Eye trajectory optimization by learning feedforward model

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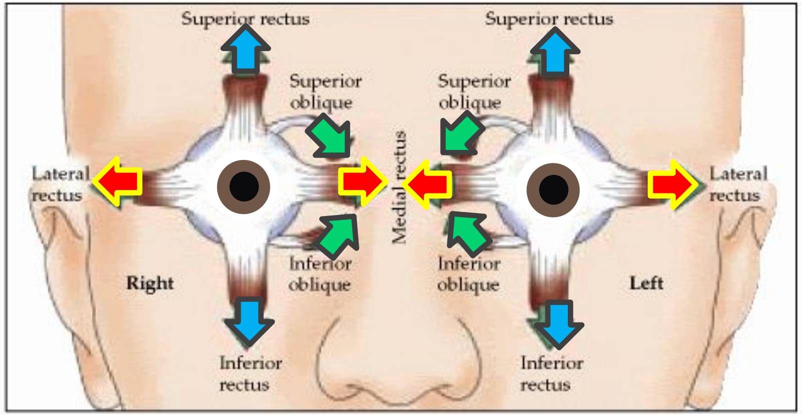
Outline

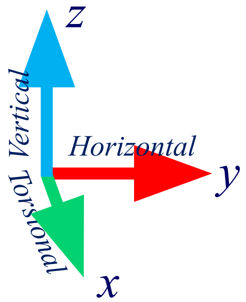
- Motivation
- Feed forward model
- Trajectory Optimization
- Training the model
- Experiments
- Conclusion

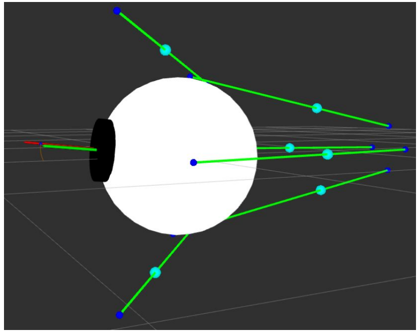
Motivation

- Non linear control
- More realistic model
- With 6 independent motors
- Using machine learning approaches
    - **Model based(me)**
    - **Model free with 3 motors (Henrique)**

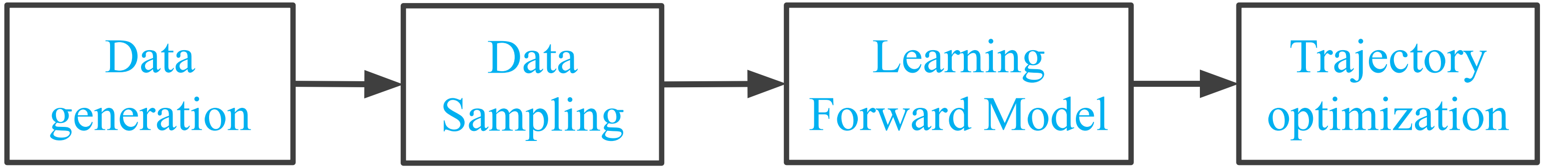
for x,y,z direction







Algorithm

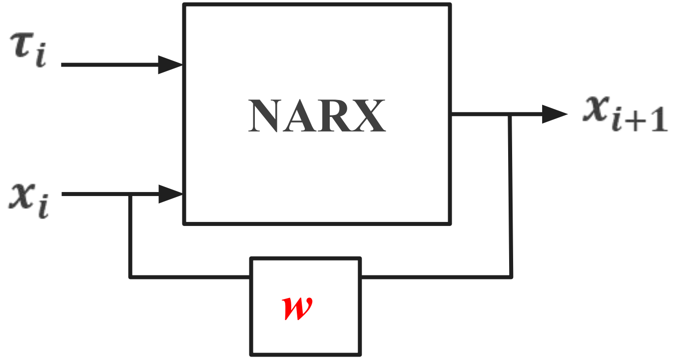

Data generation
Data Sampling
Learning Forward Model
Trajectory optimization

Feed forward model

Finding this mapping:

$$(\tau_i, x_i, x_{i-w}) \rightarrow x_{i+1}$$

- State vector x is the eye orientation
  $$x = [r_x, r_y, r_z.]$$
- And τ is control input:
  $$\tau = [m_1, m_2, m_3, m_4, m_5, m_6]$$
- w is the feedback delay (time window)



