→ When moving the following assumptions are made

1. Assuming that kinetic friction acting at point of con
~~No slipping at the point of contact with the ground~~

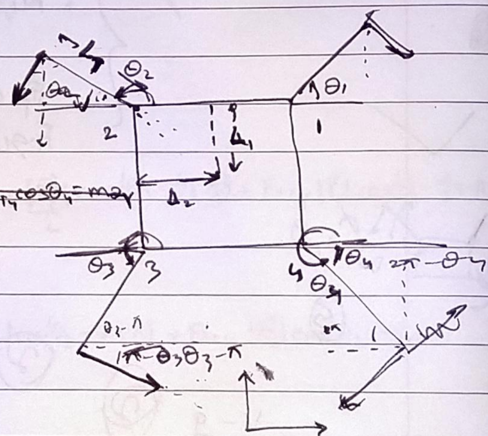
2. The angular acceleration ~~at the joints is 0~~ at the driving joints is 0

3. The friction forces is what causes the quadruped to move

4. All equations together form a system of linear equations.

5. Movement is along a flat ~~plan~~ even plane. or atleast the point of contacts with the ground form flat even plane.

F_{fr_1}



~~$F_{fr_1}\cos\theta_1 + F_{fr_2}\cos\theta_2 + F_{fr_3}\cos\theta_3 + F_{fr_4}\cos\theta_4 = ma_y$~~

$$F_{fr_1}\cos\theta_1 + F_{fr_2}\cos\theta_2 + F_{fr_3}\cos\theta_3 + F_{fr_4}\cos\theta_4 = ma_y$$

$$F_{fr_1}\sin\theta_1 + F_{fr_2}\sin\theta_2 + F_{fr_3}\sin\theta_3 + F_{fr_4}\sin\theta_4 = ma_x$$

$$\gamma_1 N_1 + \gamma_2 N_2 + \gamma_3 N_3 + \gamma_4 N_4 = ma_z$$

where $\gamma_i = \begin{cases} 0 & \text{if leg is not in contact with the ground} \\ 1 & \text{if the leg is in contact with the ground} \end{cases}$

6

6

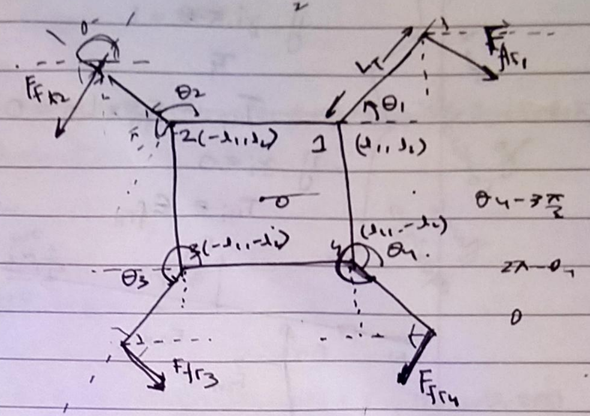
8^{x}

8^{x+6+4}

Sh

$\pi-\theta_2$ $\theta_2-\frac{\pi}{2}$

Fnet $\cancel{F_{fr_1}\cos\theta_1 + F_{fr_2}\cos(\pi-\theta_2)} + F_{fr}$



$$F_{fr_1}\cos\theta_1 + F_{fr_2}\cos(\pi-\theta_2) + F_{fr_3}\cos\left(\frac{3\pi}{2}-\theta_3\right) + F_{fr_4}\cos\left(\theta_4-\frac{3\pi}{2}\right) = ma_Y = F_Y$$

$$F_{fr}\sin\theta_4 - F_{fr_2}\sin(\pi-\theta_2) + F_{fr_3}\sin\left(\frac{3\pi}{2}-\theta_3\right) - F_{fr_4}\sin\left(\theta_4-\frac{3\pi}{2}\right) = ma_x = F_x$$

$$\gamma_1 N_1 + \gamma_2 N_2 + \gamma_3 N_3 + \gamma_4 N_4 - mg = ma_z = F_z$$

where $\gamma_i = \begin{cases} 0 & \text{if foot } i \text{ is not in contact with the ground} \\ 1 & \text{if foot } i \text{ is in contact with the ground.} \end{cases}$

$3\pi-\theta_3$

$\cancel{F_{fr_1} \le \mu N_1}$

$\cancel{F_{fr_2} \le \mu N_2}$

$\cancel{F_{fr_3} \le \mu N_3}$

$\cancel{F_{fr_4} \le \mu N_4}$

$F_{fr_1} = \mu N_1$

$F_{fr_2} = \mu N_2$

$F_{fr_3} = \mu N_3$

$F_{fr_4} = \mu N_4$

$$\vec{P}_{N_1} = (l_1 + r\cos\theta_1)\hat{i} + (l_2 + r\sin\theta_2)\hat{j} + 0\hat{k}$$

$$\vec{P}_{N_2} = (-l_1 + r\cos\theta_2)\hat{i} + (l_2 + r\sin\theta_2)\hat{j} + 0\hat{k}$$

