Chair for Network Architectures and Services—Prof. Carle
Department of Computer Science
TU München

Discrete Event Simulation

IN2045

Overview on remaining chapters

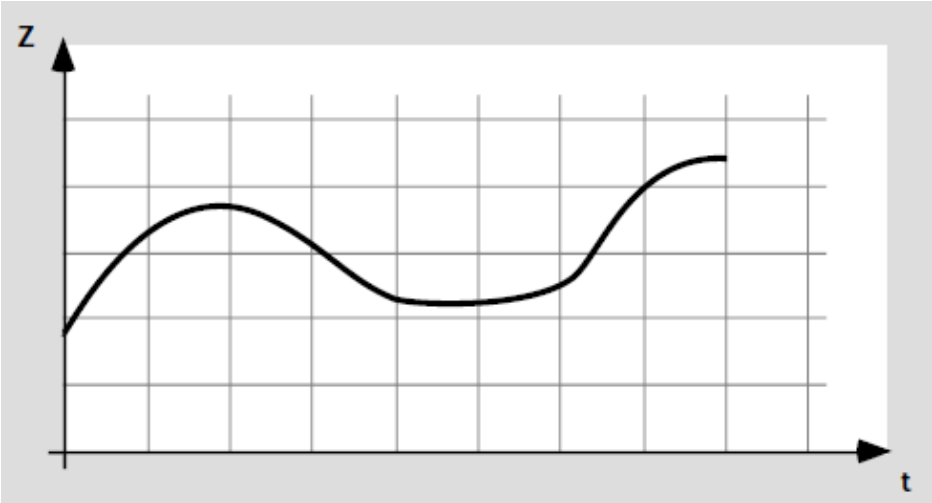
Course outline

- Chapter 0 – Introduction and Motivation
  - We just had that a few seconds ago
- Chapter 1 – Types of Simulation
  - This course coverse discrete-event simulation, but there also are other types of simulation, e.g., time-based simulation
  - Event-driven simulation
  - Process-oriented simulation

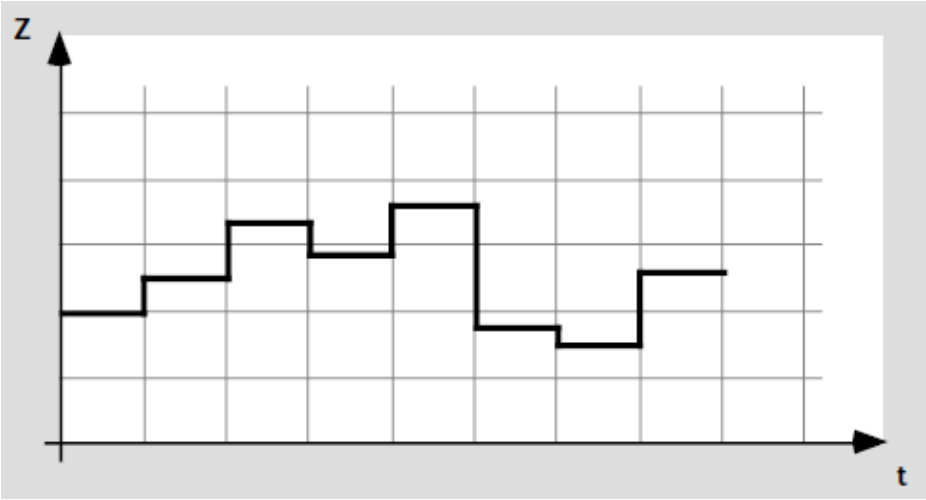
Course outline

- Chapter 2 – Statistics fundamentals
  - Motivation:
    - Evaluating the results of a simulation involves a lot of statistics...
    - ...and designing a model usually does so, too.
    - Most of this should be known from highschool and/or from previous introductory courses
  - Introduction: Waiting queue model
  - Basic terms: Random variable (discrete + continuous), probability space, distribution functions (PDF, CDF), parameters: mean/average/expected value, median, mode, standard deviation, coefficient of variation, quantiles/percentiles/quartiles, skewness, spread, covariance, correlation, autocorrelation

