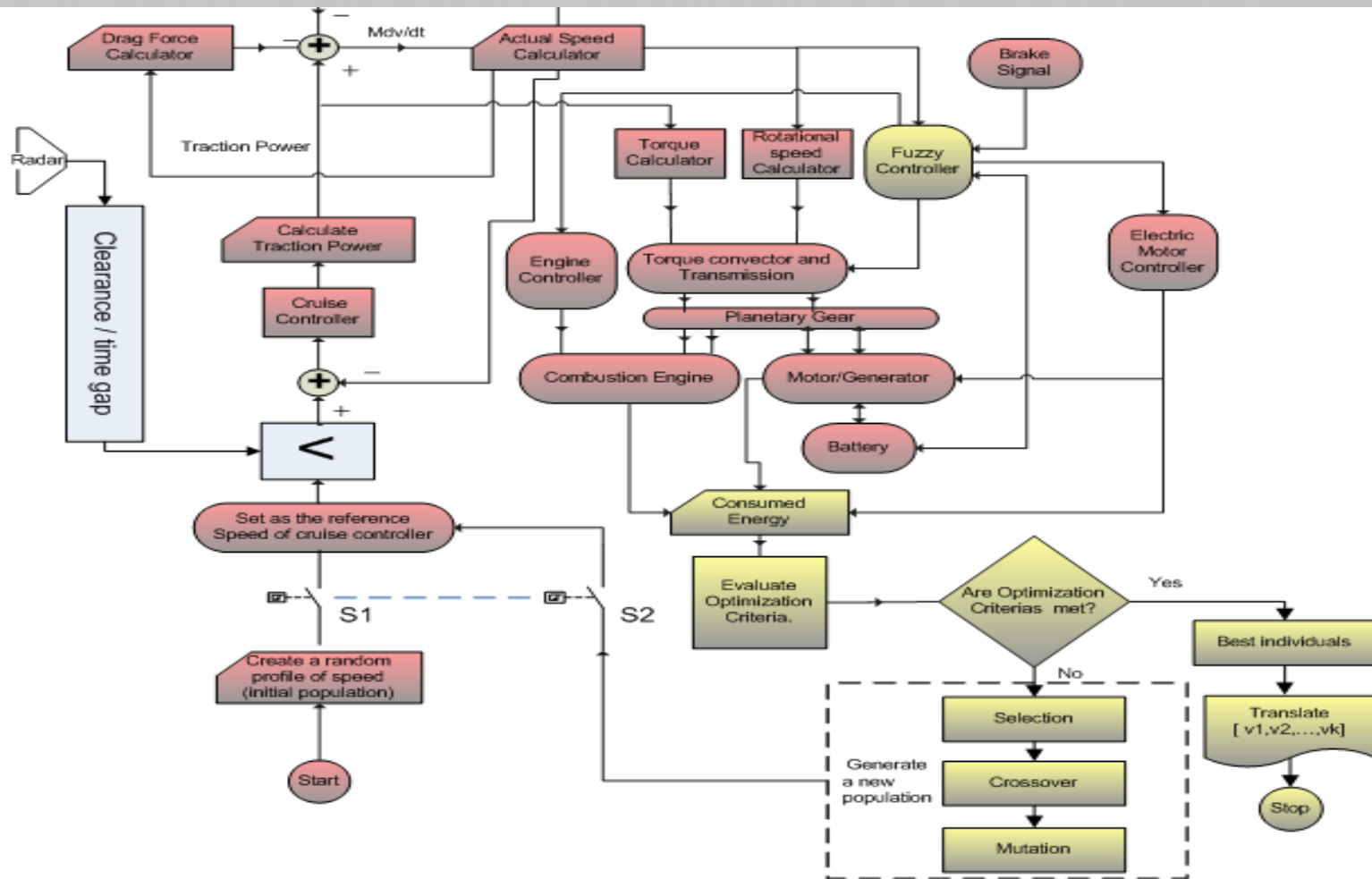


Speed calculation in each iteration of optimisation