NARX model is a dynamic **recurrent neural(RNN) network** that encloses several layers with feedback connections,

$x_{i+1} = f(x_{[i-w,..,i]}, \tau_i)$, *where f is the NARX model*

Trajectory Optimization- model

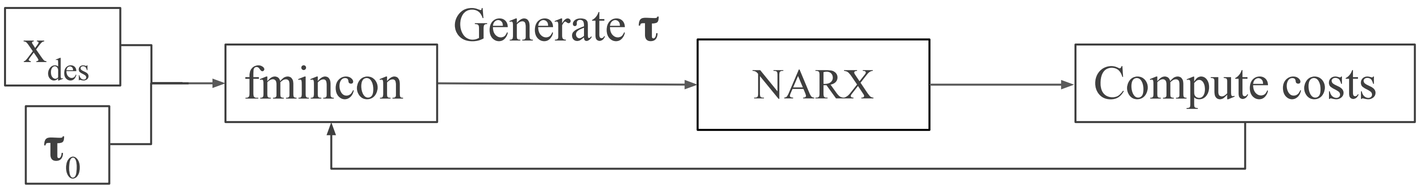
$$\pi(t)^* = \min_{\tau} \sum_{\alpha} \lambda_\alpha . J_\alpha$$

s.t. $\tau_0 < \tau_i < \tau_T,\ i = 1 \ldots T,\ \forall i, \exists k \in i, \boldsymbol{k\ is\ the\ saccade\ duration}$

- $J_D = 1 - \frac{1}{1+\beta k}$ Duration
- $J_V = \|v_k - v\_des\|$ Velocity
- $J_A = \|x_k - x\_des\|$ Accuracy
- $J_F = \left\|\sum_{i=1}^{k} F_i\right\|$ Force

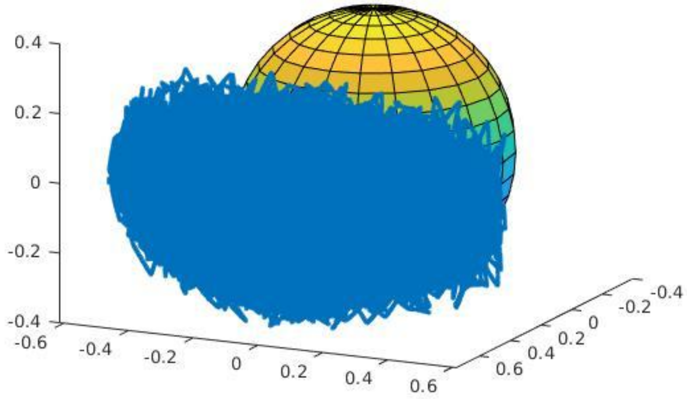
} J_{DVAF}

Trajectory Optimization



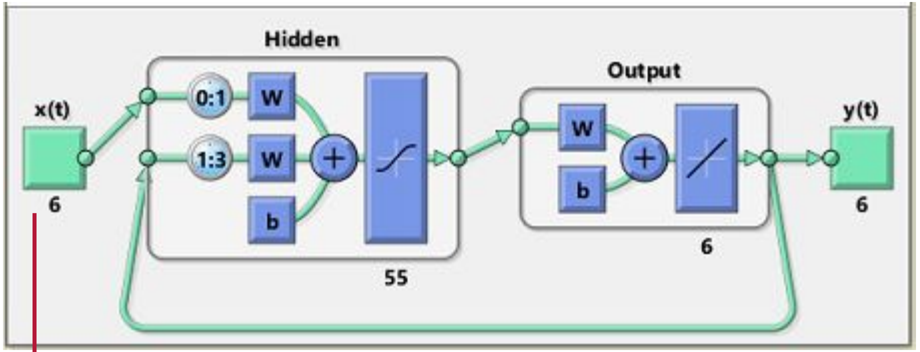
Feed forward model learning -dataset

- 20M samples(random saccades)
- Covers the entire workspace uniforml
- Frequency is 1 ms
- Continues movement of the eye

