Bolyai Institute
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EFOP-3.6.1-16-2016-00008

International Spring School on Computer-aided Modelling of Dynamical Systems

Bolyai Institute, University of Szeged, June 13-15, 2019

Venue: Bolyai Institute, University of Szeged, Szeged, Aradi vértanúk tere 1.

Audience: MSc and PhD students, researchers

Length: 24 hours

Language: English

Prerequisites: Knowledge of Mathematica and Matlab at basic level; courses of master level on differential and difference equations. Programming experience is advantageous.

Conditions:

– Participation is free. Participants have to mention this support when the participation is referred.
– Participants receive electronic handouts.
– Own laptops needed with newest Mathematica installed (install kit will be given in advance)
– Participants have to manage and cover their accommodation and travel by themselves.
– Application forms should be sent to karsai.janos@math.u-szeged.hu.

Coordinator, contact: János Karsai associate professor, University of Szeged, karsai.janos@math.u-szeged.hu

Web: www.model.u-szeged.hu

Acknowledgements
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Schedule

Thursday; June 13, 2019	
08.30 –9.30	Registration, administration
9.30 – 9.40	Welcome address
9.40 – 10.30	Opening talk: Mathematical modelling of infectious diseases *Gergely Röst, Bolyai Institute*
10.30– 10.45	Mathematica overview. Current developments on Mathematica: what’s new? *János Karsai, Bolyai Institute*
10.45– 11.00	Coffee break
11.00 – 12.00	Introduction to reliable computations *Tibor Csendes, Kalmár Institute, University of Szeged*
12.00 – 13.00	Lunch break
13.00– 15.00	Preparation: Structure programming, dynamic manipulations and basic tools to study differential equations in Mathematica *János Karsai, Bolyai Institute*
15.00 – 15.15	Coffee break
15.15 – 18.00	Parametric numeric solutions, fitting problems, dependence on parameters *János Karsai, Bolyai Institute*
18.00 –	Get-Together party

Friday; June 14, 2019	
08.30 – 10.00	Reliable computations I *Boglárka G.-Tóth, Kalmár Institute*
10.00 – 10.15	Coffee break
10.15 – 12.00	Reliable computations II *Boglárka G.-Tóth, Kalmár Institute*
12.00 – 13.00	Lunch break
13.00 – 15.00	Discrete systems with Mathematica; Recursions, iterations, recurrent equations, discretization … *János Karsai, Bolyai Institute*
15.00 – 15.15	Coffee break
15.15 – 17.30	Advanced tools for differential equation: event handling, discrete variables, Poincare mapping, impulses; qualitative methods *János Karsai, Bolyai Institute*

Saturday; June 15, 2019	
08.30 – 10.00	Delay differential equations with Mathematica *János Karsai, Bolyai Institute*
10.00 – 10.15	Coffee break
10.15 – 12.00	Spatio-temporal models with Mathematica 12.0 *János Karsai, Bolyai Institute*
12.00 – 13.00	Lunch break
13.00 – 14.45	Reliable computations in dynamical systems I *Ferenc Bartha, Bolyai Institute*
14.45 – 15.00	Coffee break
15.00 – 17.00	Reliable computations in dynamical systems II *Ferenc Bartha, Bolyai Institute*

Lecture Abstracts

Mathematical modelling of infectious diseases

Gergely Röst, Bolyai Institute, University of Szeged, rost@math.u-szeged.hu

In this talk we give a brief introduction into the mathematical models of infectious disease dynamics. After a short historical overview, we review some mathematical tools such as ordinary, delay and partial differential equations, and provide examples when they can be effectively applied to describe the dynamics of particular diseases such as malaria, influenza, ebola, or chickenpox.

Introduction to reliable computations

Tibor Csendes, Kalmár Institute, University of Szeged, csendes@inf.u-szeged.hu

The talk will be devoted to the motivating problems, where reliable computation is needed. I'll also introduce interval arithmetic and related theoretical basis for verified computing. We shall also cover automatic differentiation. Those who want to prepare themselves, slides of a related doctoral course is available:

http://www.inf.u-szeged.hu/~csendes/goslides.pdf

Mathematica overview. Current developments on Mathematica: what's new?

János Karsai, Bolyai Institute, University of Szeged, karsai.janos@math.u-szeged.hu

The talk gives a summary and presents the new features in versions 11.x. here we emphasize the parts that can be of importance in dynamical systems (but not only). We try to illustrate that Mathematica is not only for mathematicians.

Preparation: Structure programming, dynamic manipulations and basic tools to study differential equations in Mathematica

János Karsai, Bolyai Institute, University of Szeged, karsai.janos@math.u-szeged.hu

A short summary is given on expressions, functions, structures, patterns, substitutions, on list programming (rule-based, structure operations …) and operations over functions. Finally, some tools for dynamic applications will be considered. In more details:

Summary of basic concepts and visualization

- Structures, types, Head operations, lists, Sequences, patterns, rules
- functions vs. expressions; pure form of functions in more details
- Structure operations, matrix operations
- Built-in plots in 2D and 3D, dynamic visualization, graphics structures.

List programming

- Rule-based programming
- Structure operations on lists: Map, Apply, Thread, Fold, Accumulate, ...

Operations over functions

- Operations: Derivative , InverseFunction, Composition, Operate, Through, …
- Function objects: Function, InterpolatingFunction, BooleanFunction, Transformations, ...

