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Neural network simulation of δ-correlated stochastic signals

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Introduction

Classical approximation methods being used for prediction of the behaviour of explored systems, are generally based on the analysis of well-known analytical expressions, which are far too simple to describe the real physical processes.

Introduction

Correct interpretation of the experimental data can be achieved by simulation-based fitting (SBF).

The idea of SBF is the approximation of experimental data by synthetic data obtained via simulation modelling.

Introduction

Compared to standard data fitting techniques, SBF has the advantage that it fits natural physical parameters of the system itself and gives a direct insight in how they affect the experimental characteristics of the system.

Introduction

Simulation model ("white-box" model):

- Precise result
- Computationally expensive

Simulation-based fitting:

- Parameters are modified
- Structure holds constant

Thus, we can perform "black box" modelling:

- Still operates with real physical parameters
- Much faster

Introduction

A classical example of “black box” are artificial neural networks (ANNs):

- Universal approximators
- Noise-stable
- Generalization ability

ANN approximation:

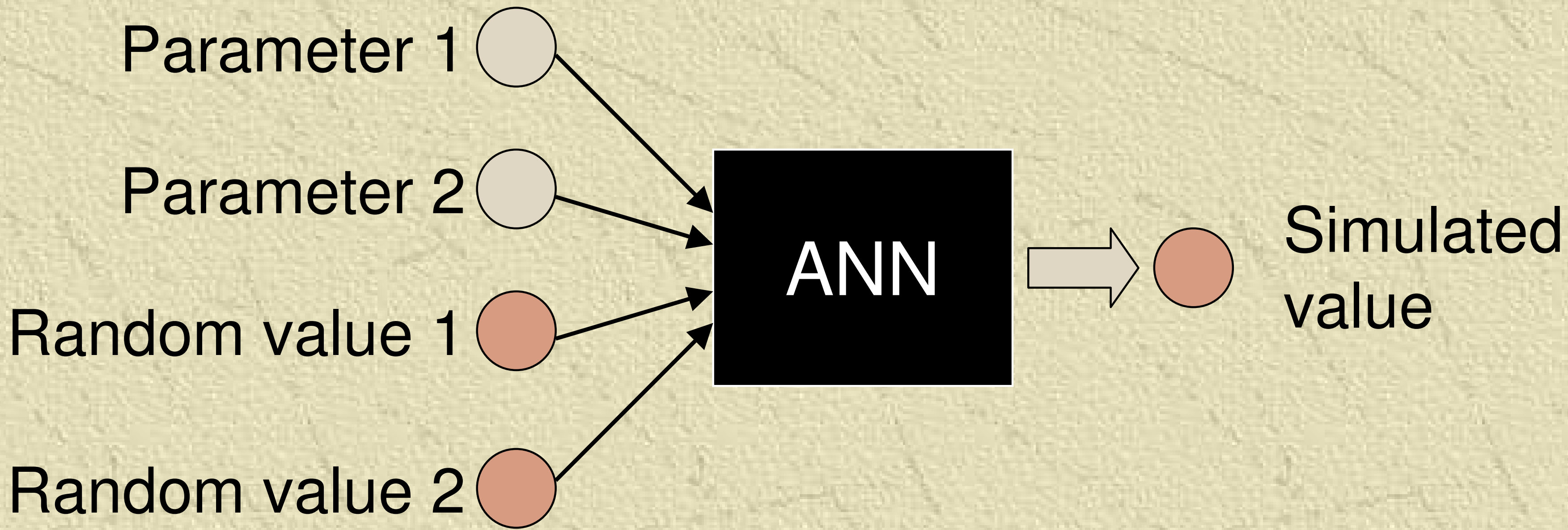
- Decreases fitting time
- Decreases noise uncertainty

