Modeling with Mathematica

Compact course
Brno University of Technology, December 17-21, 2012

Lecturer: János Karsai associate professor, University of Szeged

Length: 5x6 hours in computer cabinet

Language: English

Schedule: Classes will be held in the intervals 9.00 - 12.00 and 13.00 - 16.00 with a short break in the middle.

Method: The participants and the lecturer work on computer simultaneously. In every topic, a short introduction and description are followed by solving practical problems and developing applications with *Mathematica*.

Handouts: Participants will receive a DVD containing the following interactive collections:

[1] Mathematical and visualization packages: Mathematica 8, course material
[2] Computer-aided study of mathematical models with Mathematica 8, course material
[3] Basic Mathematical tools for Life Sciences (lecture presentations)
[4] Mathematics for Pharmacy Students (lecture presentations)
[5] More collections on www.model.u-szeged.hu

Tentative Program

The schedule of the program below can change according to the special requirements of the audience and the current progress of classes due to special problems arise.

December 17, Monday

- A crash-introduction by examples
- A systematic introduction to the language, structures and functions of *Mathematica*
  - Basic concepts: Front-End functions, Kernel, typesetting, cells, Help, export, import
  - Notebook operations I: styles, stylesheets
  - Basic operations: Numeric and symbolic operations, variables, algebraic manipulations
  - Lists, vectors and arrays, elementary list operations, export, import
  - Definitions, setting (immediate and delayed), substitution rules, functions
  - Functions vs. expressions
- Basic Plots: Trust and danger
- Introduction to dynamic visualization (Animate, Manipulate)
- Graphics and visualization, Part I
  - Summary of plotting statements in 2D (Plot, ParametricPlot, ListPlot,...)
  - Graphics structures
  - Exercise: Visualization of a moving point in 2D

December 18, Tuesday

- Graphics and visualization, Part II
  - Summary of plotting statements in 3D (Plot3D, ParametricPlot3D, ListPlot,...)
  - Graphics structures in 3D
  - Exercise: Visualization of a moving point in 3D
  - 3D plots: Plotting functions of two variables, parametric curves and surfaces
- Linear Algebra: vectors, matrices, transformations, eigenvalues, eigenvectors, etc.

- Experimental and visual exercises in Calculus 1D to nD:
  - Calculus summary
  - Graphical, experimental study of the properties of functions, parametric lines and surfaces, scalar fields, vector fields
  - Limits, derivatives, integral, series expansions
  - Tangent and normal vectors, planes
  - Maxima-minima, zeros
- Working with complex functions
- Simple tools to solve and visualize vector fields and ODE's
- Elementary data handling, stochastics
  - Experimental data, plotting data, data transformations
  - Fitting
  - Probability, distributions, statistics
  - Presentation graphics

December 19, Wednesday

- Elements of programming: Object types, assignments, functions
  - Remember: settings, substitution rules, functions
  - Structures, types, Head, Head operations, type check, logical functions
  - Sequence vs. List
  - Patterns: parameter type-check in rules and functions
  - Piecewise or conditional definition of functions, recursions
  - Conditions vs. patterns
- Structure and function operations
  - Rule-based programming
  - Structure programming: Map, Apply, Thread, ...
  - Rotating lists, and applications to numerical algorithm
  - Operations over functions: composition, lists of functions, ...
- Iteration, nesting
  - Recursion vs. iterations
  - Iterations, fixed points of mappings
  - Simple iterations
  - Numerical applications: Newton iteration, gradient method, Euler method to solve ODE's, etc,

December 20, Thursday

- Graphical programming
  - Remember: Graphics, Graphics3D
  - A very interesting structure: GraphicsComplex
  - Generating Graphics from numerical data and vice versa
  - Simple graphics manipulations: replace anything by anything
  - Simple graphical constructions: advanced applications to scientific and engineering visualizations: functions, vector- and scalar fields
  - Programming exercises on Iterative forms, fractal constructions: simple constructions, generating trees
- Advanced applications for difference systems
  - cobweb diagram, bifurcation diagram
  - Discretization of ODE's, PDE's
  - Cellular automata
- Advanced applications for differential equations
  - The phase-map and Ljapunov's methods: a visual approach
  - Differential systems with Dirac delta
  - Poincare maps
- Programming paradigms in Mathematica: a systematic overview
  - Procedural programming
  - Functional programming

- Rule-based programming

December 21, Friday

- Elements of package development
- How to develop dynamic applications
  - Introduction to dynamic structures and operations
  - Control objects, event handler
  - Exercises to develop lecture presentations
- Additional topics
  - Advanced notebook operations: options, option inspector
  - Stylesheet design, automatic numbering, hyperlinks, ...
  - Export, import: HTML, XML, MathML, TeX, XLS, …
- Summary, discussion