The use of body side-slip dynamics in simulator motion cueing

Nikhil Garrett

Dr Matt Best

Vehicle Dynamics and Control 2011
5th April 2011, Cambridge

Loughborough University

Contents

- Driver-in-the-Loop Overview
- The motion cueing problem
- Body sideslip cueing
- Testing
- Future work
- Conclusions

- Driver-in-the-Loop Overview

Driver-in-the-Loop Overview

- Well established in Automotive industry & Research
- Ergonomics, Driver training, Virtual vehicle testing
- Motion platform common feature

Driver-in-the-Loop Overview

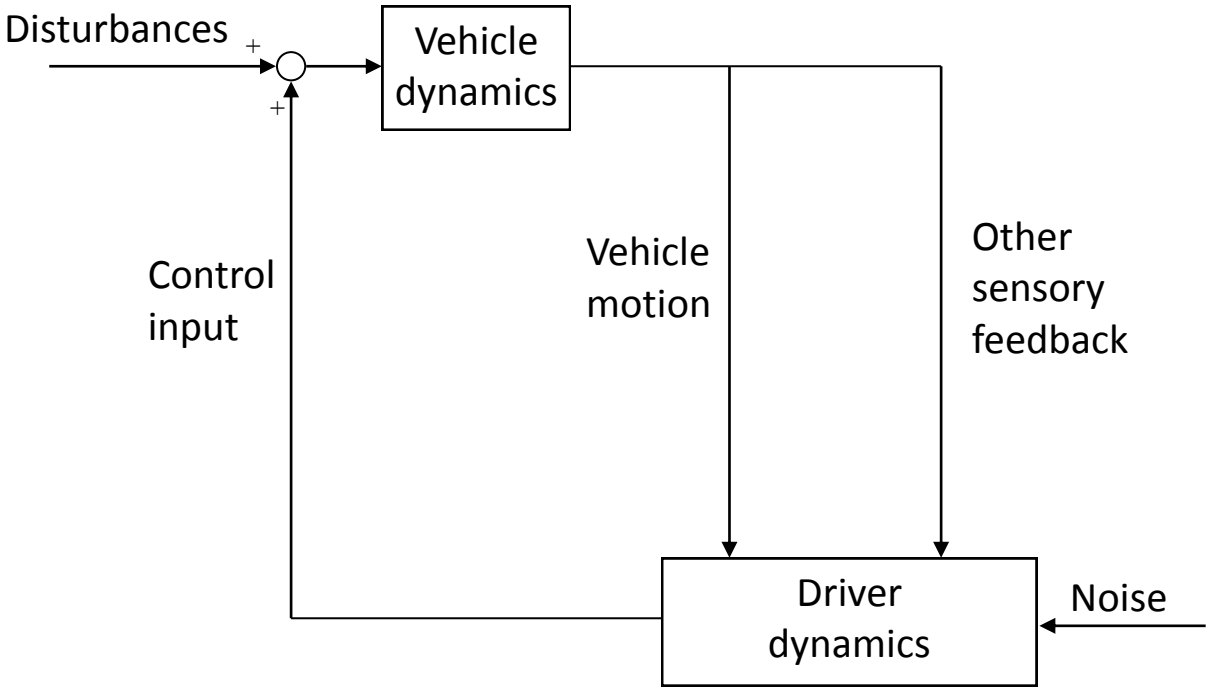
- The motion cueing problem

The motion cueing problem

- Limited motion workspace
  - Loughborough simulator: ±0.5m, ±20°
- Miscues highly undesirable
- How do we choose what to reproduce?

