Learning to Drive Based on Multiple Sensor Cues

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Neurowissenschaftliche Systemtheory
Elektro- und Informationstechnik

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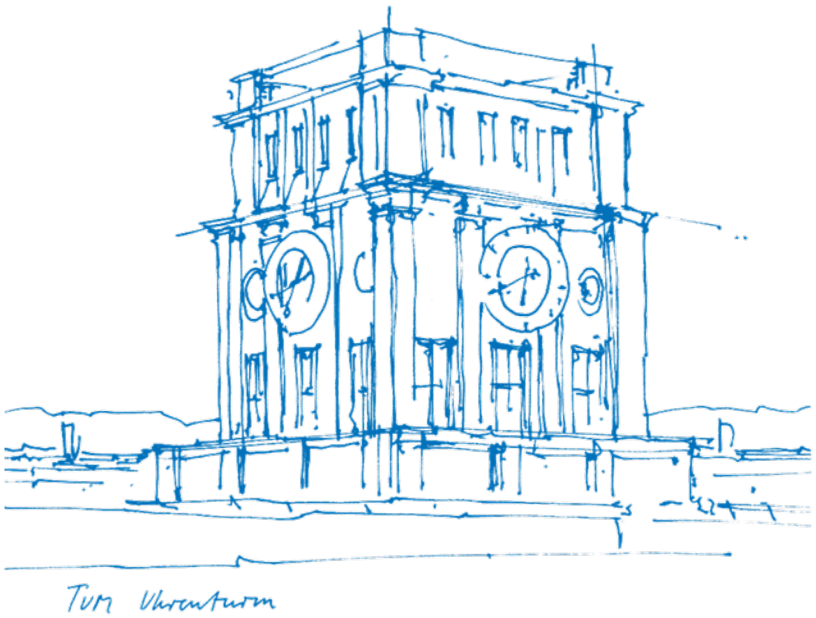


Overview

Neurowissenschaftliche Systemtheorie
Elektro- und Informationstechnik
Technische Universität München

Project Description

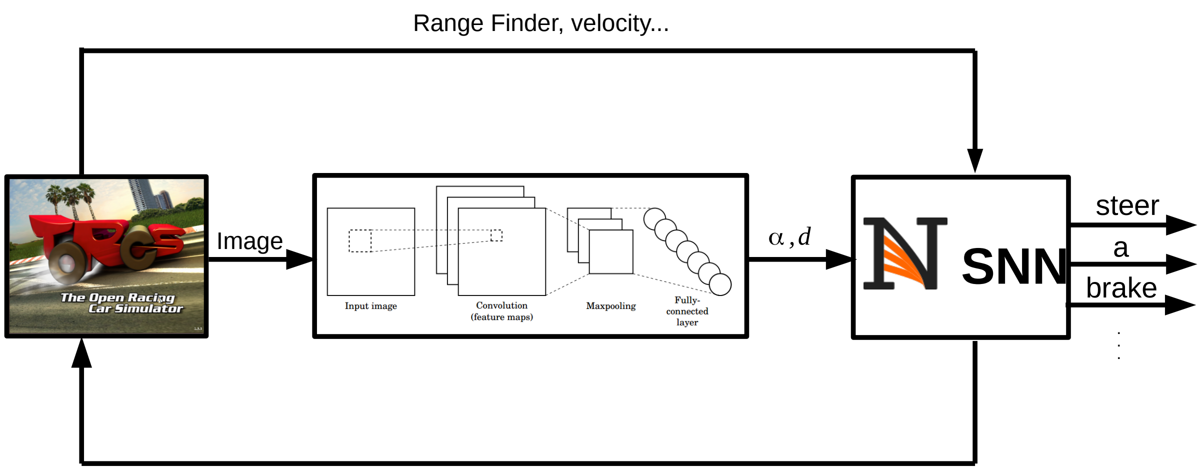


Abbildung: System Architecture

System Architecture

- Regression Problem - Supervised Learning Techniques for SNN and CNN
- CNN - Learning misplacement and angle w.r.t. the track axis
- SNN - Learning steer, acceleration and brake commands

