The Perception and Control of Yaw Centres during simple manoeuvres.

Malcolm Burgess
Chief Engineer Vehicle CAE
Lotus Engineering

Lotus Active Rear Steer Car

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- Rear Steer – Background
- Simple vehicle dynamic theory
- Pseudo-static analysis
- Control of the Yaw Centre
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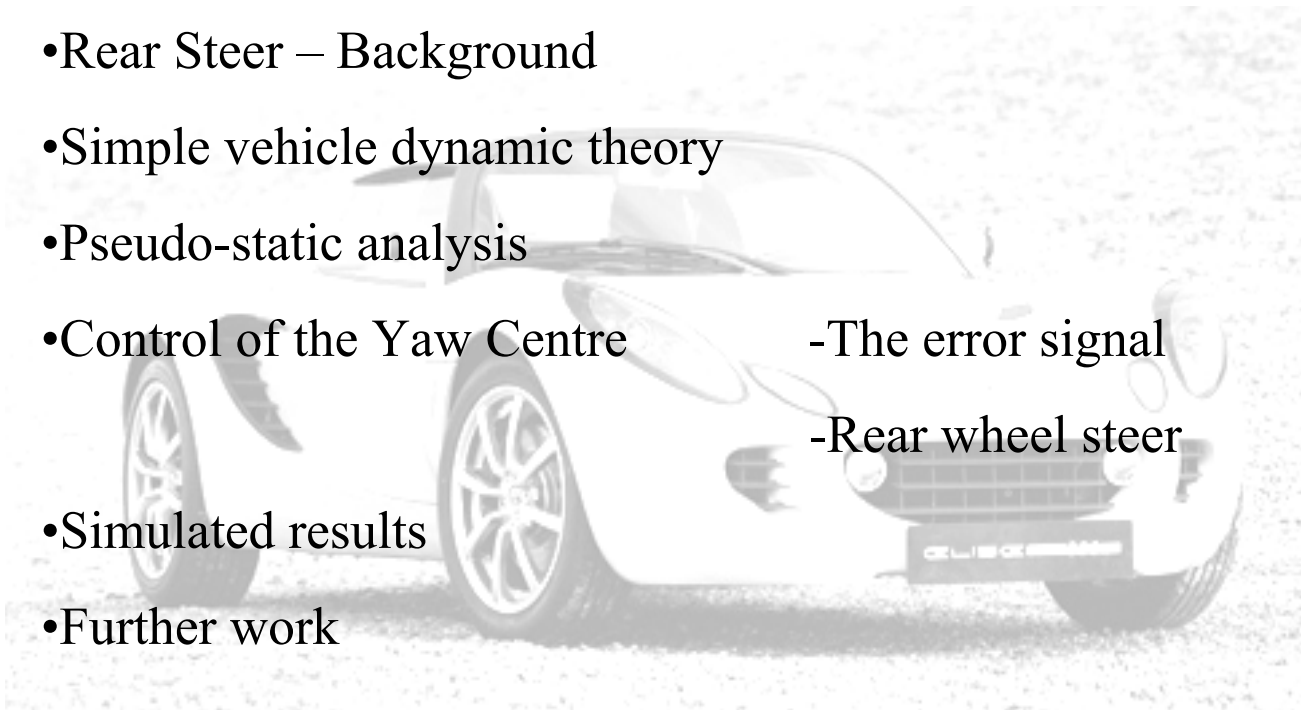
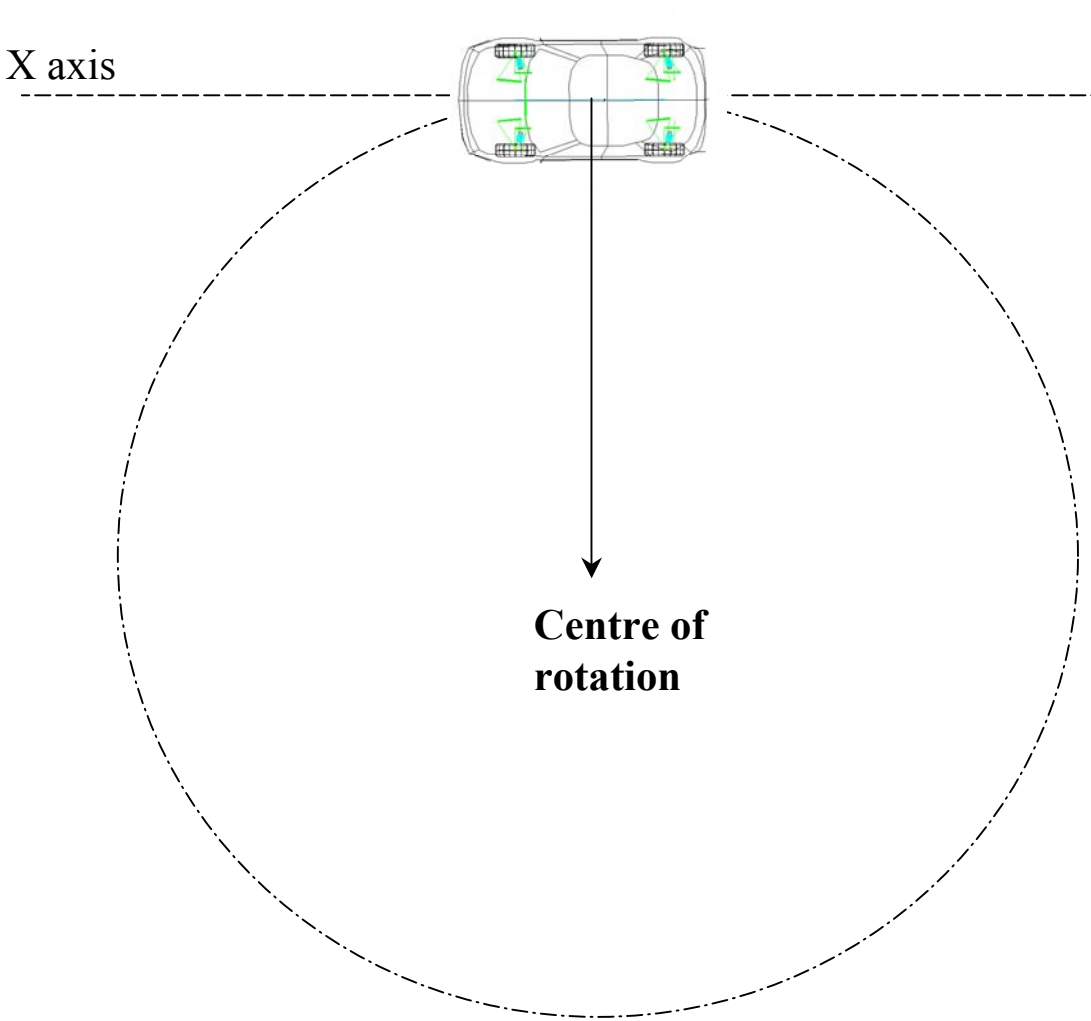
  - -Rear wheel steer
- Simulated results
- Further work



