

On Structural Identification of 2D Regression Functions for In-door Bluetooth Localization

EUROCAST 2009

Workshop on Heuristic Problem Solving

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Based on material of a Diploma Thesis
written by Thomas Treutner

Aim: Indoor localization of mobile phones

What?

- **Indoor** localization
- .. using off-the-shelf devices
- .. with „sufficient“ accuracy

How?

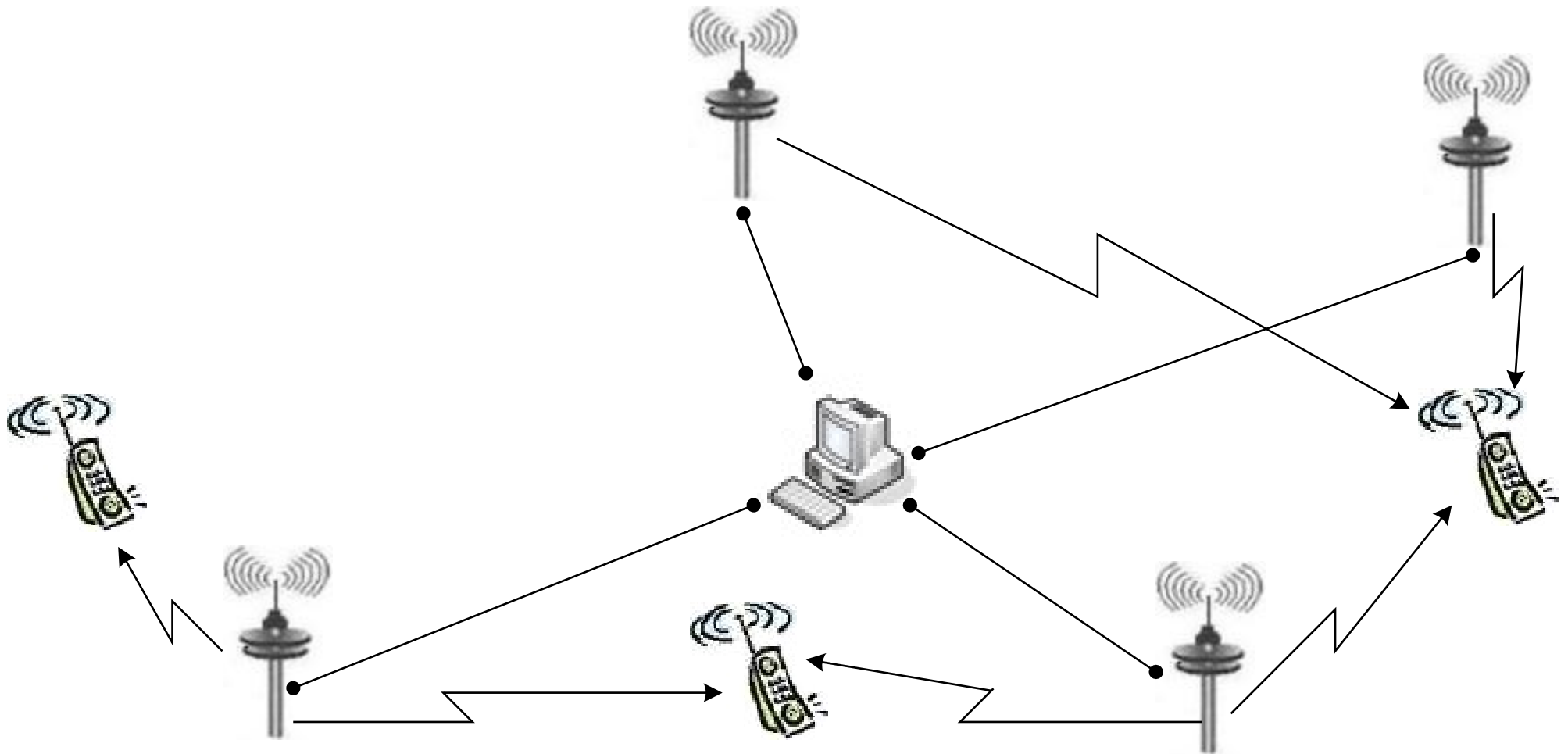
- **Bluetooth** widely available
- Range sufficient for room level
- Accuracy is the problem!



Overview
Data acquisition
Data analysis
Results

Motivation
Bluetooth
Related work

System Architecture



Bluetooth: what it can and can't do

Bluetooth has been designed as cable replacement for

- interoperability
- low power
- low cost
- **robustness** in 2.4 GHz spectrum (Frequency Hopping)



⇒ multi-path propagation, reflection, absorption, etc. are common and even expected for Bluetooth signals

⇒ (absolute or relative) **signal strength not linearly dependent on distance!**

Indoor Localization

High accuracy and precision

- Ultrasound (e.g. „Relate“, „Active Bats“, „Cricket“)
- UWB (e.g. „Ubisense“)
- Video (e.g. „TrackSense“)

⇒ Accuracy range: cm

Low cost (off-the-shelf HW)

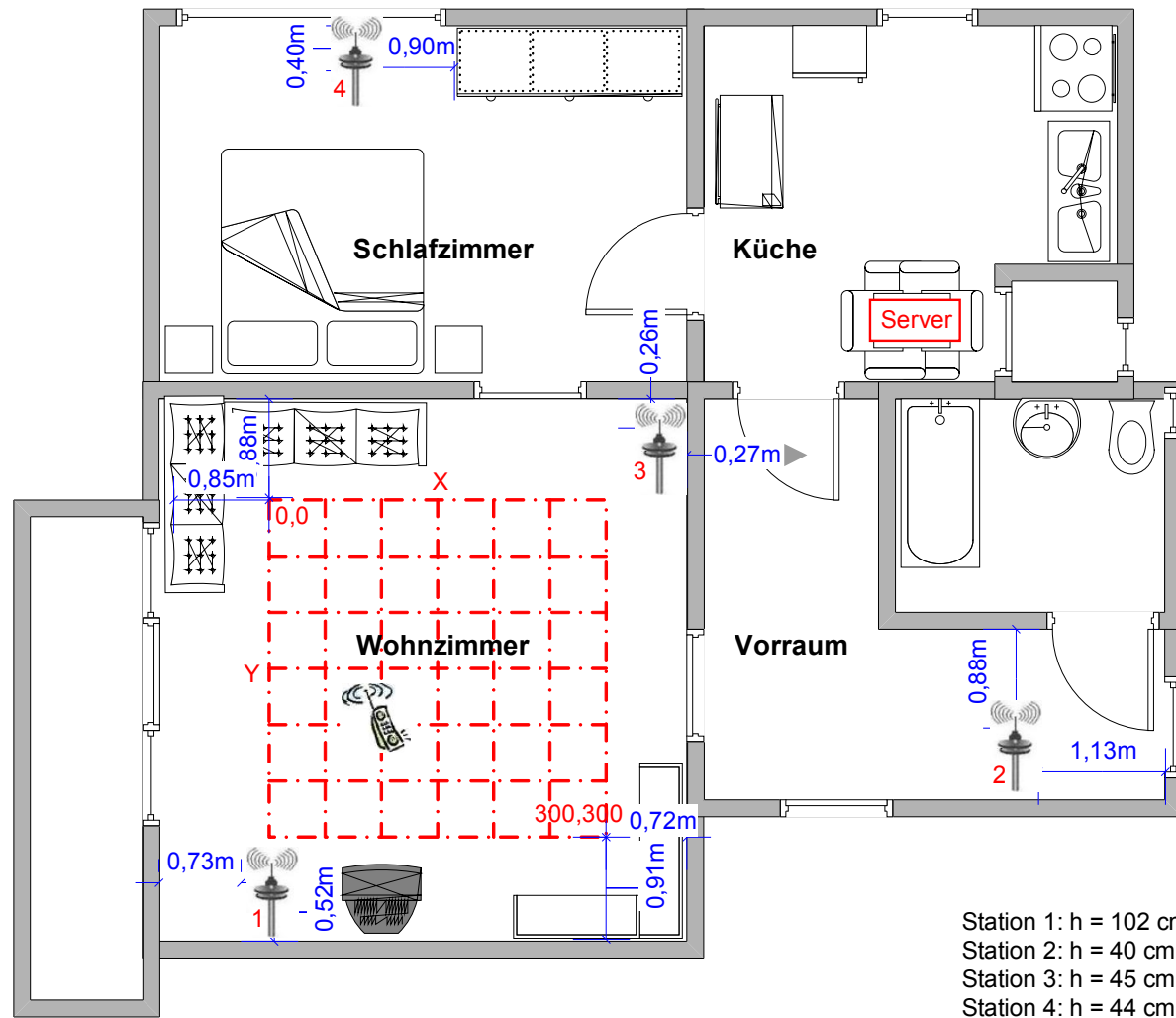
- Infrared (e.g. „Active Badge“, „Smart Badge“)
- WLAN (e.g. „PlaceLab“, „RADAR“, „Ekahau“)
- Bluetooth
- (GPS)

⇒ Accuracy range: m / room

Test Setup

- Multiple fixed Bluetooth dongles at different heights
- Mobile device at constant height (ca. 50cm)
- Systematic set of points for measurement
 - Grid 7x7 with 50cm width \Rightarrow 3m x 3m
 - 15 min. RSSI measurements for each point every 0.5 sec.