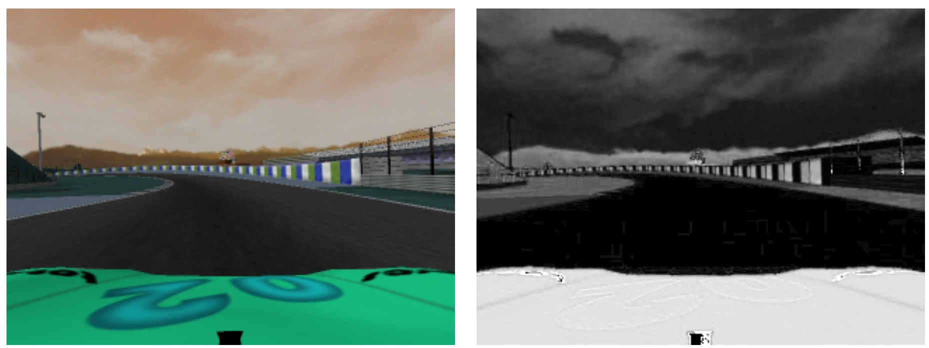
Team I

- Lukas Hausperger and Jan Zumsteg -

Convolutional Neural Network I: Implementation

Preprocessing of input

- Normalization
- Size: $120 \times 160 \times 1$
- Saturation image (HSV color space) $\rightarrow$ highlight edges



(a) RGB image (b) Saturation image

Convolutional Neural Network I: Implementation

Network Architecture

- two separate networks to estimate misplacement and angle independently

# Layers	Type	# Neurons	# Filters	Kernel size	Pooling	Activation
1	C	-	64	11,11	Max (2,2)	ReLu
1	C	-	64	7,7	Max (2,2)	ReLu
1	C	-	64	5,5	Max (2,2)	ReLu
5	D	64	-	-	-	ReLu
1	D	1	-	-	-	linear

Tabelle: Visualization of used CNN to estimate Misplacement and Angle(**C**: Convolutional, **D**: Dense)

Training process

- Cost: mean squared error
- Optimizer: Adam with mini-batches of 30
- Early stopping

Convolutional Neural Network I: Evaluation

Training data

- Supervising driver: Berniw (built-in TORCS driver), ROS-driver (Florain Mirus)
- Test set: Wheel2 and CG track 2, Training set: all other road tracks (shuffled)

Prediction (Wheel2)

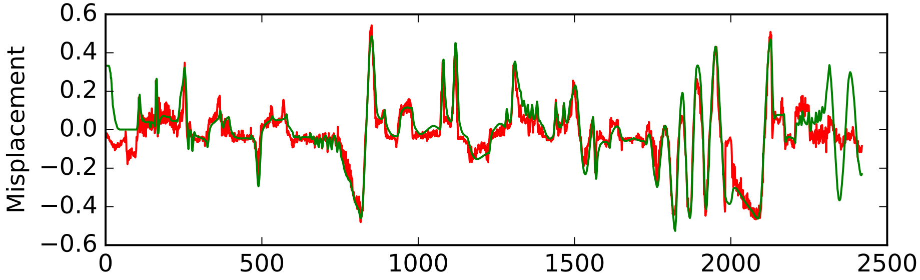


Abbildung: Misplacement (red: Prediction, green: ground truth), **MAE: 0.0549**

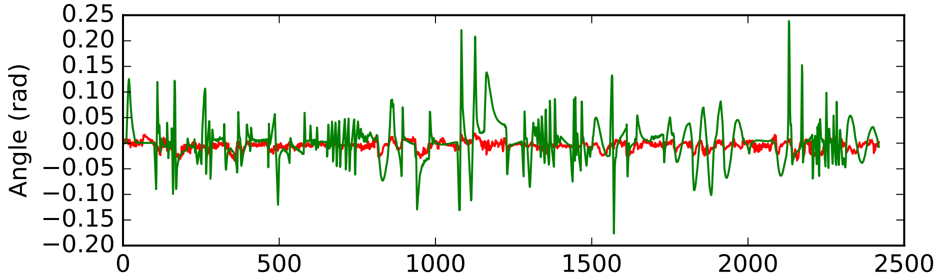


Abbildung: Prediction of Angle (red: Prediction, green: ground truth), **MAE: 0.0244**

