Active Stabilisation of Motorcycle Roll Dynamics at Low Speeds

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Introduction

The main goal of this project was to realise a steering controlled stabilisation system for a motorcycle with the aim of increasing safety at low speeds.

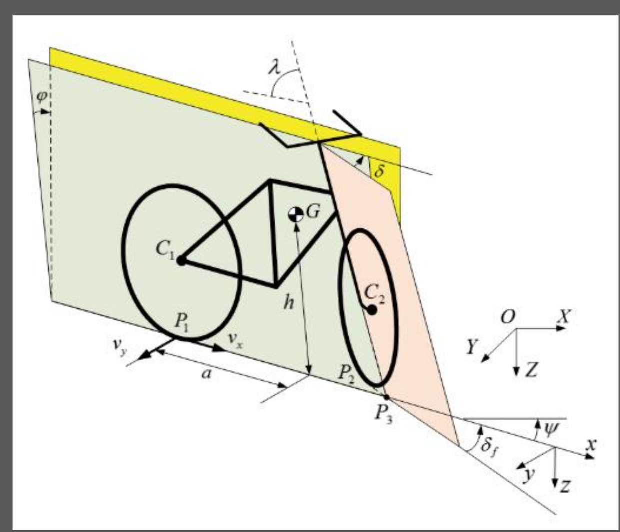
Safer motorcycles would allow drivers who commute alone to travel to work by motorcycle instead of by car, whilst still ensuring their safety. This change would help solve problems with traffic flow and parking shortages.

Motorcycle Modelling

The roll and steering systems of the motorcycle were modelled using the following transfer functions.

$$\frac{\varphi(s)}{\delta(s)} = \frac{-s\frac{ah\sin(\lambda)v_x}{bh} + \frac{acg\sin(\lambda)}{bh^2} - \frac{\sin(\lambda)v_x^2}{bh}}{s^2 - \frac{g}{h}}$$

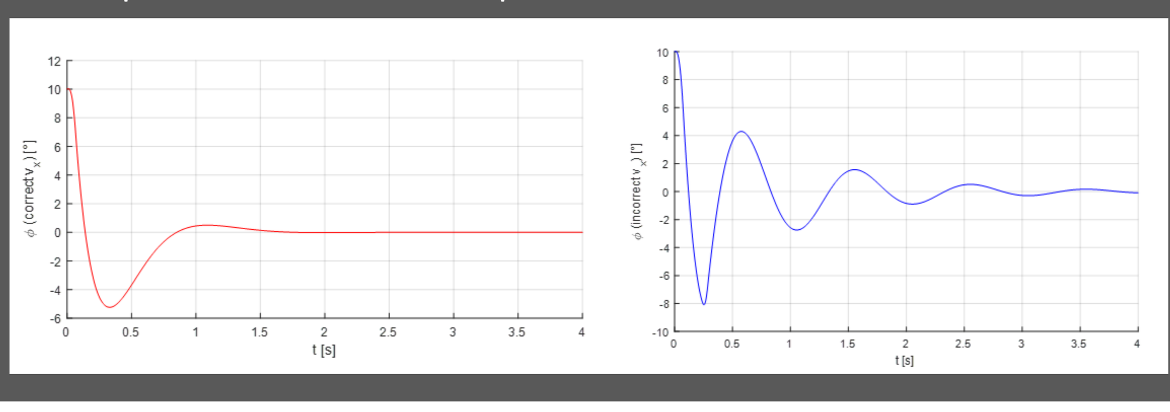
$$\frac{\delta(s)}{V_{A,s}(s)} = \frac{\frac{n_{g,s}\eta_{g,s}k_{m,s}}{J_sL_{A,s}}}{s^3 + s^2\frac{R_{A,s}}{L_{A,s}} + s\frac{n_{g,s}{}^2\eta_{g,s}k_{m,s}{}^2}{J_sL_{A,s}}}$$



Using the roll transfer function, the optimum motorcycle geometry for control was determined.

$$\frac{a}{b} \to 1 \qquad h \to 0 \qquad c < 0 \qquad \sin(\lambda) \to 1 \Leftrightarrow \lambda \to \frac{\pi}{2}$$