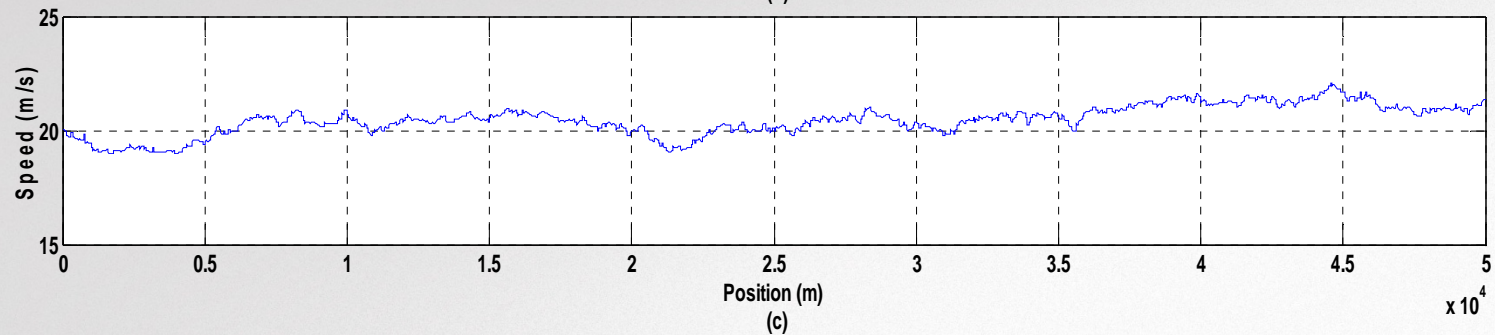
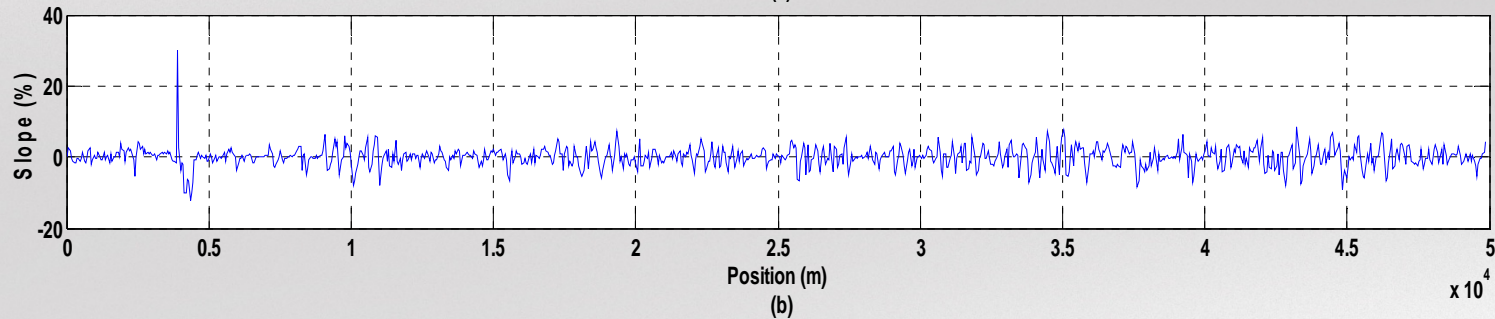
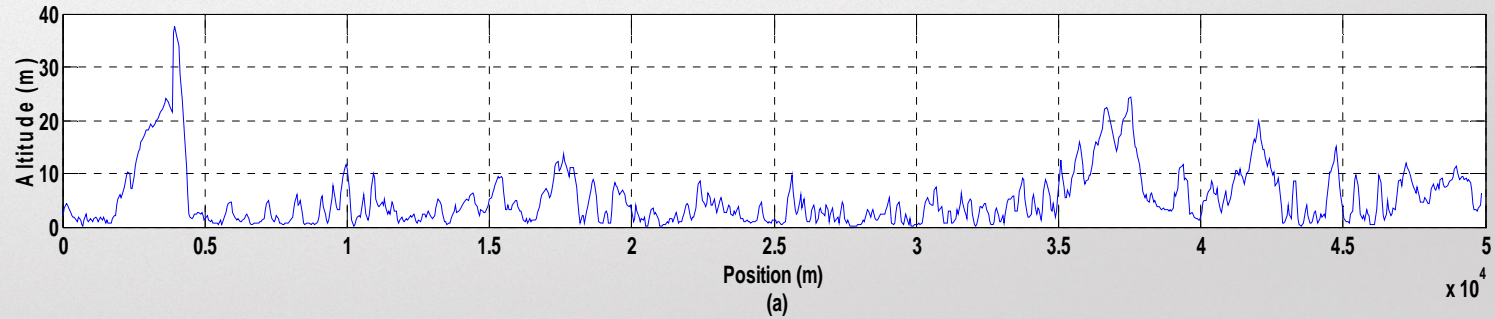


