Chair of Robotics, Artificial Intelligence and Real-time Systems
Department of Informatics
Technical University of Munich

Training a Spiking Neural Network using R-STDP to perform Autonomous Target Tracking on a Snake Car Robot

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September 25, 2018

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Task: Target Tracking

- Target Tracking SNN

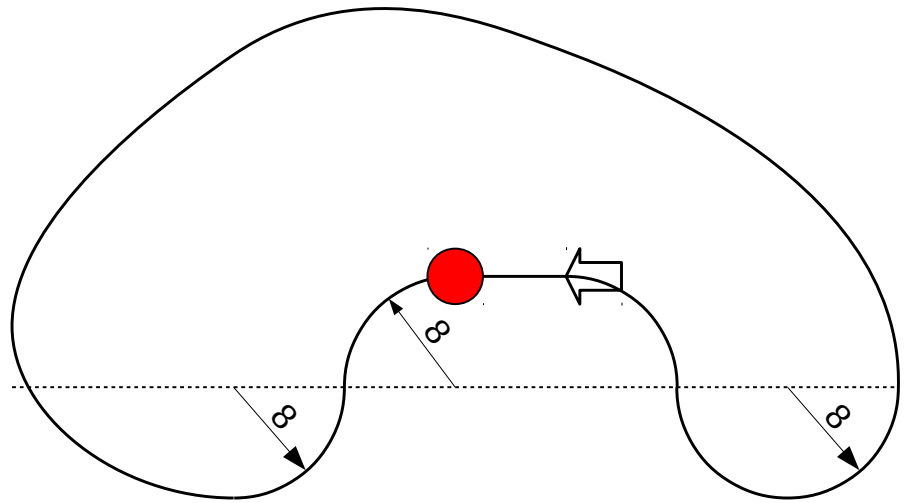

Figure 1: Target tracking SNN evaluation environment.

Task: Target Tracking

- Target Tracking SNN
- Prevent collisions with walls
- Obstacle Avoidance SNN
- R-STDP learning rule