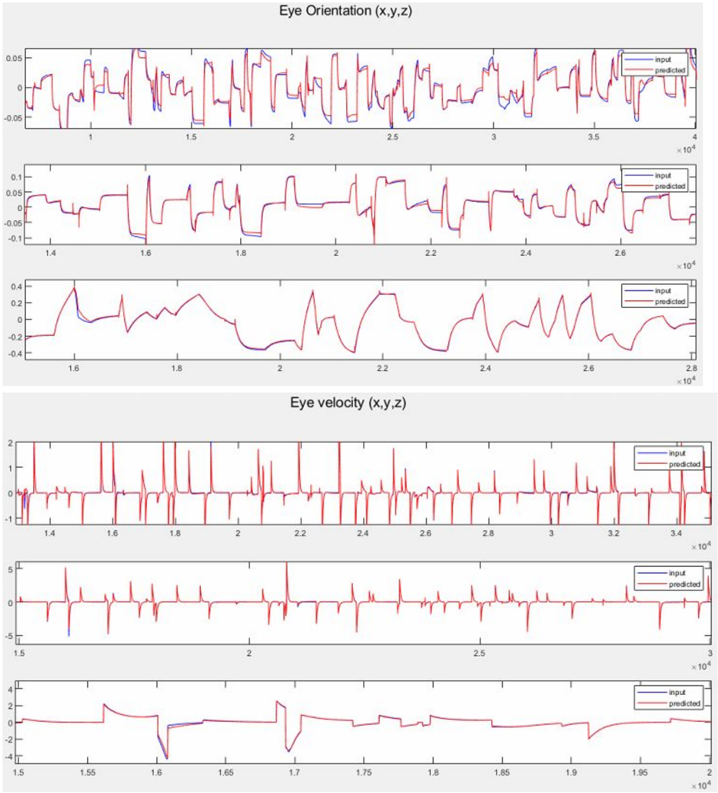


Feed forward model learning

NARX network model

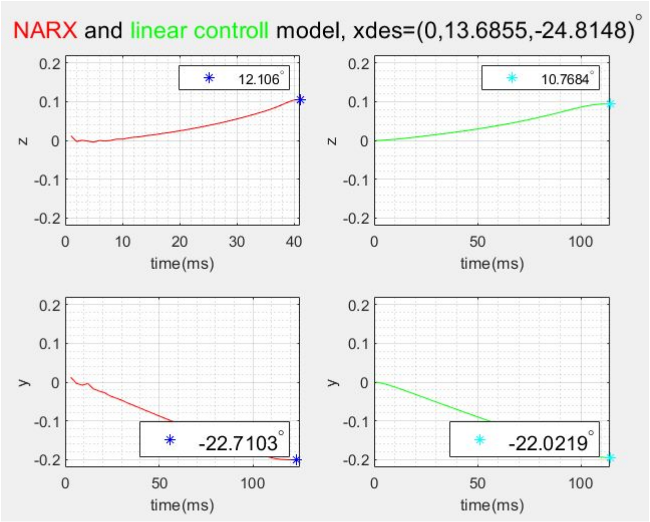


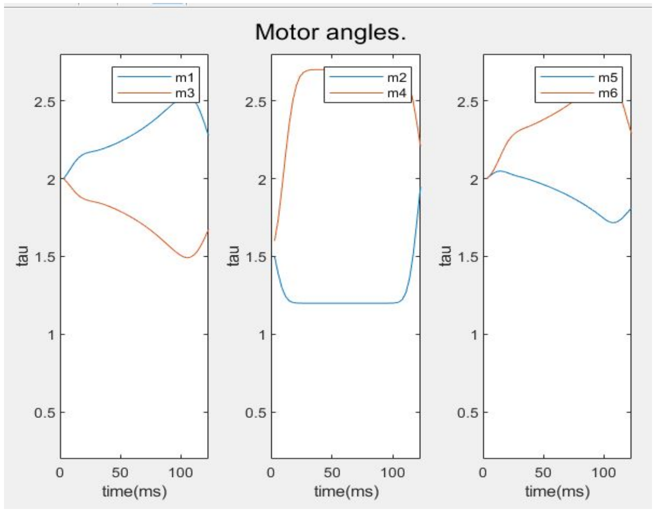
$$x = [r, \dot{r}] \qquad \mathbf{r} = (r_x, r_y, r_z)$$