Statistics fundamentals



Continuous



Discrete

Course outline

- Chapter 3 – Random variables
  - Motivation: Chapter 0 just showed that random numbers are an important simulation ingredient
  - How to generate random numbers that follow a specific distribution
    - Inversion method, accept-reject method, ...
  - Distributions and their characteristics
    - e.g., uniform, normal, exponential, lognormal,...
  - How to generate uniform [pseudo-]random numbers
    - Linear congruential generators, Mersenne Twister, ...
  - How to assess the quality of a [P]RNG
    - Autocorrelation, serial test, spectral test, ...
  - More statistics fundamentals:
    - Statistical tests
    - χ^2 test

Random number generator

Example:

00101110101001101100010011101010100011

00101110101001101100010011101010100011

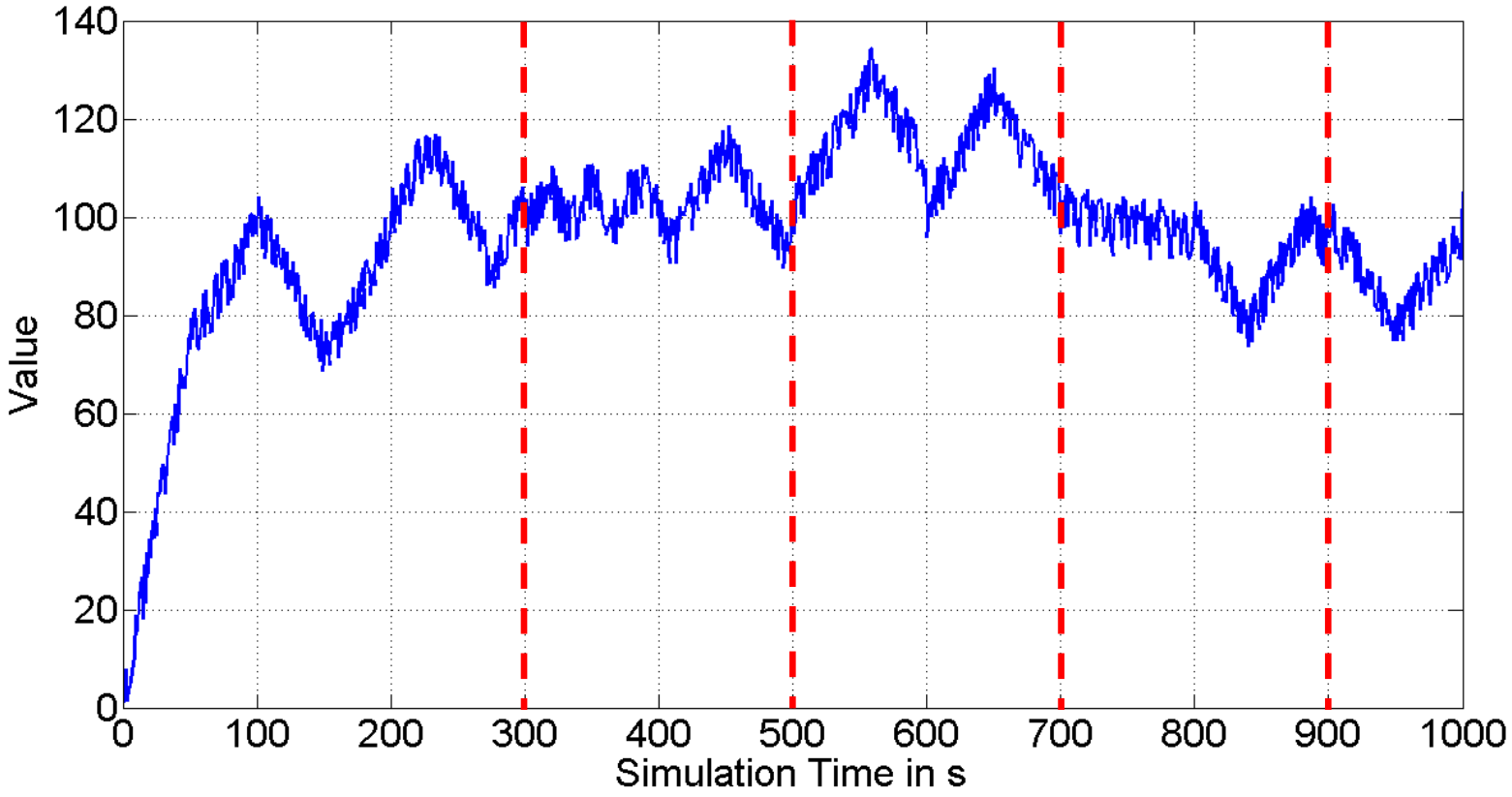
Random

Autocorrelation Lag 4

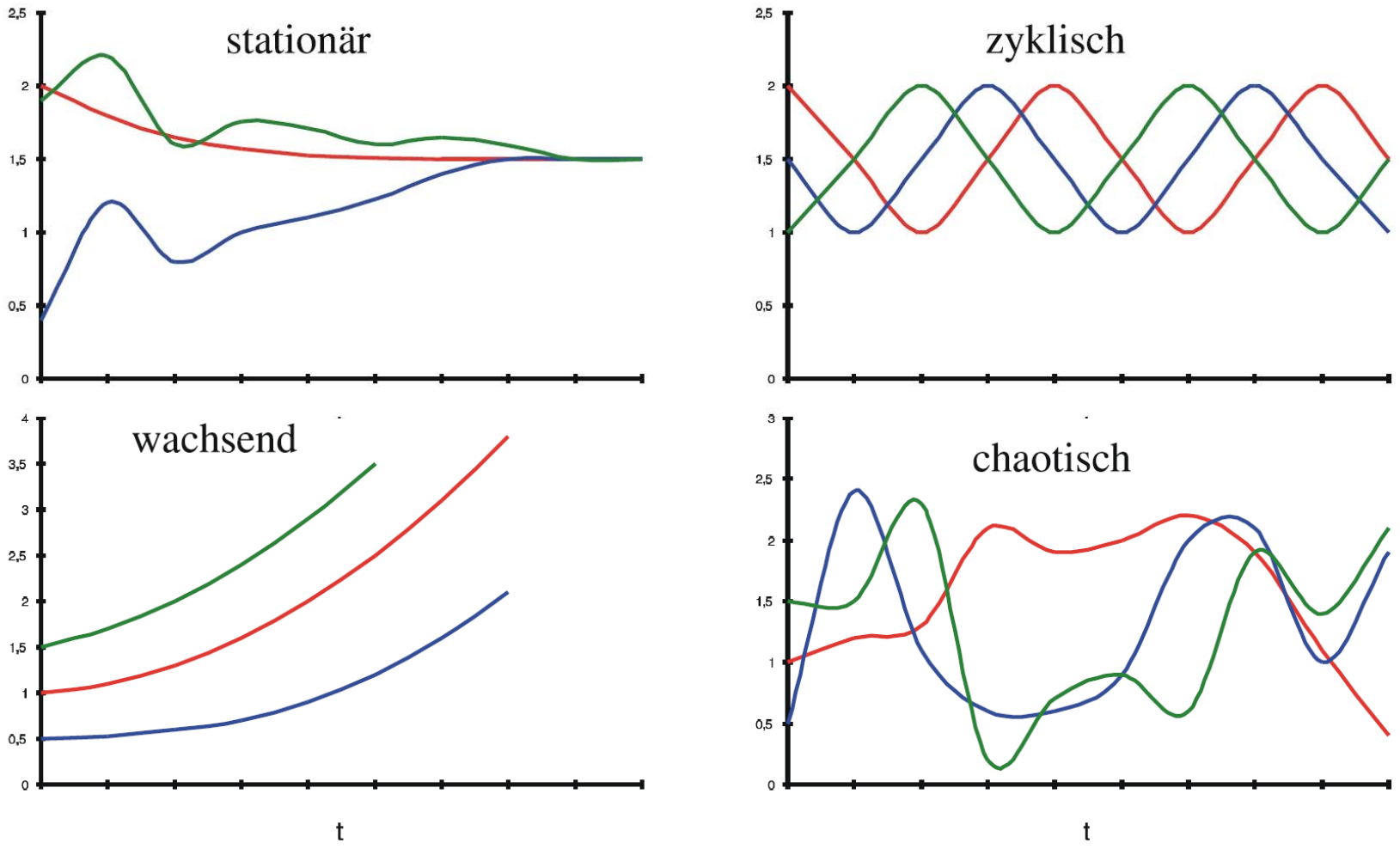
Course outline

- Chapter 4 – Evaluation of simulation results
  - Estimators
  - Confidence intervals