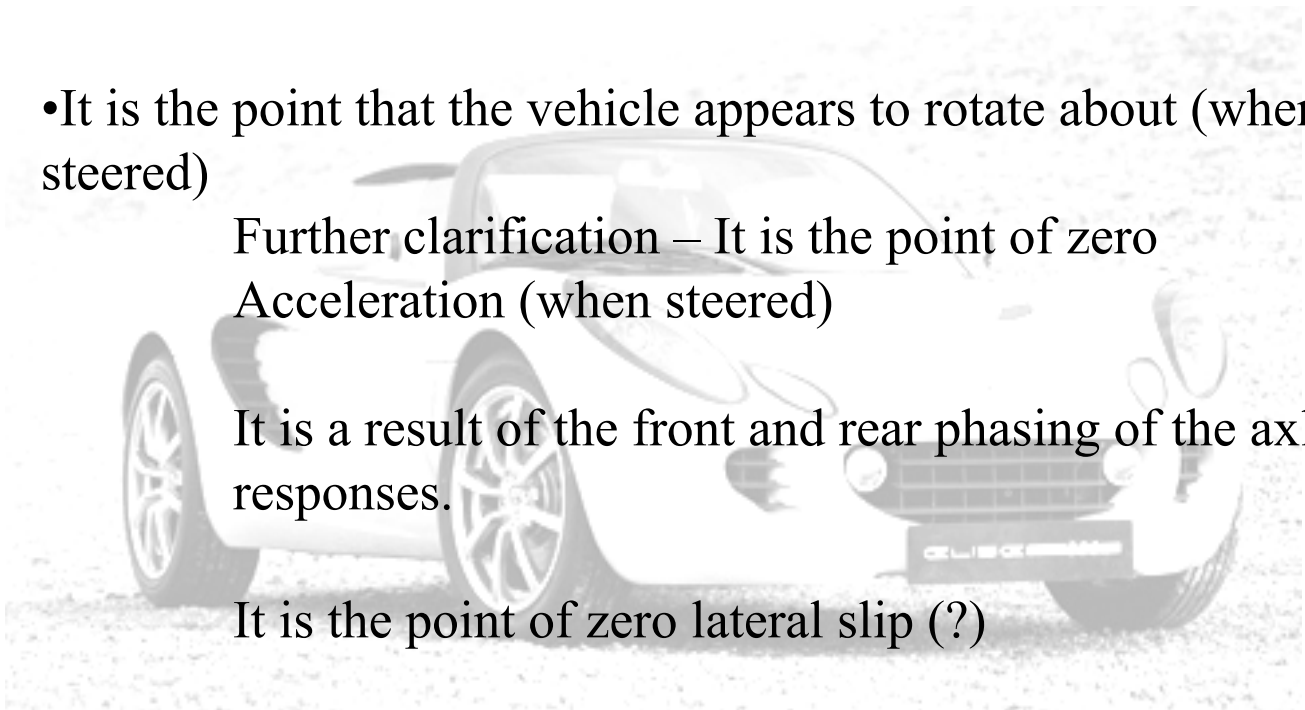
Firstly !



- Forward motion ?
- Perception ?

Description of a Yaw centre

What is a Yaw Centre ?



•It is the point that the vehicle appears to rotate about (when steered)

Further clarification – It is the point of zero Acceleration (when steered)

It is a result of the front and rear phasing of the axle responses.

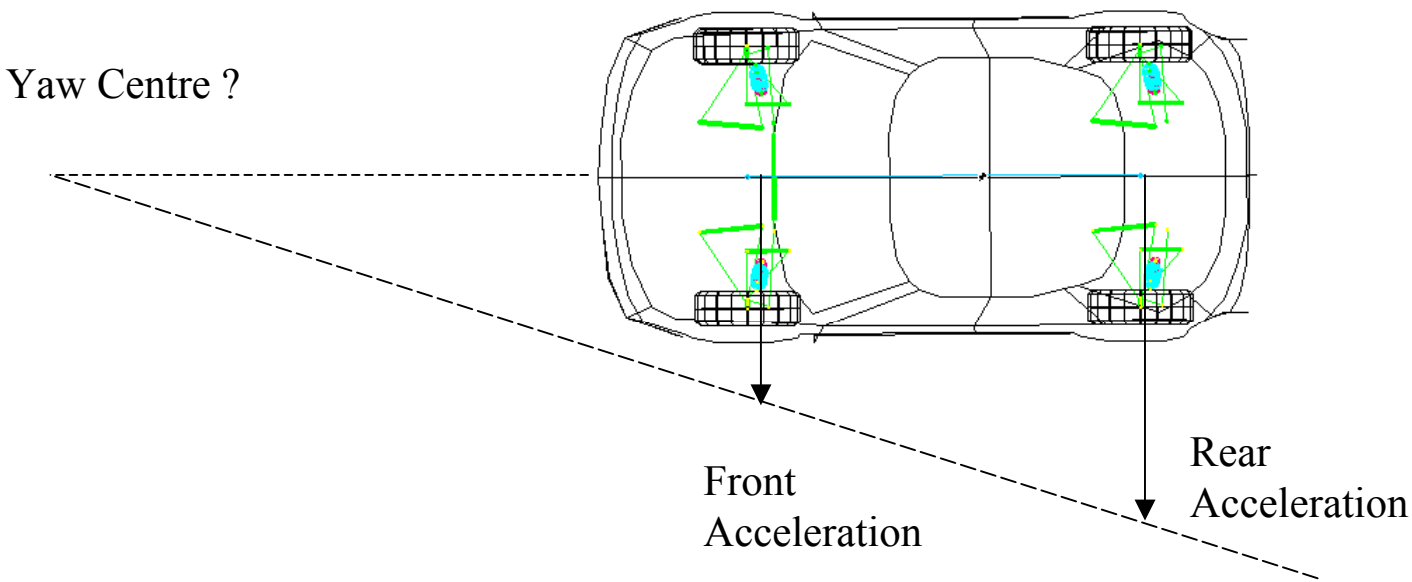
It is the point of zero lateral slip (?)

Description of a Yaw centre

How could we measure it ?

Measure the acceleration at the front and rear of the car, and calculate where the zero acceleration is

Diagram 1 . Acceleration yaw centre



Description of a Yaw centre

Where should it be ?

Behind the driver – somewhere near the rear axle

Could you sense it with your eyes closed ?

Generally accepted that it can be sensed (with eyes closed)

What effects it ?

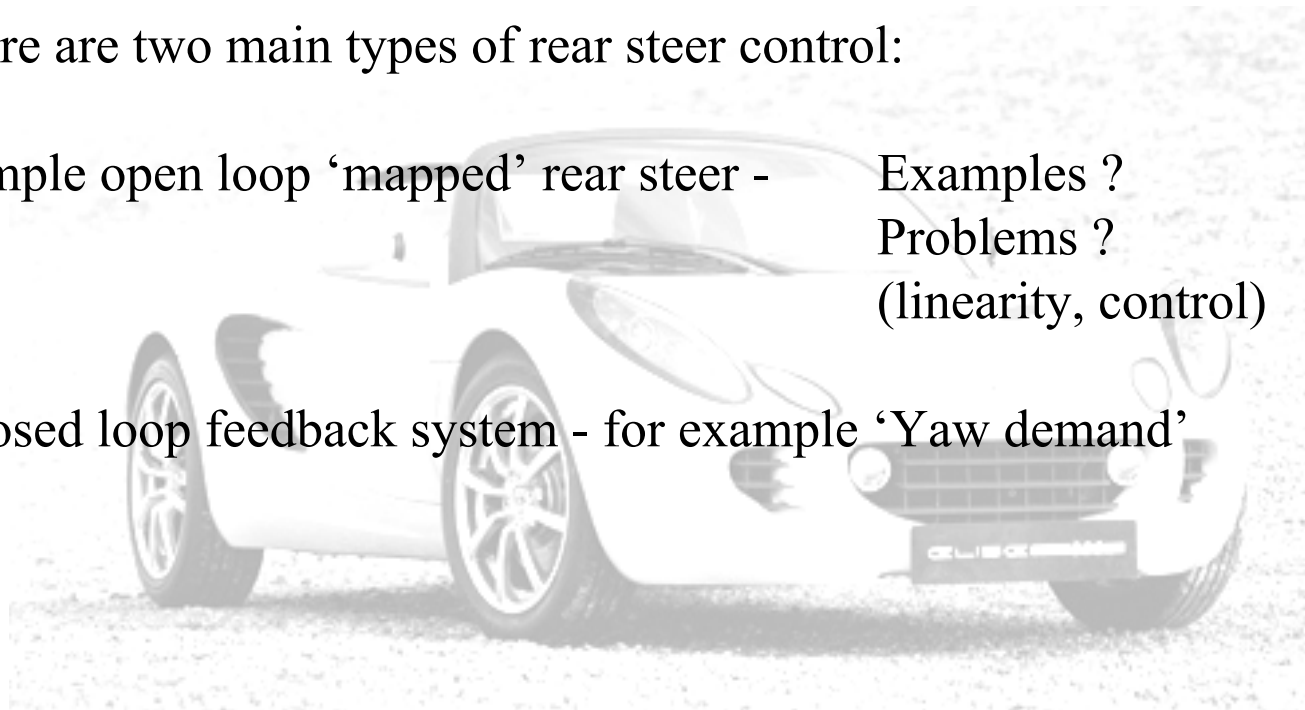
Suspension Characteristics (particularly the rear)
Ackermann
Tyre characteristics
Lateral stiffness of the suspension (mainly rear)
Damping