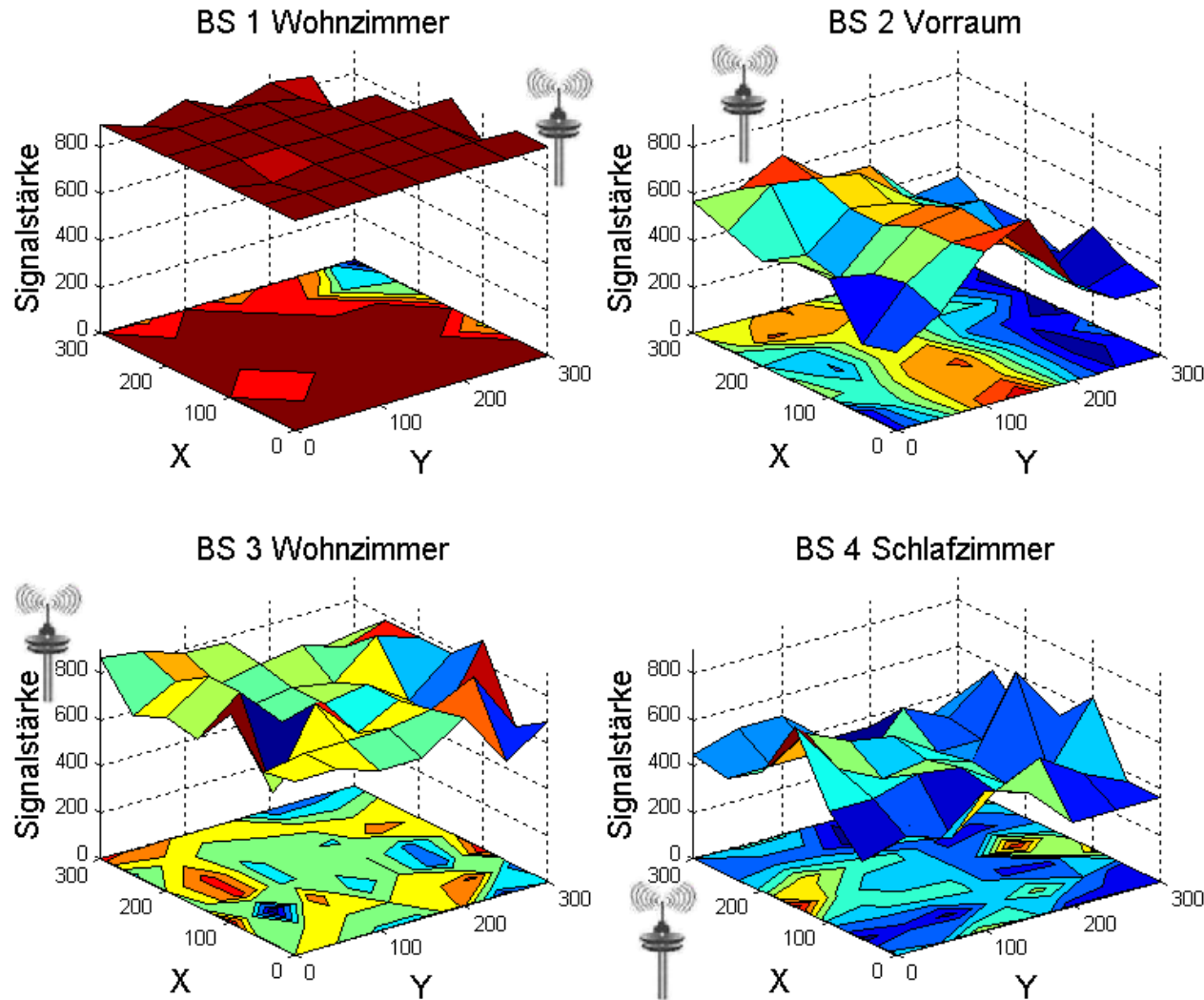
Test Setup



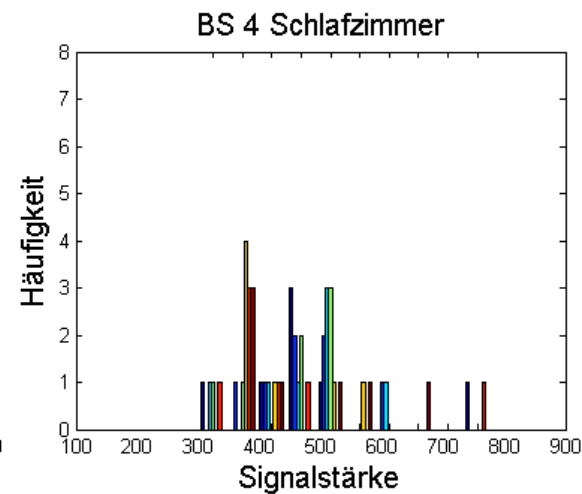
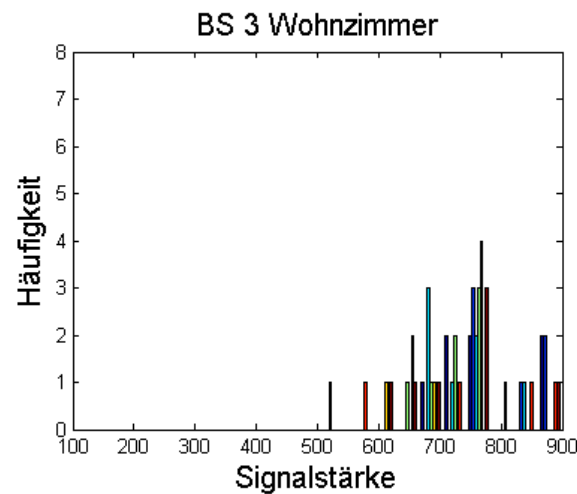
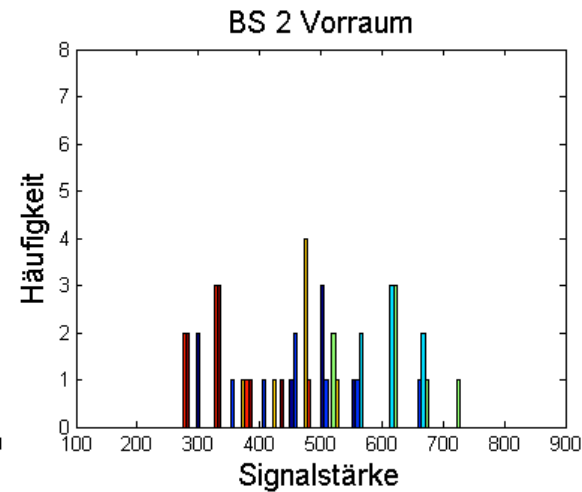
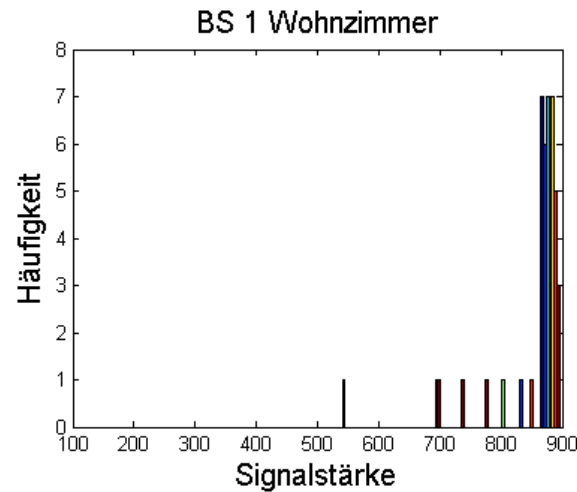
Test Setup



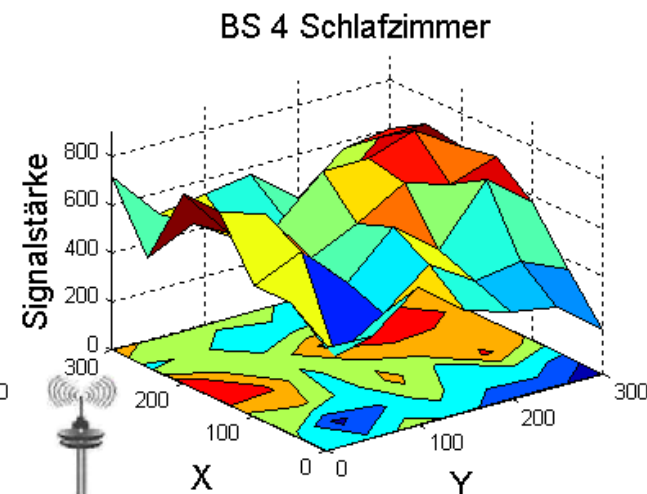
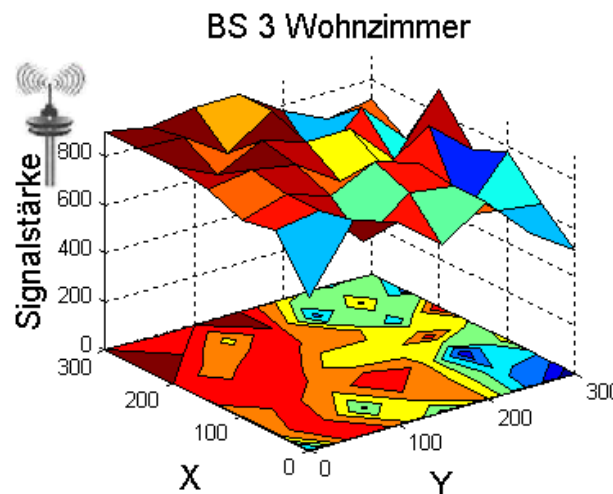
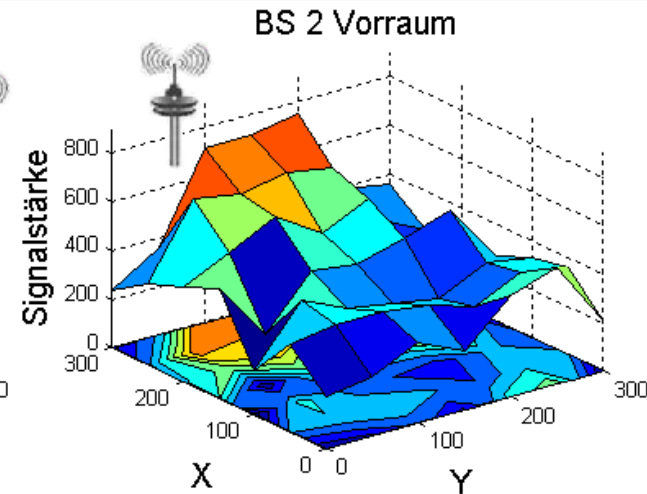
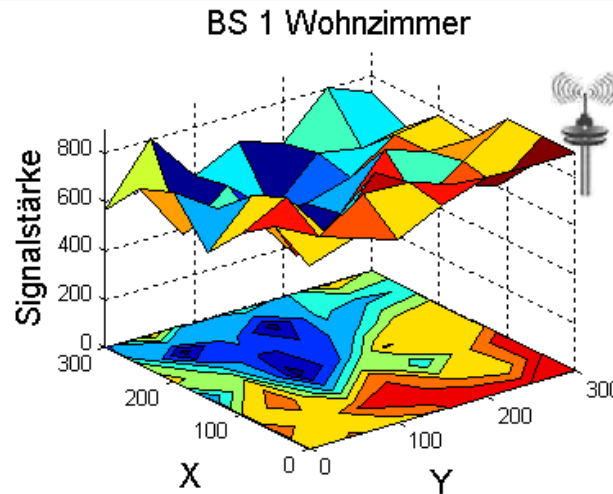
Initial Measurements class 2 device



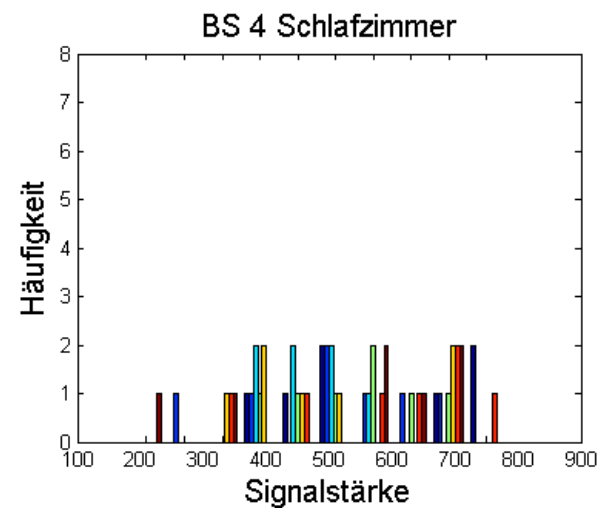
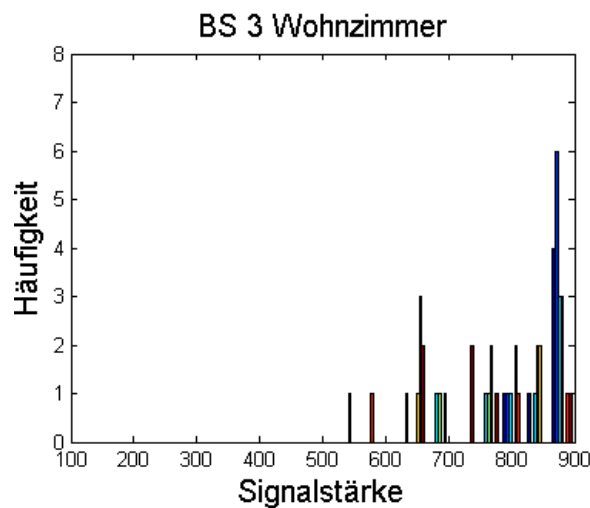
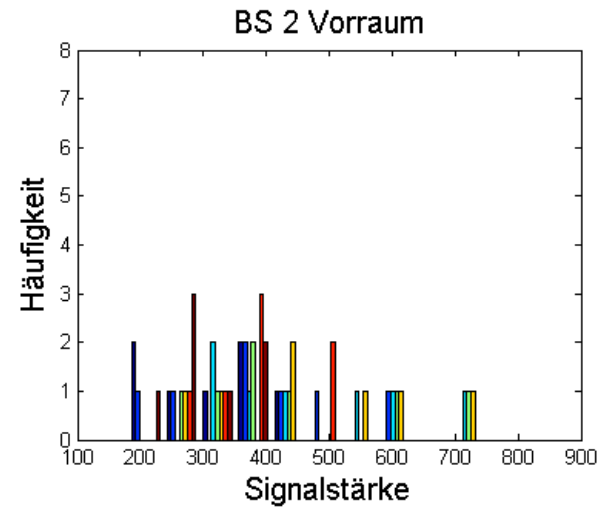
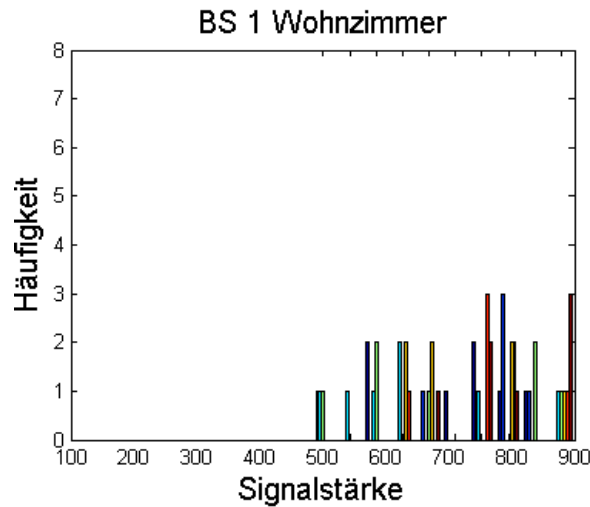
Initial Measurements class 2 device