  - Central limit theorem
    - Basically: „Do a lot of simulation runs, calculate averages, and you'll get a normally distributed output“
  - Batch means
  - Stationarity
  - How to lie with statistics

Batch Means


140
120
100
80
60
40
20
0
Value
0
100
200
300
400
500
600
700
800
900
1000
Simulation Time in s

Stochastic processes: taxonomy



How to lie with statistics; e.g.: Pie diagrams

- What percentage does the pie represent?

- Even if percentage is written out as text, we subconsciously get a false impression („oh, that seems to be quite a lot“)

Course outline

- Chapter 5 – Experiment planning
  - Motivation:
    - Usually a lot of model/simulation parameters
    - Some have great influence on the results, but which ones are that?
    - We usually can't try out all possible parameter combinations
  - Hypothesis testing, revisited
  - Linear regression
  - Analysis of Variances (ANOVA)
  - Factorial design

Factorial design

Problem:

- Large number of parameters
- No detailed knowledge of the impact of the parameters

Idea:

- Variation of simulation parameters (valid configurations)
- Evaluation of the system performance
- Identification of the impact of each parameter on the system performance

Simulation / Parameter	X1	X2	X3	X4	Result (X1,X2,X3,X4)
# 1	+	-	-	+	38
# 2	o	+	+	o	12
# 3	-	o	-	+	43
# 4	-	+	+	+	12
# 5	-	-	-	-	15
# 6	o	o	o	o	8

Course outline

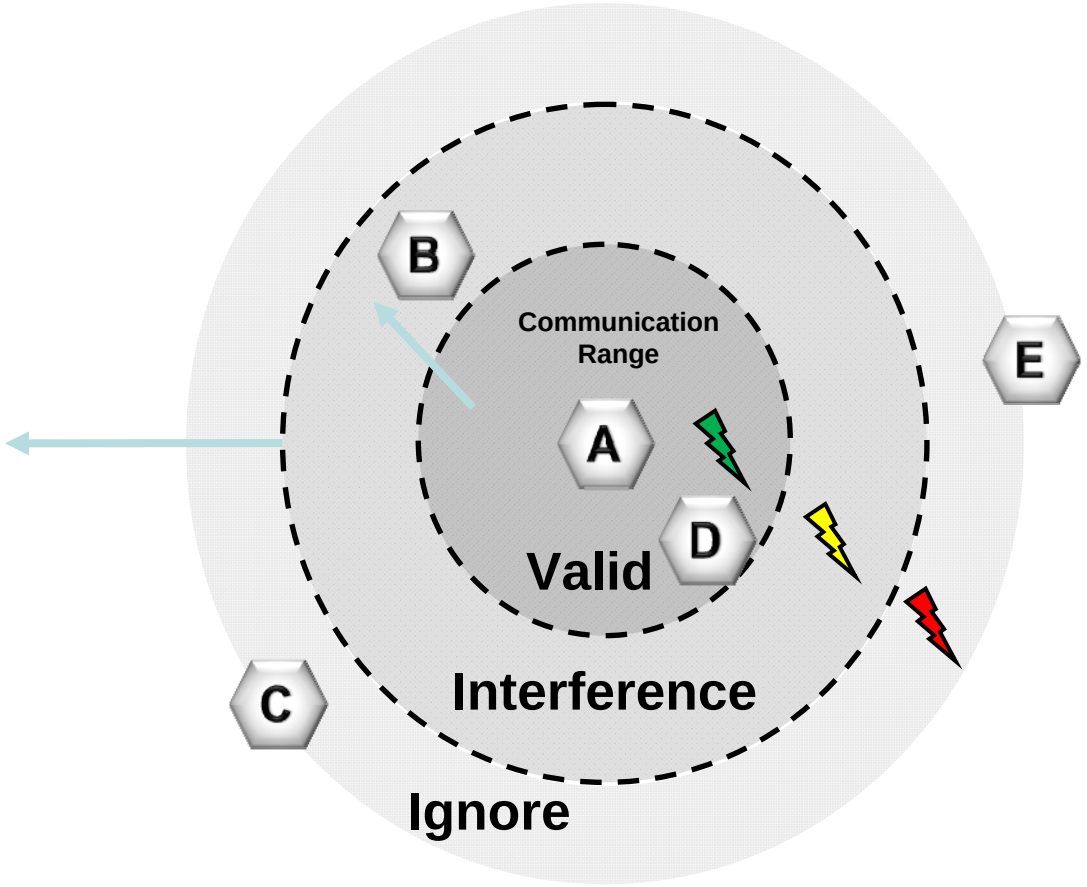
- Chapter 6 – Parallel simulation
  - Motivation: General trend to parallel and distributed computing (e.g., multicore CPUs)
  - Demotivation: It's complicated; the gain is much smaller than the number of CPUs; it usually makes more sense to run multiple simulations in parallel
  - Conservative approach
    - Only evaluate events that are safe to process
    - CPUs need to synchronize on what's allowed and what not
  - Optimistic approach
    - Go ahead and evaluate events
    - Be prepared to undo evaluation if it turns out that another CPU changes simulation state in the past (because it was slower in processing its events / had more events / ...)