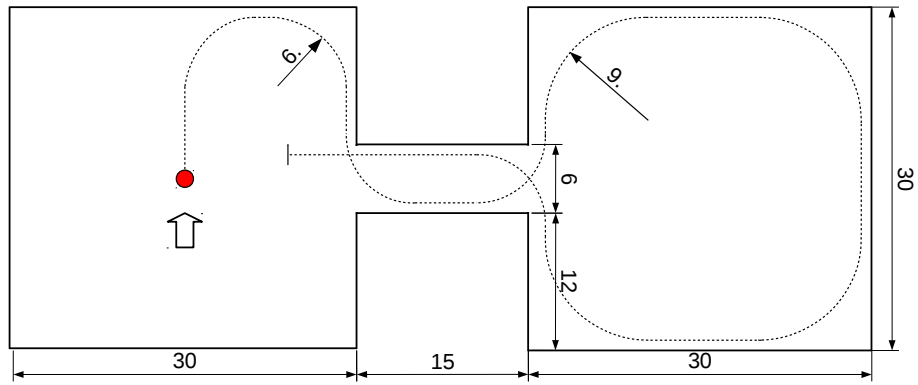

Figure 2: Evaluation environment

Target Following SNN

- Infrared image 32×32 pixel resolution

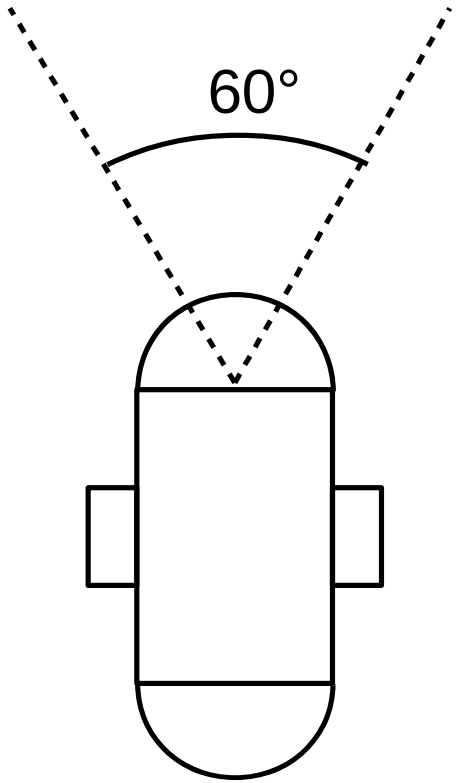

Figure 3: Infrared vision sensor

Target Following SNN

- Infrared image 32 × 32 pixel resolution
- Image preprocessing

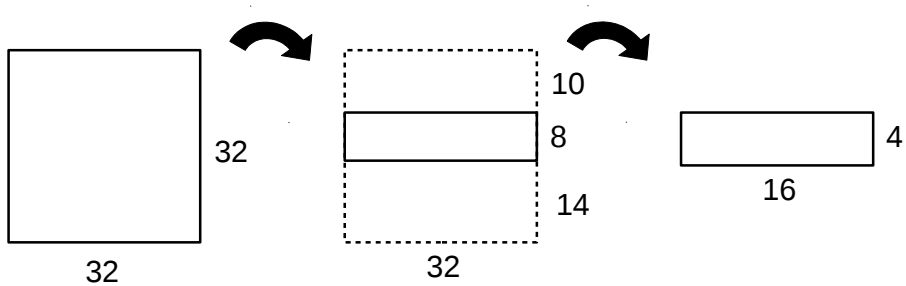

Figure 4: Image preprocessing in 3 steps

Target Following SNN

- Infrared image 32×32 pixel resolution
- Image preprocessing
- 64 Poisson input neurons
- Feed forward architecture
- Left and Right LIF output neurons

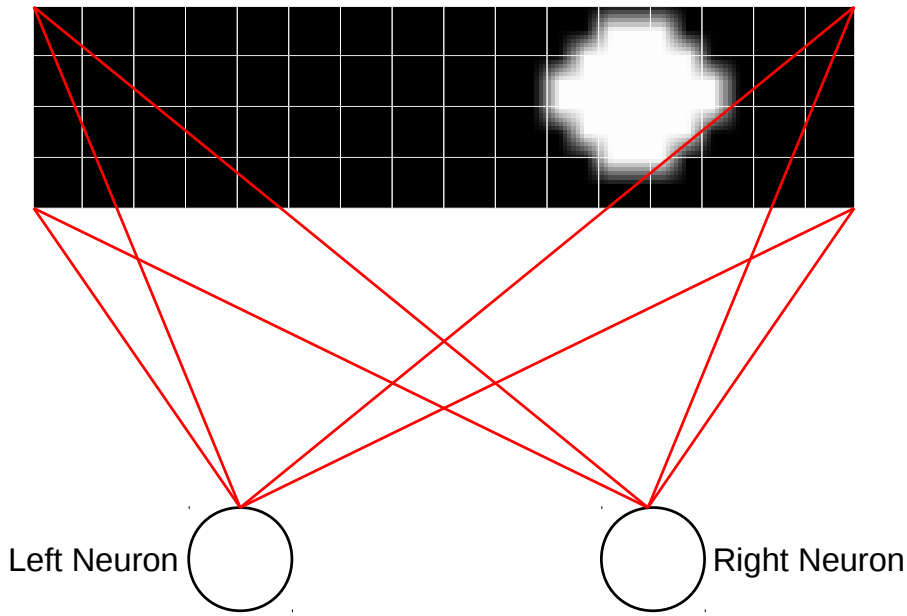

Figure 5: Target following SNN architecture

Target Following SNN cont.

- Output interpreted as angle

$$decode\left(n_{spikes}\right) = \frac{n_{spikes}}{n_{max}}$$

$$\alpha = \alpha_{max}\left(n_l - n_r\right)$$

$$\alpha_t = c\alpha + (1 - c)\,\alpha_{t-1}$$

Target Following SNN cont.

- Output interpreted as angle
- Reward depends on Angle between head module and target

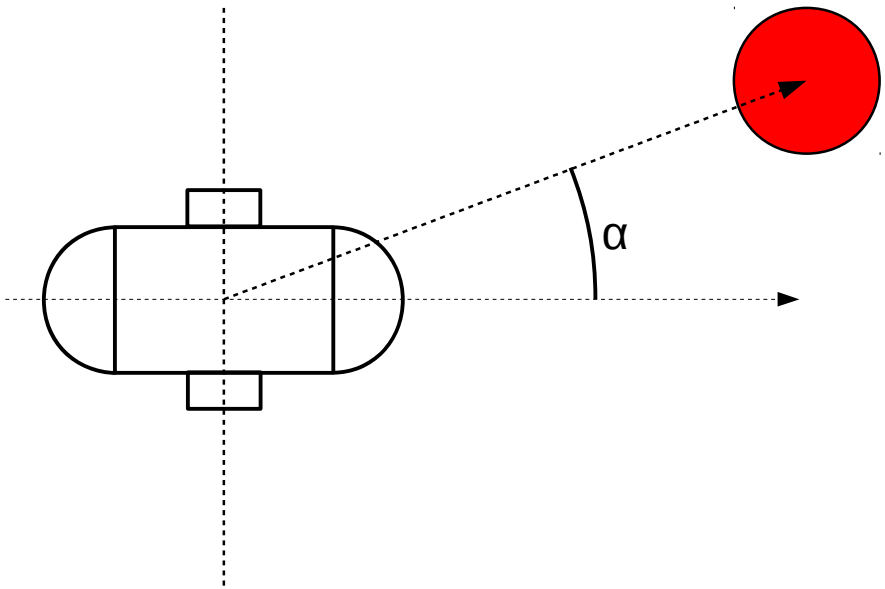

Figure 6: Angle between robot head module and target.

