DYNAMIC MODELING AND CARACTERIZATION OF A HEXAPOD CRAWLING ROBOT

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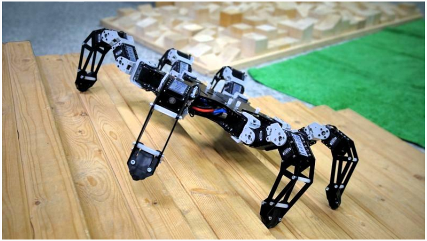
Introduction - Hexapod Robot

- Multi-legged robots vs wheeled platforms.
- Cost: large number of degrees of freedom (DoF).



Phantom AX

Motivation: foot-strike detection

- Foot-strike detection without using additional sensors $\rightarrow$ minimalistic approach.
- How can we achieve that using only the position feedback from the servomotors?

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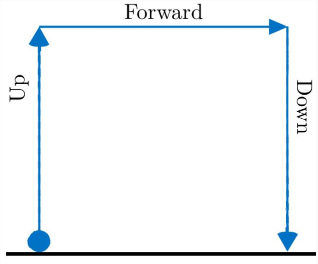

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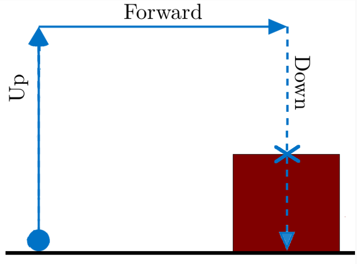

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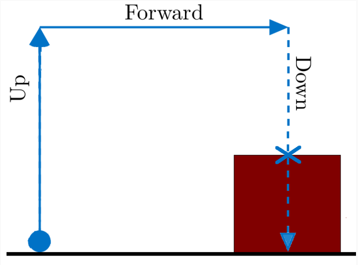

We need a dynamic model to:

- Estimate the error between the goal and the measured position.
- Compensate external forces$\rightarrow$ the locomotion can be adapted to the traversing terrain.

Dynamixel AX-12 Servomotor

- P control in position.
- Limited communication.
- No torque measurements.

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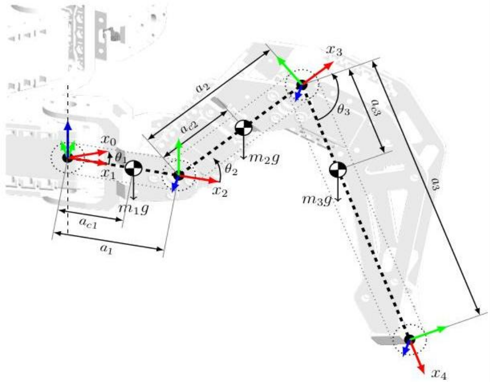
Electromechanical model:

$$J^M \ddot{\theta}^M + B\dot{\theta}^M + F^M(\dot{\theta}^M) + R\tau = K^M V$$

Leg Dynamical Model

Euler-Lagrange formalism:

$$\boldsymbol{\tau} = \frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{\boldsymbol{\theta}}}\right) - \frac{\partial \mathcal{L}}{\partial \boldsymbol{\theta}}$$



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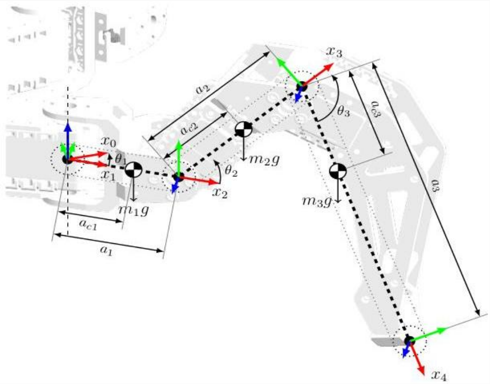
which can be written in matrix form:

$$D(\boldsymbol{\theta})\ddot{\boldsymbol{\theta}} + C(\boldsymbol{\theta}, \dot{\boldsymbol{\theta}})\dot{\boldsymbol{\theta}} + G(\boldsymbol{\theta}) = \boldsymbol{\tau}$$

where the `inertia matrix D`:

$$D(\boldsymbol{\theta}) = \sum_{i=1}^{n} \left[m_i J_{v_i}^T J_{v_i} + J_{w_i}^T\, {}^0R_i I_i {}^0R_i^T J_{w_i} \right]$$