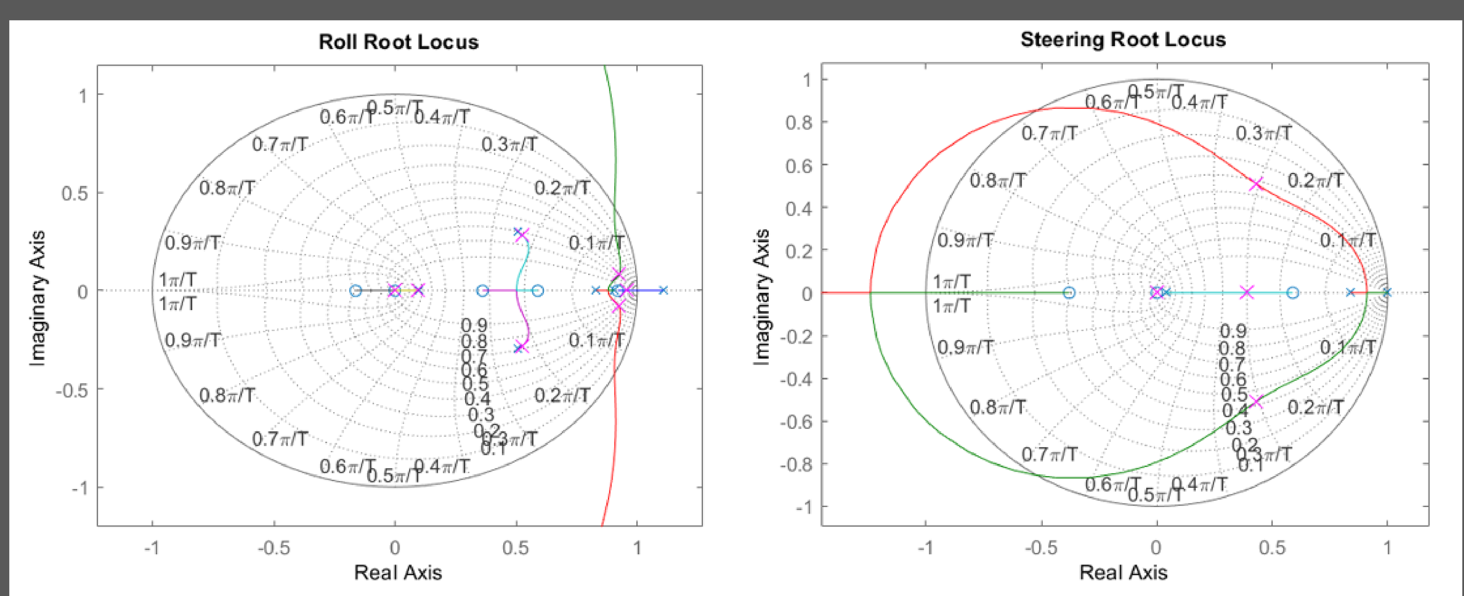
The zero in the roll transfer function was dependant on the motorcycle's velocity, meaning that an adaptive controller was required.



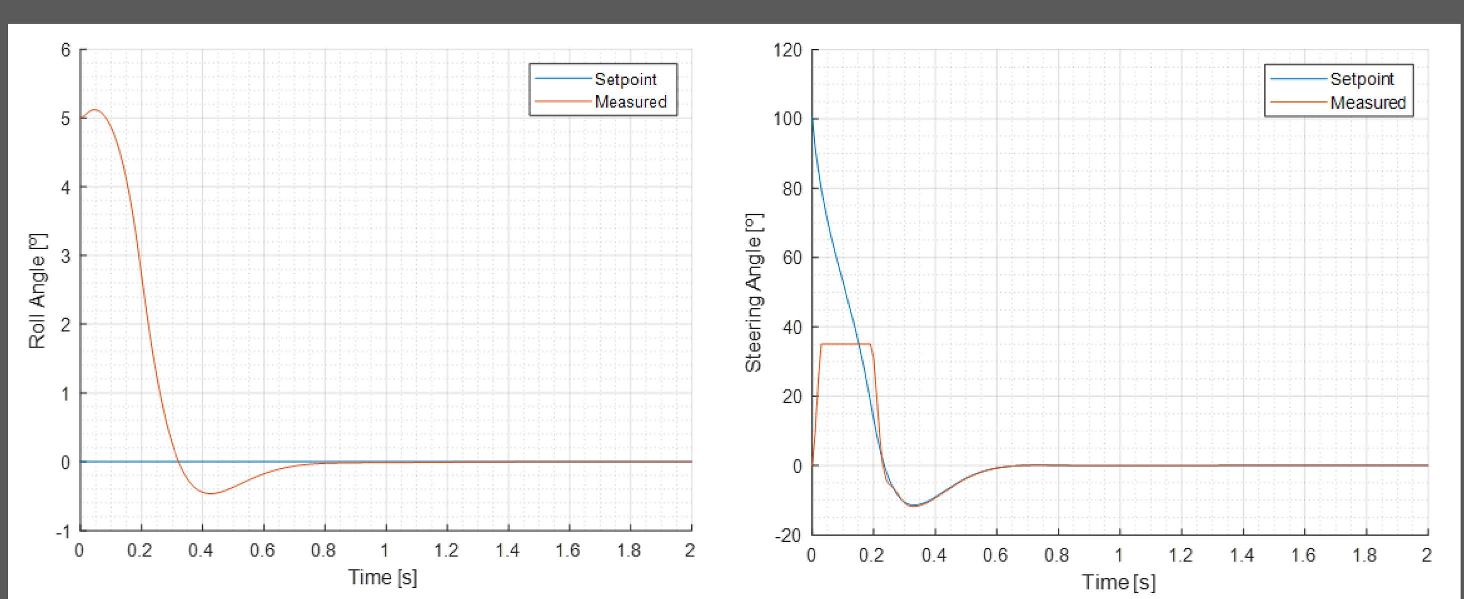
$$zero_{roll} = \frac{acg - hv_x{}^2}{av_x}$$