Spiking Neural Network I: Implementation

Neuron Model

- Leaky Integrate-and Fire (LIF)

Network Architecture

- layer-based architecture
- separate networks for each output command
- 1 input layer (24 neurons), 1 hidden layer (24 neurons), 1 output layer (1 neuron, linear activation function)

Training Process

- Offline learning with noise - Backpropagation with Adadelta Optimizer
- **Problem:** LIF neurons are not differentiable
- **Solution:** Differentiable SoftLIF neuron model for training $\rightarrow$ LIF neuron model for driving

Spiking Neural Network I: Evaluation

Training data

- Supervising driver: Berniw (built-in TORCS driver)
- Test set: Wheel2 and CG Track 2, Training set: all other road tracks(normalized & shuffled)

Steering Output

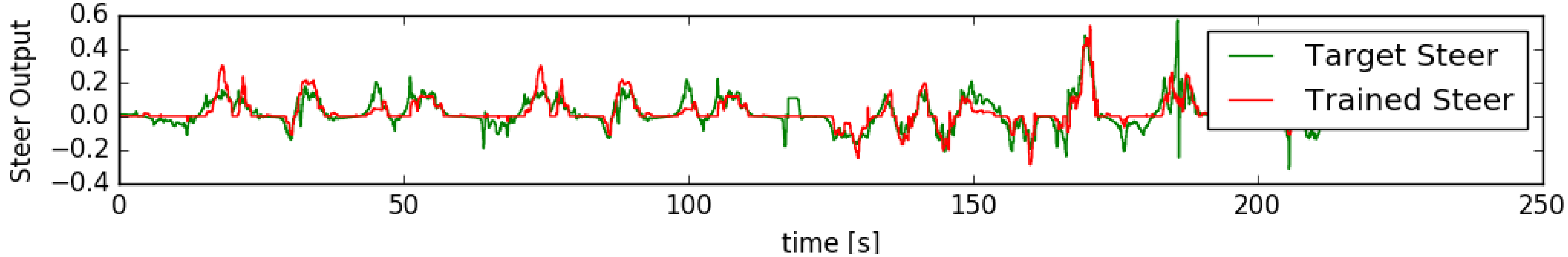


Abbildung: **SoftLIF neuron model:** predicted(red) and ground-truth(green) steer, **MAE: 0.03845**

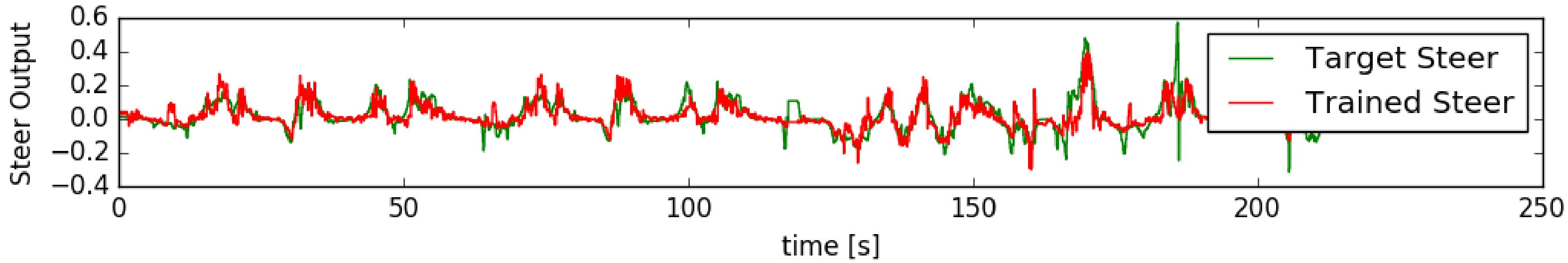


Abbildung: **LIF neuron model:** predicted(red) and ground-truth(green) steer, **MAE: 0.03978**