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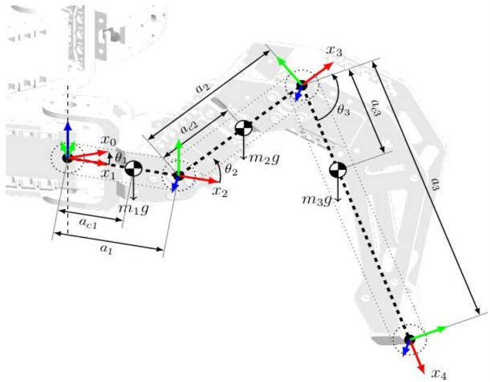
where D_w in the RR case is:

$$\begin{bmatrix} I_{2_{33}} + I_{3_{33}} & I_{3_{33}} \\ I_{3_{33}} & I_{3_{33}} \end{bmatrix}$$



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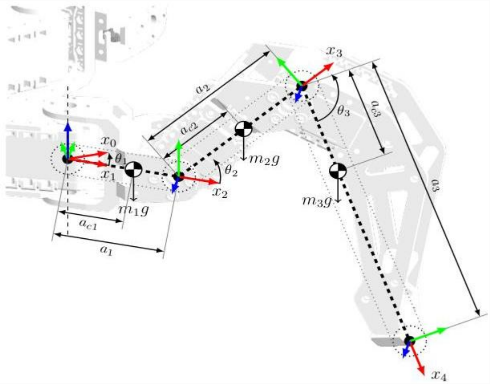
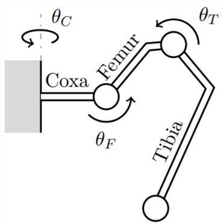
With coxa joint, $\boldsymbol{D_w}$ is:

$$\begin{bmatrix} I_{1_{33}} + I_{2_{33}} cos^2(\theta_2) + I_{3_{33}} cos^2(\theta_2 + \theta_3) & 0 & 0 \\ 0 & I_{2_{33}} + I_{3_{33}} & I_{3_{33}} \\ 0 & I_{3_{33}} & I_{3_{33}} \end{bmatrix}$$



Combining actuator and leg dynamics



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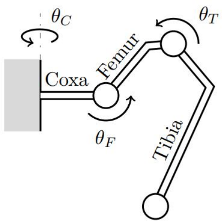

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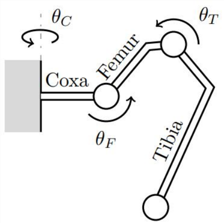

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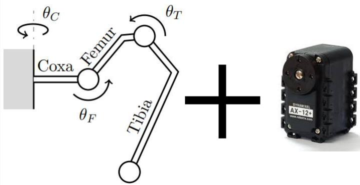
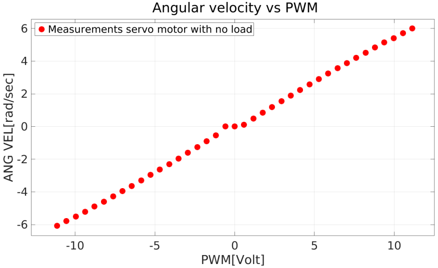


Complete dynamic model of a leg:

$$\boxed{D'(\boldsymbol{\theta})\ddot{\boldsymbol{\theta}} + C'(\boldsymbol{\theta})\dot{\boldsymbol{\theta}} + F_{fric}(\dot{\boldsymbol{\theta}}) + G'(\boldsymbol{\theta}) = K'V}$$

Servomotors characterization

- Linear relationship between applied voltage and meassured velocity.