Motorcycle Simulation

Poles and zeros were placed on root locus plots to achieve desired performance The root locus allows the designer to check the system's stability. Here both systems had 0.707 damping. The natural frequencies of the roll and steering systems were 12 rad s^{-1} and 75 rad s^{-1} respectively.



Transient plots were used to test controller performance.



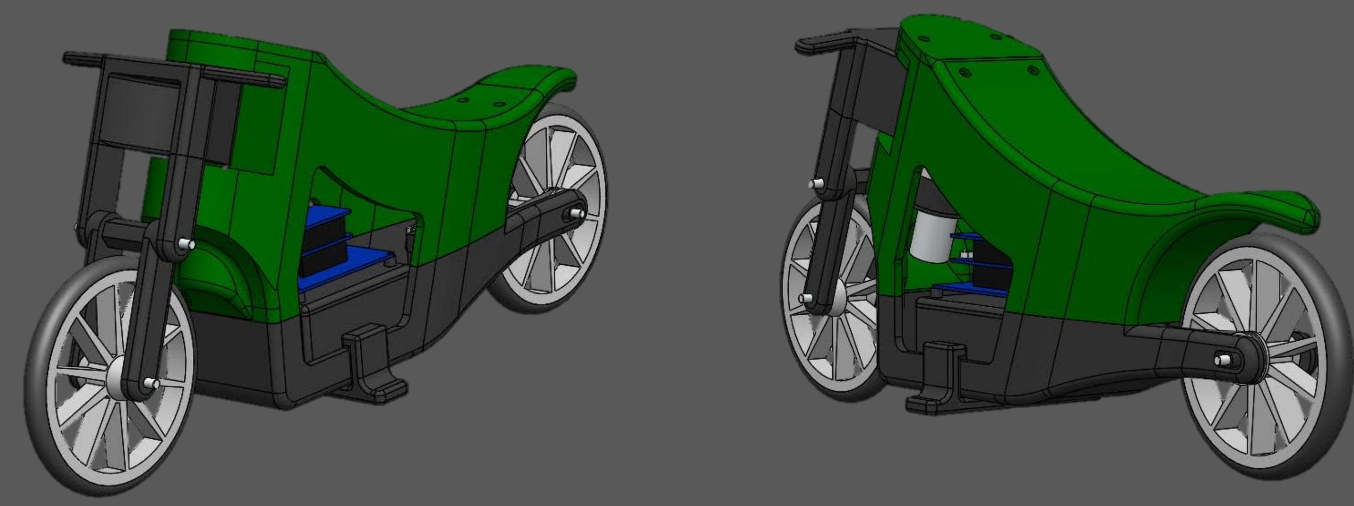
Conclusions and Future Work

This project was successful in achieving balance control of a stationary motorcycle. The author gained significant insights into systems engineering and the model based design approach and overall the project was a very positive experience.

Mechanical modelling, design for control and manufacture were the main focus of this project. While the author was satisfied with these areas, there is scope to improve the control algorithms used for stabilisation. Potential areas of research include, designing a non-linear state-space controller, further study on stabilisation while moving, improved disturbance rejection and designing a control algorithm that will function when there is a person on the motorcycle.