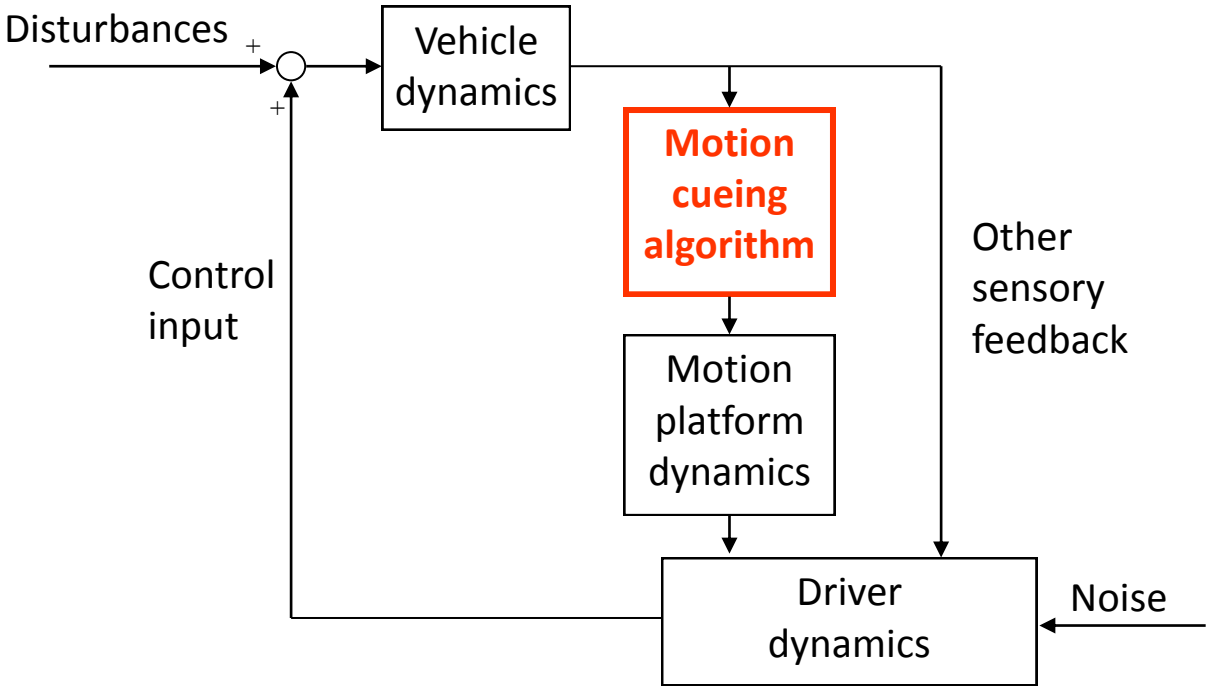
The motion cueing problem

Driver-vehicle system – Real vehicle



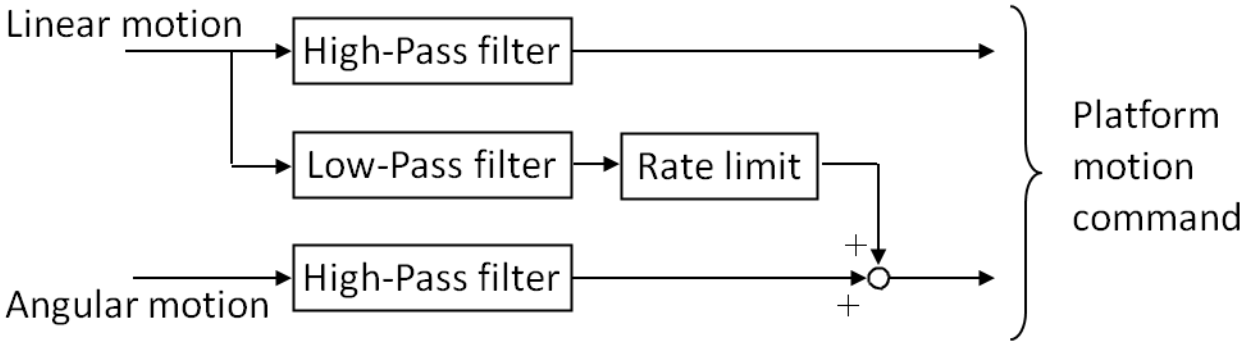
The motion cueing problem

Driver-vehicle system – Simulator



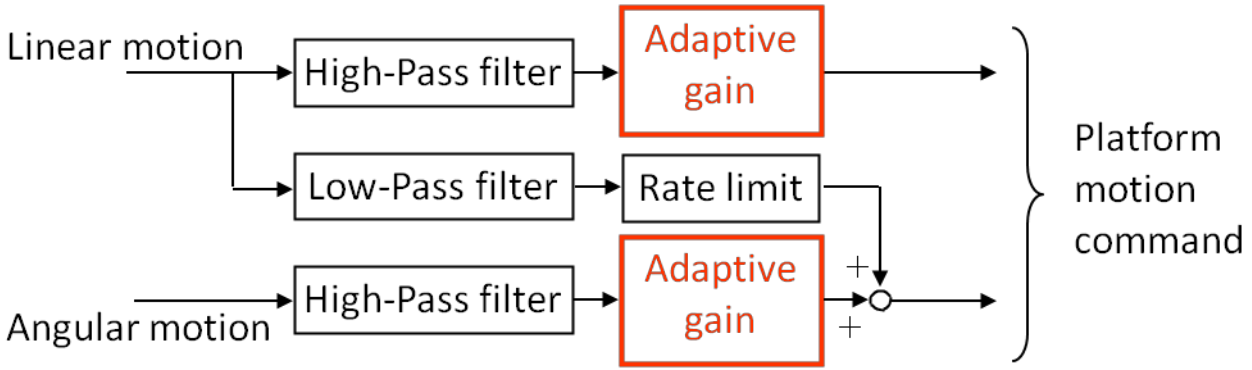
Existing approaches

- Classical (linear filters)