Characterization of Servomotor and Dynamic model

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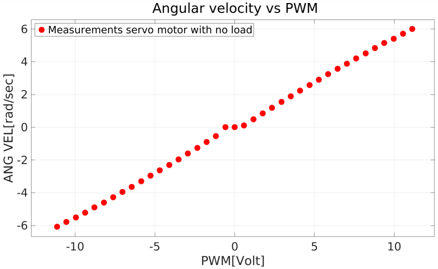
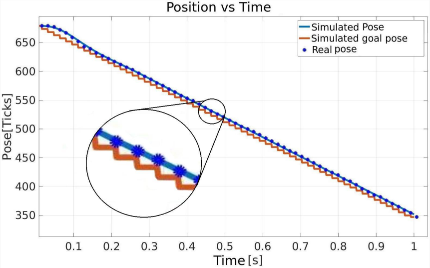
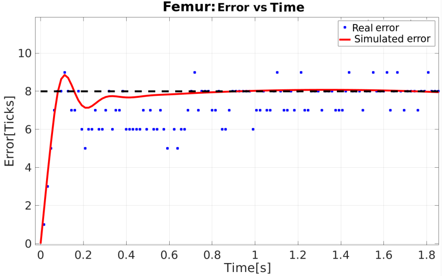




Complete behaviour simulation:

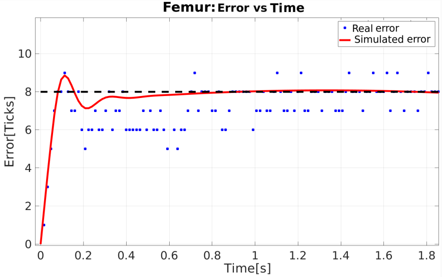
- Full dynamic model
- Interpolation
- P control

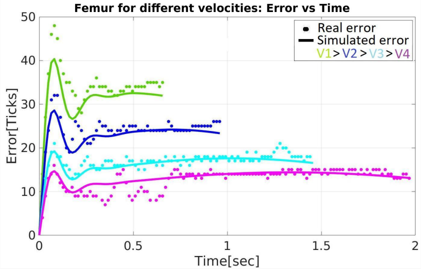
Treshold



Threshold offset established with mean value of simulation.

Treshold





Threshold offset established with mean value of simulation.

Different Thresholds for different velocities.
Adaptive gait from the Dynamic model.

Examples of threshold

Overestimated threshold

[ ]pdfmark=/AN

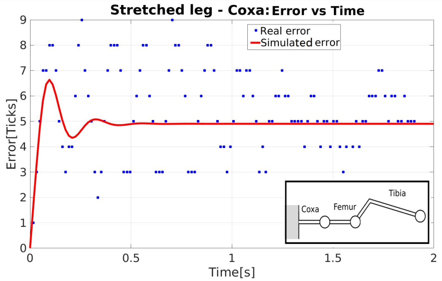
/F (images/vid1.mp4) /Poster true

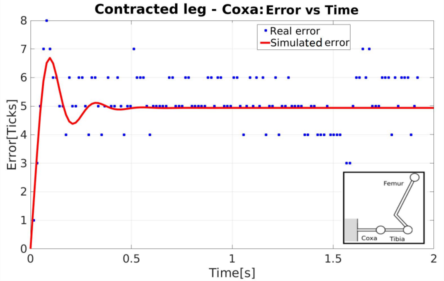
Precise threshold

]pdfmark=/AN

/F (images/vid2.mp4) /Poster true

Error analysis in coxa measurements





- Vibrations in the leg, not considered in our simulation.
- Bigger Treshold error.
- Less inertia moment implies less vibration.
- Future improvement: trapezoidal acceleration and a PID controler.

Conclutions and future work

Challenge

- Improve comunication with servo motor $\rightarrow$ reducing reading delay.
- Trapezoidal aceleration profile.
- Add PID control.

Conclutions

- Characterization of servo motor.
- Implementation and simulation of leg dynamics.
- Tresholds were determined using the dynamic model $\rightarrow$ capability of traversing irregular terrains.

Thank you!

Questions?