Course outline

- Chapter 7 – Advanced topics
  - Simulation of mobility (e.g., smartphones within a wireless network)
  - Human mobility patterns
  - Characteristics of mobility patterns (node distributions, speed distributions, correlated movements, …)
  - Synthetic mobility models
  - Point fields
  - Random graphs

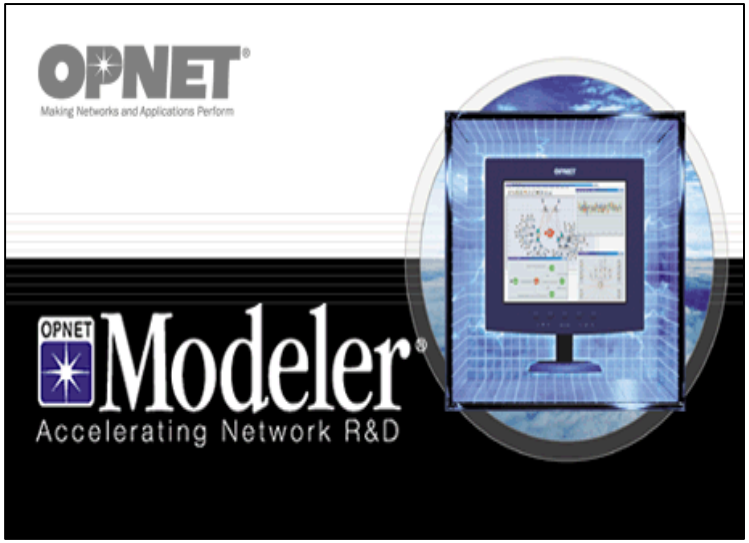
Course outline (tentative)

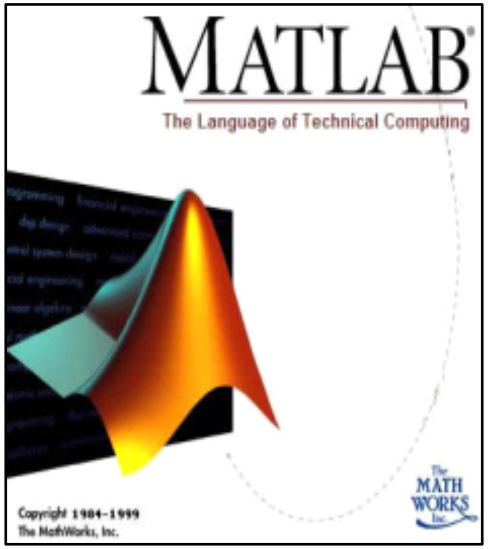
- Example:
  - Wireless Communication (Disc Model)