Existing approaches

- Adaptive filters



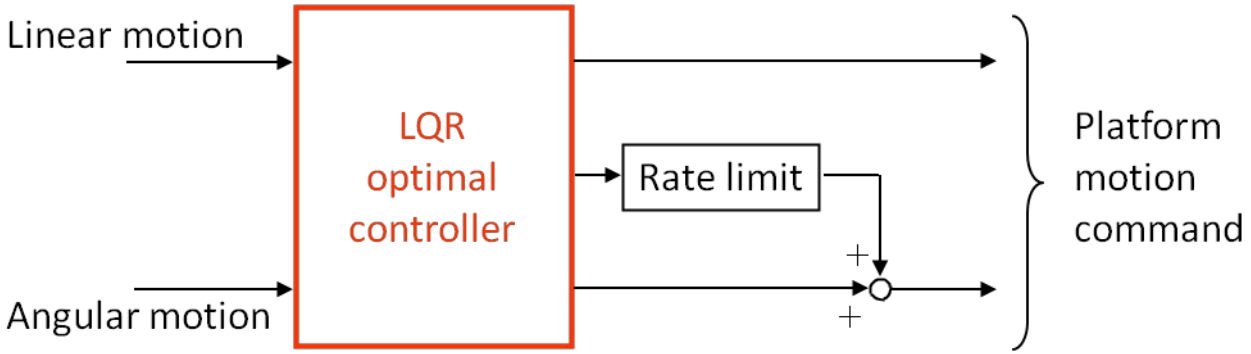
$$J = fn\{ s^2, \quad x_p^2, \quad \Delta P^2 \}$$

$$\dot{P}_i = -K_i \frac{\partial J}{\partial P_i}$$

(s = Motion error, x_p = Platform states, P = Adaptive gain, K = Step size)

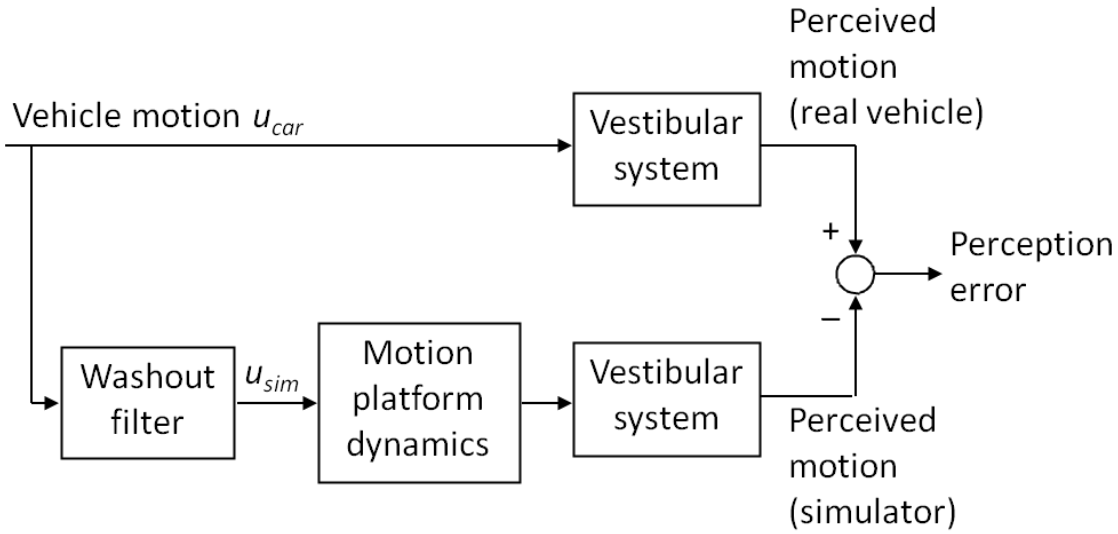
Existing approaches

- Linear Quadratic Regulator (LQR)



Existing approaches

- Linear Quadratic Regulator (LQR)

