Model-Informed Eigenmode Discovery and Control for Locomotion through CPG-Based Deep Learning

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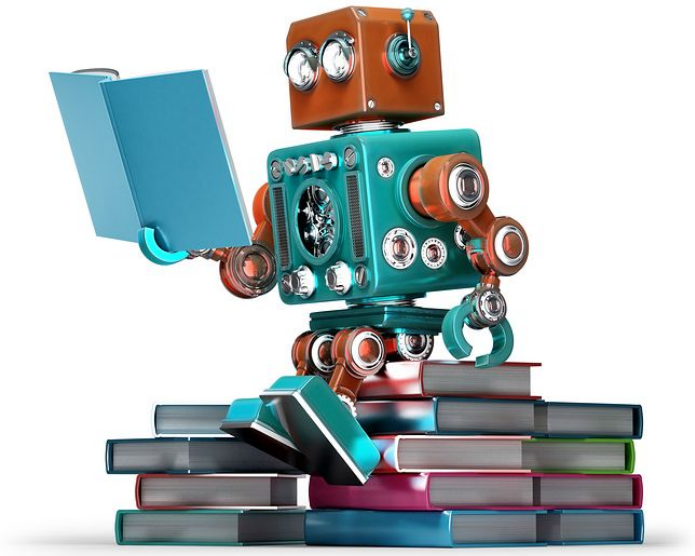
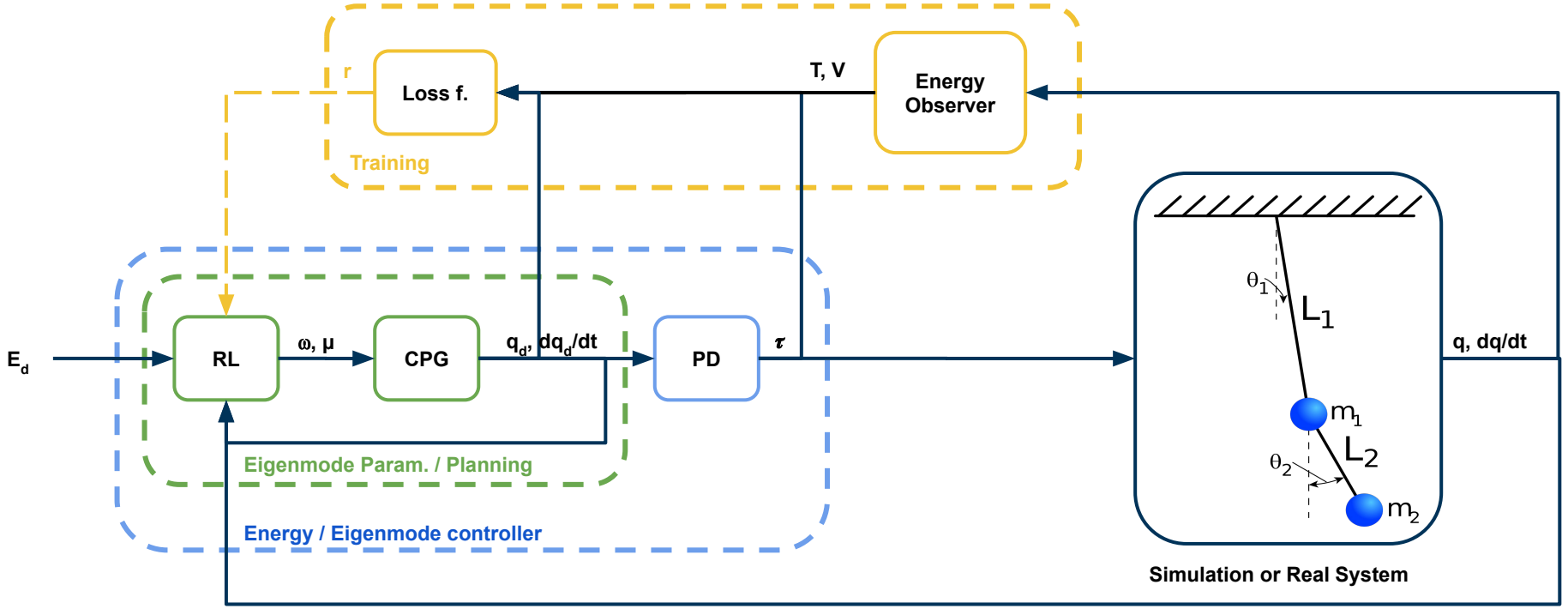


2.2 Eigenmode Discovery & Control



Loss function:

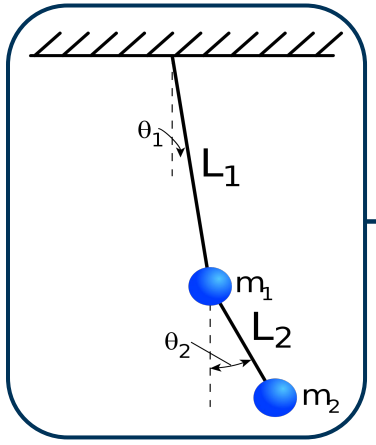
$$r = g(E_d - (T+V))^{w_1} g(\tau)^{w_3} g(||q - q_d|| + ||\dot{q} - \dot{q}_d||)^{w_3}$$

Polar CPG:

$$\begin{pmatrix} \dot{r} \\ \dot{\phi} \end{pmatrix} = \begin{pmatrix} (\mu^2 - r^2)r \\ \omega \end{pmatrix} \qquad q_d = \begin{pmatrix} r\cos\phi \\ r\sin\phi \end{pmatrix}$$

$$\dot{q}_d = \begin{bmatrix} \mu^2 - r^2 & \omega \\ \omega & \mu^2 - r^2 \end{bmatrix} \begin{pmatrix} r\cos\phi \\ r\sin\phi \end{pmatrix}$$

2.3 Model Identification



Simulation or Real System
Trajectory Recordings

Loss

Training

Loss f.

q, dq/dt

f(x) = Δx / Δt

Numerical Diff.

d²q/dt²

+

-

e

$L_\theta = T_\theta - V_\theta$

L_θ

$\hat{\ddot{q}} = (\nabla_{\dot{q}} \nabla_{\dot{q}}^T L_\theta)^{-1} (\nabla_q L_\theta - (\nabla_q \nabla_{\dot{q}}^T L_\theta)\dot{q})$

d²q^/dt²

Learned EOMs

NN(θ)

T_θ , V_θ

Learned
Energy Observer

$H_\theta = T_\theta + V_\theta$

H_θ

Energy Calculations

Loss function from Cramer et al. 2020*

$$L_{acc} = \mathbb{E}\{(\ddot{q} - \hat{\ddot{q}})^2\}$$

Contributions

$$L_{con} = \mathbb{E}\{(H_\theta - \int_{t_0}^{t} \tau(t_c)\dot{q}(t_c)dt_c)^2\}$$

$$L_{mec} = \mathbb{E}\{(T_\theta - \dot{q}^T(\nabla_{\dot{q}} \nabla_{\dot{q}}^T L_\theta)\dot{q})^2 + (\nabla_{\dot{q}} V_\theta)^2\}$$

$$Loss = L_{acc} + L_{con} + L_{mec} + \alpha L_2(\theta)$$