Target Following SNN cont.

- Output interpreted as angle
- Reward depends on Angle between head module and target
- Left and right neuron get the opposite rewards of each other

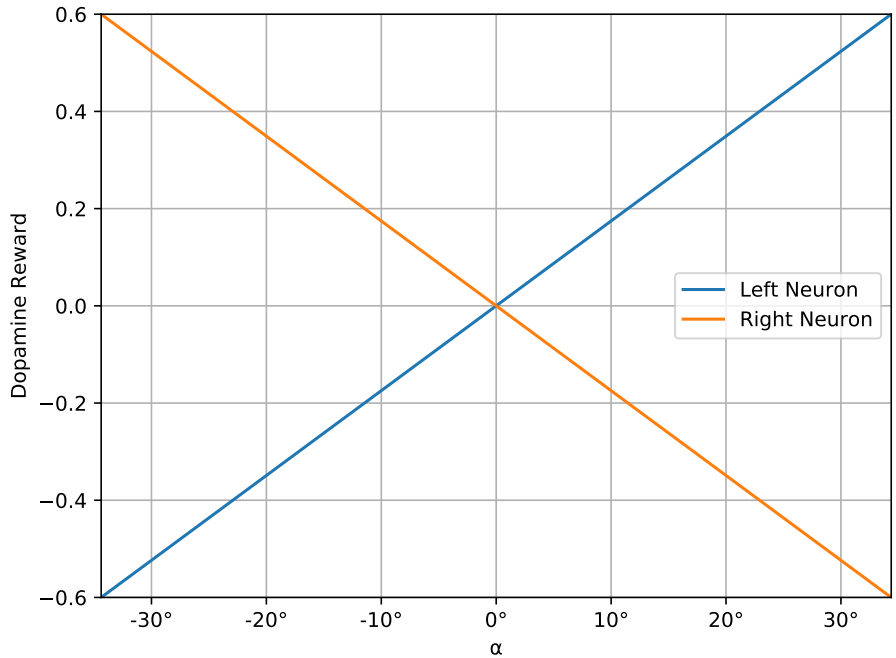

Figure 7: Target following reward function

Obstacle Avoidance SNN

- Four proximity sensors

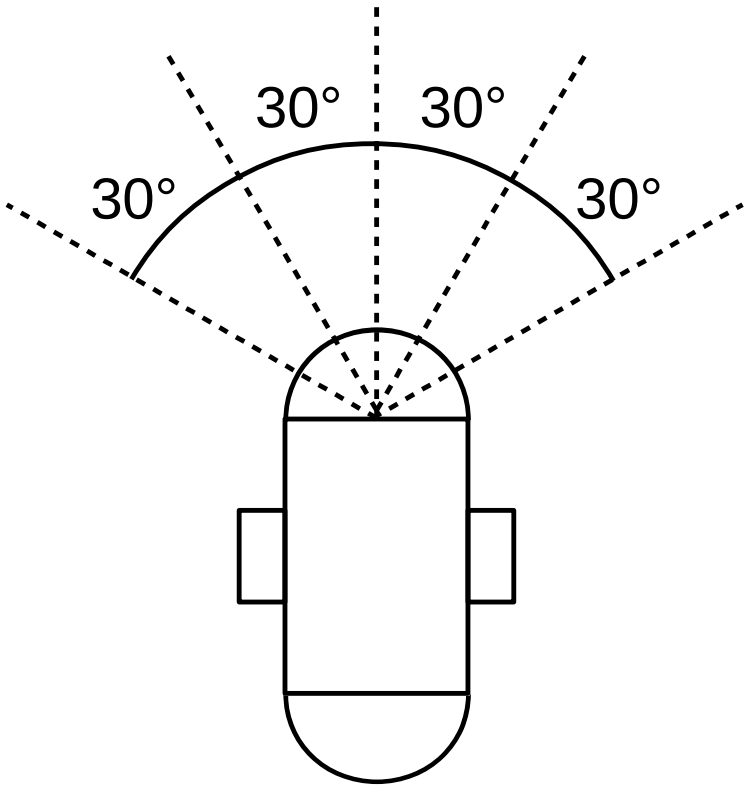

Figure 8: Proximity sensors

Obstacle Avoidance SNN

- Four proximity sensors
- Proximity data preprocessing

- Data in range $[0; 3]$
- Mapped to range $[0 : 1]$
- 0: No obstacle or at maximum distance
- 1: Close obstacle

