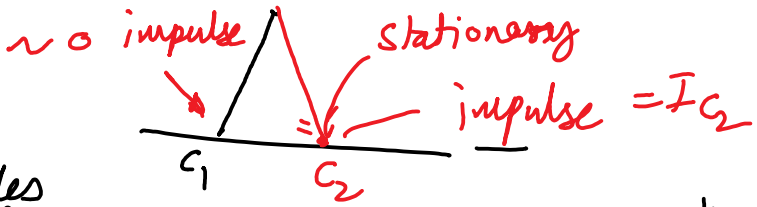
Foot-strike

$$\int_{t^-}^{t^+} M(q)\,\ddot{q}\,dt = \int_{t^-}^{t^+} B(q,\dot{q})\,dt + \int_{t^-}^{t^+} J_{C_1}^T P_G\,dt + \int_{t^-}^{t^+} J_{C_2}^T P_{C_2}\,dt \quad \text{from SS}$$

$= 0$ (coriolis, centripetal, gravity) $= 0$

t^- to t^+ is a really short time



angles

$$M(q)\left(\dot{q}^+ - \dot{q}^-\right) = J_{C_2}^T \left(\int_{t^-}^{t^+} P_{C_2}\,dt\right) \quad I_{C_2}$$

q equations ← equation

change in $\dot{q}$

$\dot{q}^+ = \{\dot{x}^+, \dot{y}^+, \dot{\theta}_1^+, \dot{\theta}_2^+\}$ = unknowns } 6 unknowns =

$I_{C_2} = I_{C_2}^x, I_{C_2}^y$ = unknowns

$V_{C_2}^+ = 0 \Rightarrow J_{C_2}^+ \dot{q}^+ = 0$ → 2 more equations

$$M(\dot{q}^+ - \dot{q}^-) = J_{C_2}^T I_{C_2}$$

$$J_{C_2}^T \dot{q}^+ = 0$$

$$M\dot{q}^+ + J_{C_2}^T I_{C_2} = M(q)\dot{q}^- \quad \} \ (I)$$

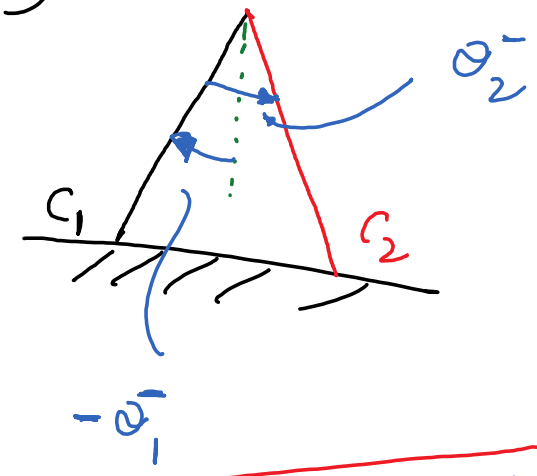
rewrite (I)

$$\Rightarrow \begin{bmatrix} M & -J_{C_2}^T \\ J_{C_2}^T & 0 \end{bmatrix} \begin{bmatrix} \dot{q}^+ \\ I_{C_2} \end{bmatrix} = \begin{bmatrix} M\dot{q}^- \\ 0 \end{bmatrix}$$

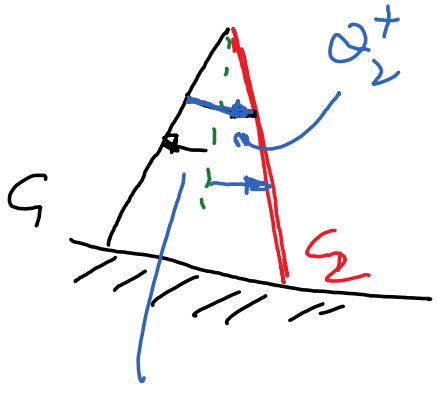
algebraic equation

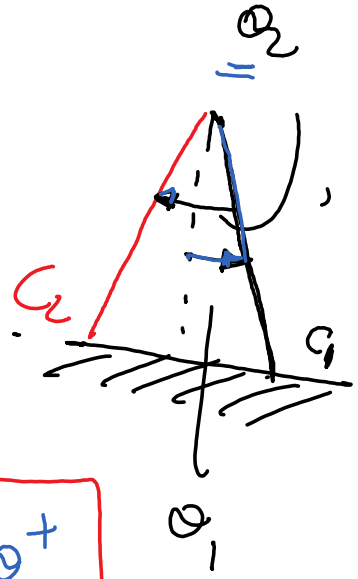
What about the angle

(−)



(+)





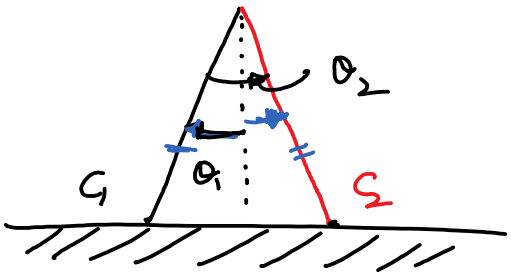
$$\theta_1 = \theta_2^+ - (-\theta_1^+) = \theta_2^+ + \theta_1^+$$

$$\omega_1 = \omega_1^+ + \omega_2^+$$

$$\theta_2 = -\theta_2^+$$

$$\omega_2 = -\omega_2^+$$

(3) Detect ground



$y_{G_2} - y_{G_1}$ = height of swing leg G_2 wrt stance leg G_1

$= 0$

→ $y_{G_2} = y_{G_1}$ → detect the ground

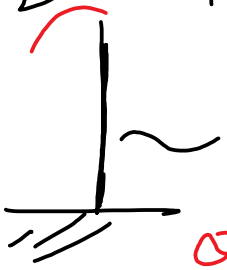
$\theta_1 = (\theta_2 - \theta_1)$

→ $\theta_2 = 2\theta_1$

One issue

$\theta_2 = 2\theta_1$ is not true time

(1) ✗

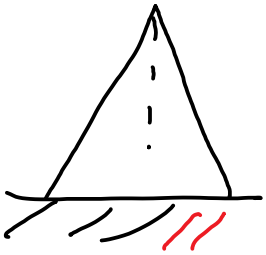


When legs are nearly vertical

$\theta_2 = 2\theta_1$

$\theta_1 < -0.05$

(2) Normal ✓



see collision.m 'event' in ode45.

z_0 = initial condition

$-\theta_2$

$\theta_1 = 0.2$

$\theta_2 = -0.4$

$\dot{\theta}_1 =$

$\dot{\theta}_2 =$

onestep

1) single_stance
2) detect_ground / collision
3) foot-strike

t	θ_1	$\dot{\theta}_1$	θ_2	$\dot{\theta}_2$
0				
0.001				
⋮				

use one_bounce

animate ( )