Basic tools to study and visualization of differential equations

- Vector fields, streams in 2D and 3D, equilibria
- Symbolic and numeric solution of differential equations, interpolation
- Stability of equilibria by linearization

Parametric numeric solutions, fitting problems, dependence on parameters

János Karsai, Bolyai Institute, University of Szeged, karsai.janos@math.u-szeged.hu

Fitting of the parameters of differential equations to experimental data is a tricky problem especially if the equation can be solved only numerically. ParametricNDSolve and other sophisticated tricks may help.

ParametricNDSolve gives ParametricFunction objects which can be handled as black-boxes similarly to symbolically defined functions. It also enables to study the dependence of the solutions on parameters.

References:

[1] Karsai J.: Computer-aided study of mathematical models with Mathematica, course material

Discrete systems with Mathematica: Recursions, iterations, recurrent equations, discretization …

János Karsai, Bolyai Institute, University of Szeged, karsai.janos@math.u-szeged.hu

Now, we will consider the tools used to study discrete dynamical systems via examples.

Iteration, nesting

- Recursion vs. iterations
- Iterations, fixed points of mappings
- Numerical applications: Euler method to solve ODE’s, Picard iteration, etc.

Applications to difference systems

- Solving, visualizations, Cobweb diagram, fixed points, stability of fixed points
- Example: the logistic mapping with *Mathematica*, bifurcation diagram
- More tools for Discrete Calculus, discretization of ODE’s, PDE's

Advanced applications for difference systems

- Program development: the Euler’s method
- More tools for Discrete Calculus Discretization of ODE’s, PDE's, moving average, image processing (…) by rotating lists
- Iterative forms, fractal constructions: simple constructions, generating trees

Advanced tools for differential equation: event handling, discrete variables, Poincare mapping, impulses

János Karsai, Bolyai Institute, University of Szeged, karsai.janos@math.u-szeged.hu

Discrete effects, event handling

- Impulses, discontinuous right hand side: WhenEvent, DiscreteVariables
- Collecting data at events: Sow, Reap; Poincare mapping
- Symbolic studies: Differential systems with Dirac delta

Computing tools helping qualitative methods of differential equations

- Investigation of linear systems
- Qualitative method 1: Stability by linearization
- Technical interrupt: Advanced visualization of scalar fields
- Qualitative method 2: Stability by auxiliary functions (Liapunov’s second method)
- Visualization of families of trajectories, the method of phase mapping.

Delay differential equations with Mathematica

János Karsai, Bolyai Institute, University of Szeged, karsai.janos@math.u-szeged.hu

We investigate some simple examples with Mathematica to illustrating the Mathematica tools used and the main theoretical problems when delay appears.

- Symbolic and numeric solutions of equations with constant delay
- Linear equation with one delay, characteristic equation
- Linearization
- Equations with several delays

Spatio-temporal models with Mathematica 12.0

János Karsai, Bolyai Institute, University of Szeged, karsai.janos@math.u-szeged.hu

We consider the Mathematica tools to study spatio-temporal models via elementary problems, such as partial differential equations and cellular automata. The new Mathematica versions have more and more functions concerning either symbolically of numerically given regions (integration, numerical solution of PDE's on regions); new tools concerning numerical study of differential equations, such as finite element method).

Reliable Computation I -II

Boglárka G.-Tóth, Kalmár Institute, University of Szeged, boglarka@inf.u-szeged.hu

We will try out the Intlab toolkit of Matlab where reliable computations are supported. We'll make calculations with interval arithmetic and automatic differentiation, and also try complete algorithms for solving global optimization problems and systems of nonlinear equations.

Reliable computations in dynamical systems I-II

Ferenc Bartha, Bolyai Institute, University of Szeged, barfer@math.u-szeged.hu

In this lecture we will consider ordinary differential equations (ODE) and use the so-called Lohner method to carry out time integration. As in the preceding talks on Reliable Computing, we shall work with sets of solutions, sets of states instead of scalars. We will learn about the importance of choosing the representation of the system state and also investigate how to propagate such sets of states under the flow generated by the ODE. The computed trajectories may then be used to establish rigorous Poincare maps and prove qualitative properties of the ODE.

Technical Information

Internet:

SSID: Eduroam (with own account)

SSID: Bolyai; password given at arrival

Computers:

Participants will work on their own computers. The training on reliable computations with Matlab will be given in a computer room.

Software installation:

Wolfram Mathematica 12.0

Download:

http://www.model.u-szeged.hu/data/etc/courses/school-2019/Mathematica_12.0.0_WIN.rar

Activation: Each participant will receive activation code personally.

Handouts, downloads:

http://www.model.u-szeged.hu/data/etc/courses/school-2019/2016-Cellular-talk.rar

http://www.model.u-szeged.hu/data/etc/courses/school-2019/2018-Delay.rar

http://www.model.u-szeged.hu/data/etc/courses/school-2019/2018-math-modeling-new.rar

http://www.model.u-szeged.hu/data/etc/courses/school-2019/2018-math-packages.rar

http://www.model.u-szeged.hu/data/etc/courses/school-2019/2019-Discrete-effects.rar

http://www.model.u-szeged.hu/data/etc/courses/school-2019/global-optimizations.pdf

More materials available from the web:

In cases, login is needed to www.model.u-szeged.hu (user: stud, pw: szte)

http://www.model.u-szeged.hu/index.php?action=edoc

In particular:

- Mathematical and visualization packages: Mathematica
- Computer-aided study of mathematical models with Mathematica
- Polner M.: Partial Differential Equations: Theory and numerical methods
- Vizi Zs.: Visual Introduction to Bifurcations
- Dénes A., Röst G., Karsai J.: Experimental Studies in Population Dynamics
- Karsai J.: Math lectures for Life Science students
- Karsai J.: Mathematical Models