ANN simulation of stochastic signal

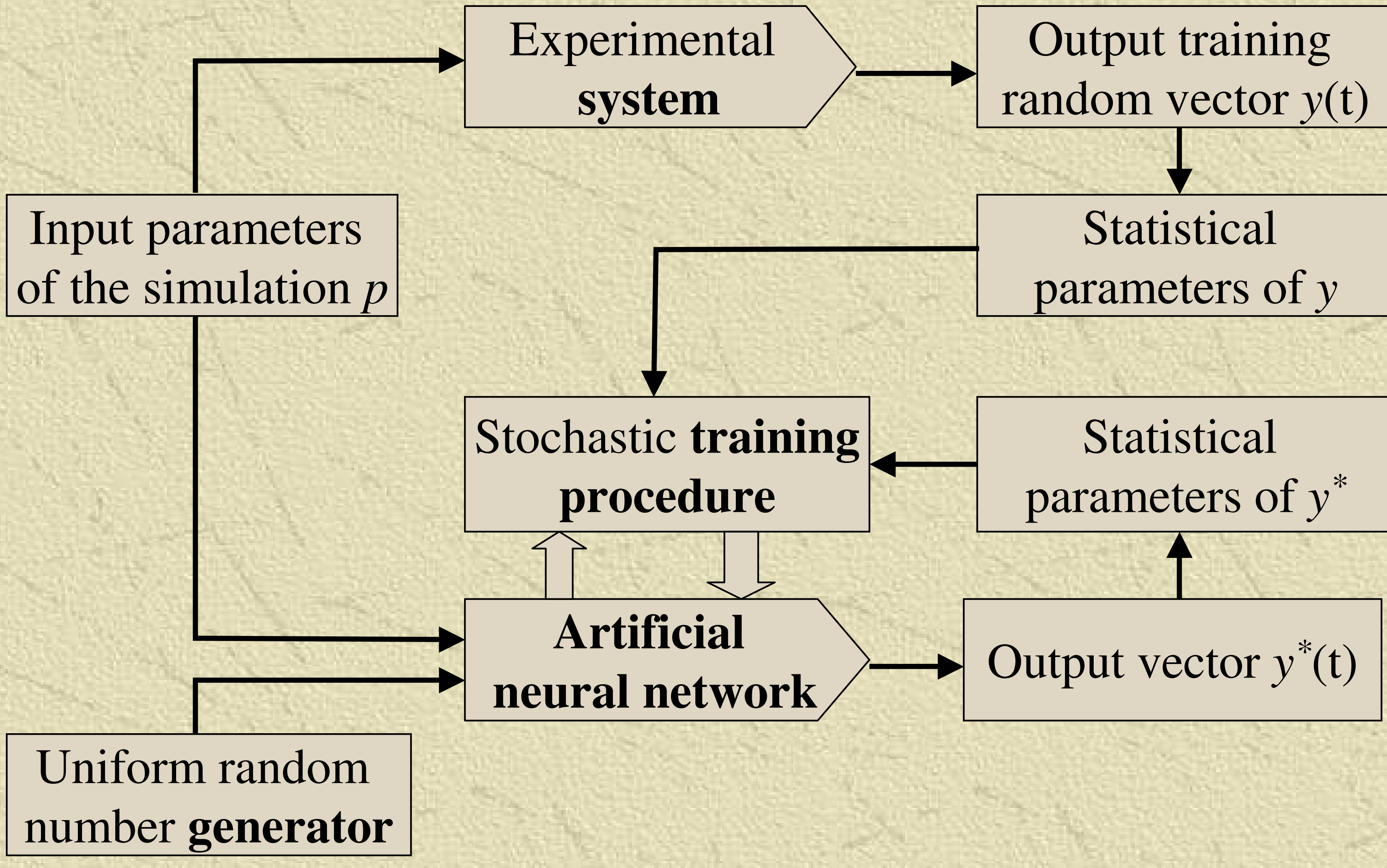
Two approaches:

- Use stochastic ANN (Boltzmann machine, bit-stream network, etc)
- Use modified feed-forward network (multi-layer perceptron)

ANN simulation of stochastic signal



Training algorithm



Simulation of the test signal

Test signal:

$y(t) = p_1 \cdot n(t) + p_2$,

where

p_1, p_2 – “simulation” parameters;

