

Dynamics, Topology and Computations

DyToComp 2015

15-20 June 2015, Będlewo, Poland

Scientific report

14 sierpnia 2015

1 Summary

Conference Dynamics, Topology and Computations - DyToComp 2015 took place between 15-20 June 2015 in the Mathematical Research and Conference Center in Będlewo, Poland. It was organized by

- Faculty of Mathematics and Computer Science, Jagiellonian University, Kraków
- European Science Foundation,
- Stefan Banach International Mathematical Center, Warszawa,
- The Committee on Mathematics of the Polish Academy of Sciences,
- Warsaw Center of Mathematics and Computer Science.

It was the fourth edition of the DyToComp conference, preceded by the conferences in 2006, 2009 and 2012. The present edition gathered 87 participants, among them many leading specialists in the area of computational and applied topology, computational dynamics and particularly computational topological dynamics. There have been 17 invited, one hour talks and 42 contributed, half-hour talks. Also 11 posters have been presented.

The mathematical conferences in Będlewo are modelled on mathematical conferences in Oberwolfach. The participants live and eat together in the facilities of the conference center. This, besides the talks, provides plenty of time and space for informal talks and discussions.

2 Description of the scientific content of and discussion at the event

The goal of the DyToComp conference series is to promote and develop interactions between topology, dynamics and computations. The scientific interest of the participants was in the areas of applied and combinatorial topology, dynamical systems, topological dynamics, numerical methods, computer assisted proofs and, particularly, in the intersection of these fields in various combinations. The topics covered included

- topological methods in computer vision
- topological data analysis
- persistent homology
- topology of configuration spaces
- dynamical methods in the topological analysis of configuration spaces of groups
- topological methods in distributed computing
- numerical methods for ordinary and partial differential equations
- rigorous algorithms for dynamical systems,
- computer assisted proofs,
- numerical algorithms for topological invariants,
- KAM theory in classical context and in relation with rigorous numerical methods,
- Conley index based numerical methods.

Vin de Silva explained how ideas of topological persistence may be expressed in the language of category theory. He showed that basic concepts extend quite widely and in particular Reeb graphs and join-trees can be thought of as persistent invariants, enjoying some of the same properties as persistence diagrams.

Michael Farber considered large random simplicial complexes and their topological and geometric properties. He focused on a model involving several probability parameters describing the statistical properties of random complexes in various dimensions. The Homological Domination Principle states that the Betti number in one specific dimension (the Critical Dimension), which depends on the probability multi-parameter, significantly dominates all other Betti numbers. As a step to understand the general picture of properties of random simplicial complexes with a fixed critical dimension he stated a few conjectures.

Yasuaki Hiraoka in the talk “Random topology, minimum spanning acycle, and persistent homology” studied a higher dimensional generalization of Frieze’s $\zeta(3)$ -limit theorem. He generalized the Erdős-Rényi graph process using the d -Linial-Meshulam process as a model for random simplicial complexes and spanning acycles as a higher dimensional analogue of spanning trees. The main result stated that the expected weight of the minimum spanning acycle behaves in $O(n^{d-1})$.

Katherine Turner discussed the topological summary statistics called persistent homology rank functions. Using principal components analysis for those functions she analyzed examples using point processes and real world data involving colloids and sphere packings.

Amit Patel in his talk *Persistent homology for maps* considered the homology of fibers of maps to a Riemannian manifold. He made a survey on the well group for maps that are generalizations of persistent homology groups to higher dimensional spaces. He presented recent result on both mathematical and algorithmic sides.

Nikolay Makarenko discussed the use of methods of mathematical morphology, fractal geometry and computational topology to various applications including the solar magnetic fields, texture analysis and brain activity.

Iskander Taimanov in the talk “Topological analysis of three-dimensional geological models” discussed topological characteristics of random fields that are used for numerical simulation of oil and gas reservoirs. He also presented numerical algorithms for computing such characteristics.

Paweł Pilarczyk gave an overview of a computational framework for automatic classification of global dynamics in a dynamical system depending on a few parameters. Framework is based on a set-oriented topological approach, using Conley’s idea of a Morse decomposition, combined with rigorous numerics, graph algorithms, and computational algebraic topology. This method provides a concise and comprehensive classification of all the dynamical phenomena found across the given parameter ranges and at a prescribed resolution.

Massimo Guzzo in his talk described the technique of fast Lyapunov indicators computations with a filtering window that can be used to detect the stable-unstable manifolds with high accuracy. He illustrated the method on the critical problem of detection of the so-called tube manifolds of the Lyapunov orbits of L1, L2 in the planar circular restricted three-body problem.