Initial Measurements class 3 device



Initial Measurements class 3 device



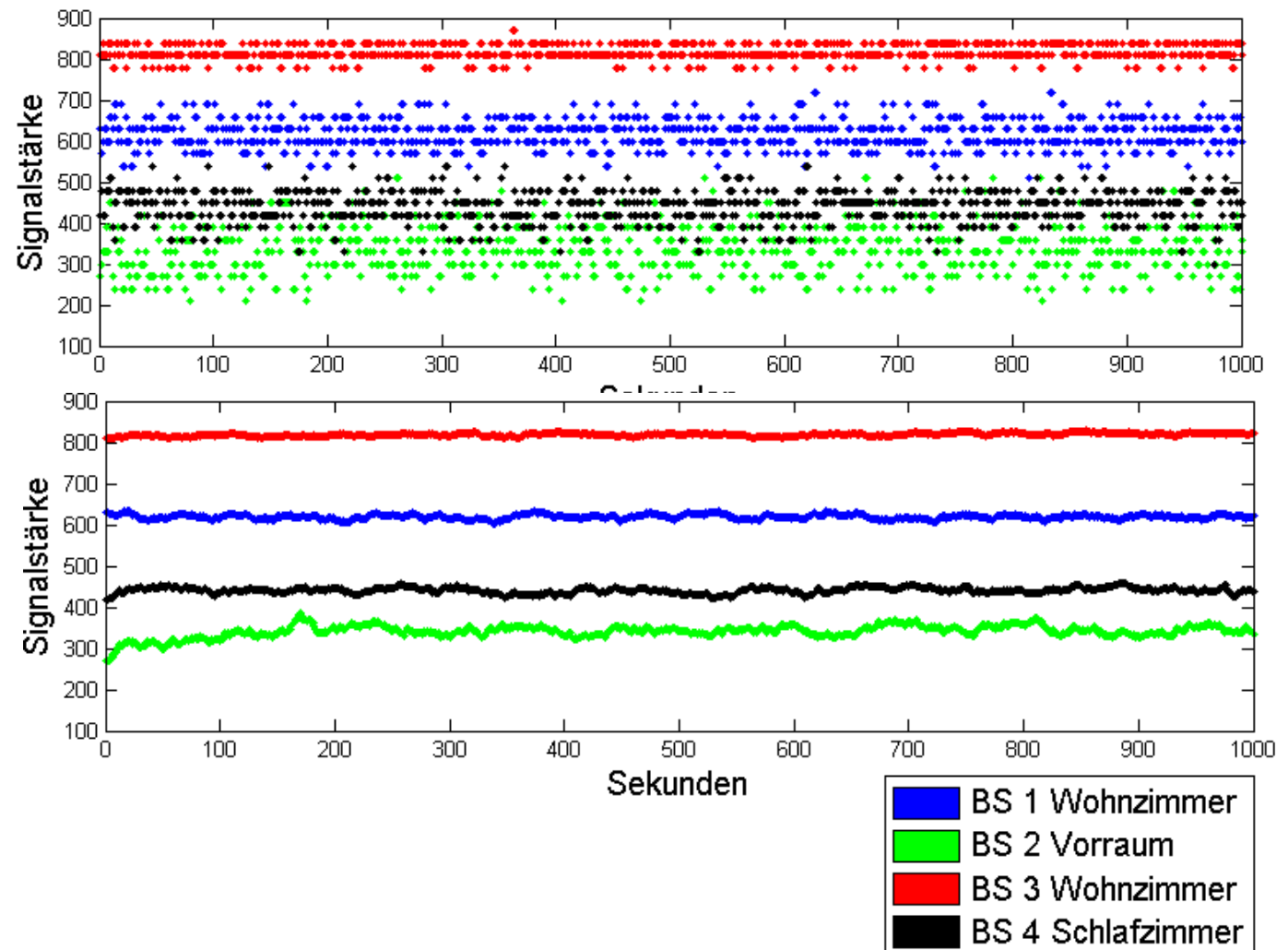
Standard Multilayer Perceptron

Standard MLP used for estimation of X and Y coordinates from signal strength readings

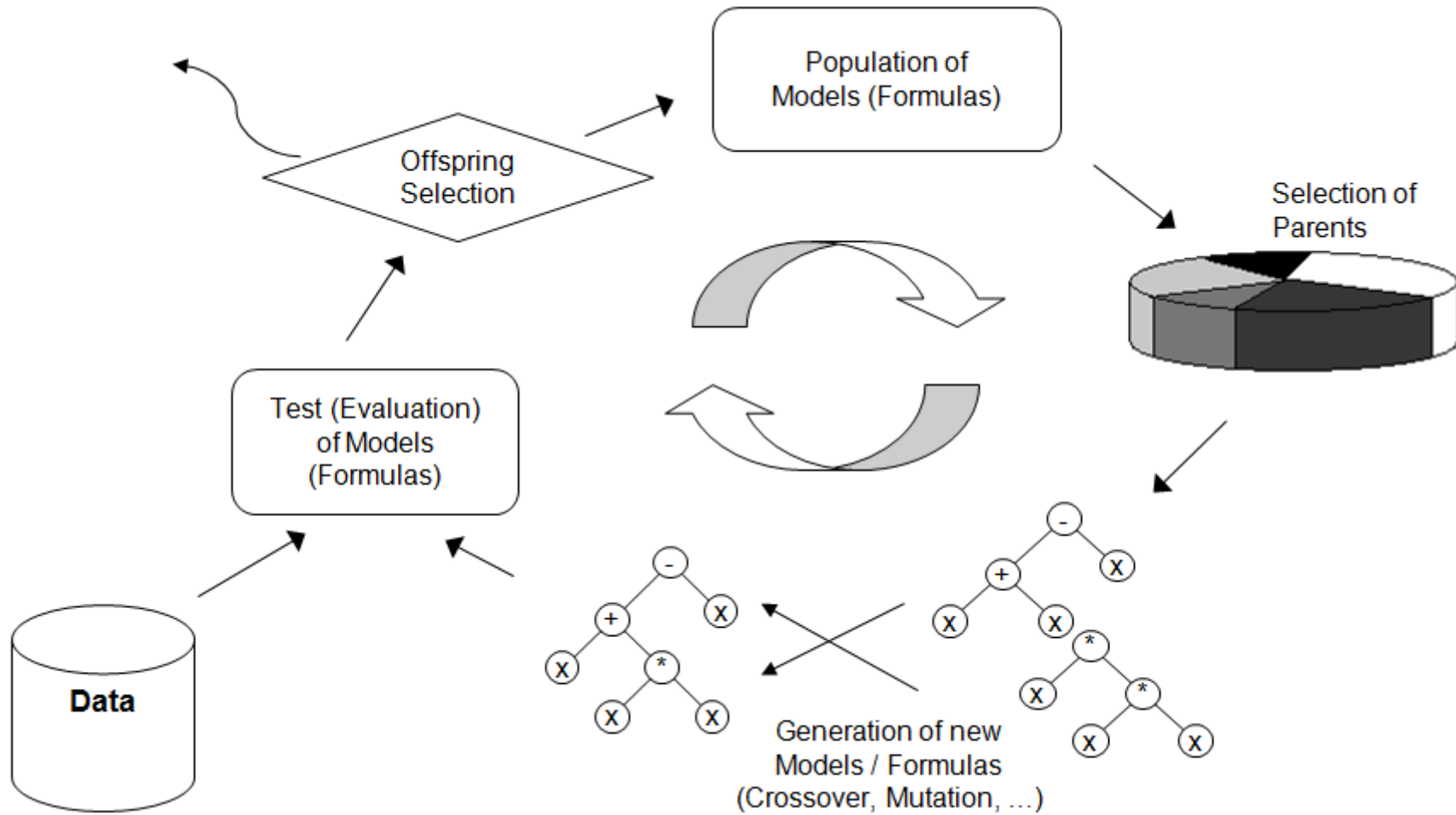
- Network structure 4-60-30-2, fully connected
 - Mapping 4 fixed dongles \Rightarrow 2 coordinates
- Training
 - After smoothing, scaled to 0.1 - 0.9
 - 67 (smoothed) measurements for each grid point
 - 60% for training, 20% for validation, 20% for test
 - Manually stopped for minimum error rate on test set