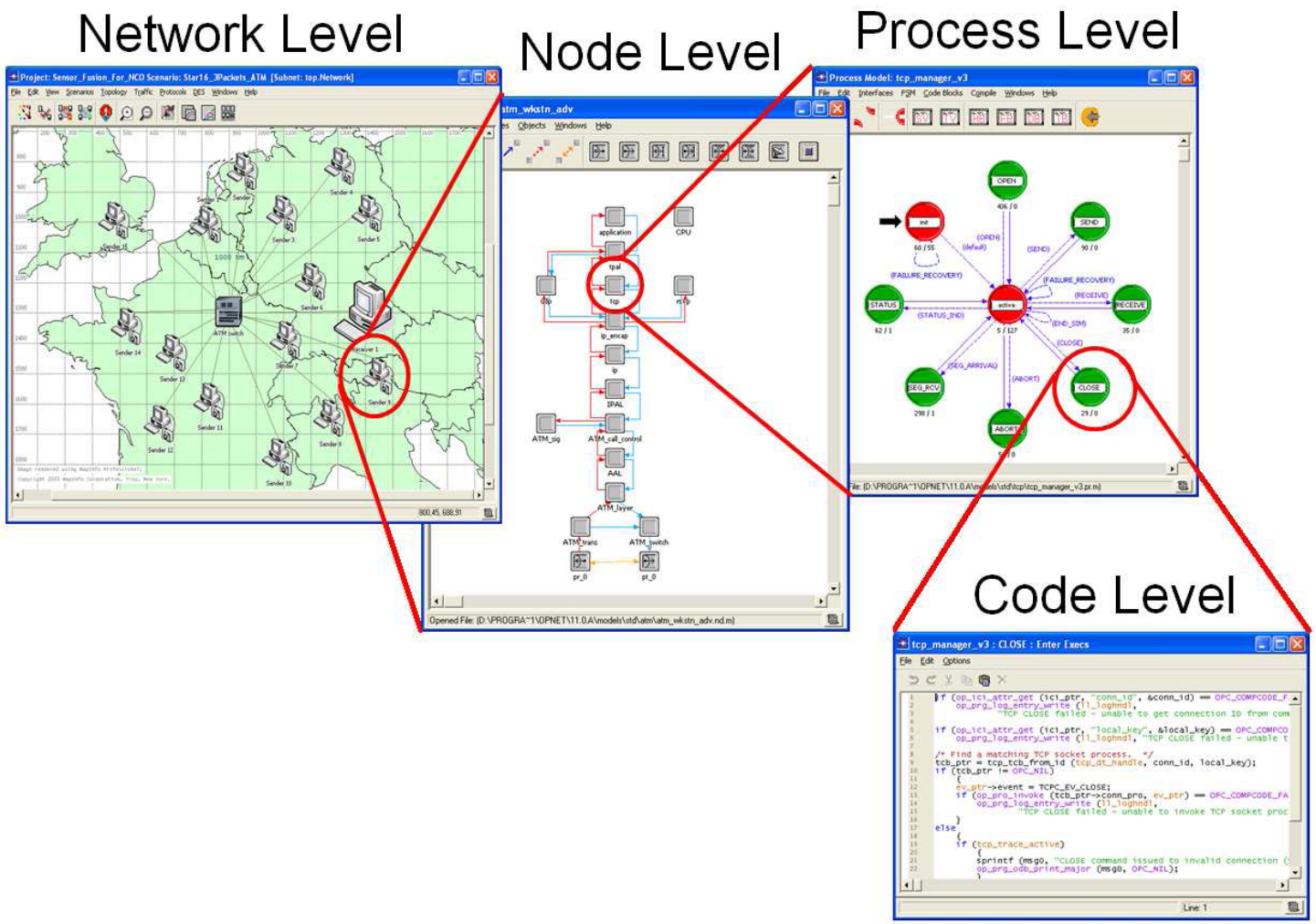
Course outline

- Tools (in exercises):
  - ❑ OPNet
