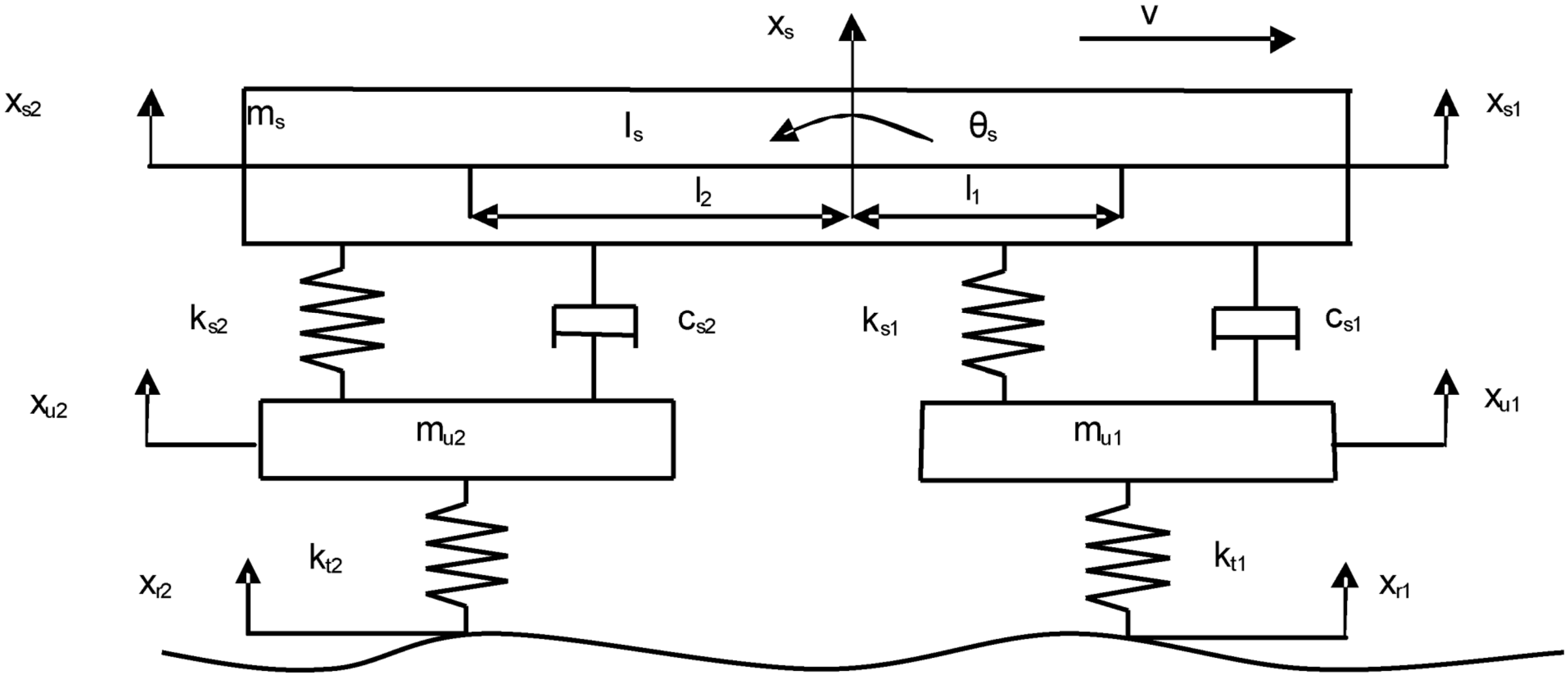
Half car model

Half car model assumptions

- Vehicle is defined as a two wheeler which has 4 DOF.
- Tire can be modeled as single spring or spring-damper sub-system.
- Spring rate and damper coef. can be modeled with linear equations.
- CG of the vehicle, spring rates and damper coef., mass of sprung and unsprung masses are inputs.