Obstacle Avoidance SNN

- Four proximity sensors
- Proximity data preprocessing
- 4 Poisson input neurons
- Feed forward architecture
- Left and right LIF output neurons

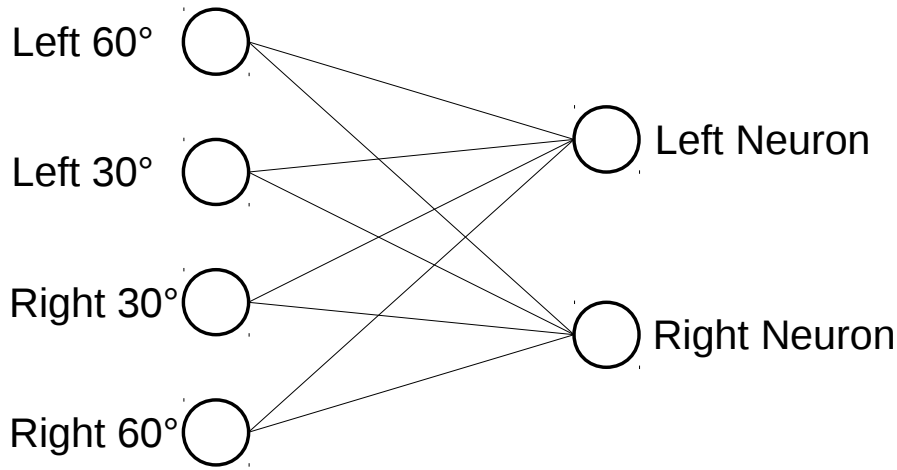

Figure 9: Obstacle avoidance SNN architecture

Obstacle Avoidance SNN cont.

- Output interpreted as angle

$$decode\left(n_{spikes}\right) = \frac{n_{spikes}}{n_{max}}$$

$$\alpha = \alpha_{max}\left(n_l - n_r\right)$$

Obstacle Avoidance SNN cont.

- Output interpreted as angle

$$decode\left(n_{spikes}\right) = \frac{n_{spikes}}{n_{max}}$$

$$\alpha = \alpha_{max}\left(n_l - n_r\right)$$

- Event based rewards on Episode failure
- Left and right neuron get the opposite rewards of each other
- 4 Reward cases, collision and target lost, obstacle left or right side

Controller Selection

- Both SNN return an angle
- Select one as command for the robot
- Choose the target tracking angle except if that brings the robot too close to an obstacle.