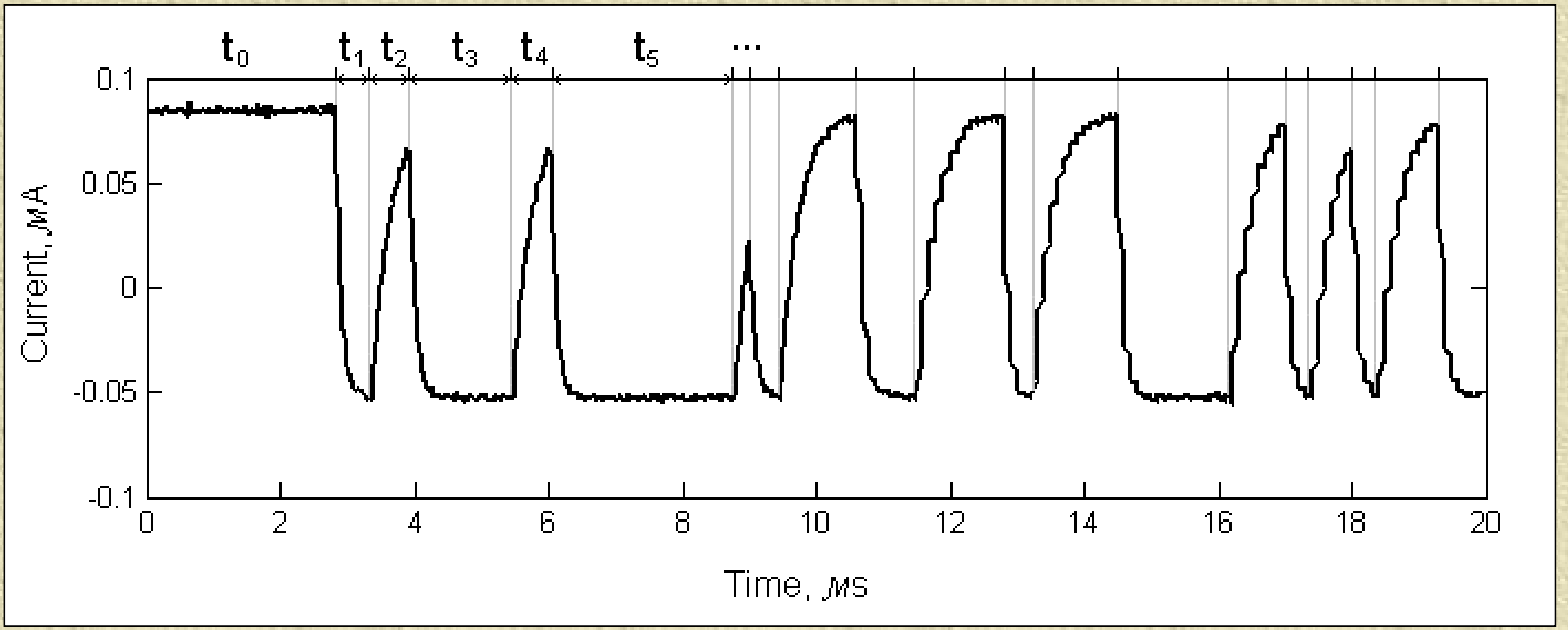
$n(t)$ – Gaussian stochastic signal (m=0, σ=1).

ANN configuration: 3-layered perceptron (8x8x1) of hyperbolic tangent neurons. Two uniformly distributed random signals were taken as inputs.