Optimizer and ACC flowchart



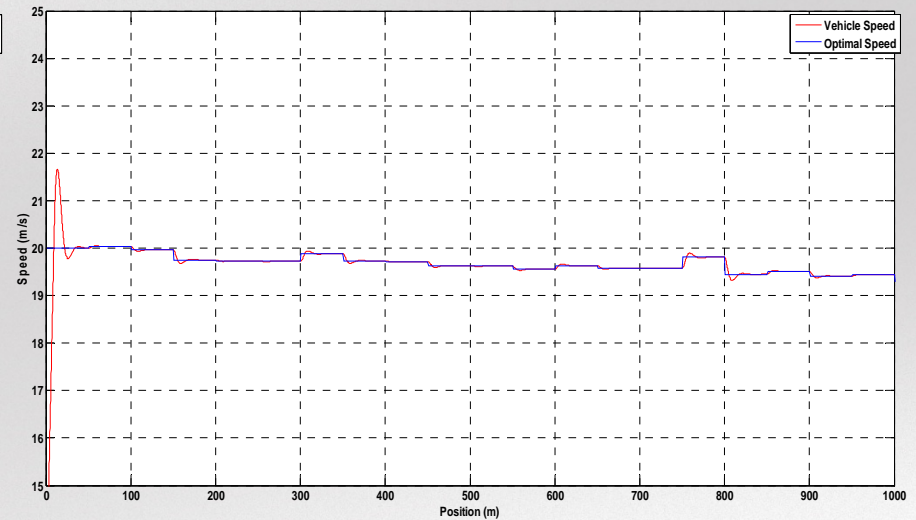
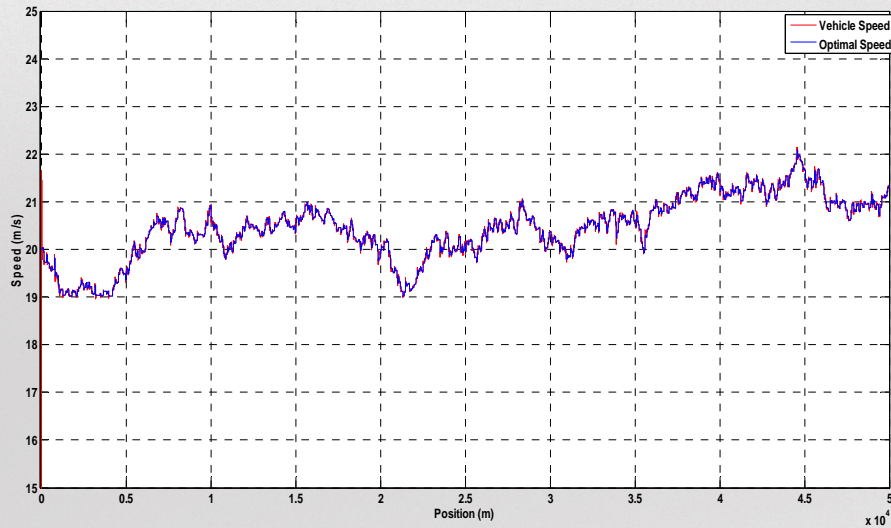