Jordi-Lluis Figueras presented numerics, rigorous numerics and rigorous results of how hyperbolic invariant tori bifurcate to strange invariant objects.

Hidekazu Ito in talk “Integrable and superintegrable vector fields and their normal forms at equilibria” discussed the existence of a convergent normalization under the assumption that the vector field is “superintegrable” in such a way that the transformed system can be solved explicitly.

James Meiss in his talk discussed discretization methods for topological analysis of time-series data. Instead of standard cubical multivalued map he used simplicial complex constructed from a fuzzy version of the witness-landmark relationship. The goal of this approach is to obtain a natural discretization that is more tightly connected with the invariant density of the time series itself.

Sayan Mukherjee considered the asymptotic consistency of maximum likelihood parameter estimation for dynamical systems observed with noise. He showed that under suitable conditions on the dynamical systems and the observations, maximum likelihood parameter estimation is consistent. He also exhibited classical families of dynamical systems for which maximum likelihood

estimation is consistent.

Gianni Arioli presented new results, some of them computer assisted, concerning the existence of non-symmetric solutions and the non-existence of symmetric solutions for the symmetric boundary value problems.

3 Assessment of the results and impact of the event on the future direction of the field

The main goal of DyToComp conference series is to develop and promote interactions between topology and dynamics. They have common roots but over time these disciplines specialized and spread apart, often forgetting about their common origin. Surprisingly, the ground for a reunification was provided by the computational methods enabled by the development of fast computers of the XXI century.

The outstanding feature of DyToComp conferences is that it gathers in one place people normally spreaded around the world working in their specific fields. Many leading scientists representing topology and/or dynamics were present. They have the opportunity to learn about the very recent new interactions between topology and dynamics in various areas. This stimulates their own research and opens the way to new interactions and common projects. As always this is a particularly strong outcome of DyToComp.

It is clear that the conference was very successful: it is enough to list very high professional level of talks, big number of informal interactions between participants and very good opinions. As consequence the dates of the next event in this series have already been fixed for 17-23th June 2018.

4 Final programme of the meeting

MONDAY, 15 JUNE

8:00–9:00	BREAKFAST	
9:00–9:50	V. de Silva, <i>Topological persistence via category theory</i>	
10:00–10:50	M. Farber, <i>Topology of large random spaces</i>	
	COFFEE BREAK	
11:30–12:20	P. Pilarczyk, <i>A combinatorial-topological approach to automatic classification of global dynamics</i>	
12:30–13:00	J. Mireles James, <i>Coexistence of stationary hexagons and rolls in a spatial pattern formation problem: a computer assisted proof</i>	
13:00	LUNCH	
15:30–16:00	P. Skraba, <i>An approximate nerve theorem</i>	
	PARALLEL SESSION I	PARALLEL SESSION II
16:00–16:30	M. Capiński, <i>Arnold diffusion in the elliptic restricted 3-body problem</i>	A. Borat, <i>Higher dimensional motion planners for $F(R^n, k)$</i>
16:30–17:00	A. Śluszyk, <i>New central configurations in the planar 6-body problem</i>	M. Cohen, <i>The probability of choosing the unknot among 2-bridge knots using random Chebyshev billiard table diagrams</i>
	COFFEE BREAK	
17:30–18:00	A. Prokopenya, <i>Integrable cases of evolutionary equations in the restricted three-body problem with variable masses</i>	M. Ethier, <i>Persistence of singular eigenspaces</i>
18:00–18:30	W. Zakrzewski, <i>Recent progress on quasi-integrability</i>	M. Juda, <i>Scalable homology computing</i>
18:30–19:00	V. Gaiko, <i>Bifurcational and topological methods for low-dimensional polynomial dynamical systems</i>	J. Costa, <i>The topos foundation of persistence</i>
19:00	DINNER	

TUESDAY, 16 JUNE

8:00–9:00	BREAKFAST
9:00–9:50	M. Guzzo, <i>Numerical computation of stable and unstable manifolds with fast Lyapunov indicators. Applications to the three body problem</i>
10:00–10:50	J. Figueras, <i>How hyperbolic invariant tori bifurcate to strange objects: from numerics to rigorous results</i>
	COFFEE BREAK
11:30–12:20	Y. Hiraoka, <i>Random topology, minimum spanning acycle, and persistent homology</i>
12:30–13:00	P. Franek, <i>Robust properties of zero sets via homotopy theory</i>
13:00	LUNCH
15:30–16:00	H. Koch, <i>On hyperbolicity in the renormalization of near-critical area-preserving maps</i>
	PARALLEL SESSION I
16:00–16:30	A. Luque, <i>Computer assisted proofs in KAM theory</i>
16:30–17:00	A. Wasieczko-Zajac, <i>Geometric proof of strong stable/unstable manifolds with application to the Restricted Three Body Problem</i>
17:00–17.30	C. Reinhardt, <i>Rigorous computation of unstable manifolds for nonlinear parabolic PDEs via the parametrization method</i>
	COFFEE BREAK
18:00	POSTER SESSION
19:30	BONFIRE
	PARALLEL SESSION II
16:00–16:30	V. Kurlin, <i>Homologically persistent skeleton in computer vision and beyond</i>
16:30–17:00	I. Knyazeva, <i>Computational topology approach for pattern recognition in 2D images</i>
17:00–17.30	A. Rieser, <i>A topological approach to spectral clustering</i>