Simulation of the test signal: results

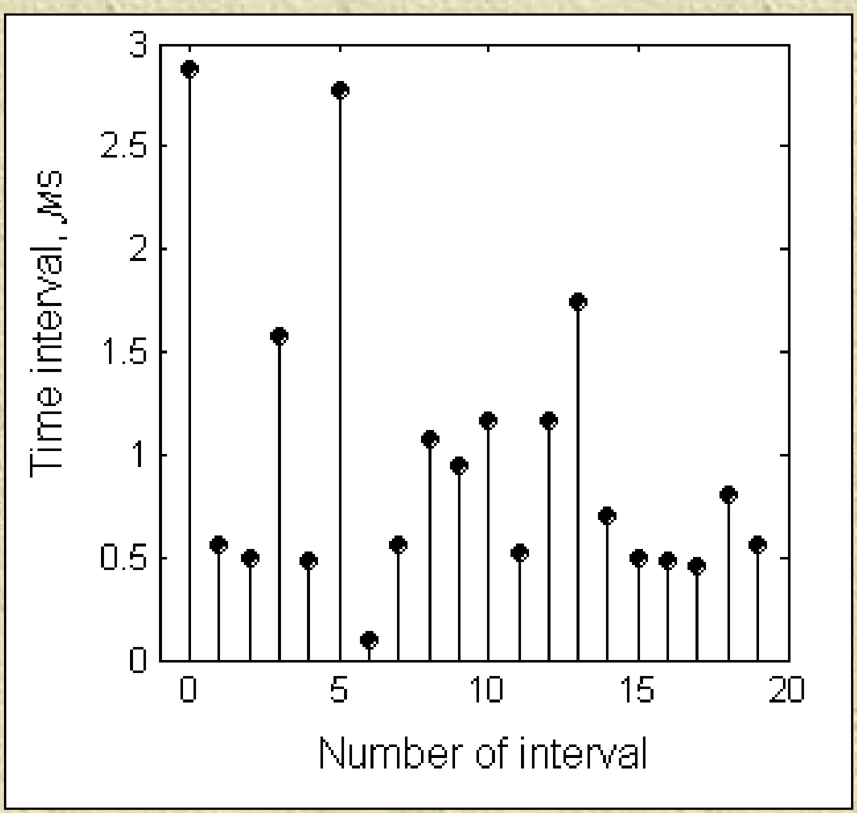
Description	**Simulated**	**Theoretical**
mean	0.9914	1.0
standard deviation	0.5167	0.5
λ, critical value for Kolmogorov-Smirnov criterion	0.0834	1.358
conclusion of Kolmogorov-Smirnov criterion with the desired significance level of 0.05	$\lambda_{sim} < \lambda_{theor}$ => the distribution can be considered as a normal one	

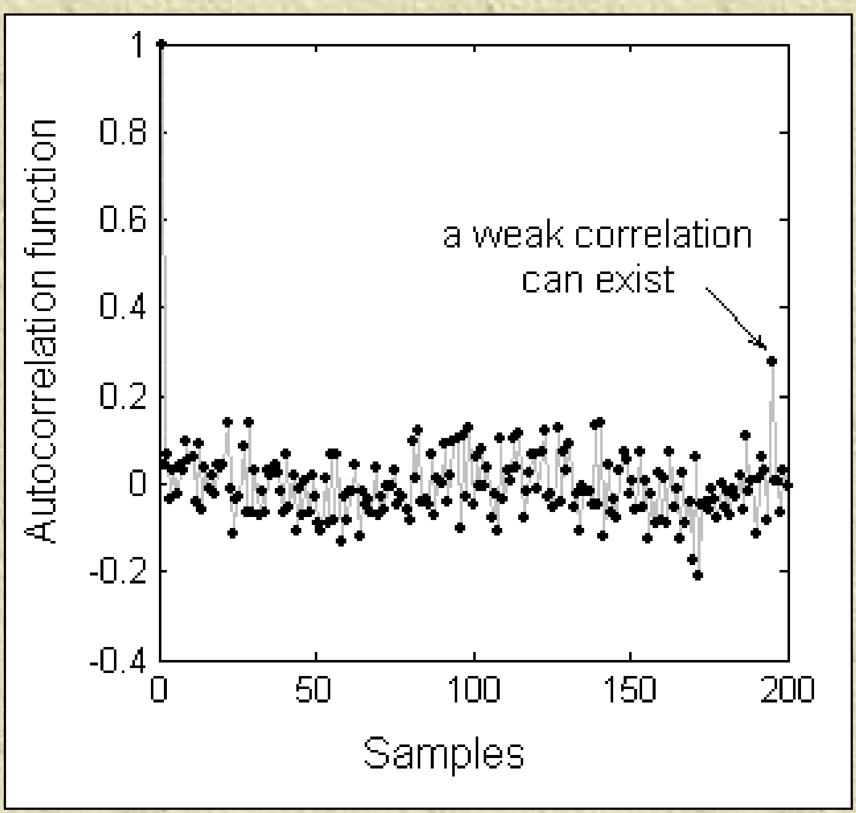
Simulation of fluctuating transition in a noise generator: the source signal



The experimental signal from a semiconductor noise generator.

Simulation of fluctuating transition in a noise generator: pre-processing





The discrete-event form of the experimental signal (left) and its autocorrelation function (right)

Simulation of fluctuating transition in a noise generator: ANN configuration

To simulate the produced "interval function" four uniformly distributed random vectors were taken.