Simulation and results





Simulation and results





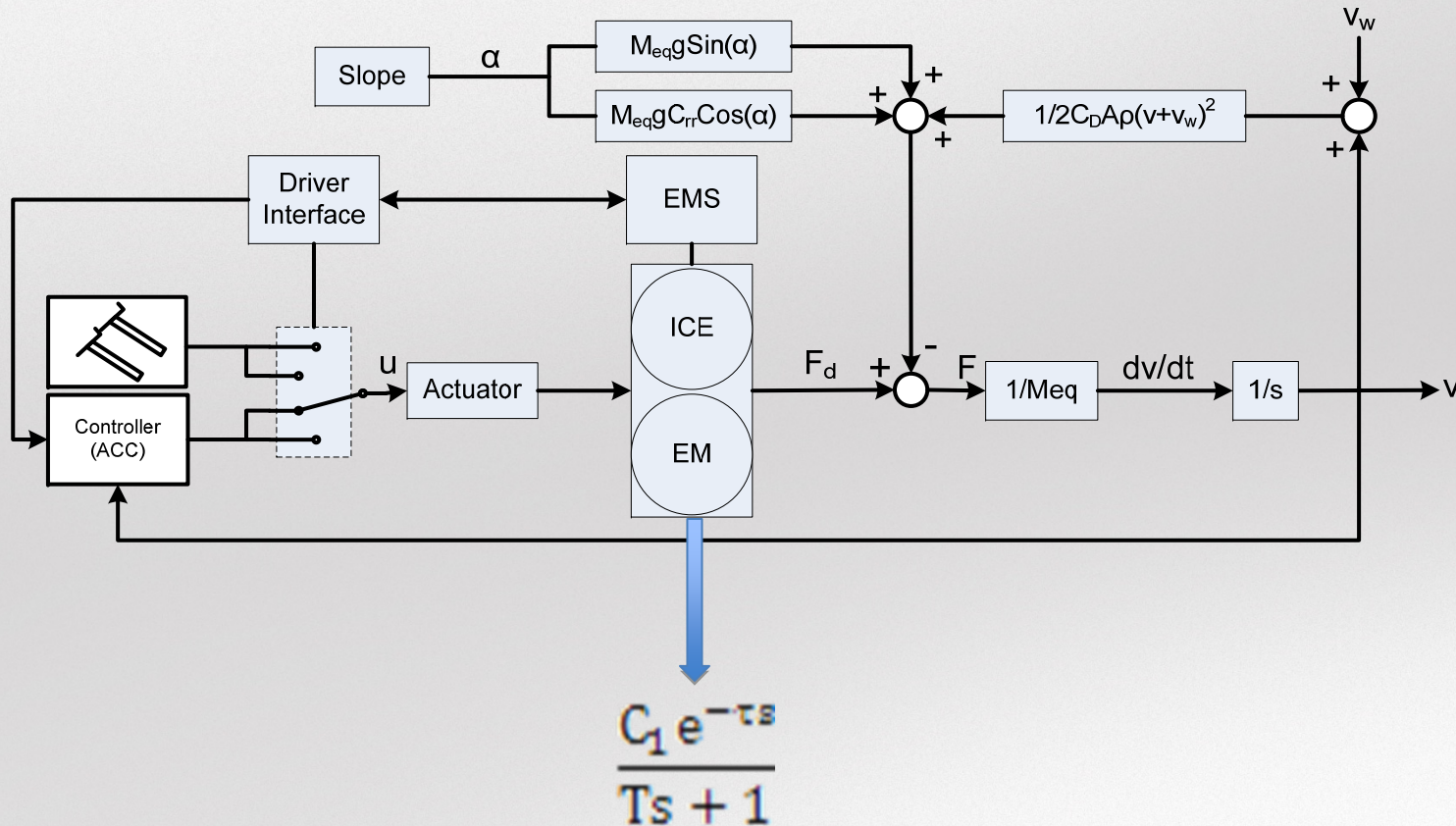
Simulation and results

Fuel consumption for the three driving patterns

The simulated model with different ACC set -point	FC (L/100km)
PHEV with the optimal speed and the real road data	5.1
PHEV with selective control	5.41
PHEV with constant speed	5.59



Cruise control model (transfer function and state-space model)



$C_1=743$, $T=1s$, $\tau=0.2s$. For the modelled vehicle $M_{eq} \approx 1500$ kg, $g=9.8$ m/s² and the total coefficient of drag force is 0.72 N/(m/s)²



Cruise control model (transfer function and state-space model)

$$\dot{v} = \frac{1}{M_{eq}} (F_d - 0.72v^2)$$

$$\dot{F}_d = \frac{1}{T} (C_1 u(t - T) - F_d)$$

$$y = v$$

Regards with the perturbation around the operation points via differentiating the state equations the new state equations can be presented as the linear state equations as follow:

$$\frac{d}{dt} \dot{v} = \frac{1}{M_{eq}} (\delta F_d - 1.44v\delta v)$$

$$\frac{d}{dt} \dot{F}_d = \frac{1}{T} (C_1 \delta u(t - T) - \delta F_d)$$

$$y = \delta v$$



Cruise control model (transfer function and state-space model)