Half car model schematic



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Symbols

$X_s = Displacement\ of\ CG$

$X_{s1} = Displacement\ of\ body\ at\ front\ wheel\ axis$

$X_{s2} = Displacement\ of\ body\ at\ rear\ wheel\ axis$

$X_{u1} = Displacement\ of\ front\ unsprung\ mass$

$X_{u2} = Displacement\ of\ rear\ unsprung\ mass$

$X_{r1} = Road\ input\ acting\ on\ front\ wheel$

$X_{r2} = Road\ input\ acting\ on\ rear\ wheel$

$I_s = Mass\ moment\ of\ inertia\ of\ the\ vehicle\ body$

$m_s = Mass\ of\ vehicle\ body\ (considered\ as\ sprung\ mass)$

$m_{u1} = Unsprung\ mass\ of\ front\ wheel\ system$

$m_{u2} = Unsprung\ mass\ of\ rear\ wheel\ system$

$\theta_s = Rotation\ of\ vehicle\ body$

$l_1 and\ l_2 = Distance\ of\ wheel\ axis\ to\ CG$

$k = Rate\ of\ an\ individual\ spring$

$C = Coefficient\ of\ an\ individual\ damper$

Defining the system

1 $$m_s\ddot{x}_s + c_{s1}(\dot{x}_{s1} - \dot{x}_{u1}) + c_{s2}(\dot{x}_{s2} - \dot{x}_{u2}) + k_{s1}(x_{s1} - x_{u1}) + k_{s2}(x_{s2} - x_{u2}) = 0$$

2 $$I_s\ddot{\theta}_s + l_1(c_{s1}(\dot{x}_{s1} - \dot{x}_{u1}) + k_{s1}(x_{s1} - x_{u1})) - l_2(c_{s2}(\dot{x}_{s2} - \dot{x}_{u2}) + k_{s2}(x_{s2} - x_{u2})) = 0$$

3 $$m_{u1}\ddot{x}_{u1} - c_{s1}(\dot{x}_{s1} - \dot{x}_{u1}) - k_{s1}(x_{s1} - x_{u1}) + k_{t1}(x_{u1} - x_{r1}) = 0$$

4 $$m_{u2}\ddot{x}_{u2} - c_{s2}(\dot{x}_{s2} - \dot{x}_{u2}) - k_{s2}(x_{s2} - x_{u2}) + k_{t2}(x_{u2} - x_{r2}) = 0$$

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Defining the system

- $x_s = (l_2 x_{s1} + l_1 x_{s2}) / l$
- $\theta_s = (x_{s1} - x_{s2}) / l$

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Defining the system

$$[M]\{\ddot{X}\}+[C]\{\dot{X}\}+[K]\{X\}=\{P\}$$

$$[M]=\begin{bmatrix} l_2 m_s/l & 0 & l_1 m_s/l & 0 \\ I_s/l & 0 & -I_s/l & 0 \\ 0 & m_{u1} & 0 & 0 \\ 0 & 0 & 0 & m_{u2} \end{bmatrix}$$

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Defining the system

$$[C]=\begin{bmatrix} c_{s1} & -c_{s1} & c_{s2} & -c_{s2} \\ l_1 c_{s1} & -l_1 c_{s1} & -l_2 c_{s2} & l_2 c_{s2} \\ -c_{s1} & c_{s1} & 0 & 0 \\ 0 & 0 & -c_{s2} & c_{s2} \end{bmatrix}$$

$$[K]=\begin{bmatrix} k_{s1} & -k_{s1} & k_{s2} & -k_{s2} \\ l_1 k_{s1} & -l_1 k_{s1} & -l_2 k_{s2} & l_2 k_{s2} \\ -k_{s1} & k_{s1}+k_{t1} & 0 & 0 \\ 0 & 0 & -k_{s2} & k_{s2}+k_{t2} \end{bmatrix}$$

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$$\{P\} = \begin{Bmatrix} 0 \\ 0 \\ k_{t1}x_{r1} \\ k_{t2}x_{r2} \end{Bmatrix}, \quad \{X\} = \begin{Bmatrix} x_{s1} \\ x_{u1} \\ x_{s2} \\ x_{u2} \end{Bmatrix}$$

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Vehicle specs

Parameters	Mean values
m_s	1794.4 kg
I_s	3443.05 kgm^2
m_{u1}	87.15 kg
m_{u2}	140.4 kg
l_1	1.271 m
l_2	1.716 m

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Vehicle specs

Parameters	Mean values
k_{s1}	66824.4 N/m
k_{s2}	18615.0 N/m
c_{s1}	1190 Ns/m
c_{s2}	1000 Ns/m
k_{t1}	101115.0 N/m
k_{t2}	101115.0 N/m

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Response to a bump input