$$\vec{P}_{N_3} = (-l_1 + r\cos\theta_3)\hat{i} + (-l_2 + r\sin\theta_3)\hat{j} + 0\hat{k}$$

$$\vec{P}_{N_4} = (+l_1 + r\cos\theta_4)\hat{i} + (-l_2 + r\sin\theta_4)\hat{j} + 0\hat{k}$$

$$\vec{F}_{fr_1} = F_{fr_1}(\cancel{\cos\theta_1\, \hat{i} + \sin\theta_1\, \hat{j}} + 0\hat{k})$$

$$\vec{F}_{fr_2} = F_{fr_2}(\cos$$

$$\vec{F}_{fr_1} = F_{fr_1}\left(\cos\left(\theta_1-\frac{\pi}{2}\right)\hat{i} + \sin\left(\theta_1-\frac{\pi}{2}\right)\hat{j}\right)$$

$$\vec{F}_{fr_2} = F_{fr_2}\left(\cos\left(\theta_2+\frac{\pi}{2}\right)\hat{i} + \sin\left(\theta_2+\frac{\pi}{2}\right)\hat{j}\right)$$

$$\vec{F}_{fr_3} = F_{fr_3}\left(\cos\left(\theta_3+\frac{\pi}{2}\right)\hat{i} + \sin\left(\theta_3+\frac{\pi}{2}\right)\hat{j}\right)$$

$$\vec{F}_{fr_4} = F_{fr_4}\left(\cos\left(\theta_4-\frac{\pi}{2}\right)\hat{i} + \sin\left(\theta_4-\frac{\pi}{2}\right)\hat{j}\right)$$

$$\cancel{\vec{F}_{fr_1} \times \vec{P}_{N_1} + \vec{F}} \quad \cancel{\sum |\vec{F}_{fr_i} \times \vec{P}_{N_i}|\gamma_i} = N_z$$

$$\sum |\vec{F}_{fr_i} \times \vec{P}_{N_i}|\gamma_i = N_z$$

$$\gamma_4 N_4(l_1 + r\cos\theta_4) + \gamma_1 N_1(l_1 + r\cos\theta_1) + \gamma_2 N_2(-l_2 + r\cos\theta_2) + \gamma_3 N_3(-l_1 + r\cos\theta_3) = N_y$$

$$\gamma_1 N_1(l_2 + r\sin\theta_1) + \gamma_2 N_2(l_2 + r\sin\theta_2) + \gamma_3 N_3(-l_2 + r\sin\theta_3) + \gamma_4 N_4(-l_2 + r\sin\theta_4) = N_x$$

do not consider these equations

At the point of contacts

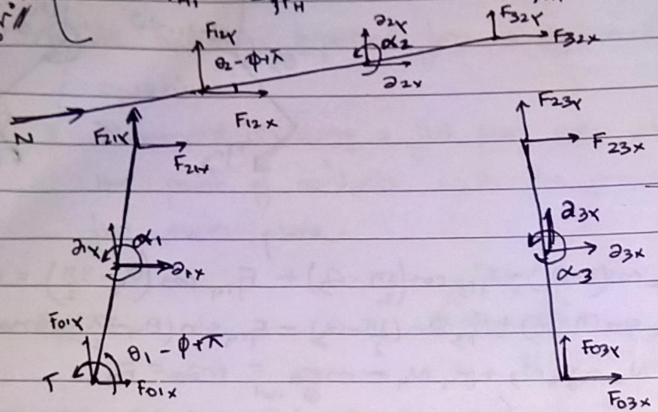
if $\gamma_i \cancel{=0} = 1$

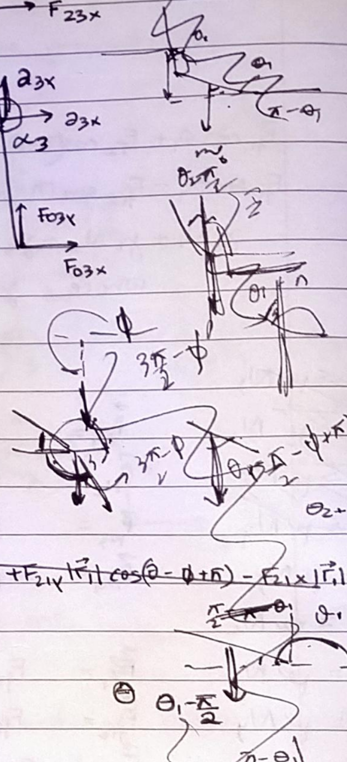
F_{f_i}

$T_{H_i} - F_{f_{T_i}} \times L_{T_i} = 0$

if $\gamma_i = 0$

$T_{H_i} = \epsilon_{f_{T_H}}$ where $\epsilon_{f_{T_H}}$ is a constant





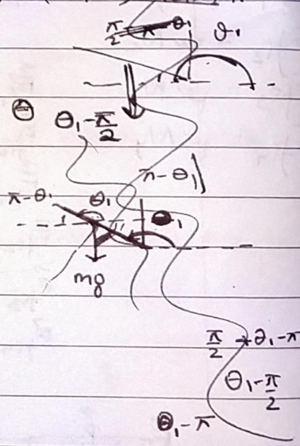
$\cancel{F_{01X} + F_{21X} = m_1 a_{1X}}$