Training Environment

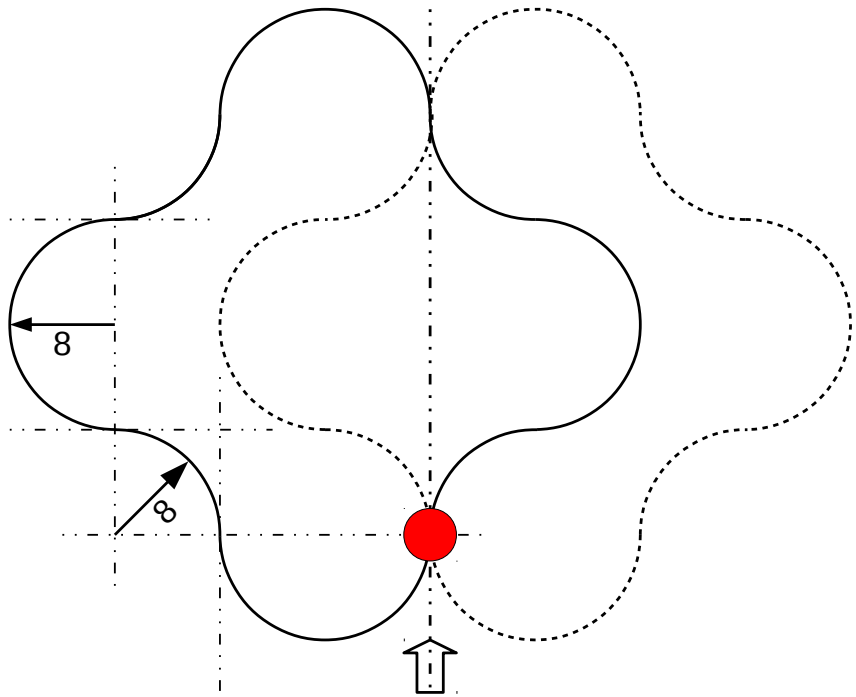

Figure 10: Target tracking SNN training path

Training Target Tracking SNN

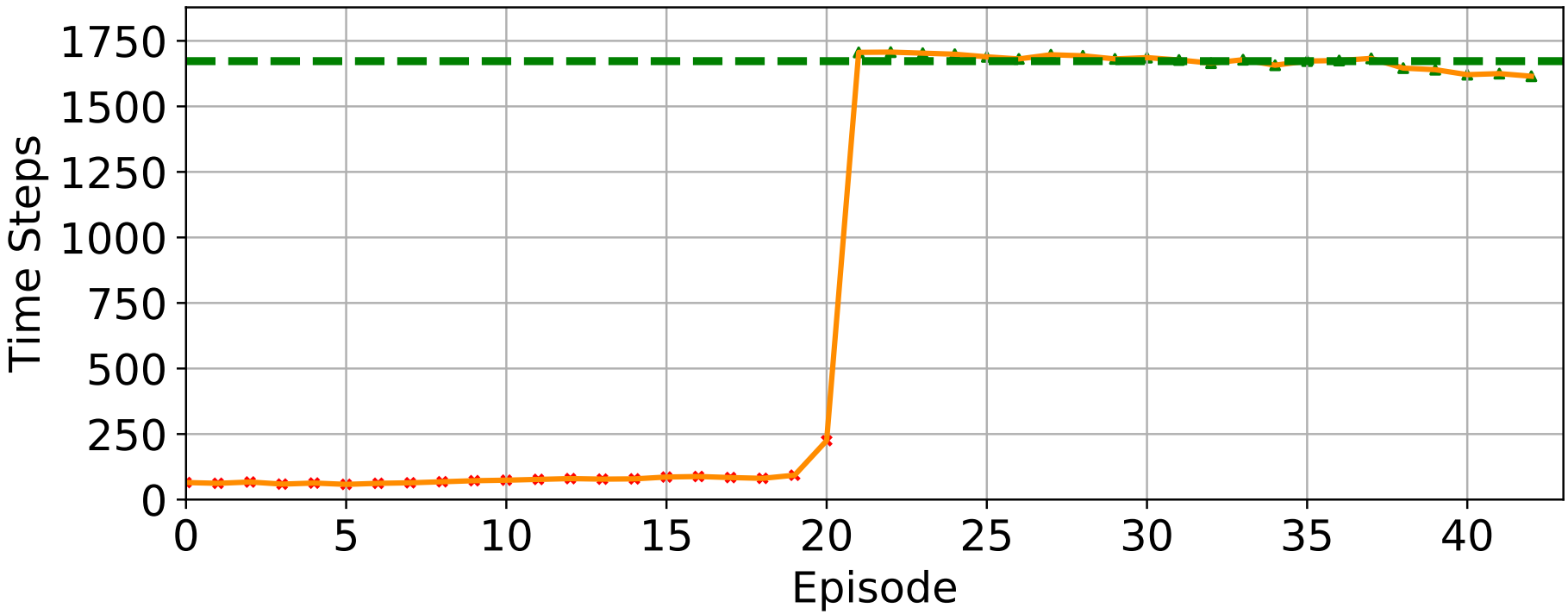

Figure 11: Target Tracking Training

Training Target Tracking SNN