Smoothing

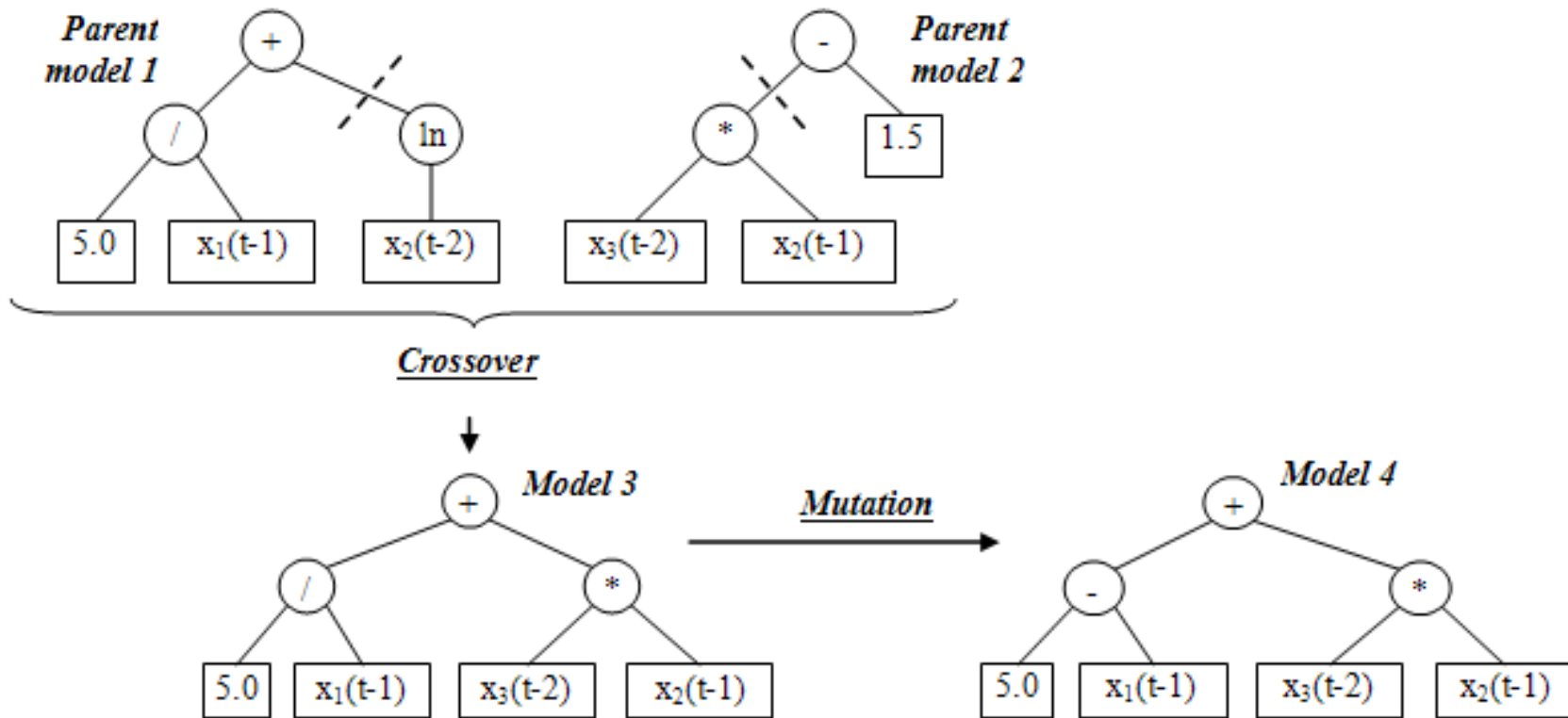
Alpha = 0.05



Extended Genetic Programming

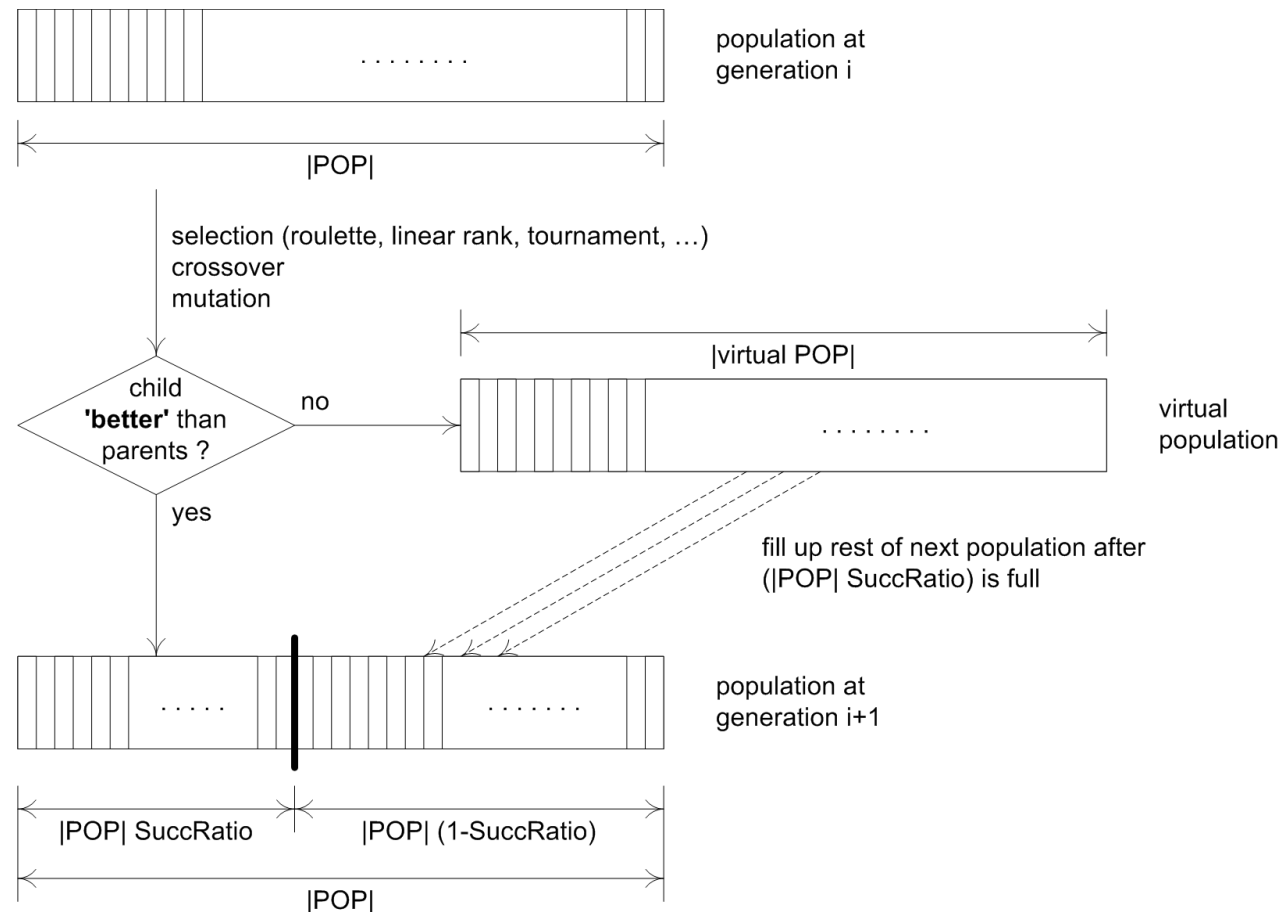


Extended Genetic Programming



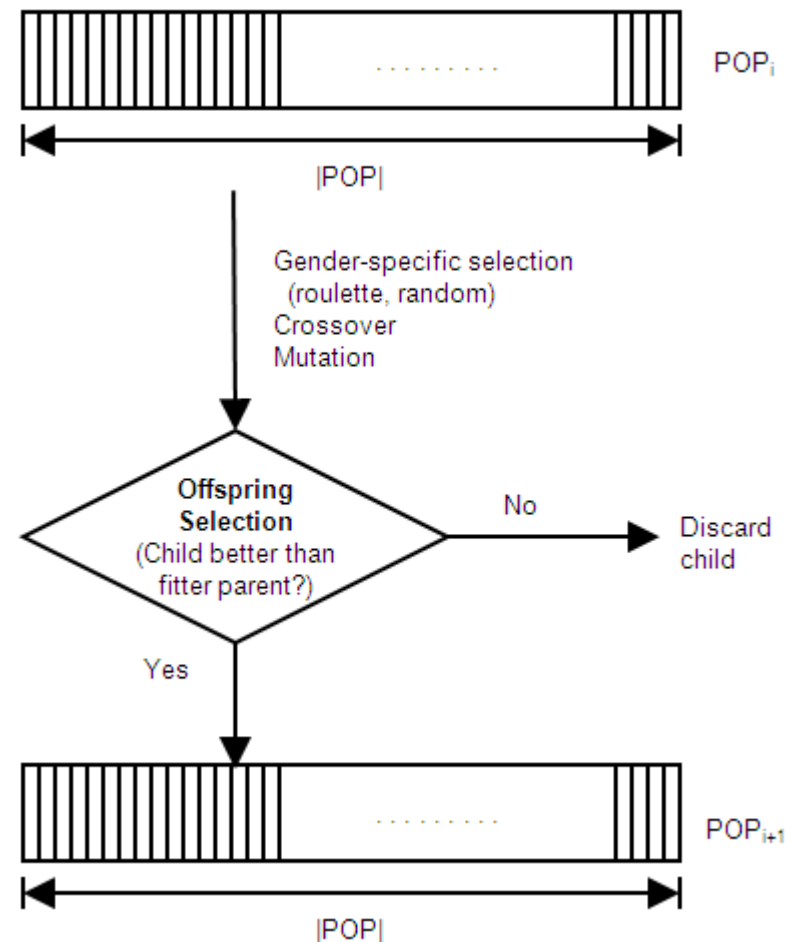
Extended Genetic Programming

Offspring Selection:



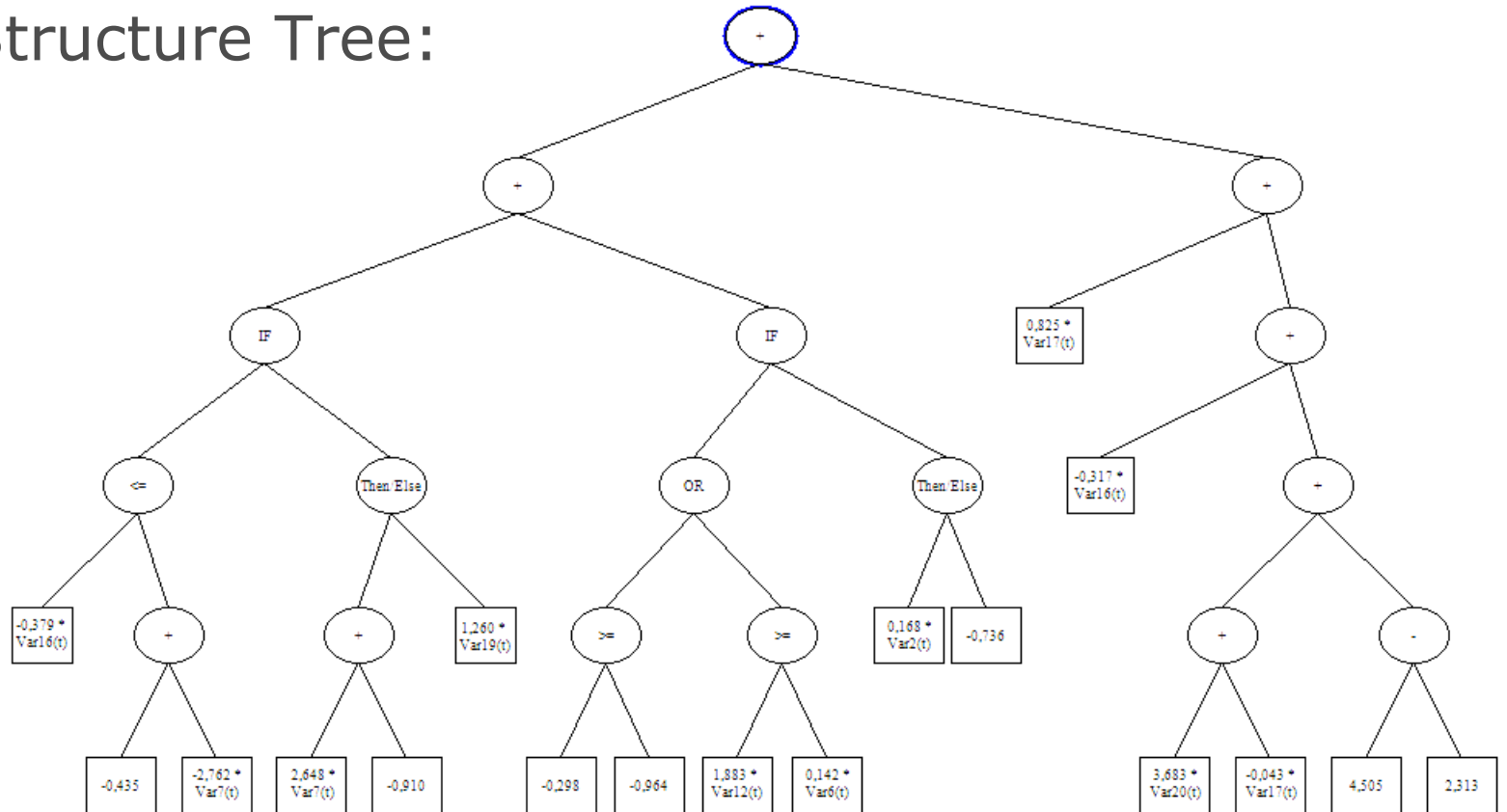
Extended Genetic Programming

Strict Offspring Selection as used here in GP:



Extended Genetic Programming

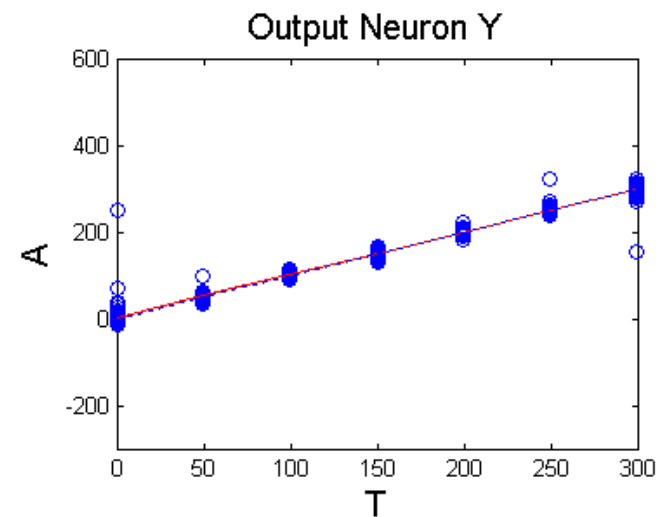
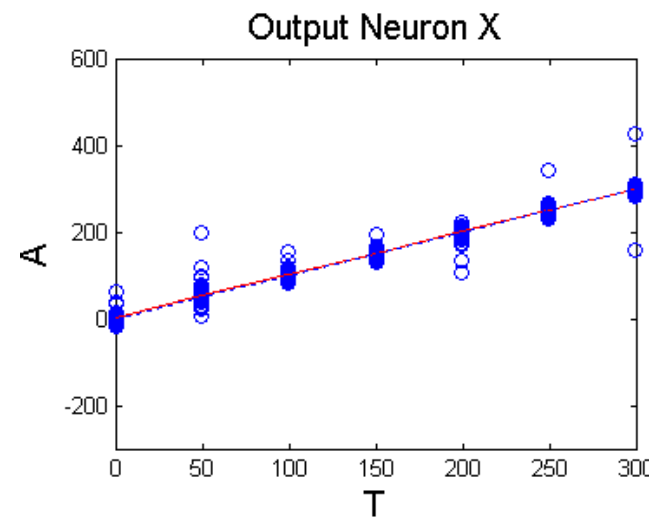
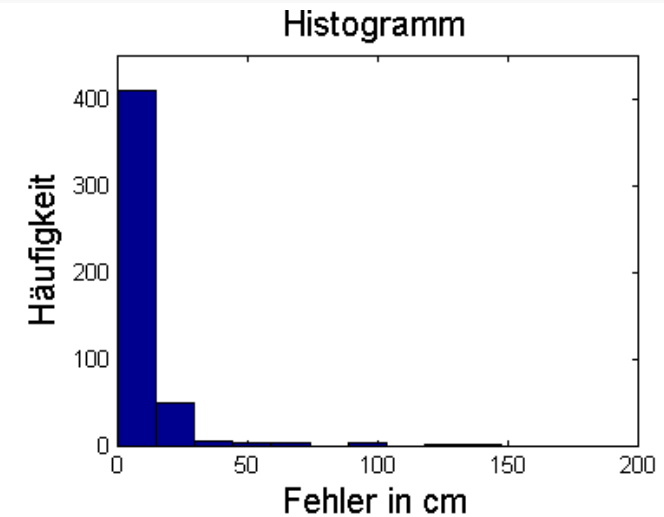
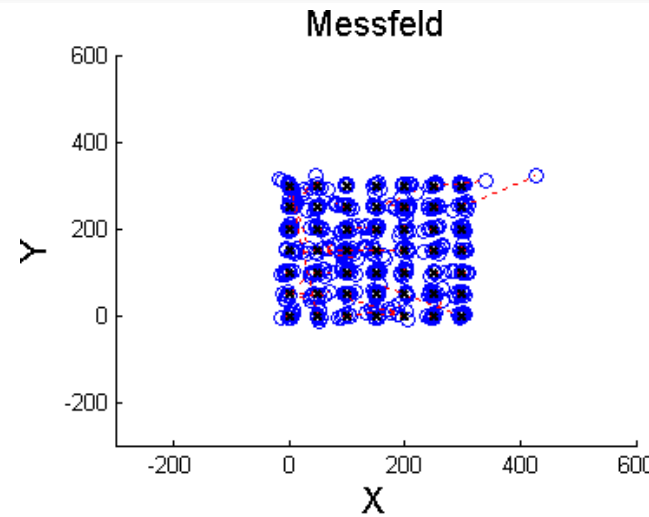
Exemplary Structure Tree:



<http://www.heuristiclab.com>

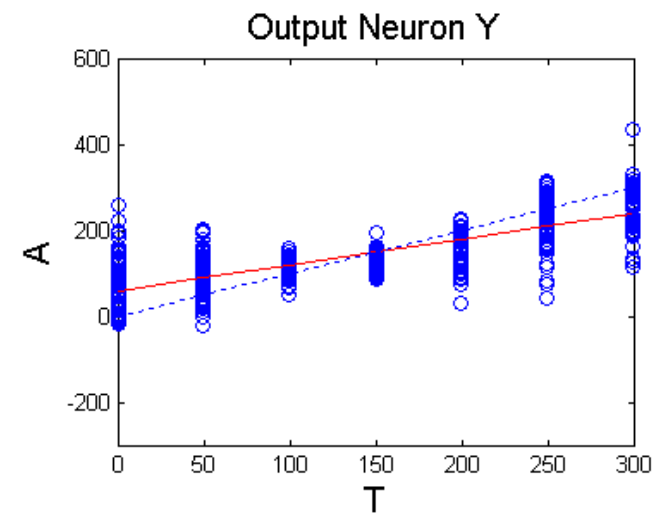
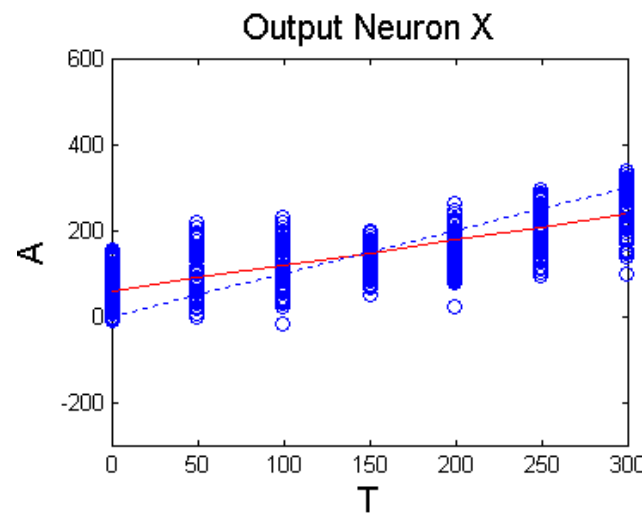
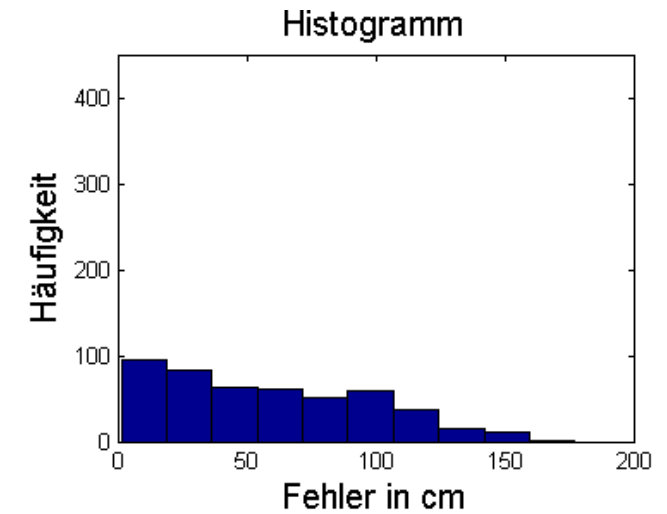
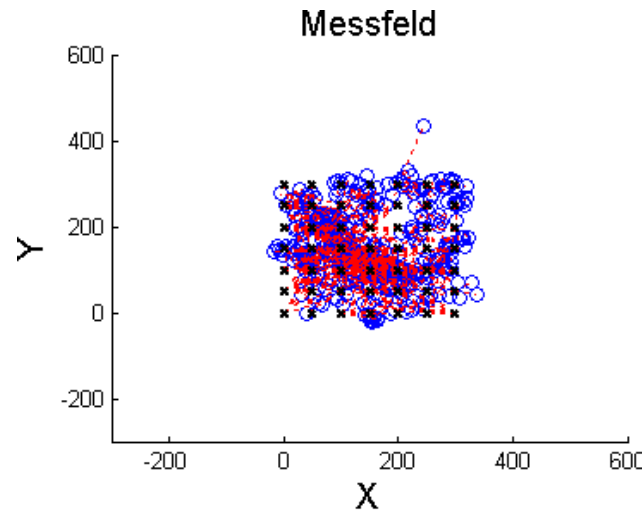
MLP: Class 2 device Results with smoothing

Average absolute error 9.6 cm
median 5.4 cm



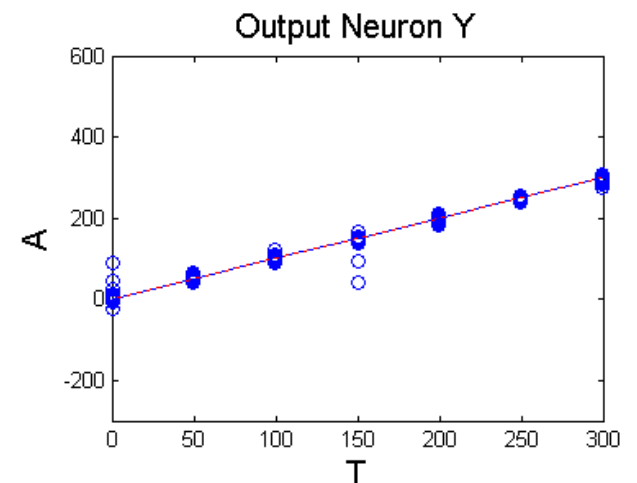
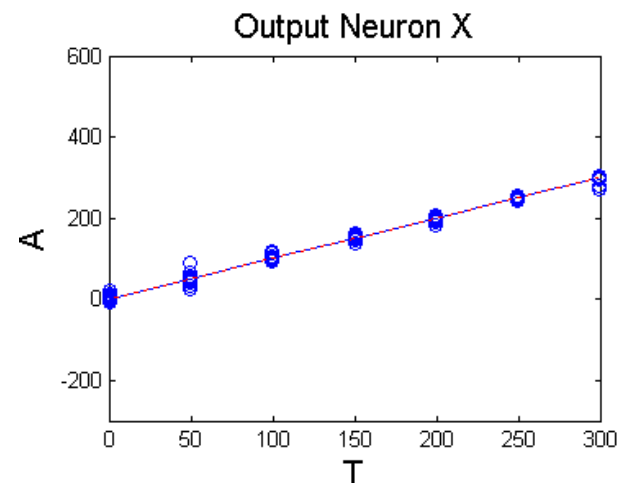
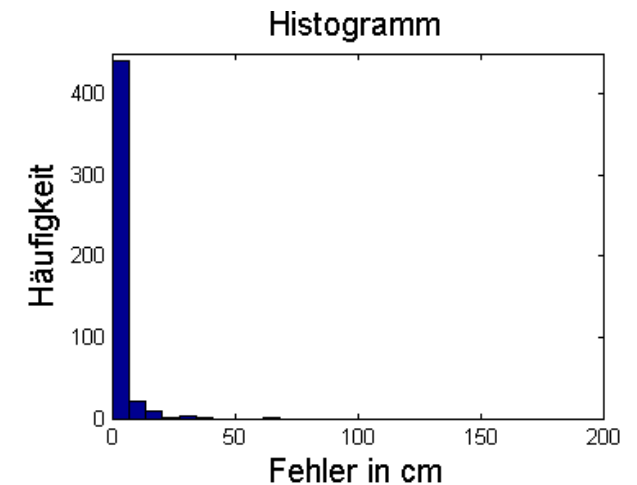
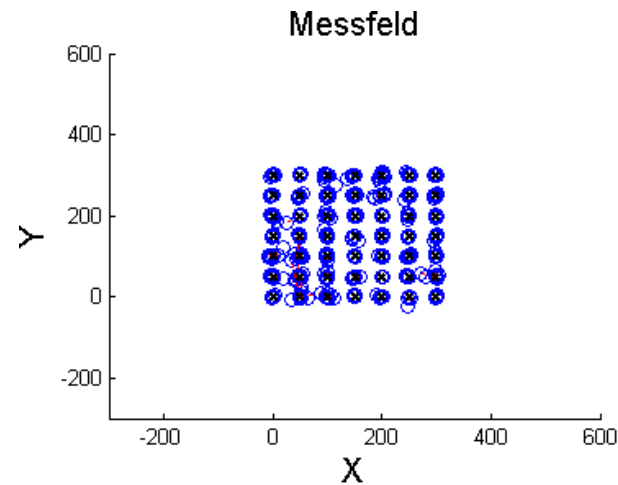
MLP: Class 2 device Results w/o smoothing

Average absolute error 58.5 cm
median 53.9 cm



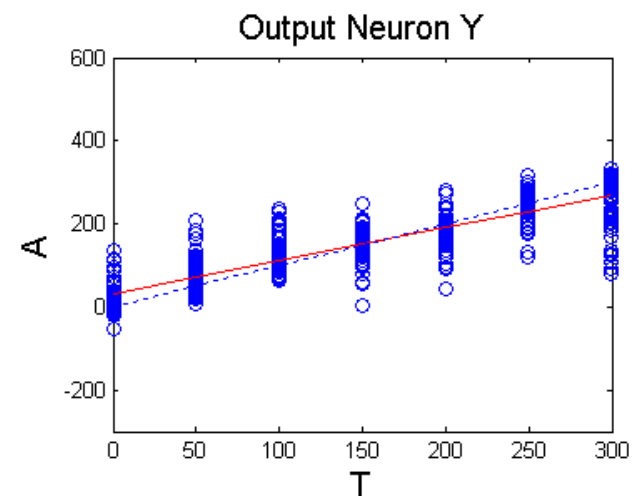
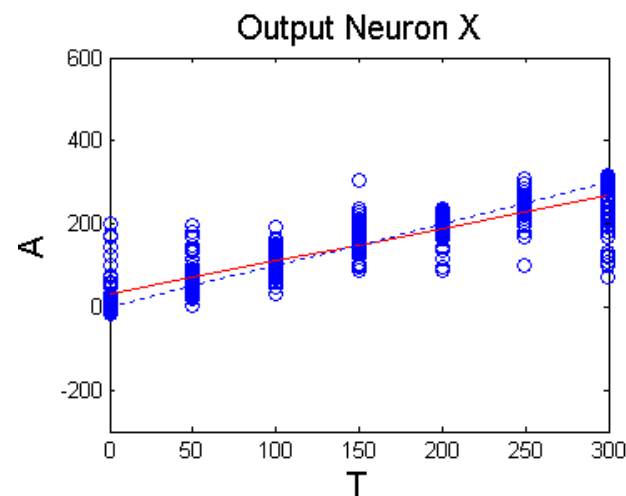
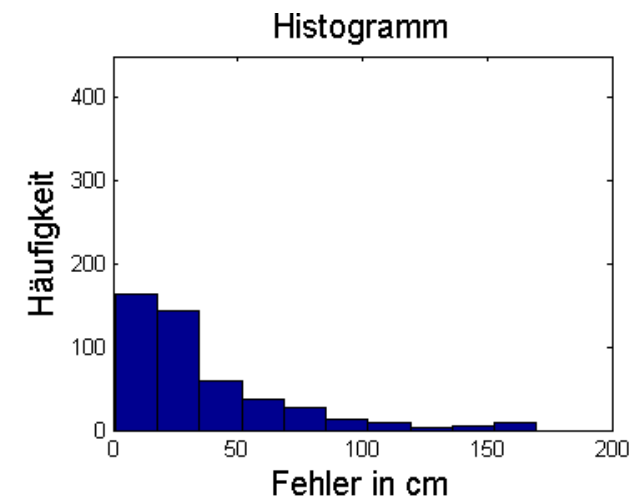
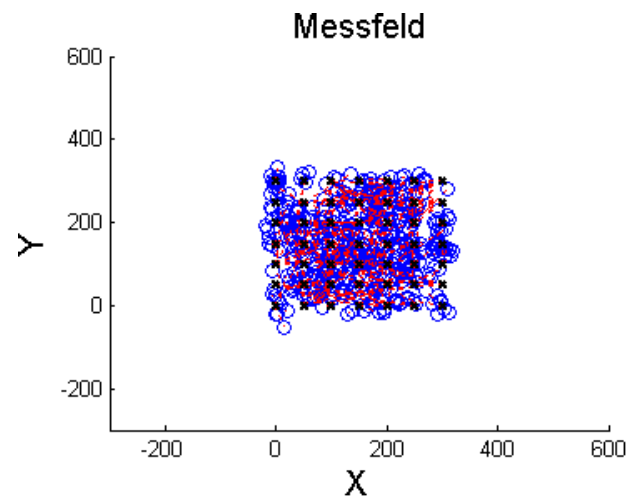
MLP: Class 3 device Results with smoothing

