One-sided cooperation between human driver and active accelerator pedal

Chris Rosier
Dr David Cole
Centre for Sustainable Road Freight

- A collaboration between Cambridge and Heriot Watt Universities and the freight transport industry
- Research into low carbon vehicle engineering and logistics
Aim:

To reduce to the energy consumption of HGVs by improving the driver’s control of the accelerator pedal
Haptic Feedback

**Advantages:**
- Continuous support to driver
- Doesn’t distract the driver’s vision
- Long-term effect

**Disadvantages:**
- Must be built in to vehicle
- Can be disliked by driver
Objective:

*Develop a mathematical model of the driver’s cognitive control of a vehicle with active pedal force*
1. Introduction

2. Vehicle and Driver Models

3. Active Pedal Force

4. Conclusions & Further Work
Driver-Pedal Interaction

\[ v(t) = \sum \int_{t^*}^{t^* + t_p} f(t) dt \]

driver control

\[ f_1 = f_{\text{pedal}} \]

driver force

human driver \( K_{1p} \)

target speed \( T_1 \)

vehicle states \( x_1: \phi_{\text{pedal}}, \dot{\phi}_{\text{pedal}}, y, v \)

vehicle model \( A, B, C, D \)

pedal and foot

pedal displ. \( \phi_{\text{pedal}} \)

engine and vehicle

Preview
Vehicle Dynamics

\[ F_{\text{Aero}} = \frac{1}{2} \rho C_D A v^2 \] or

\[ F_{\text{Aero}} = kv \]

Linearized aerodynamic drag
Optimise by minimising a cost function:

\[ V_1(k) = \sum_{i=1}^{N_p} q_1v (v(k + i) - r_v(k + i))^2 \]

\[ + \sum_{i=1}^{N_p} q_1\phi \phi^2(k + i) \]

\[ + \sum_{i=0}^{N_p-1} f_1^2(k + i) \]

- speed error
- pedal displacement
- pedal force
1. Introduction
2. Vehicle and Driver Models
3. Active Pedal Force
4. Conclusions & Further Work
Active Pedal Force

- **sustainable objective**
- **pedal controller** $K_{2p}$
- $V_2(Q_2, R_2)$
- **feedback force** $f_2$
- **pedal force feedback control**
- **target speed** $T_2$
- **driver control**
- $V_1(Q_1, R_1)$
- **driver objective**
- $f_1$ (human driver $K_{1p}$)

**vehicle states $x_2$:** $\phi_{pedal}, \dot{\phi}_{pedal}, y, v$

**pedal and foot**

**pedal displ.** $\phi_{pedal}$

**engine and vehicle model** $A, B, C, D$

**vehicle states $x_1$:** $\phi_{pedal}, \dot{\phi}_{pedal}, y, v$
Cooperative Control

- The driver and active pedal take each other’s objective and action into account.
- A ‘global’ cost function is defined as a weighted sum of the driver’s and active pedal’s own cost functions.
Cooperative Control

- Cooperative Control results in compromise:

- Both players compromise when cooperating.

  - Human driver stays close to target.

  - Active pedal desires lower accelerations.

- Speed focussed
  - Driver: $q_v = 80$, $q_\phi = 1$

- Eco Active Pedal:
  - $q_v = 30$, $q_\phi = 1$
One-sided Cooperative Control

- The driver takes the active pedal’s objective and action into account.
- The driver amends their cost function to a weighted sum of the driver’s and active pedal’s own cost functions.
One-Sided Cooperative Control

- Only the driver compromises:

- Human driver stays close to target
- Only the driver compromises, so end up closer to active pedal target

- Active pedal desires lower accelerations

- Driver: $q_v = 80$, $q_\phi = 1$

- Eco Active Pedal: $q_v = 30$, $q_\phi = 1$
Driving Styles

- An active pedal would need to work with a range of drivers and their individual driving styles.
- By varying the driver’s cost function weightings, different driving styles can be modelled.
- Effects of different drivers on one active pedal examined.
Pedal Force and Speed Error

Increasing weights on speed errors

One-Sided Cooperative
Fully Cooperative

RMS Driver Pedal Force (N)
1. Introduction

2. Vehicle and Driver Models

3. Active Pedal Force

4. Conclusions & Further Work
Conclusions

1. Mathematical game theory used to model interaction between driver and active pedal

2. Model Predictive Control theory used to implement two different control strategies: cooperative and one-sided cooperative

3. Parameter study has revealed a range of driving styles can be derived by varying parameters in the cost function
Further Work

- Driving simulator experiments with professional drivers
- Analysis of on-road data
- More detailed engine and fuel consumption model from real data
- Design and assessment of force feedback strategies