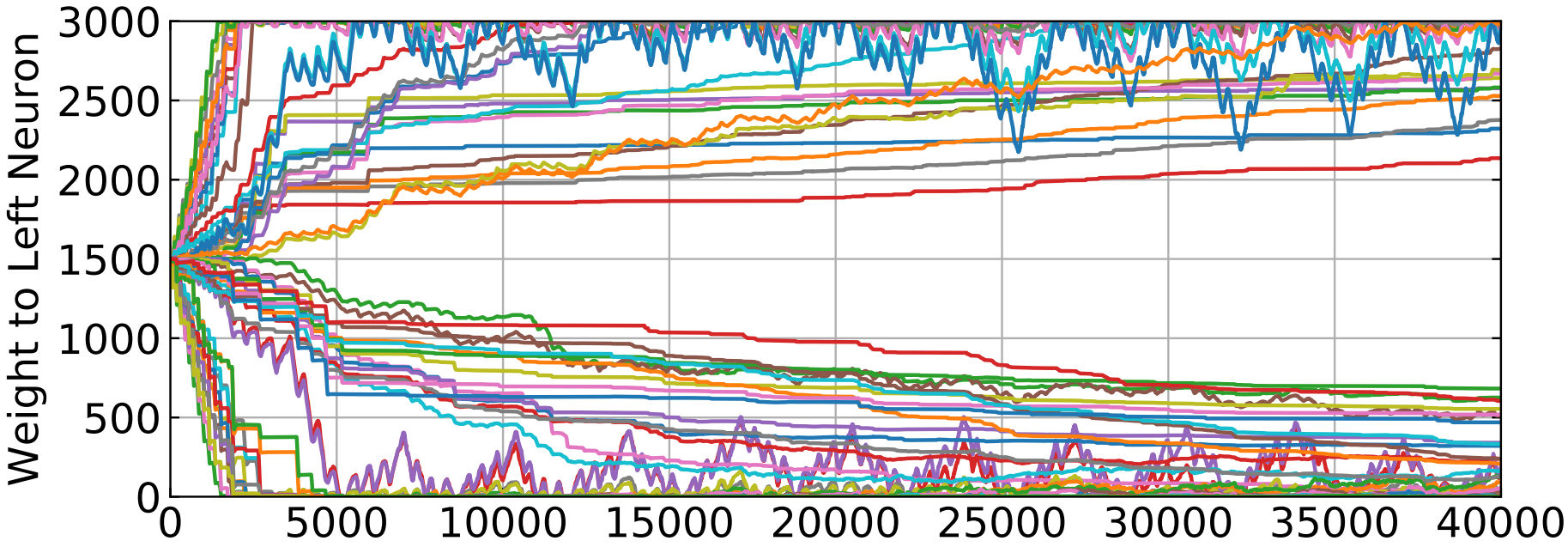

Figure 12: Left neuron weight changes during training

Training Environment

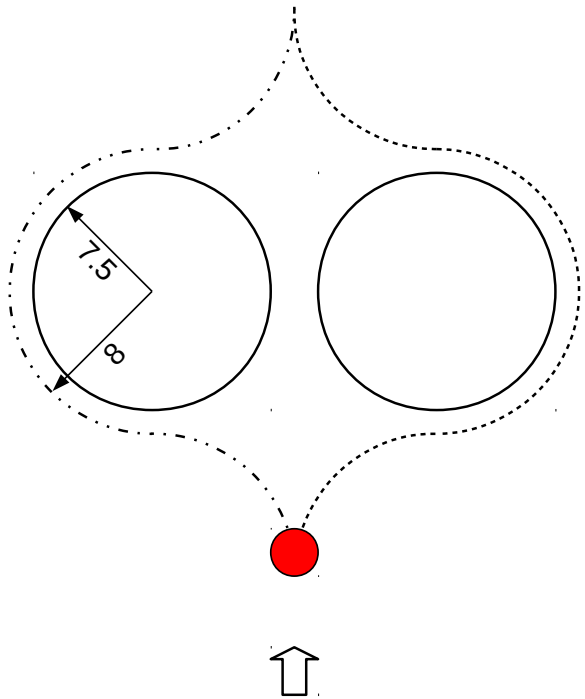

Figure 13: Obstacle avoidance SNN training path

Training Obstacle Avoidance SNN

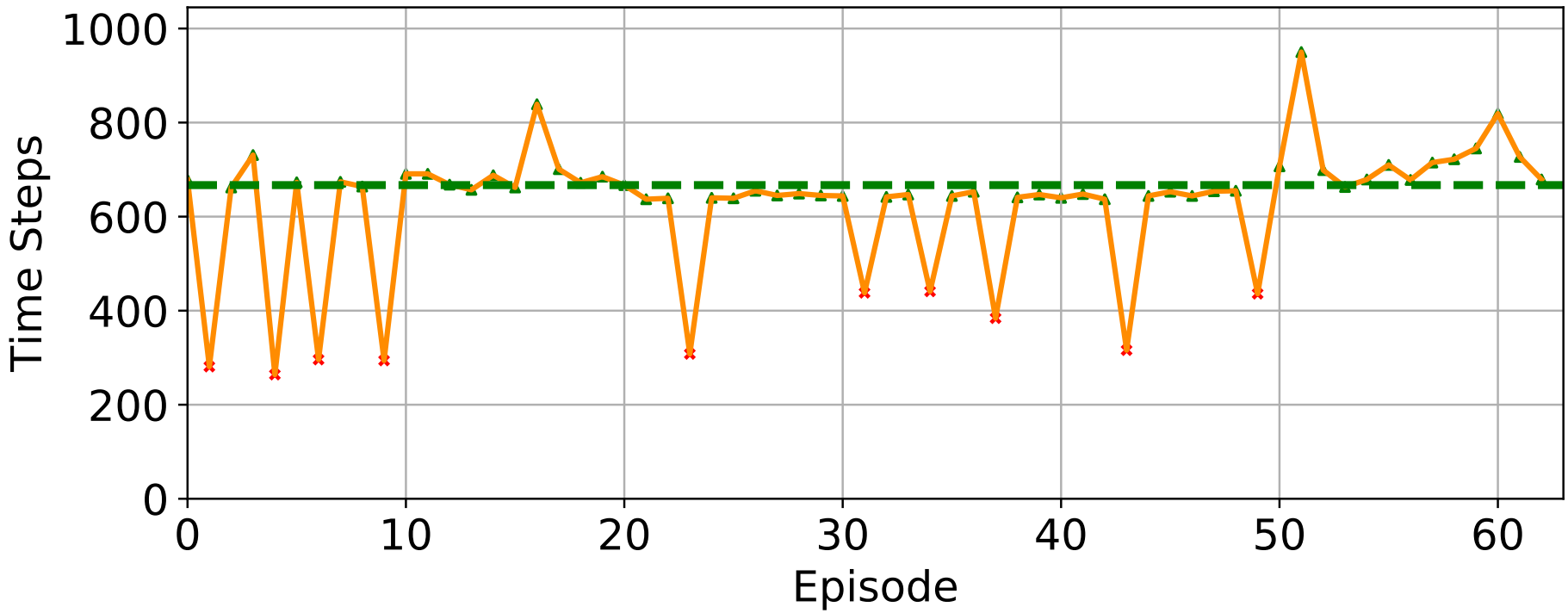