Spiking Neural Network I: Evaluation

Acceleration Output

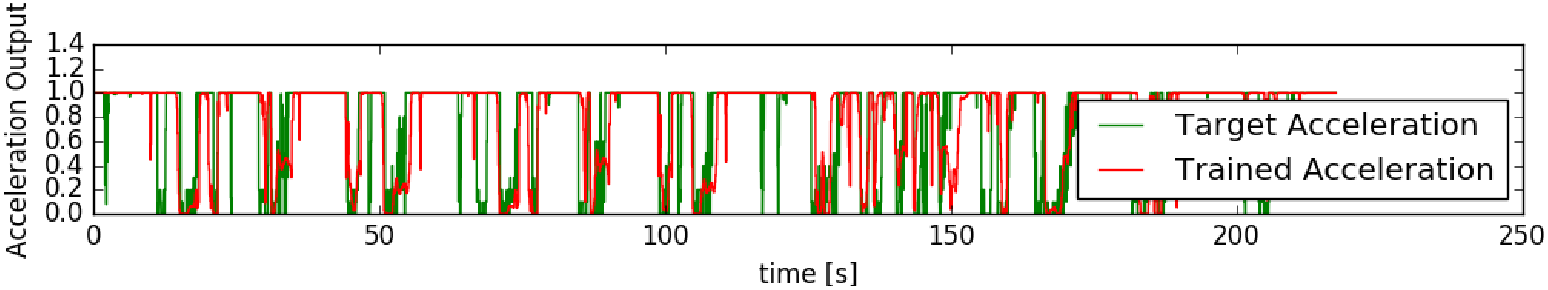


Abbildung: **SoftLIF neuron model:** predicted(red) and ground-truth(green) acceleration, **MAE: 0.17145**

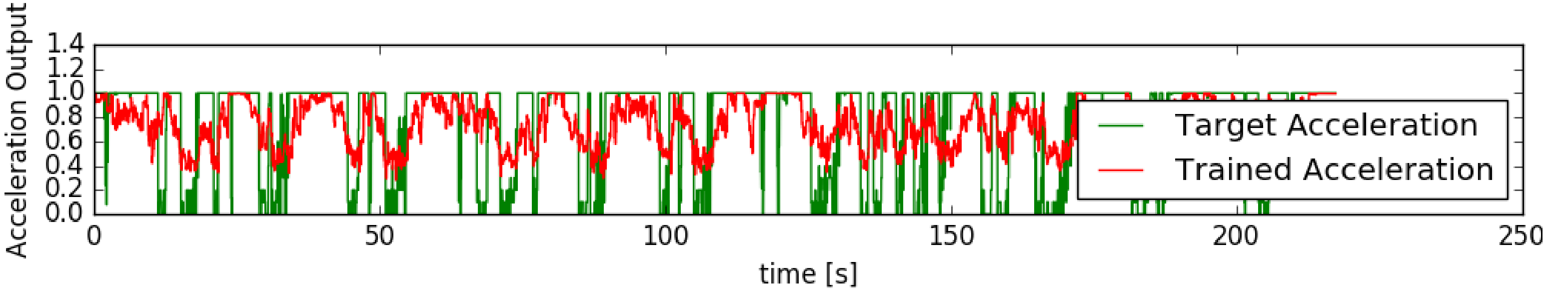


Abbildung: **LIF neuron model:** predicted(red) and ground-truth(green) acceleration, **MAE: 0.26128**

Summary: Team I

Convolutional Neural Network

- Good estimation of Misplacement
- Problem: Estimation of Angle not possible, Prediction time $\sim$ 100ms
  $\Rightarrow$ Linking with SNN not possible

Spiking Neural Network

- **Steer:** Good prediction for SoftLIF as well as for LIF neuron model
- **Acceleration:** Acceptable prediction for SoftLIF, bad translation to LIF
  $\rightarrow$ Possible reasons: little variety in training data, regression $\rightarrow$ classification ...