$F_{01Y} + F_{21Y} = m_1 a_{1Y}$

$I \alpha_1 = \sum F_{rX}$

T $-m a_{1X}$

$\cancel{F \; m a_{1X} \frac{|\vec{r}_1|}{2} \cos(\theta_1 - \phi + \pi) + m a_{1Y} \frac{|\vec{r}_1|}{2} \sin(\theta_1 - \phi + \pi) + F_{21Y} |\vec{r}_1| \cos(\theta - \phi + \pi) - F_{21X} |\vec{r}_1|}$



V	14	14	14	14	11	
E	13	13	13	13	10	12

13+4+10

62

28

13

12+1

13+

13

52

13

13

14

13

1

23

23

12

13

13

300

13

4

52 + 8+4

14

6+1

7

F

~~$F_{01x} + F_{21x} = m_1 a_{1x}$~~

$F_{01y} + F_{21y} = m_1 a_{1y}$

~~$T - m a_{1x} \frac{|\vec{r}_1|}{2}\cos(\theta_1 - \phi + \pi) + m a_{1y} \frac{|\vec{r}_1|}{2}\sin(\theta_1 - \phi + \pi) + F_{21y}|\vec{r}_1|\cos(\theta_1 - \phi + \pi) - F_{21x}|\vec{r}_1|\sin(\theta_1 - \phi + \pi)$~~
~~$+ m g_0 \sin \frac{|\vec{r}_1|}{2}\sin(\theta_1 - \phi + \pi) = I\alpha_1$~~

~~$F_{12x} + F_{32x} + N\cos(\theta_2 - \phi + \pi) = m a_{2x}$~~

$$T + F_{01x}\frac{|\vec{r}_1|}{2}\sin(\theta_1 - \phi + \pi) - F_{21x}\frac{|\vec{r}_1|}{2}\sin(\theta_1 - \phi + \pi) - F_{01y}\frac{|\vec{r}_1|}{2}\cos(\theta_1 - \phi + \pi) + F_{21y}\frac{|\vec{r}_1|}{2}\cos(\theta_1 - \phi + \pi)$$
$$= I_1\alpha_1$$

~~$F_{01x} + F_{21x}$~~

~~$F_{01x} + F_{21x} - m g_0 \cos\left(\frac{3\pi}{2} - \phi\right) = m_1 a_{1x}$~~

~~$F_{01y} + F_{21y} - m g_0 \sin\left(\frac{3\pi}{2} - \phi\right.$~~

$$F_{01x} + F_{21x} - m g_0 \cos\left(\phi - \frac{3\pi}{2}\right) = m_1 a_{1x}$$

$$F_{01y} + F_{21y} - m g_0 \sin\left(\phi - \frac{3\pi}{2}\right) = m_1 a_{1y}$$

$$F_{12x}\sin(\theta_2 - \phi + \pi)\frac{|\vec{r}_2|}{2} - F_{32x}\frac{|\vec{r}_2|}{2}\sin(\theta_2 - \phi + \pi) - F_{12y}\frac{|\vec{r}_2|}{2}\cos(\theta_2 - \phi + \pi) + F_{21y}\frac{|\vec{r}_2|}{2}\cos(\theta_2 - \phi + \pi)$$
$$= I_2\alpha_2$$

$$F_{12x} + F_{32x} + N\cos(\theta_2 - \phi + \pi) - m g_0 \cos\left(\phi - \frac{3\pi}{2}\right) = m_2 a_{2x}$$

$$F_{12y} + F_{32y} + N\sin(\theta_2 - \phi + \pi) - m_2 g_0 \sin\left(\phi - \frac{3\pi}{2}\right) = m_2 a_{2y}$$

F

$$F_{03x}\sin(\theta_3 - \phi + \pi)\frac{|\vec{r}_3|}{2} - F_{23x}\frac{|\vec{r}_3|}{2}\sin(\theta_3 - \phi + \pi) - F_{03y}\frac{|\vec{r}_3|}{2}\cos(\theta_3 - \phi + \pi) + F_{23y}\frac{|\vec{r}_3|}{2}\cos(\theta_3 - \phi + \pi)$$
$$= I_3\alpha_3$$

$$F_{03x} + F_{23x} - m_3 g_0 \cos\left(\phi - \frac{3\pi}{2}\right) = m_3 a_{3x}$$

$$F_{03y} + F_{23y} - m_3 g_0 \cos\left(\phi - \frac{3\pi}{2}\right) = m_3 a_{3y}$$

F $F_{12x} = -F_{21x}$ $\quad F_{12y} = -F_{21y}$

$F_{23x} = -F_{32x}$ $\quad F_{23y} = -F_{32y}$