Rear Steer – Background

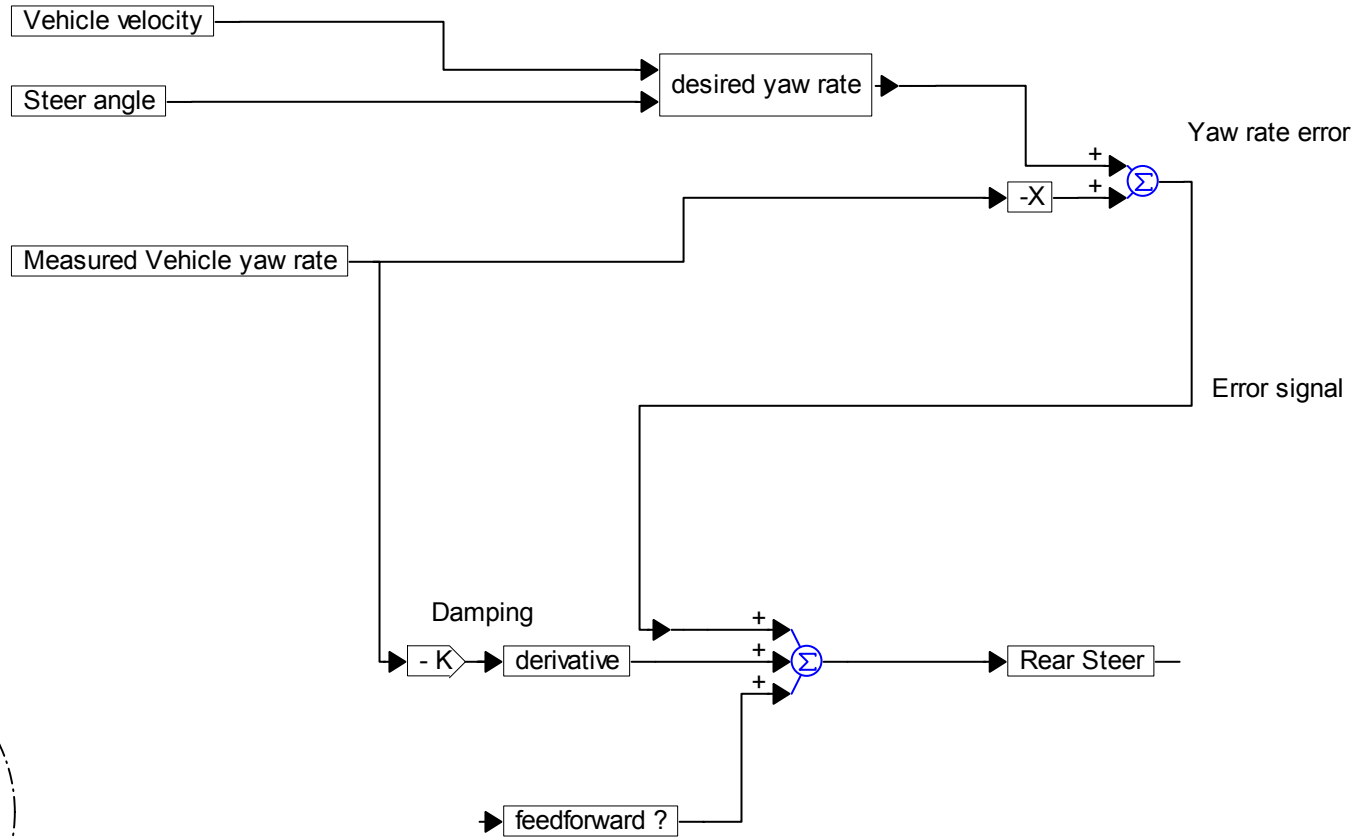
There are two main types of rear steer control:

•Simple open loop ‘mapped’ rear steer - Examples ?
Problems ?
(linearity, control)

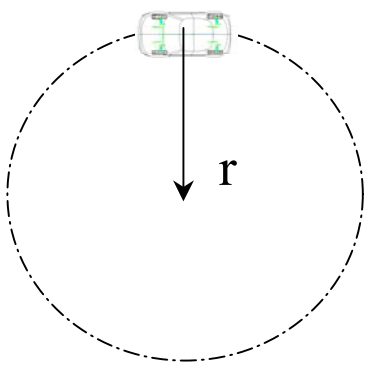
•Closed loop feedback system - for example ‘Yaw demand’



Closed loop feedback system - yaw demand

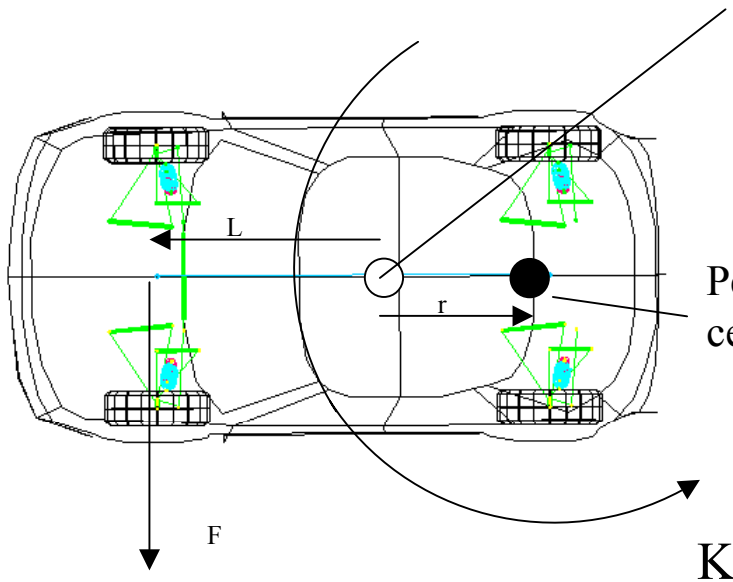


$$V = \omega \cdot r$$



Simple theory.

A vehicle that is initially steered by its front axle always yaw's about the percussion centre (near the rear axle). Initially the only force acting on the vehicle is at the front wheels (the rear wheel force build up later).