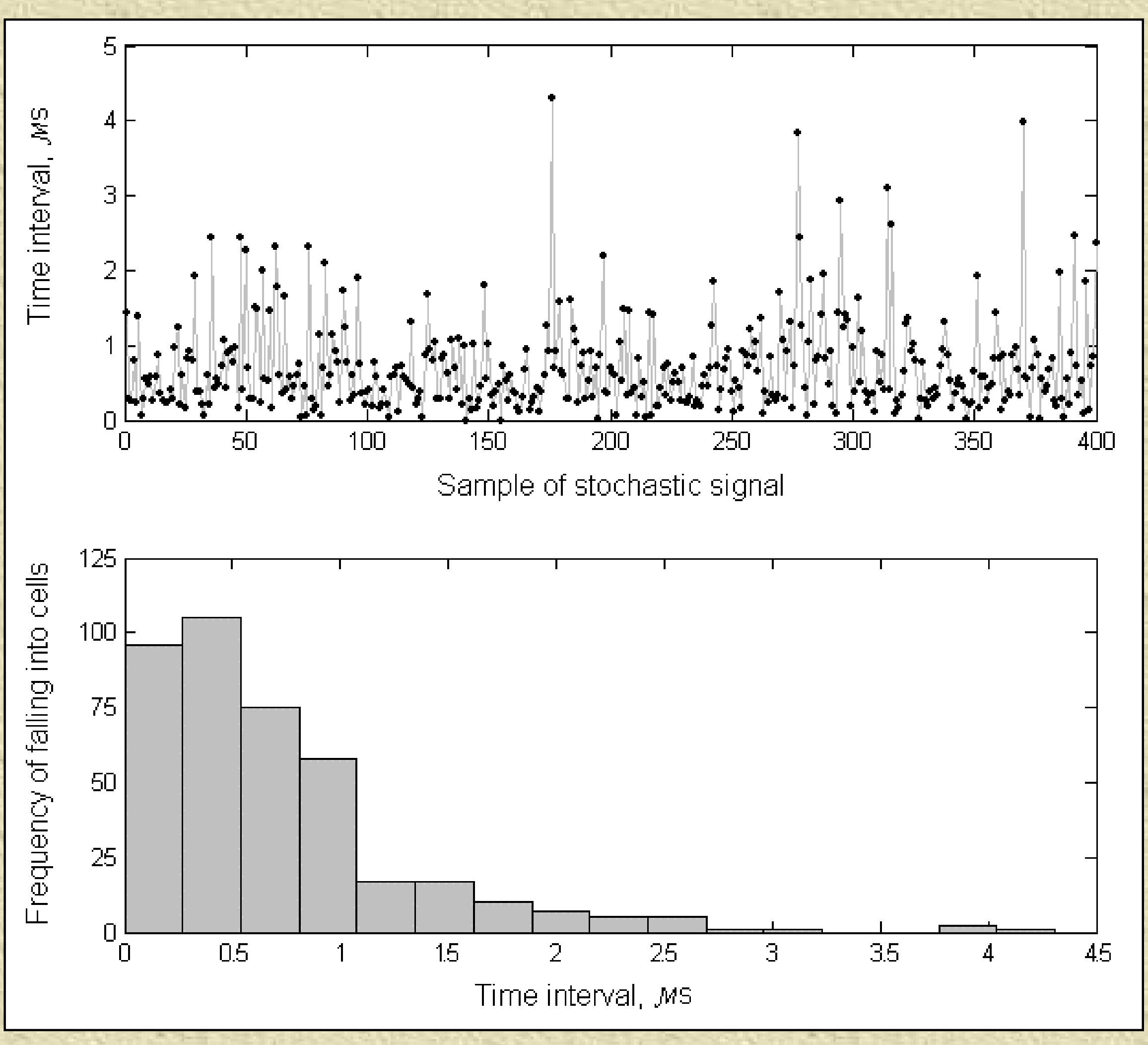
Perceptron structure:

- 3 layers (4x4x1)

Activation function:

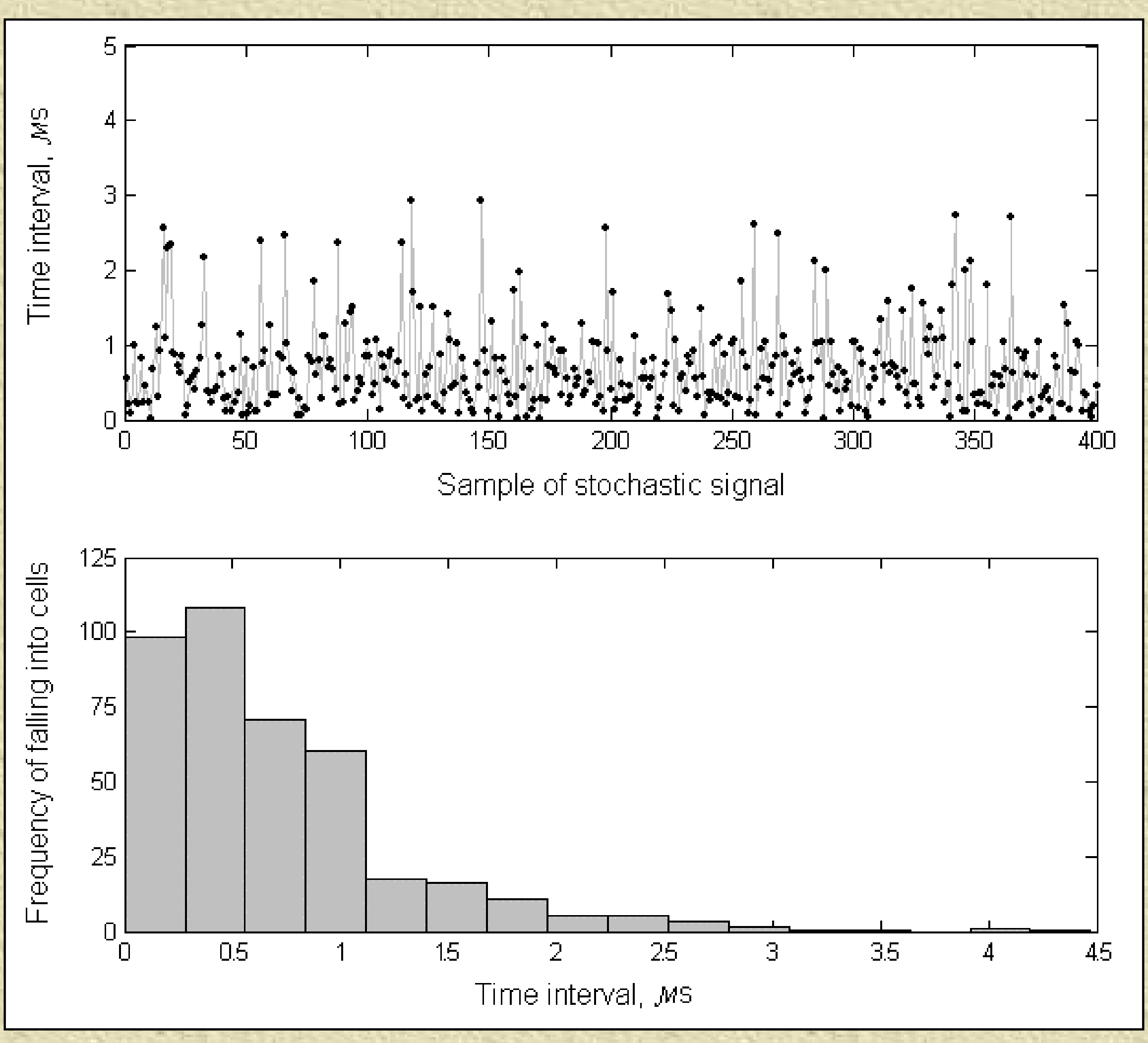
- 1st and 2nd layers: sigmoid
- 3rd layer: linear