  - ❑ Matlab

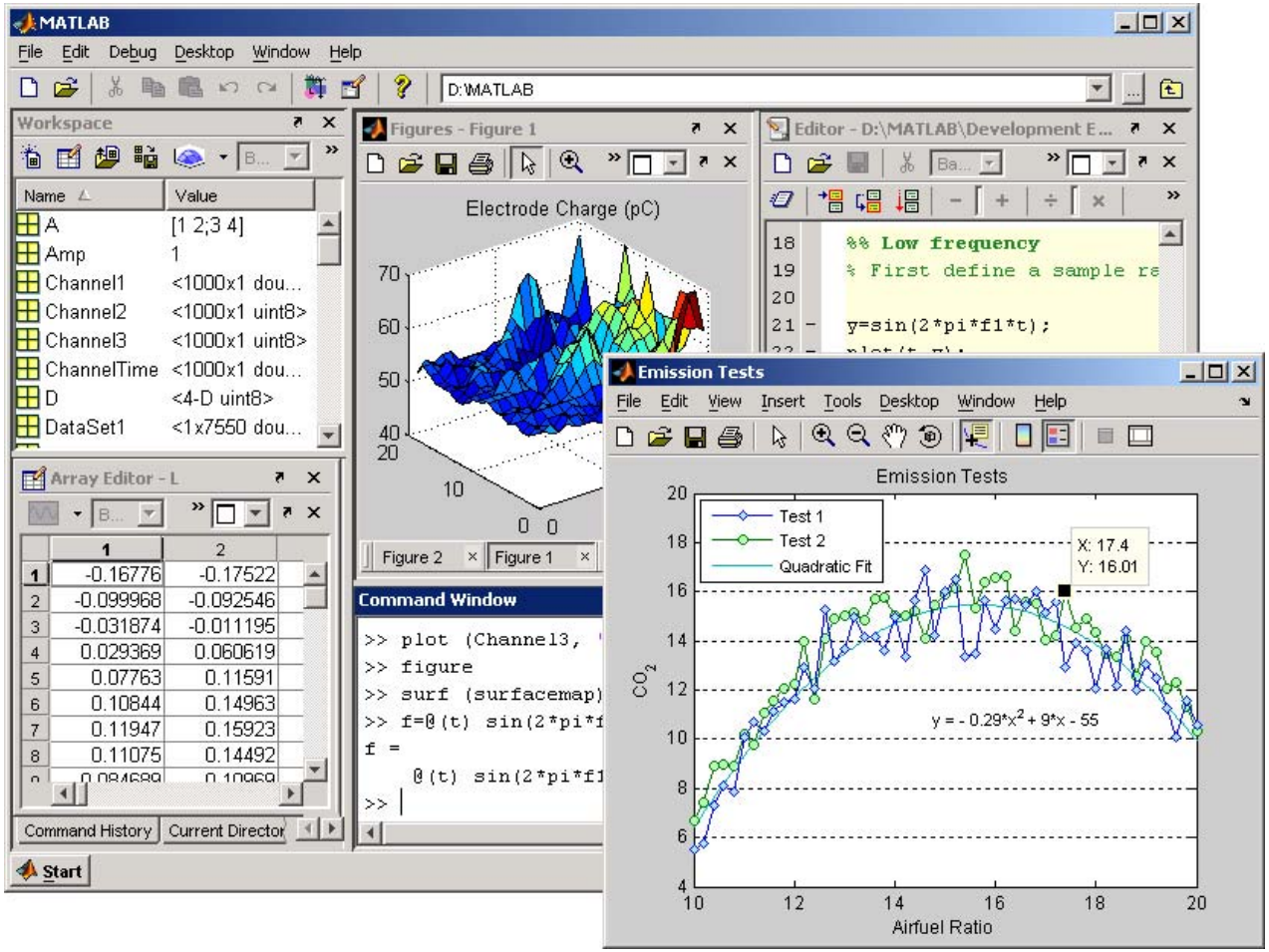




OPNET



Matlab



http://www.mathworks.de/