Centre of Gravity

Percussion centre

$a + \alpha.r = 0$

$F/M + (F.L)/I \ .r = 0$

$1/M + L./I \ .r = 0$

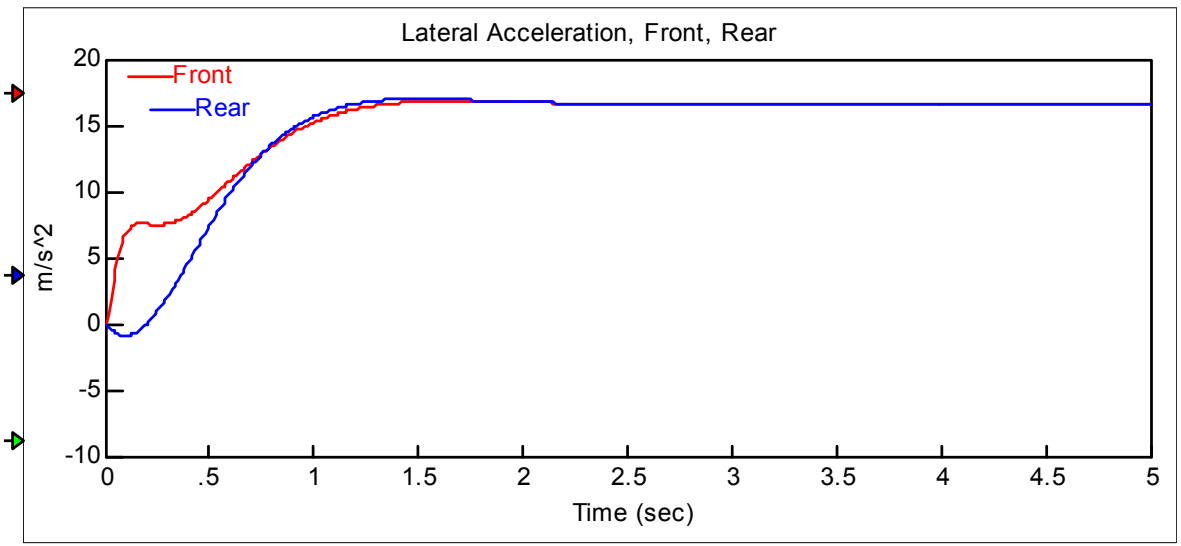
And therefore $r = - I / (M. L)$

Kinematic / compliant Rear steer has no effect

Lateral acceleration front / Rear

If the yaw centre is the instantaneous acceleration centre, then for interest it may be worth looking at simulated results for a step steer.

For a step steer manoeuvre, the accelerations front and rear, build up as below:



The front acceleration builds up first,

followed by the rear acceleration.

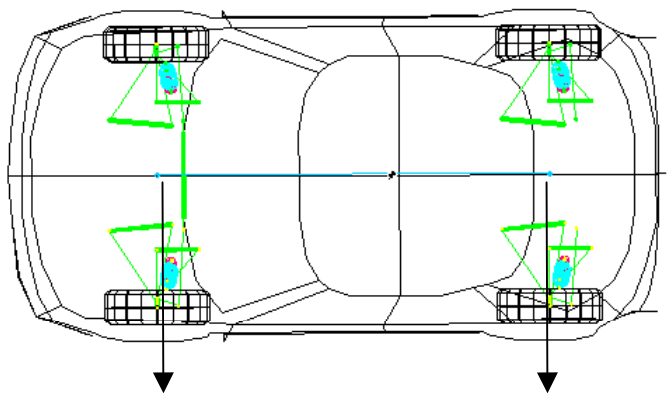
Steady state, front and rear accel'n

approx. equal

Phasing of the front and rear accelerations

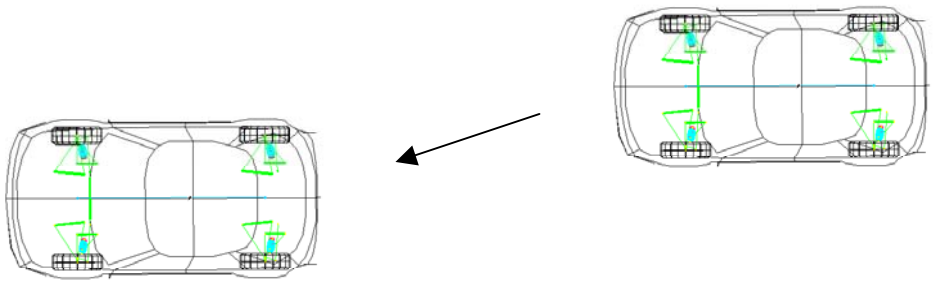
The front acceleration must lead the rear acceleration.

I this as not the case, then the vehicle would move laterally

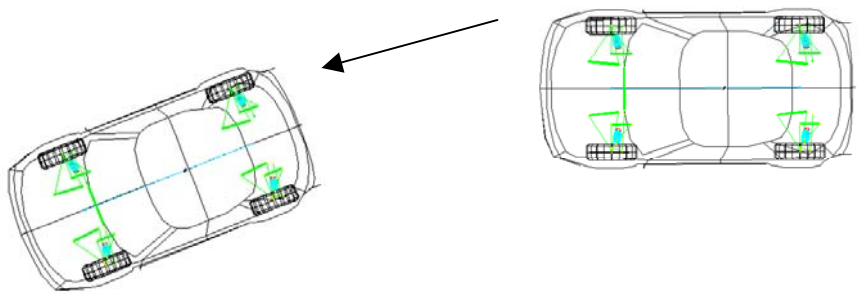


No body rotation

Vehicle response to a steering input ?



OR

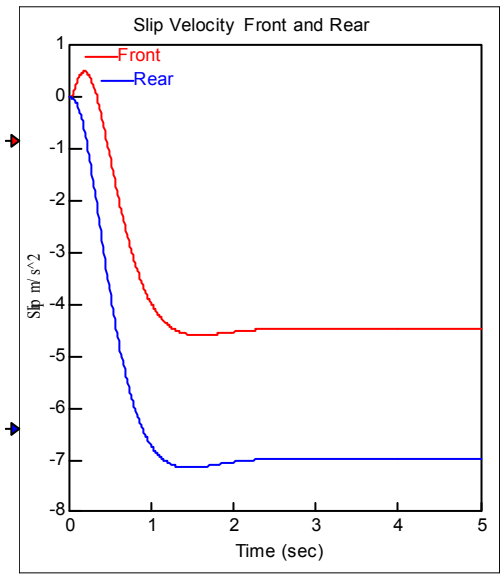


Which is the most desirable vehicle response to a steering input ?

And therefore which way should the rear wheels steer ?

Phasing is not really a choice

Body Slip angles - during a step steer Manoeuvre



Inwards

Outwards

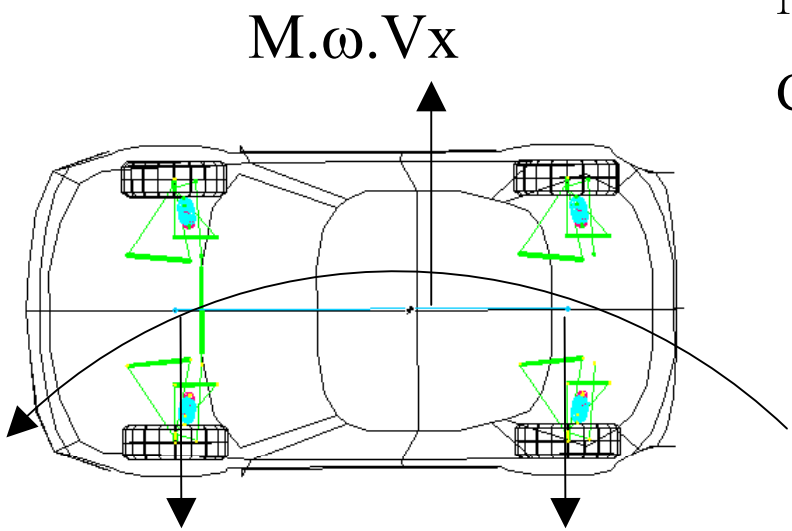
(vehicle relative to the road)

- Front initially slips inward
- Rear slips outward
- Front slips outward

Why am I bothered about the slip angle ?

Pseudo-static analysis

Since there is no forward motion:



Lateral tyre forces

Note.