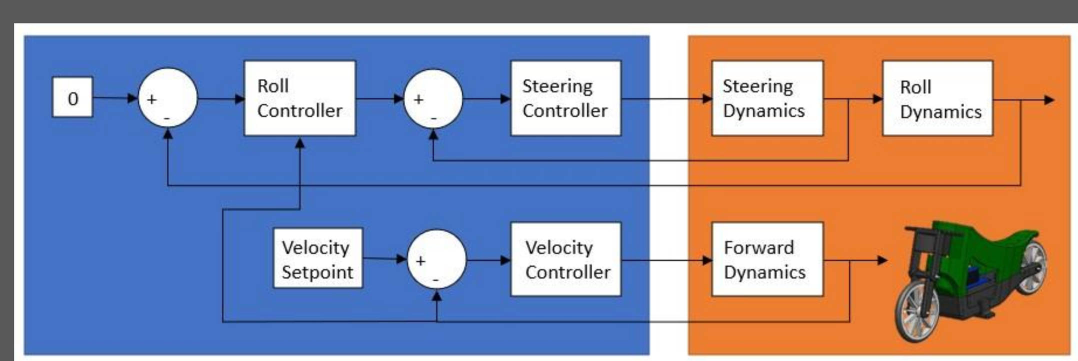
Mechanical Design and Manufacture

The SolidWorks model was designed for optimum controllability and ease of 3D printing.



Most parts were 3D printed using a rigid PLA material, however the tires were printed from a flexible TPU to increase traction. Water soluble support materials enabled fast support removal after printing. Metal parts were used where 3D printing was not sufficient.

Motorcycle Control

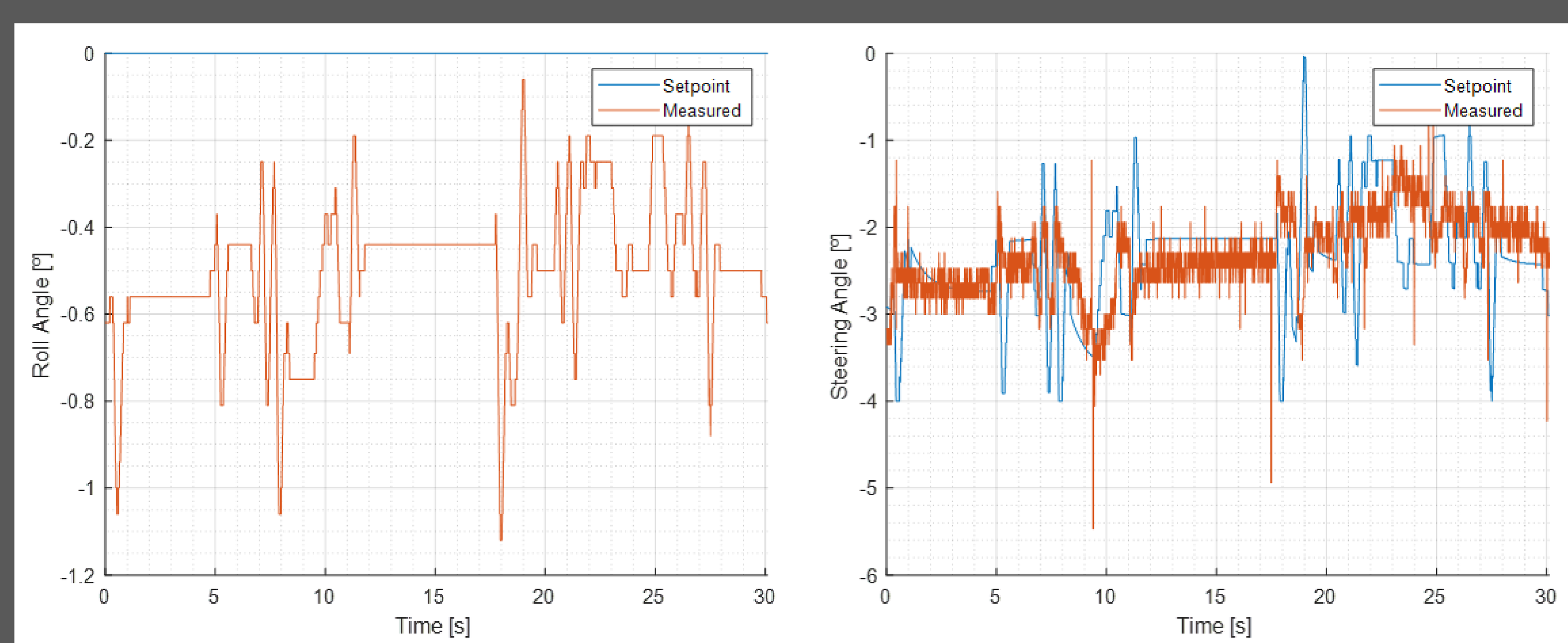


Cascaded phase lead control of steering and roll systems.

Proportional control of drive system.

Arduino MKR microcontroller, motor carrier and IMU used.

The Motorcycle was tested while balancing at zero-velocity. The roll plot shows a steady state error which was expected from a Type 0 system with a phase lead controller. Backlash in the steering gearbox resulted in non-optimal setpoint tracking.



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