Figure 14: Obstacle Avoidance Training

Training Target Tracking SNN

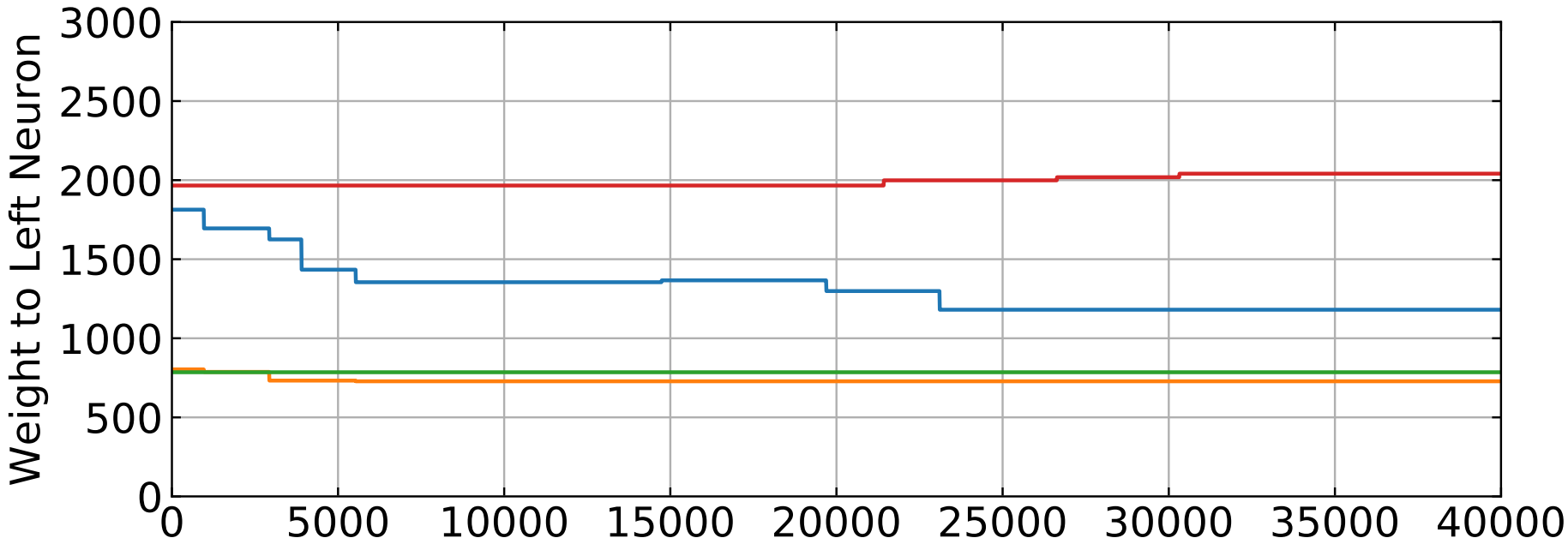

Figure 15: Left neuron weight changes during training

Evaluation

- Average error $e = 7{,}39°$

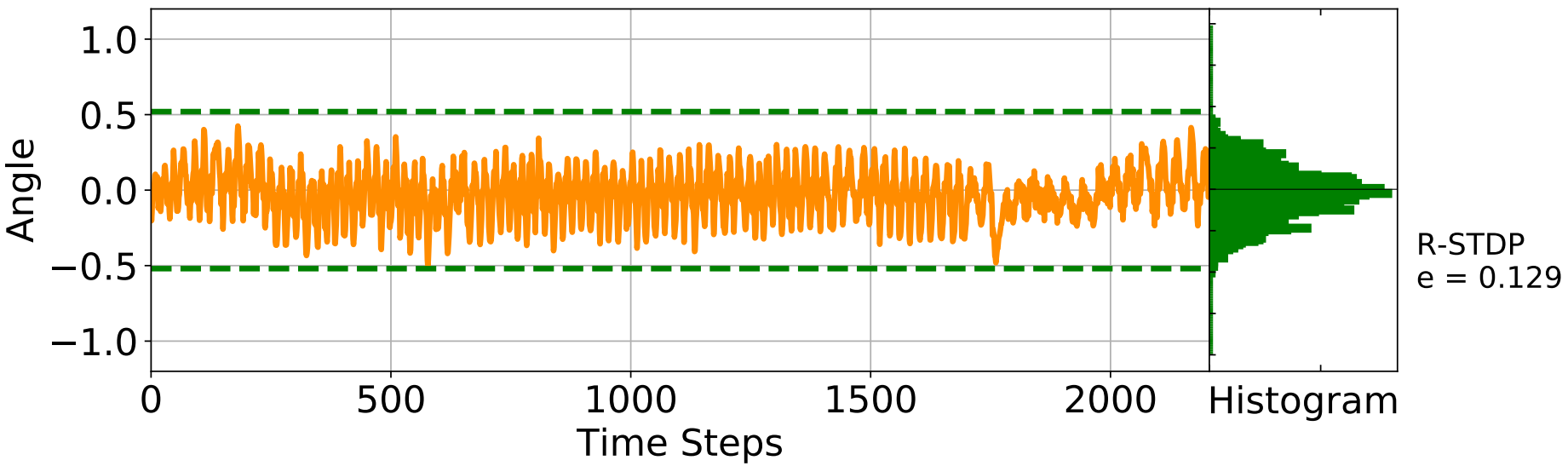