Centripetal accer'n

$=V^2/R$

or ω^2/R

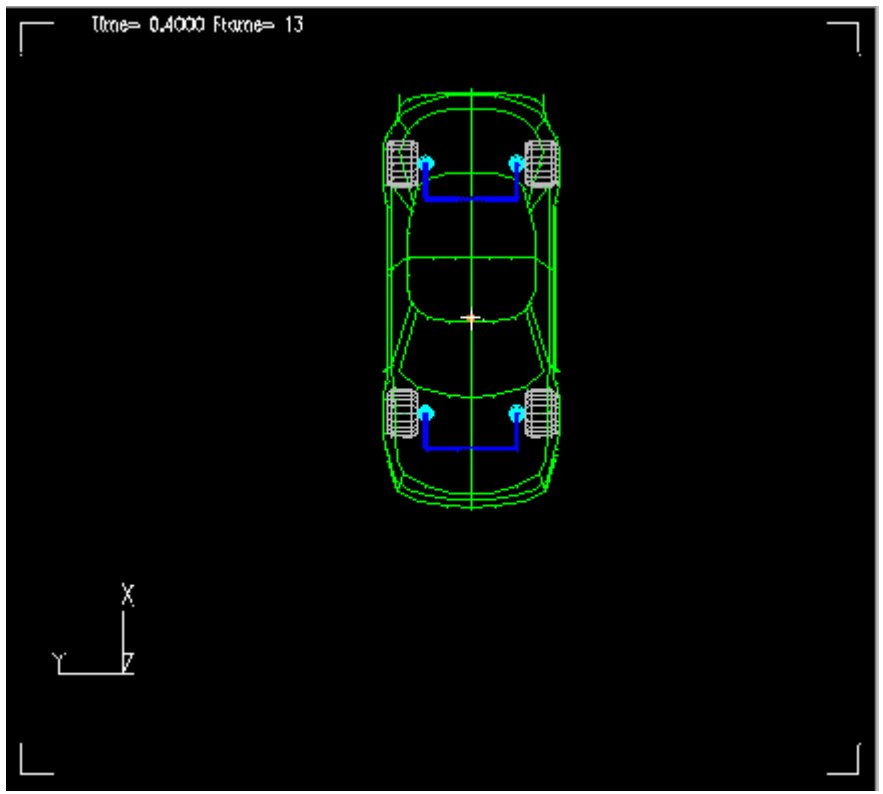
or $V \cdot \omega$

Centrifugal force ?

(only for visualisation)

Body slip during a step steer Manoeuvre

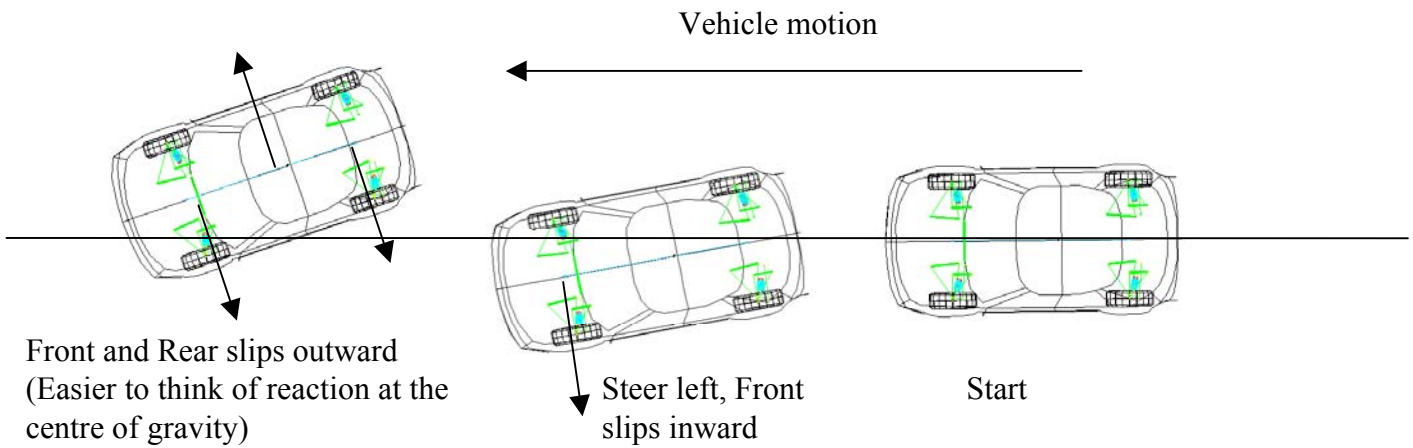
Animation from RAVEN Software



Slip relative to the road

Direction of travel

Body slip during a step steer Manoeuvre



- Could the body slip be a measure of the yaw centre - a slip yaw centre
- Slip angles cannot be measured easily on a production vehicle

Lateral acceleration components

Lateral acceleration = Transient component + centripetal component

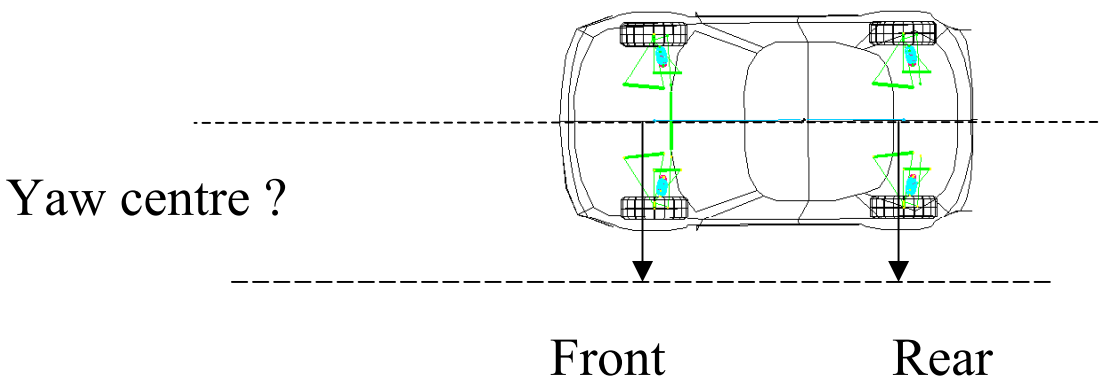
= body slip acceleration + centripetal acceleration

$= d_2/dt^2$ (slip) + ω . V

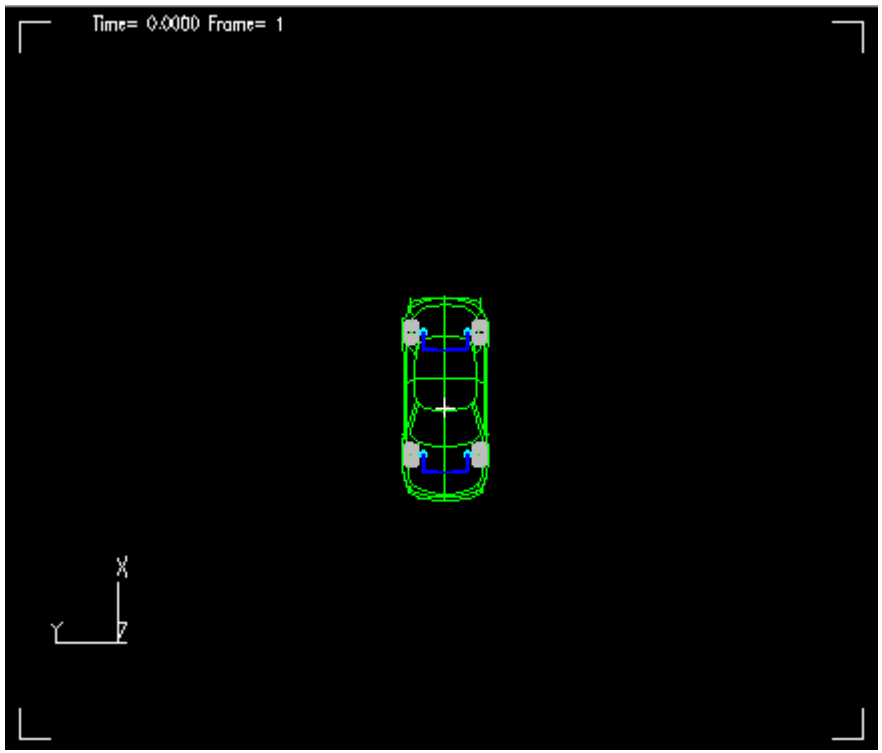
where ω is the yaw rate and V is the forward velocity

The yaw centre based on acceleration becomes **meaningless** at steady state

Steady state yaw centre ?



Steering pad Animation - increasing speed



No forward motion shown

Lateral slip

-Using pseudo-static analysis.