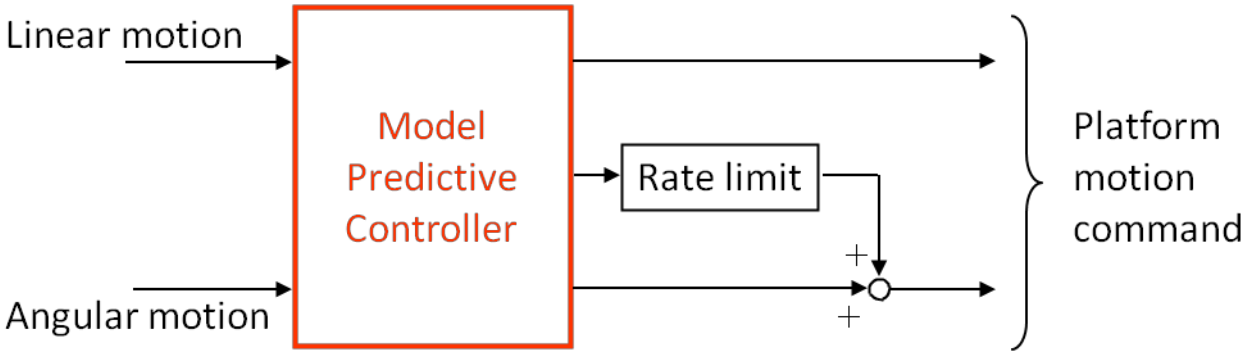


$$J = E\{e^T Q e + x_p^T R_p x_p + u^T R u\}$$

(e = Perception error, x_p = Platform states, u = Motion command)

Existing approaches

- Model Predictive Control (MPC)



$$J = fn(e^2_{t+1,\ldots,t+H_P}, x^2_{p,t+1,\ldots,t+H_P}, u^2_{t+1,\ldots,t+H_P})$$

(e = Perception error, x_p = Platform states, u = Motion command)

- Body sideslip cueing

Why body side-slip?

- Sideslip angle generally fits within yaw limit
- No need to remove information
- Vehicle dynamics-based cue – better?

Implementation

$$\beta = \frac{v}{u} \qquad \dot{\beta} = fn(u, v, \dot{u}, \dot{v})$$

$$\ddot{\beta} = fn(u, v, \dot{u}, \dot{v}, \ddot{u}, \ddot{v})$$

- Issue – second derivative of body sideslip angle contains jerk terms, $\ddot{u}$ and $\ddot{v}$

Implementation

- Solution – make use of tyre lags
  - This gives us tyre force derivative
  - Thus we can find $\ddot{y}$ and $\ddot{v}$

Contents

- Testing

Testing

- Body sideslip combined with lateral & roll motion

- Tested against Classical, Adaptive, LQR

Testing

- 24 subjects – Age range 19-75, 50/50 M/F
- Mixed experience level
  - Some with simulator experience
  - Some with ‘high-speed’ driving experience
- Bi-directional pairwise comparisons
- Randomised block order

Testing

- Five familiarisation laps, then 14 test laps
- Cueing algorithm changed after each lap
- Participants asked to compare two most recent laps

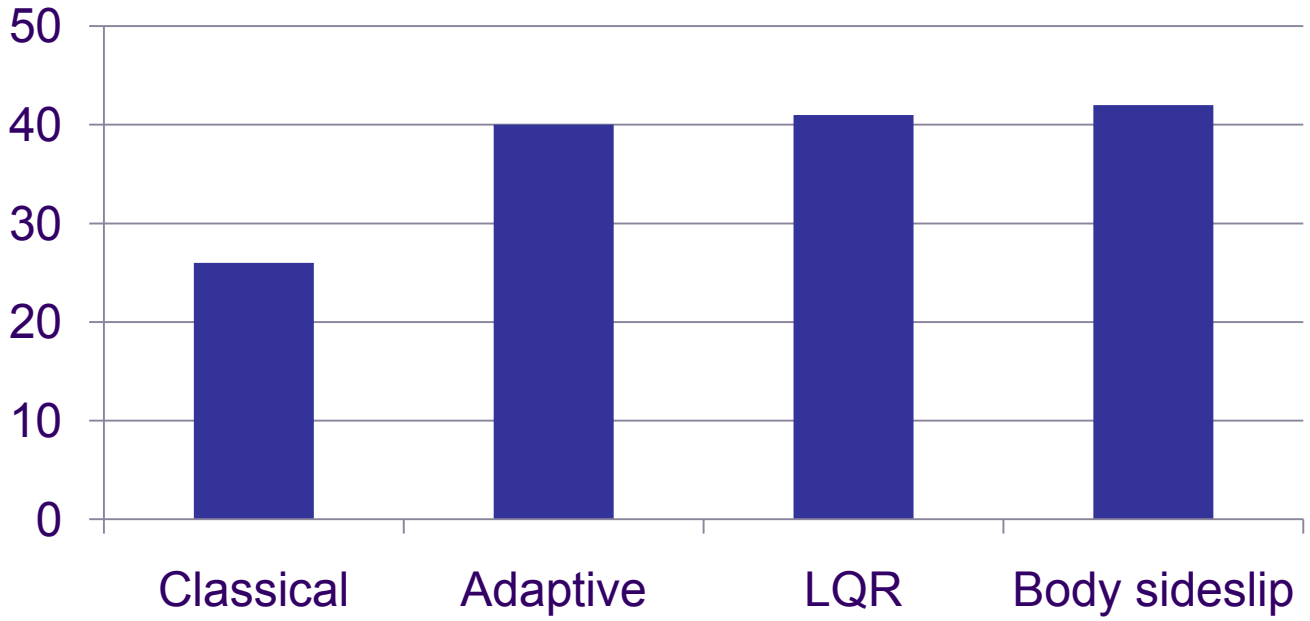
Much worse – Worse – About the same – Better – Much better