Team II

- Nimar Blume and Tim Bicker -

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Convolutional Neural Network II: Implementation

Input data

- Size: $60 \times 80 \times 3$ ($w \times h \times channels$)
- Colourspace: RGB, not normalised
- Camera perspective: driver without hood

(a) Camera perspectives

Convolutional Neural Network II: Implementation

Training: use proven architecture first to determine hyperparametres

- Cost: mean squared error
- Optimiser: Adamax
- Batch size: 32
- Split: 57180(train) + 6342(val) + 6761(test)

Network architecture

Type	# Neurons	# Filters	Pooling	Activation
C	-	96	Max(2, 2)	ReLU
C	-	128	Max(2, 2)	ReLU
C	-	64	Max(2, 2)	ReLU
D	256	-	-	ReLU
D	128	-	-	
D	64	-	-	ReLU
D	32	-	-	ReLU
D	2 / 1	-	-	linear

Tabelle: Network architecture used to predict displacement/angle of the car

Convolutional Neural Network II: Evaluation

Angle has a constant output, but not the average

Displacement had also constant output problems, MAE on test: 0.2

Possible reason: training data problems

Prediction time is from 50ms to 200ms on CPU

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Spiking Neural Network II: Implementation

Neuron Model

- Leaky Integrate-and Fire (LIF)

Network Architecture

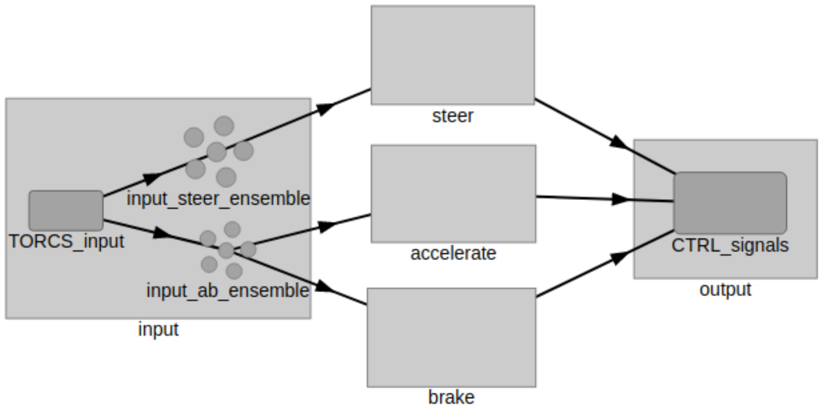

Abbildung: Nengo Architecture. Each ensemble consists for 2000 neurons for each signal. Each controller module consists of 2400 neurons. The modules use subsets of the available input signals. The DNN is in the input node.

Spiking Neural Network II: Evaluation

Training Data

- TORCS - ROS default driver
- **Benefit:** robust driving style
- **Benefit:** follows simple rules

Evaluation Metric

- evaluated on the generalization tracks: Wheel2 and CG Track 2
- **criteria 1:** lap time
- **criteria 2:** robustness

DNN simulation

- decrease of controller frequency due to forward propagation (max. 9ms)
  - asynchronous signal updates are used
- noisy data
  - additional Gaussian noise with $\sigma = 0.3$ of the signal value

Spiking Neural Network II: Evaluation

Controller with ground truth data

track	default driver	no interruption	interruption
cg track 2	1:58:15	2:00:76	2:03:84
wheel 2	4:21:45	4:26:80	4:46:51

Tabelle: Comparison of the lap times of the controller with and without 9ms artificial interruption.

Controller with noisy input

track	no interruption	interruption
cg track 2	2:04:14	2:30:31
wheel 2	4:33:75	5:28:86

Tabelle: Comparison of the lap times of the controller with and without 9ms artificial interruption.

Summary: Team II

Convolutional Neural Network

- Possible problem with training data
- Prediction time too high to be useful

Spiking Neural Network

- Driving is successful
- We could provide requirements for the DNN in terms of propagation time and error

Comparison

CNN comparison

Category	Team I	Team II
Image size	120×160 pixel	60×80 pixel
Camera perspective	With hood	Without hood
Colour space	S of HSV	RGB
Selective input data	Yes	No

SNN comparison

Category	Team I	Team II
Driver	optimized racing driver	simple driver
Architecture	Nengo deep learning	classic Nengo Ensembles
Signals	all signals for each module	subset of signals for each module