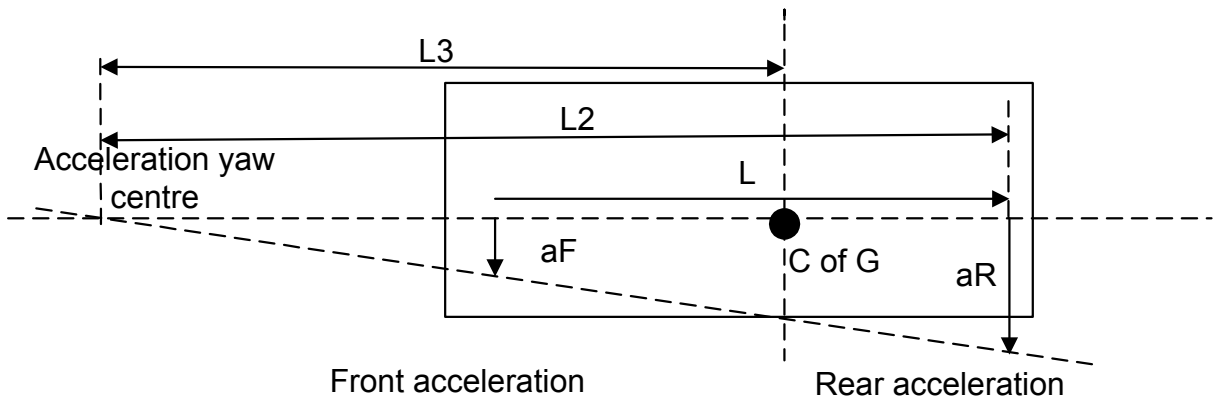
•Steady state. Yaw centre ?

•To control the slip velocity yaw centre, acceleration can still be used as an error signal

Control of the Yaw Centre - Rear wheel steer

The error signal.

If we take the original statement that the yaw centre is the point of zero acceleration then if we are to control this, we need to generate an error signal.



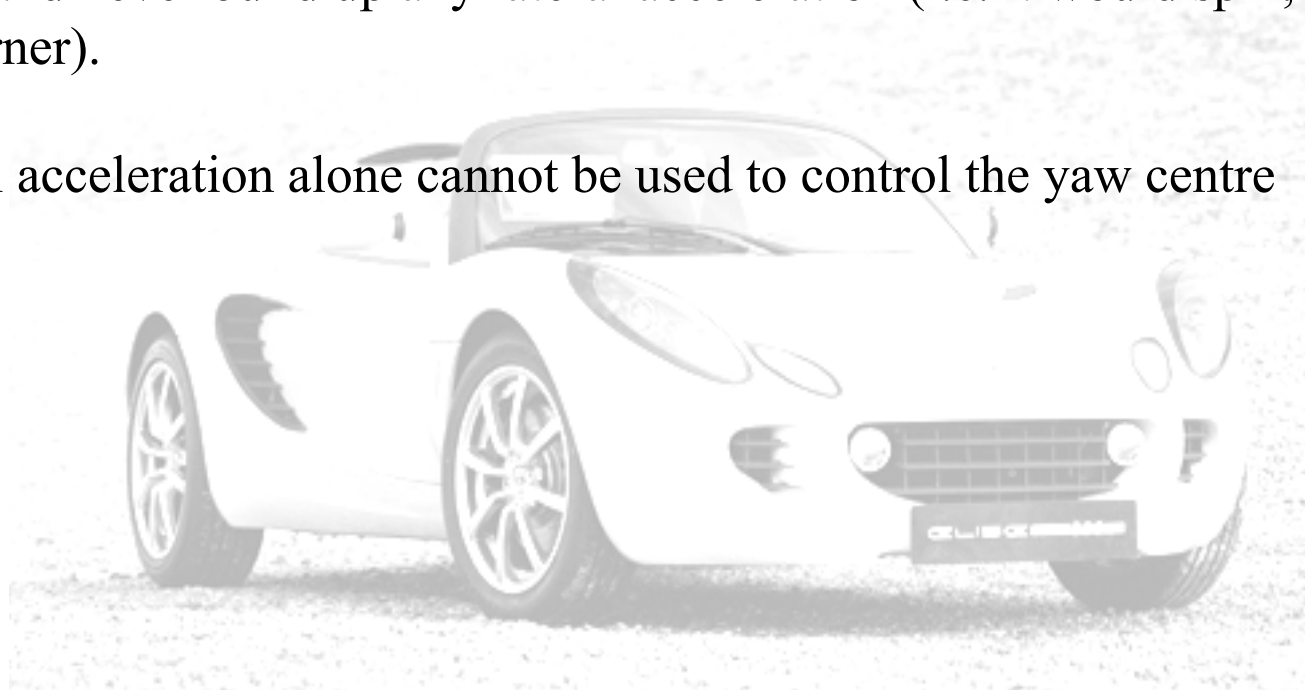
By similar triagles: $aR/L2 = (aR-Af)/L$

Yaw Centre from the rear axle is: $L2 = \frac{aR}{(aR-aF)} \times L$

The error signal

Using the lateral acceleration - the vehicle would only rotate about this point, and never build up any lateral acceleration (i.e. it would spin, but not corner).

Lateral acceleration alone cannot be used to control the yaw centre



The Car handles like it is on Rails !

What would happen if the car was on rails ?

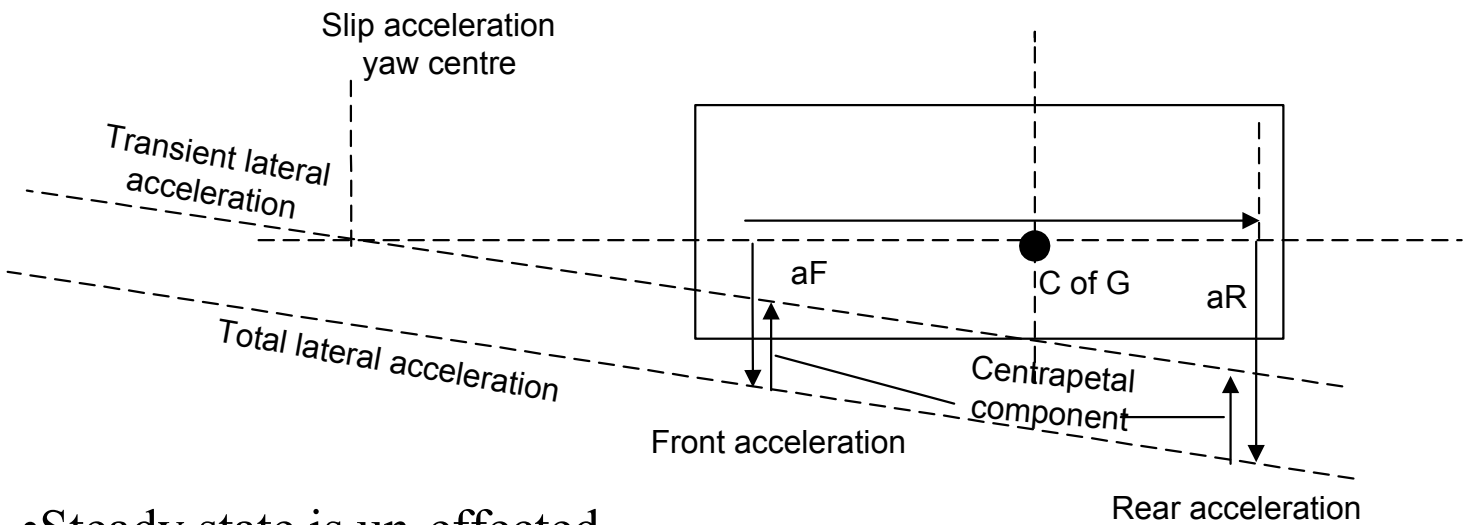
- There would be no slip
- The acceleration would be centripetal

Would this feel good ?