Testing


Simulator occupant only allowed past this point when red light is flashing

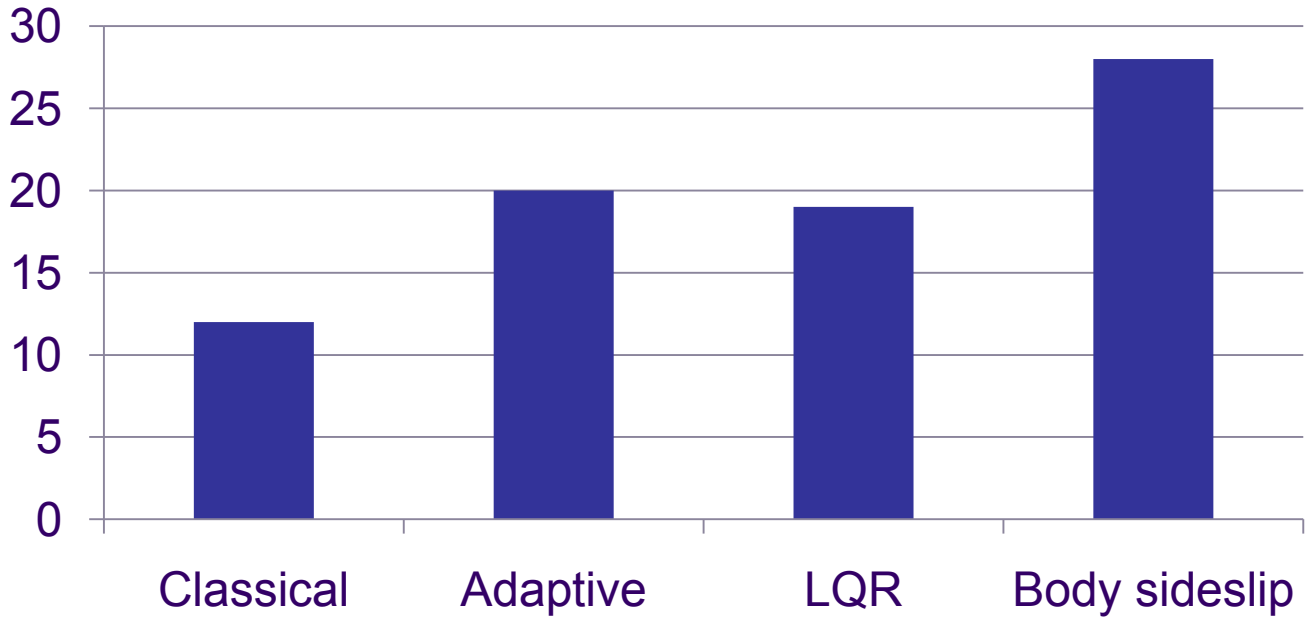
Testing

- Result – number of ‘wins’, all subjects



Testing

- Result – number of ‘wins’, subjects with consistency > 50%



- Future work

Future work

- Further develop sideslip cueing algorithm
- Compare with non-linear LQR, MPC
- Perform tests with expert drivers

- Conclusions

Conclusions

- Body sideslip cueing implemented
- Normal driving – as good as existing algorithms
- To be investigated further with expert drivers