Figure 16: Performance on Target Following Task

Evaluation

- Average error e = 7,39°
- Average error e = 8,71°

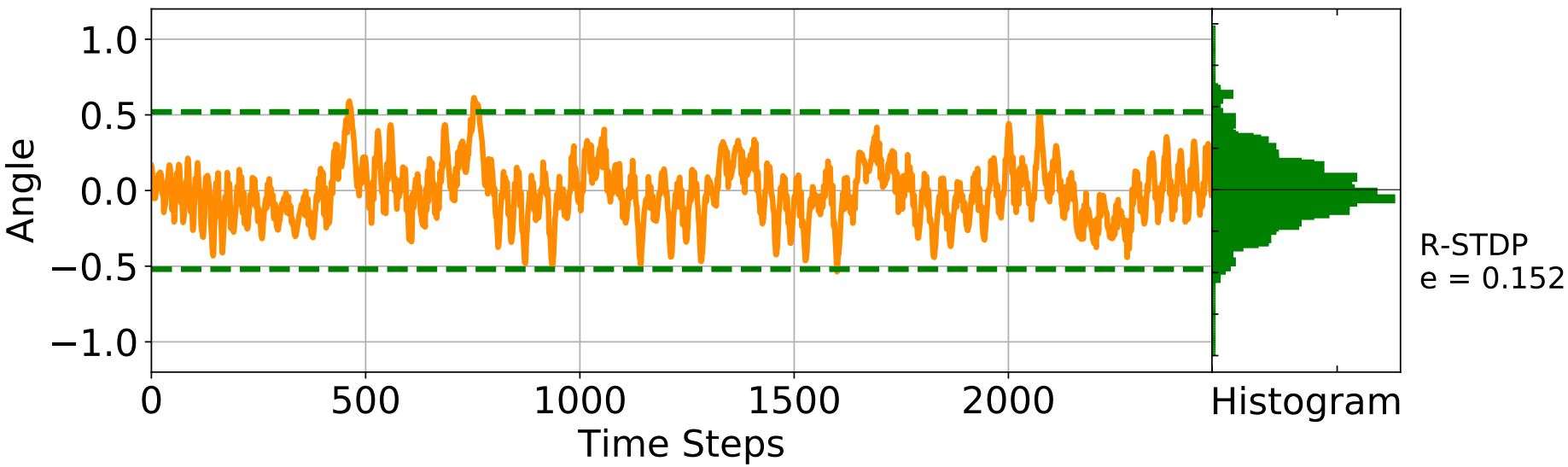

Figure 17: Performance on Target Tracking and Obstacle Avoidance Task

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