Can we test the hypothesis (that it does feels good)

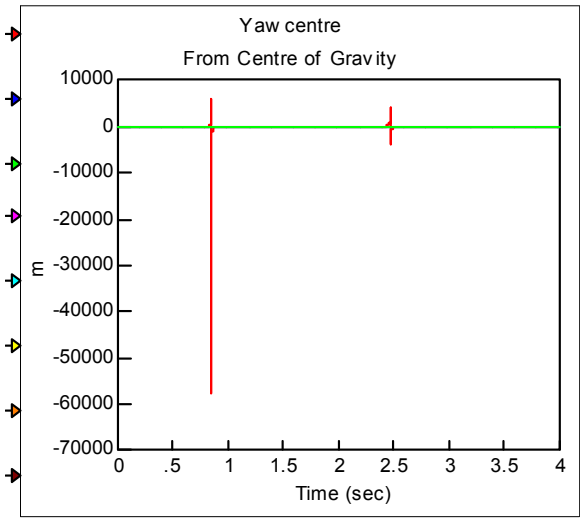
Yaw centre - slip acceleration

Measure the slip indirectly

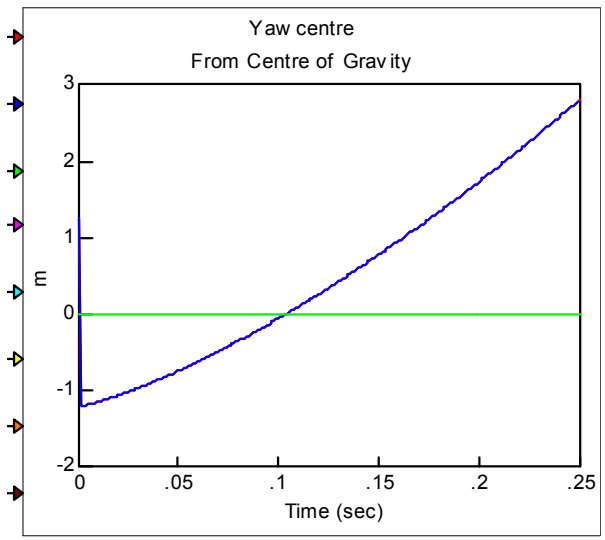


- Steady state is un-effected
- Initial transients are controlled

Passive Yaw centre (transient)

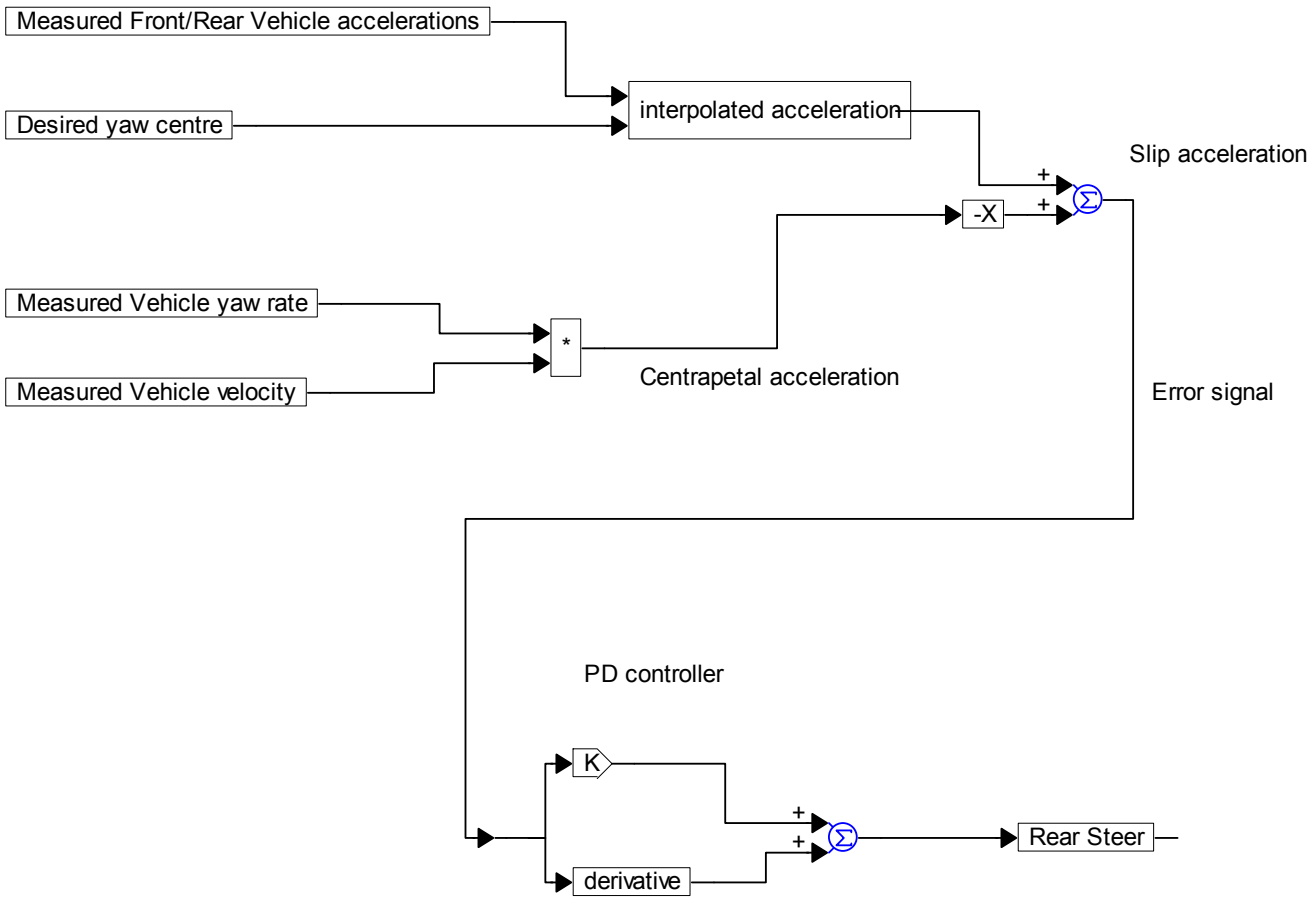


Useless plot

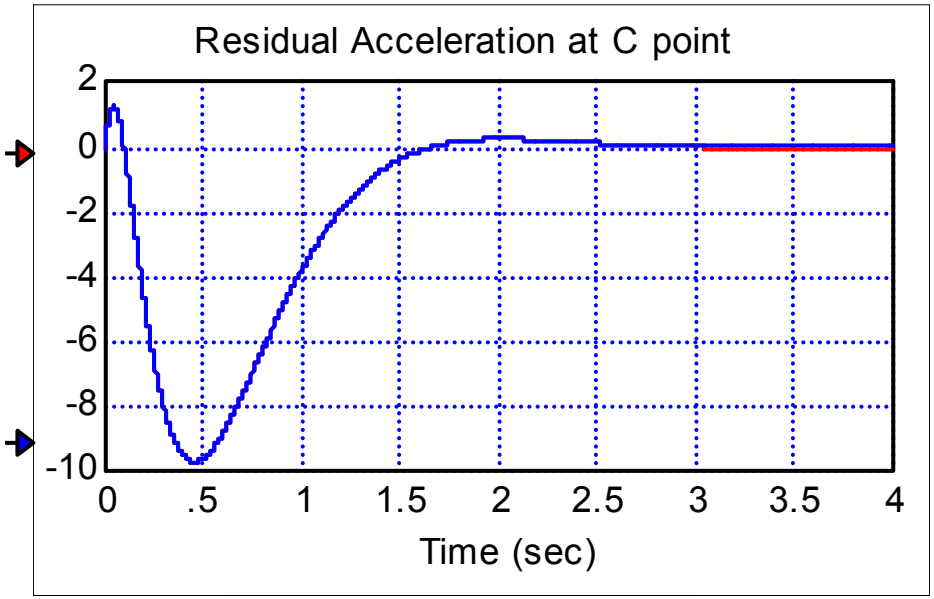


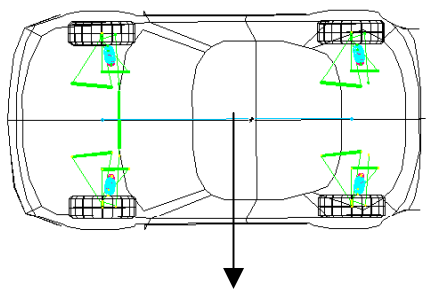
Initially at the percussion centre - then moving forward