Simulation results

Optimized trajectory for saccade [x,y,z]=[0, 13.68, -24.81]





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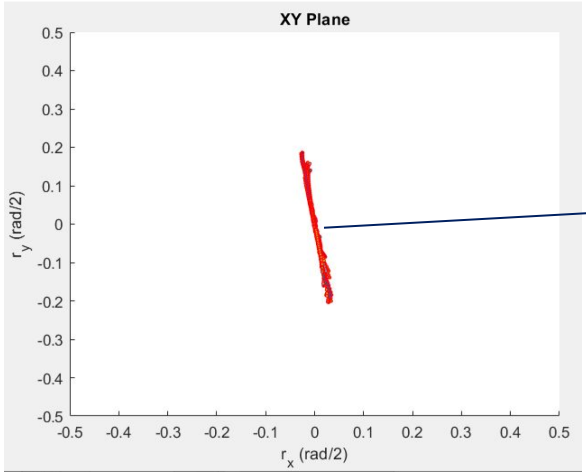
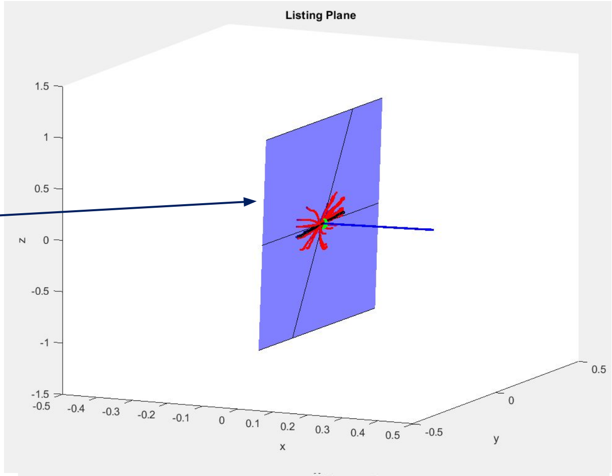
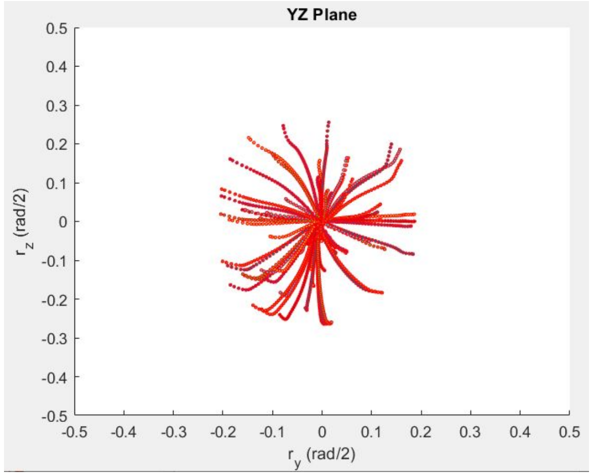
Simulation results-listing's plane

120 saccades.







Listing's law : $r_x = 0$ $\mathbf{r} = (r_x, r_y, r_z)$ rotation vector

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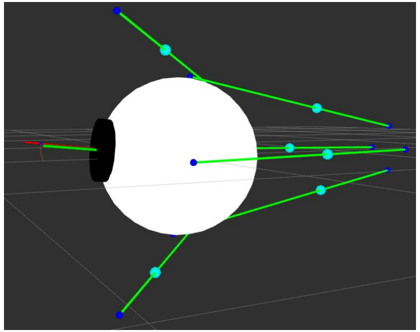
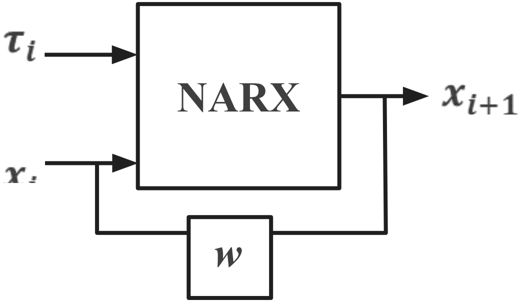
Conclusions



- The model learned a nonlinear system with 6 independent motor

- High Computational cost for new eye movement (trajectory optimization)



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