Average absolute error 3.4 cm
median 1.9 cm



MLP: Class 3 device Results w/o smoothing

Average absolute error 36.7 cm
median 25.6 cm



Structural Identification Using GP

GA / GP Parameters:

- Population Size: 747
- Max. Formula Height: 10 levels
- Standard Single Point Crossover, Point Mutation
- Generations: ?
- Strict Offspring Selection; Maximum Selection Pressure: 450

Structural Identification Using GP

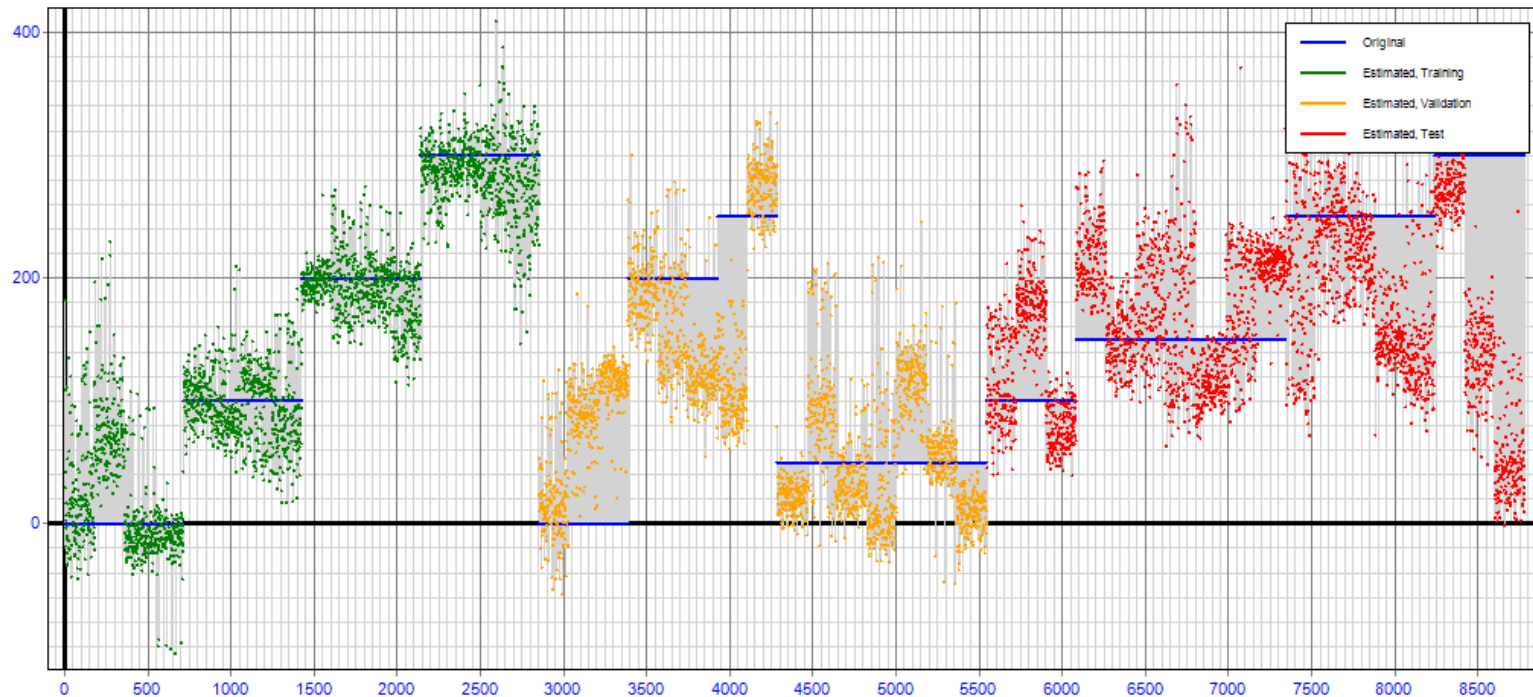
X:

Training:

avg. abs. error: 26.44
median: 26.94

Test:

avg. abs. error: 55.36
median: 42.42



Structural Identification Using GP

X:

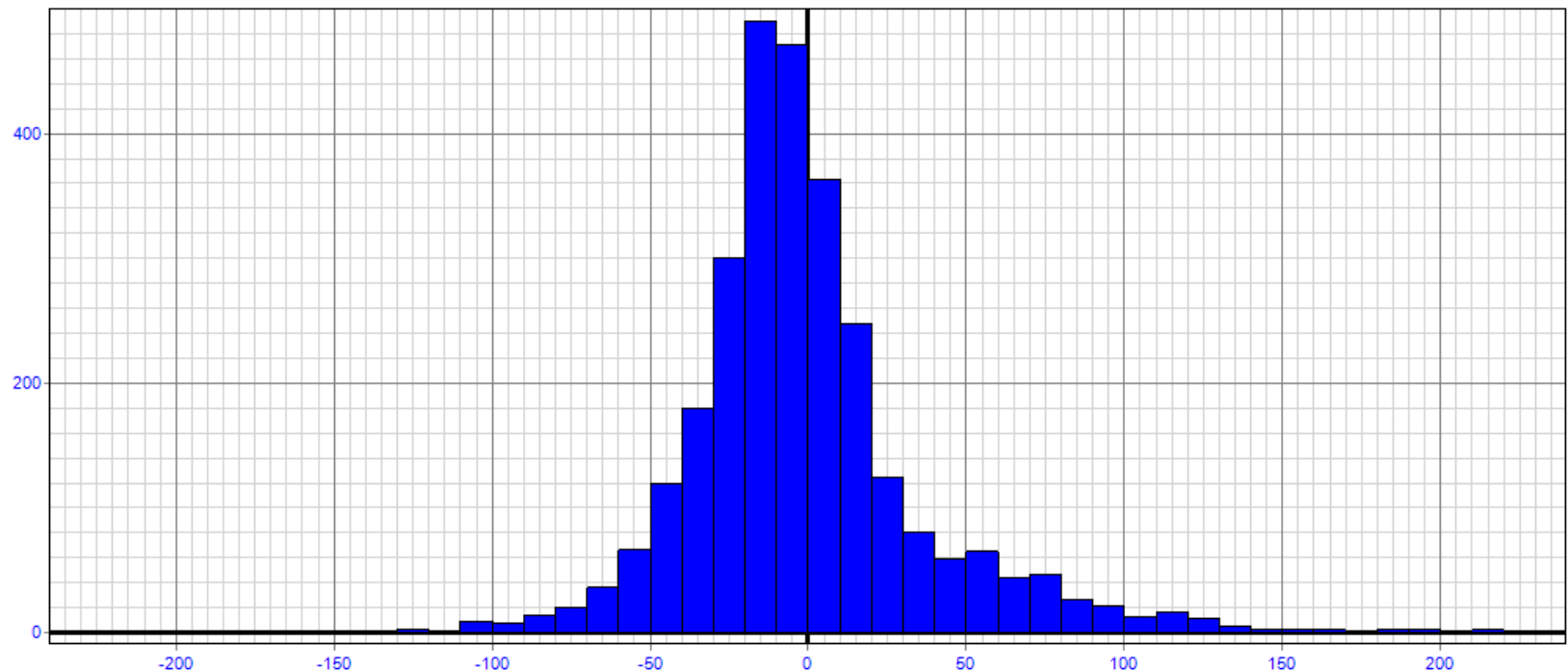
Training:

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median: 26.94

Test:

avg. abs. error: 55.36
median: 42.42

**Error Histogram
Training**



Structural Identification Using GP

X:

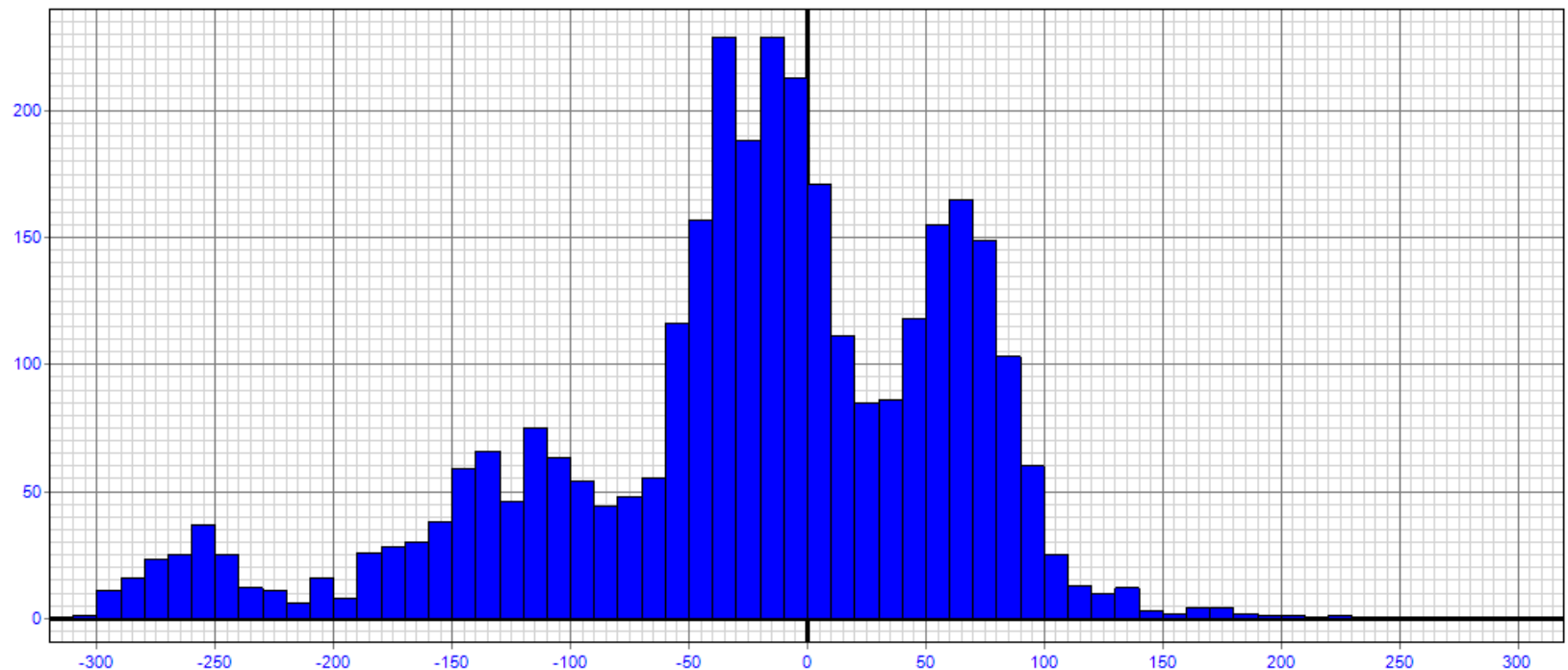
Training:

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avg. abs. error: 55.36
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**Error Histogram
Test**