New Control strategy (simplified)

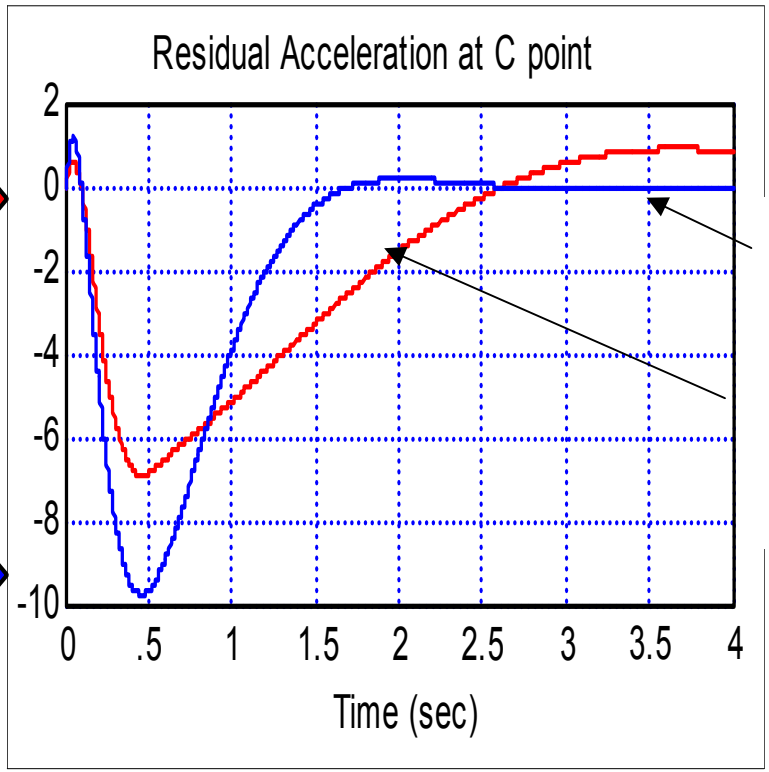


Interpolated Slip acceleration. (Passive)



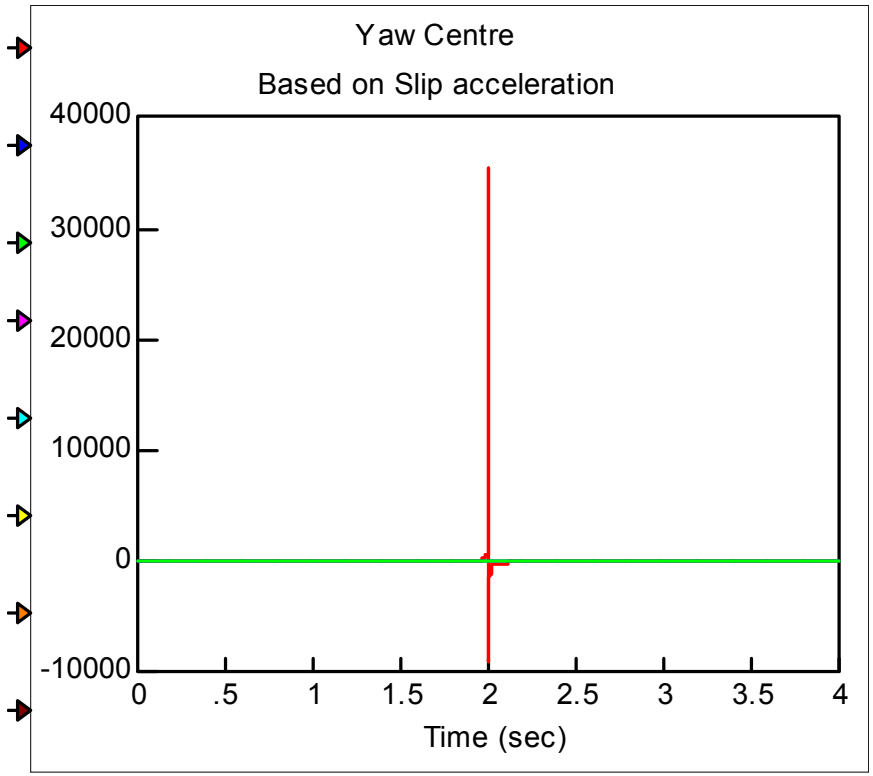


Interpolated Slip acceleration. Passive and Active



Passive

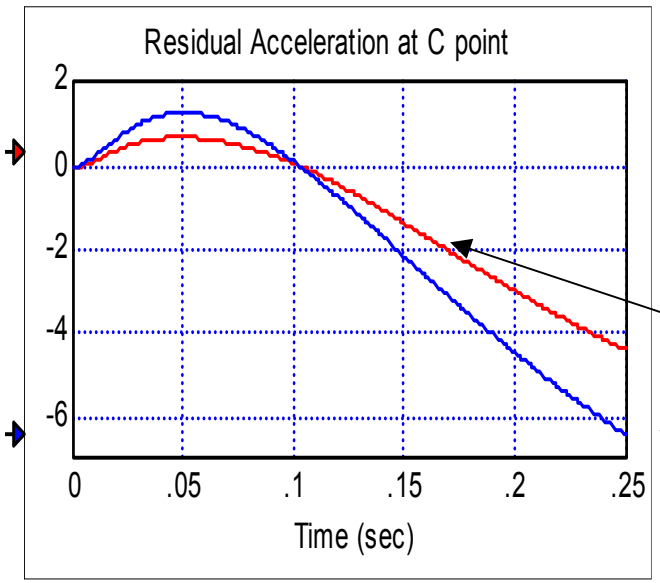
Active



Useless plot !

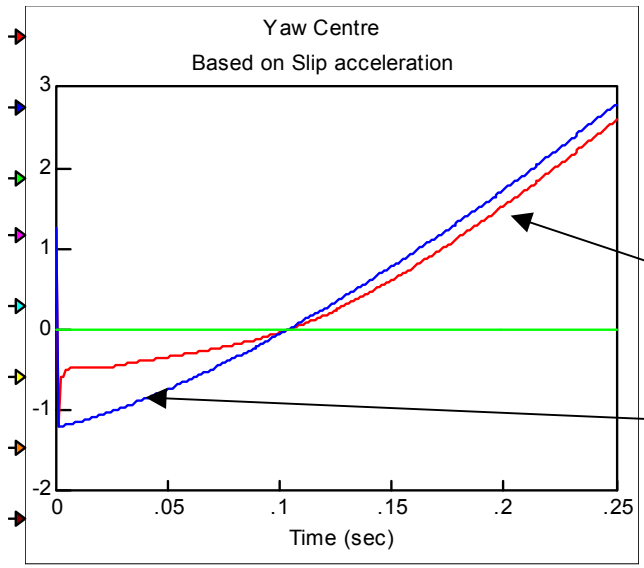
Interpolated Slip acceleration and resultant Yaw Centre

Passive and Active



Active

Passive



Active

Passive

Summary

- A signal can be generated of the lateral slip acceleration (interpolated)
- The slip acceleration can be used as an error signal to a feedback system
- This feedback can be used to move the yaw centre, but not fix it
- Steady state is unaffected

Limited subjective assessment

- Initial turn-in is faster as the yaw centre is moved forward

- If a yaw cenre is fixed beyond the front or rear axle, the vehicle has a tendancy to go unstable – due to interpolation difficulties with noise on the accelerometers.

- The vehicle does not feel better or worse – just different.

Further Work

- Limit handling

Tyre characteristics reverse at the limit (high slip angles) and rear steer can create problems.

- Signal Noise.

The accelerometers are subject to noise. Model based controllers may be an option

- Stability at varying speeds

It is not understood if different characteristics are required at different vehicle speeds.

- Combined with other control strategies – this may form one part of a larger control system.

Thank you