Simulation of fluctuating transition in a noise generator: results



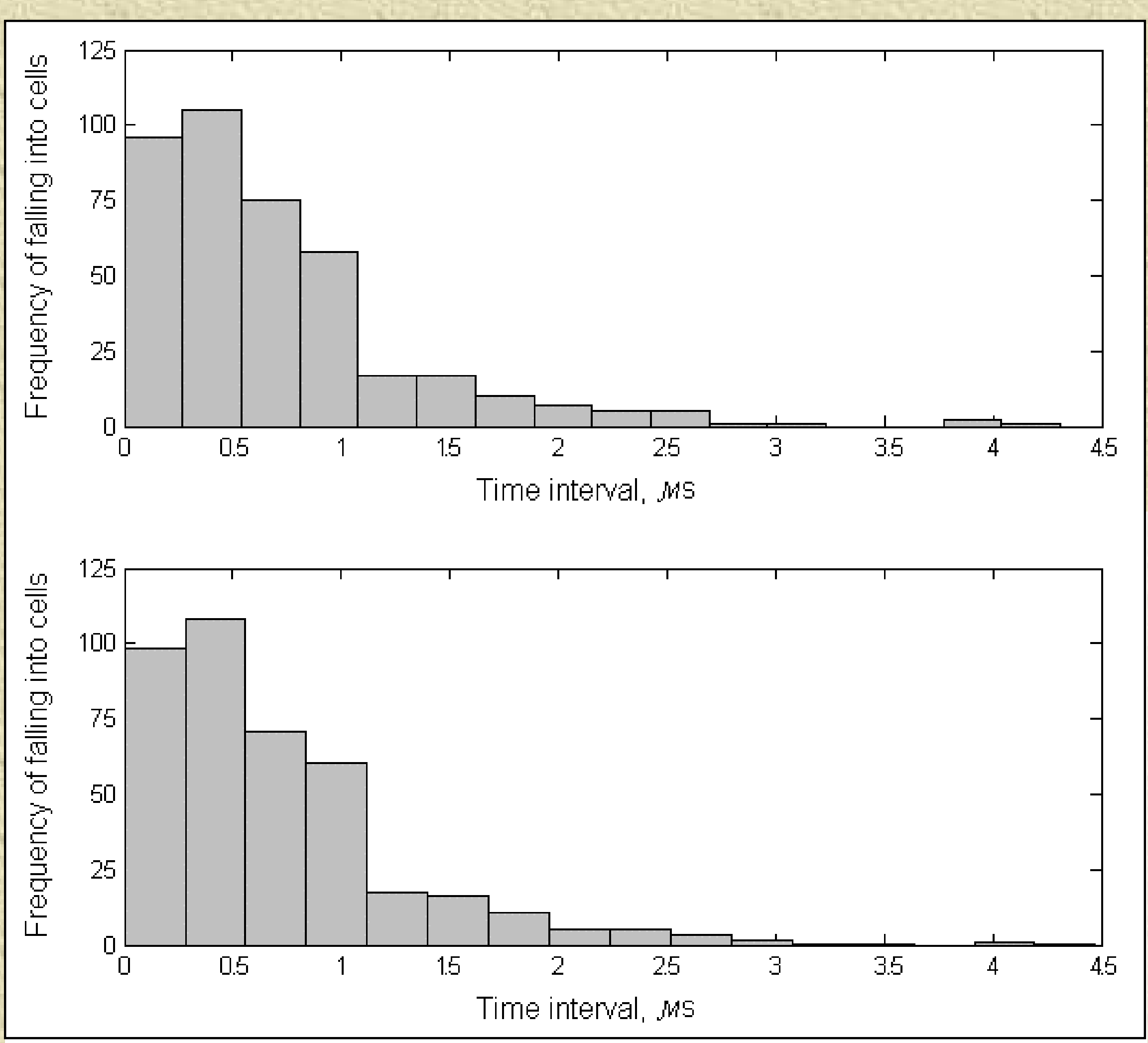
The experimental signal and its histogram

Simulation of fluctuating transition in a noise generator: results



The simulated signal and its histogram

Simulation of fluctuating transition in a noise generator: results



The experimental and simulated signal histograms

Simulation of fluctuating transition in a noise generator: results

Statistical characteristics	**Training signal**	**Simulated signal**	**Relative deviation**
mean	69.473	69.338	0.2 %
standard deviation	61.020	59.873	1.9 %
minimal value	0.0000	0.0932	–
maximal value	431.00	447.38	3.8 %

Conclusions

The proposed method showed good results in approximation of a normally distributed random signal.

The ANN was successfully applied for simulation of fluctuating transitions of the reverse biased semiconductor reference diode.

The end

Thank you