Structural Identification Using GP

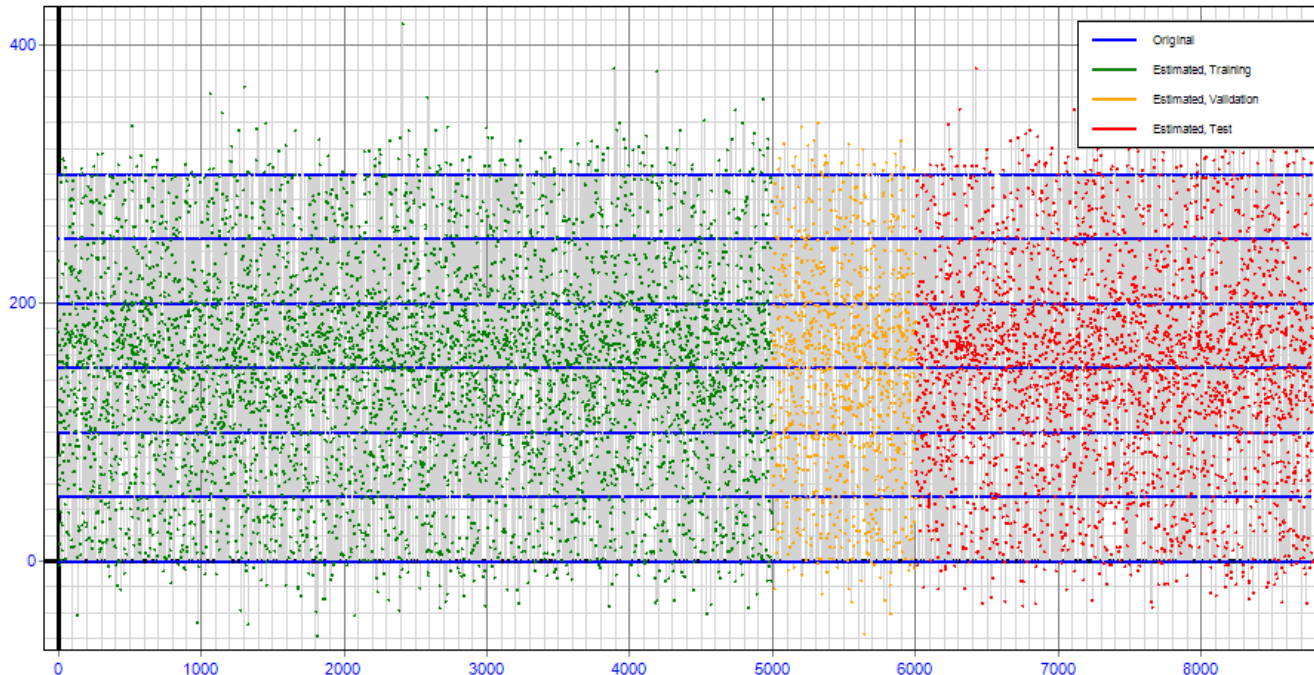
[scrambled] X:

Training:

avg. abs. error: 42.4
median: 41.871

Test:

avg. abs. error: 42.44
median: 44.15



Structural Identification Using GP

[scrambled] X:

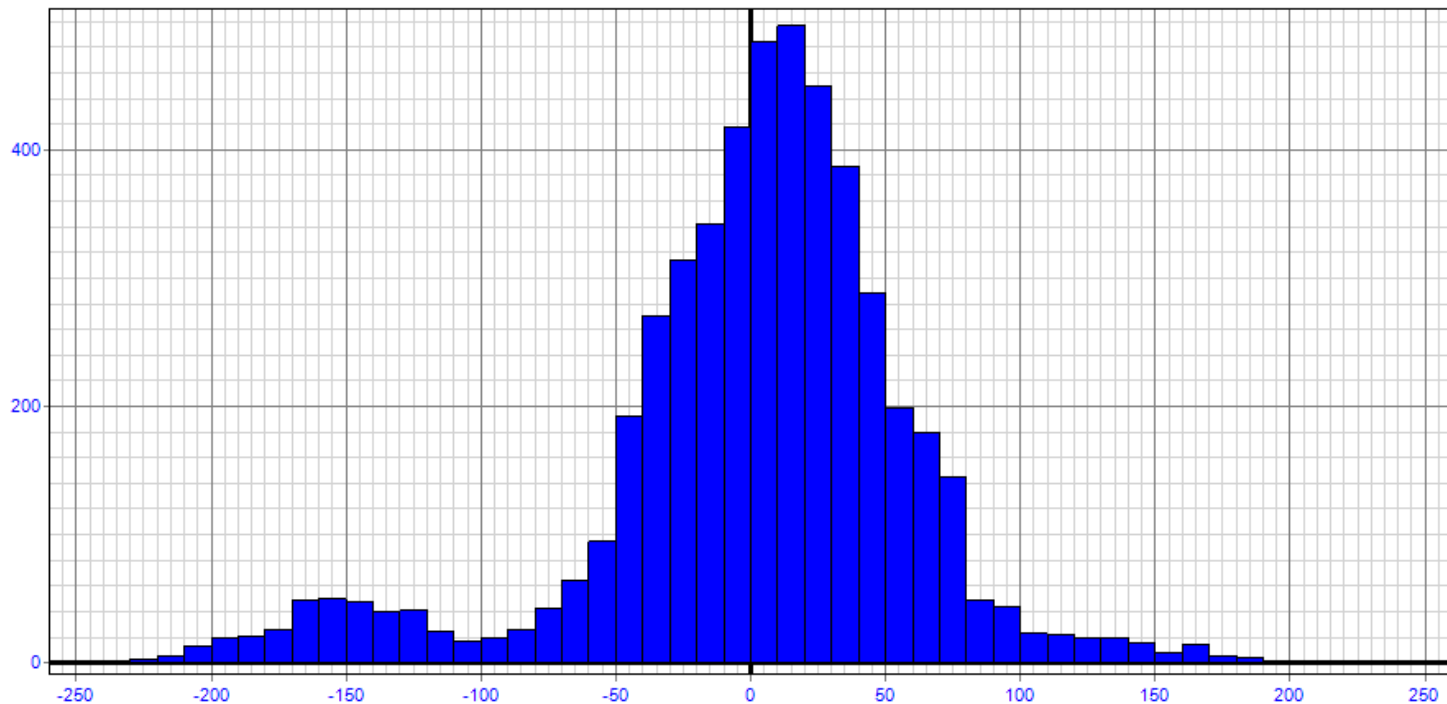
Training:

avg. abs. error: 42.4
median: 41.871

Test:

avg. abs. error: 42.44
median: 44.15

**Error Histogram
Training**



Structural Identification Using GP

[scrambled] X:

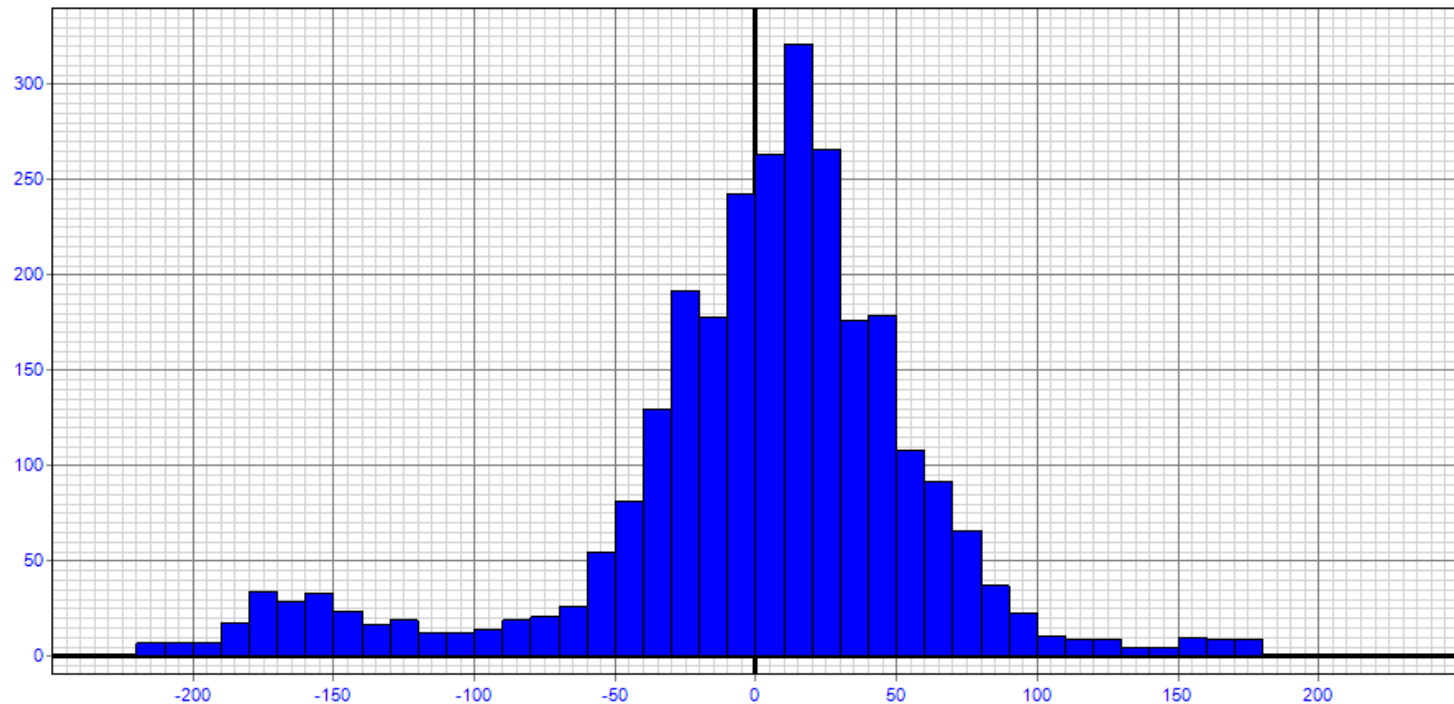
Training:

avg. abs. error: 42.4
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Test:

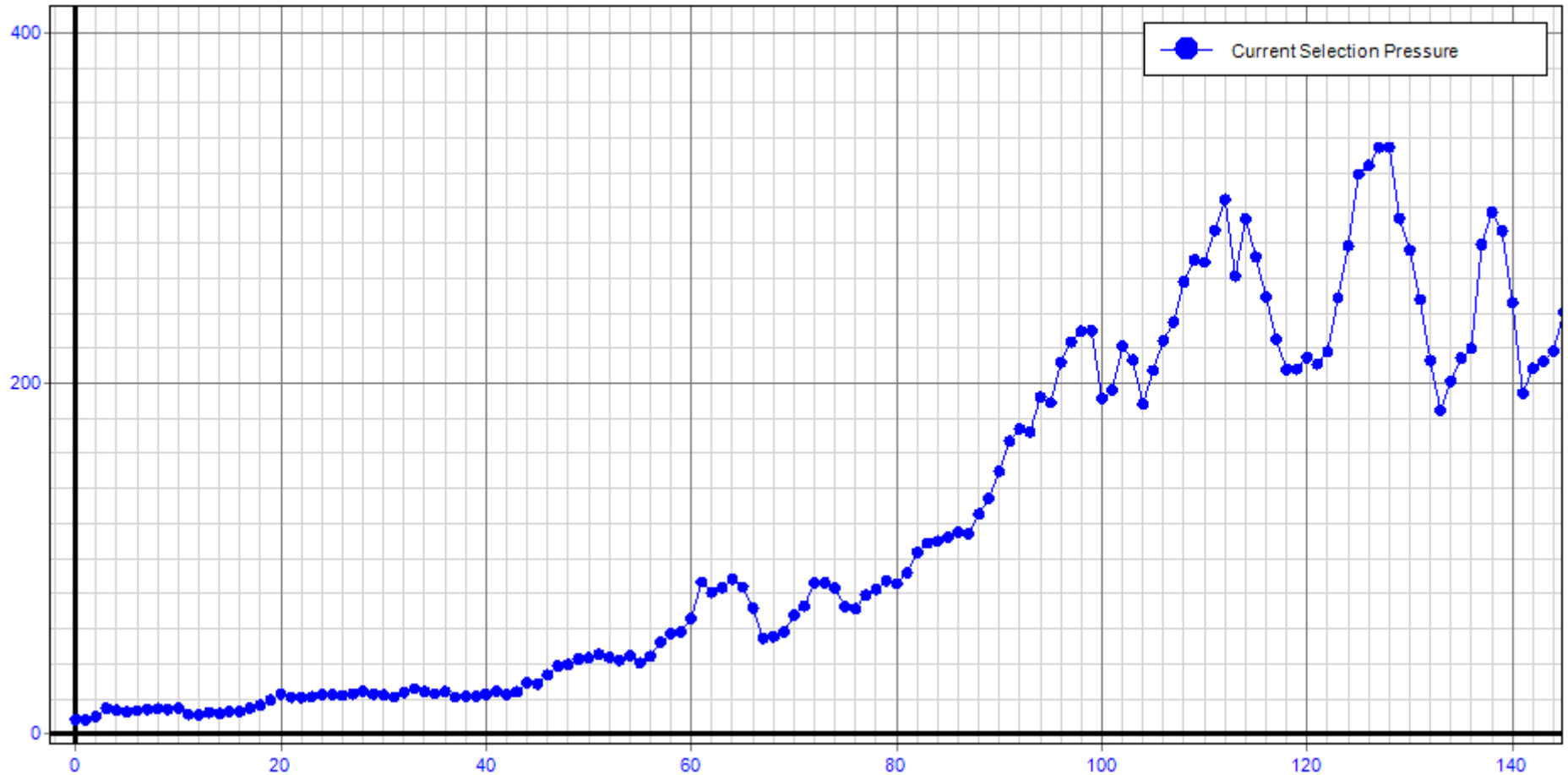
avg. abs. error: 42.44
median: 44.15

**Error Histogram
Test**



Structural Identification Using GP

Selection Pressure



Structural Identification Using GP

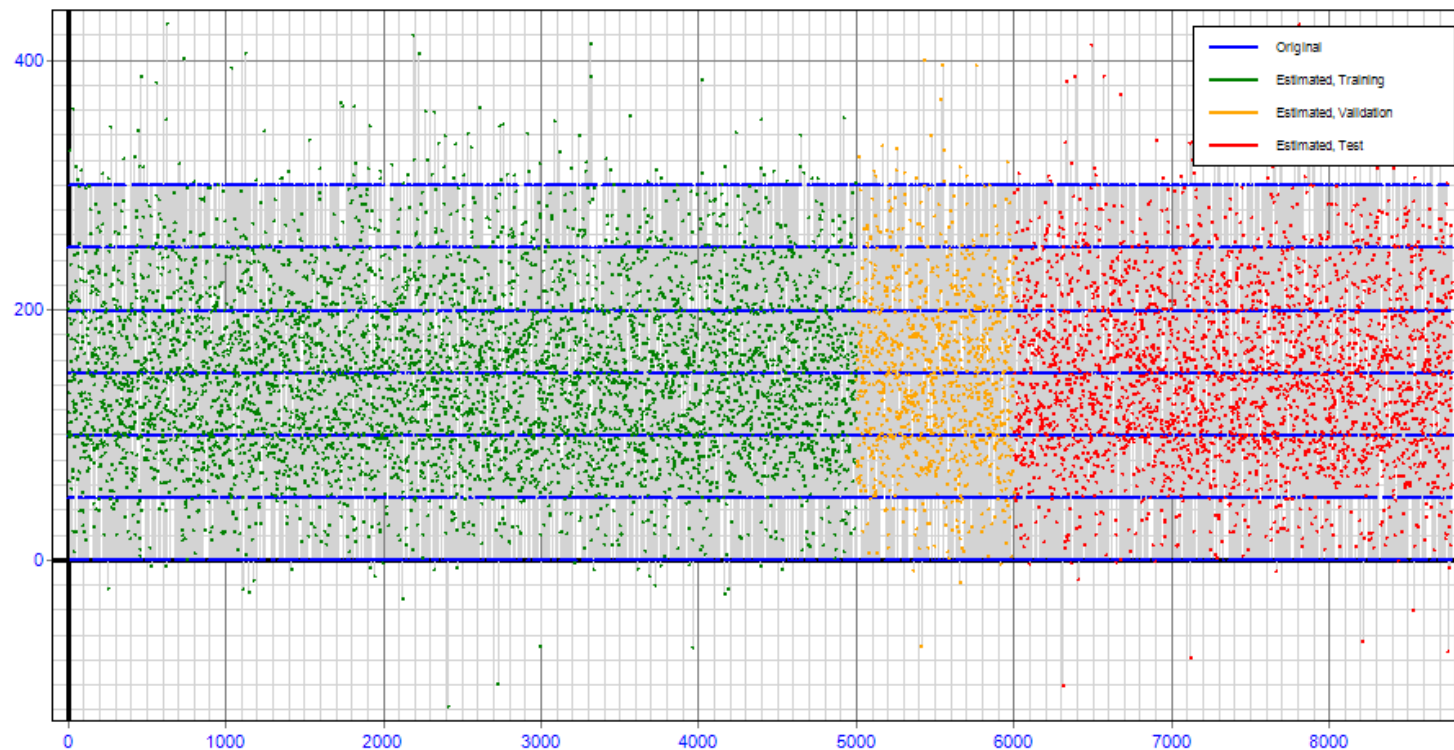
[scrambled] Y:

Training:

avg. abs. error: 55.68
median: 43.28

Test:

avg. abs. error: 55.50
median: 43.39



Structural Identification Using GP

[scrambled] Y:

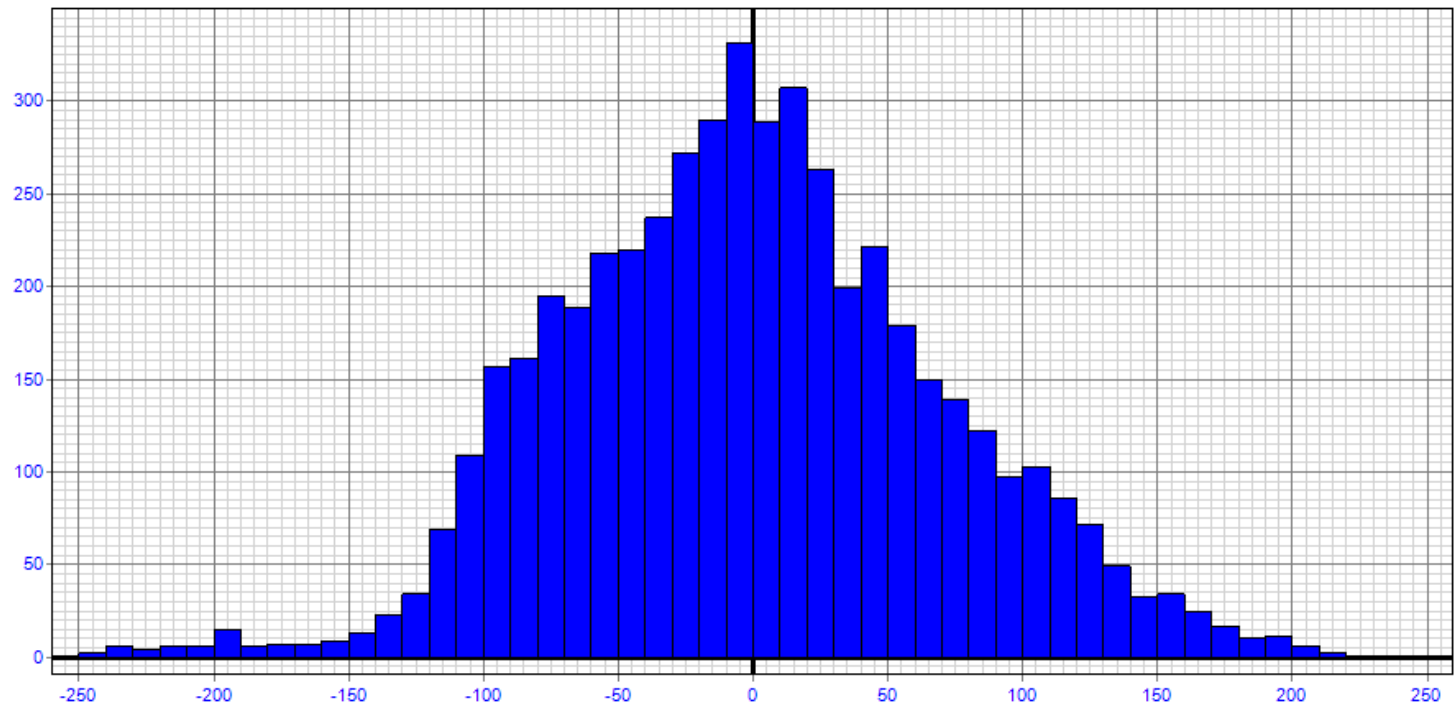
Training:

avg. abs. error: 55.68
median: 43.28

Test:

avg. abs. error: 55.50
median: 43.39

**Error Histogram
Training**



Structural Identification Using GP

[scrambled] Y:

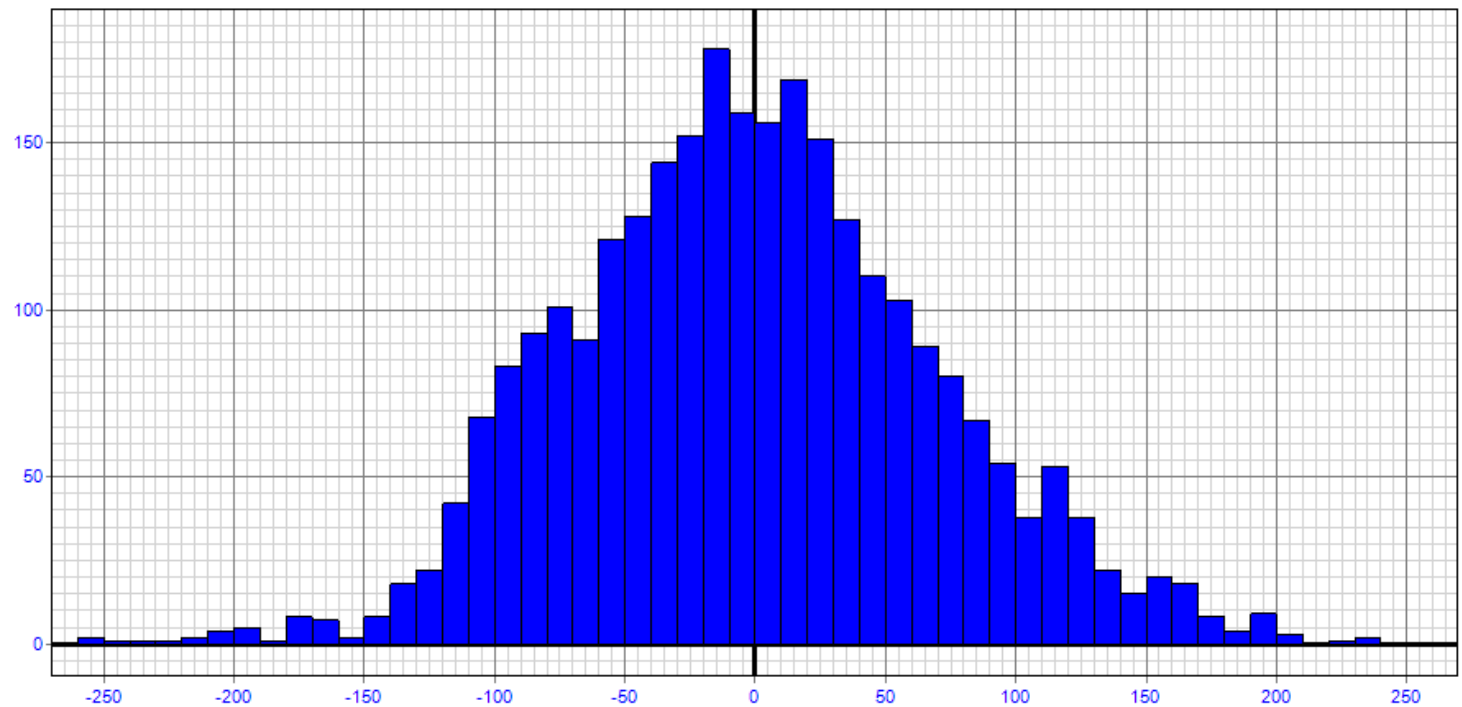
Training:

avg. abs. error: 55.68
median: 43.28

Test:

avg. abs. error: 55.50
median: 43.39

**Error Histogram
Test**



Next steps

Additional data acquisition

- Different setting, larger grid
- 6 instead of 4 base stations
- Different mobile devices for cross-checking

Improving accuracy

- MLP training/test with different data sets
- Structural identification with more complex models

Implementation of **live application**

Thank you for your attention!

Slides: <http://www.mayrhofer.eu.org/presentations>
Later questions: rene@mayrhofer.eu.org

OpenPGP key: 0xC3C24BDE
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