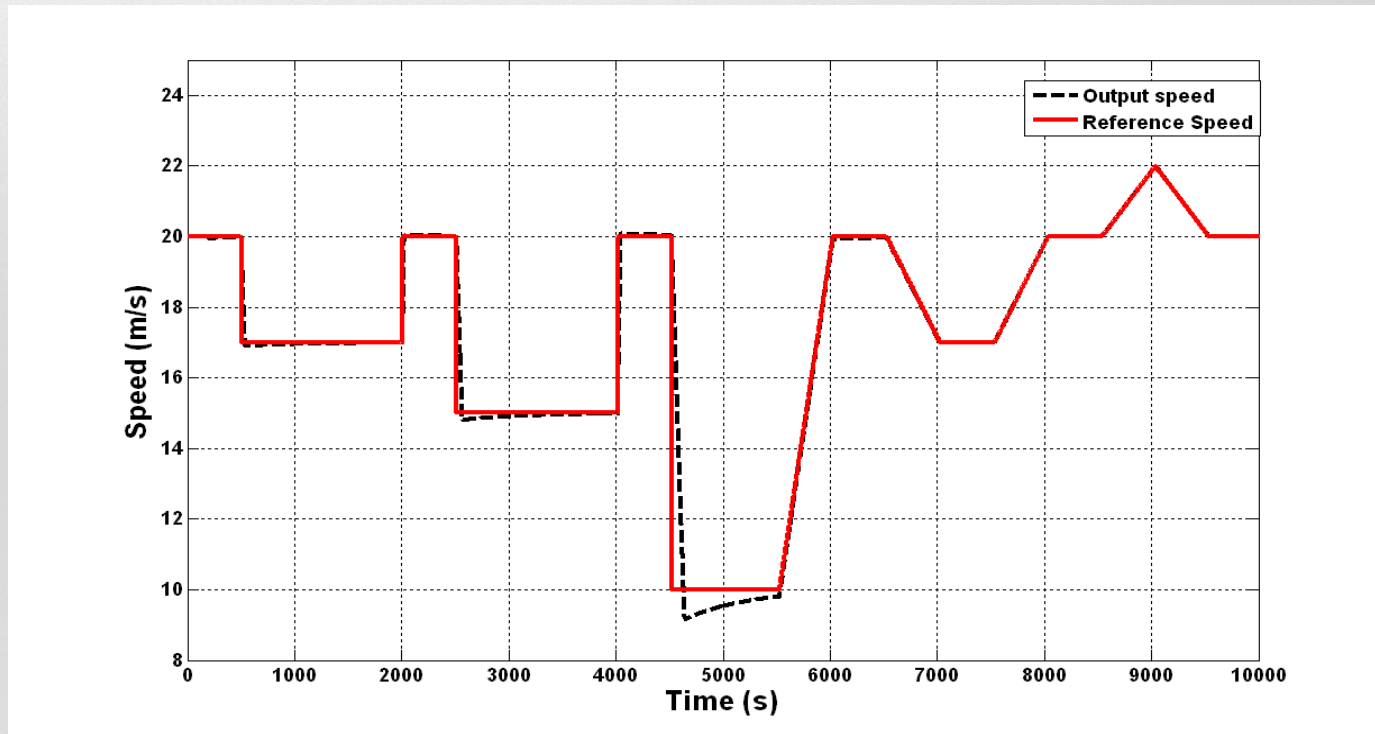
$$G_p(s) = \frac{\Delta V(s)}{\Delta U(s)} = \frac{0.496}{(s + 0.0192)(s + 1)(s + 5)}$$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -6.0192 & -5.0192 & -0.096 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} [\Delta u(t)]$$

$$y(t) = [0 \ 0 \ 0.469] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$



Simulation and results





Summary

- A fuzzy supervisory control considering in order to obtain fuel economy is designed
- A HEV model is developed.
- An optimizer with adaptive control is developed.
- The model is simulated and evaluated.



Thank You!