WEDNESDAY, 17 JUNE

8:00–9:00	BREAKFAST
9:00–9:50	K. Turner, <i>PCA of persistent homology rank functions with case studies in point processes, colloids and sphere packings</i>
10:00–10:50	H. Ito, <i>Integrable and superintegrable vector fields and their normal forms at equilibria</i>
	COFFEE BREAK
11:30–12:00	J. Gomez-Serrano, <i>Computer-assisted proofs in incompressible fluids</i>
12:45	LUNCH
13:45	EXCURSION TO THE NATIONAL PARK
14:00	EXCURSION TO POZNAŃ
19:00	DINNER

THURSDAY, 18 JUNE

8:00–9:00	BREAKFAST	
9:00–9:50	N. Makarenko, <i>Geometry and topology of digital images</i>	
10:00–10:50	J. Meiss, <i>Using witness complexes to analyze dynamical time series</i>	
	COFFEE BREAK	
11:30–12:20	S. Mukherjee, <i>Consistency of maximum likelihood estimation for some dynamical systems</i>	
12:30–13:00	M. Mrozek, <i>Constructing combinatorial multivector fields from data</i>	
13:00	LUNCH	
15:30–16:00	T. Kaczyński, <i>Towards a formal tie between combinatorial and classical vector field dynamics</i>	
	PARALLEL SESSION I	PARALLEL SESSION II
16:00–16:30	S. Pilyugin, <i>Inverse shadowing for actions of finitely generated groups</i>	H. Wagner, <i>Topological text analysis and generalized similarity measures</i>
16:30–17:00	J. Cyranka, <i>A construction of two different solutions to an elliptic system</i>	A. Rahm, <i>A software for computations on the dynamics and topology of the Bianchi groups</i>
	COFFEE BREAK	
17:30–18:00	A. Czechowski, <i>Rigorous numerics for the FitzHugh-Nagumo slow-fast system</i>	A. Rathod, <i>Min-Morse: approximability and applications</i>
18:00–18:30	R. Szczelina, <i>Rigorous integration of delay differential equations and applications</i>	C. Landi, <i>Discrete Morse theory for reducing complexes in multi-dimensional persistence</i>
18:30–19:00	A. Belova, <i>Estimation of the rotation number by interval methods</i>	K. Ziemiański, <i>Spaces of directed paths on semi-cubical sets</i>
19:00	BONFIRE	

FRIDAY, 19 JUNE

8:00–9:00	BREAKFAST	
9:00–9:50	A. Patel, <i>Persistent homology for maps</i>	
10:00–10:50	M. Kahle, <i>The most persistent cycles in random geometric complexes</i>	
	COFFEE BREAK	
11:30–12:20	I. Taimanov, <i>Topological analysis of three-dimensional geological models</i>	
12:30–13:00	T. Wanner, <i>Rigorous validation of isolating blocks for flows</i>	
13:00	LUNCH	
15:30–16:00	D. Wilczak, <i>When chaos meets hyperchaos</i>	
	PARALLEL SESSION I	PARALLEL SESSION II
16:00–16:30	F. Weilandt, <i>The discrete Conley index as the homotopy type of a space</i>	R. Castelli, <i>Fourier-Taylor parameterisation of invariant manifold for periodic orbits of vector field</i>
16:30–17:00	E. Vieira, <i>Transition matrices theory</i>	R. Sheombarsing, <i>Rigorous numerics for ODEs using Chebyshev series and domain decomposition</i>
	COFFEE BREAK	
17:30–18:00	D. Cherkashin, S. Kryzhevich, <i>Weak shadowing in topological dynamics</i>	K. Kropielnicka, <i>Effective approximation for the time dependant, linear Schrödinger equation</i>
18:00–18:30		I. Walawska, <i>Bifurcations and continuation of halo orbits – rigorous numerical approach</i>
18:30–19:00		K. Soga, <i>Numerical methods of weak KAM theory</i>
19:00	DINNER	

SATURDAY, 20 JUNE

8:00–9:00 BREAKFAST

9:00–9:50 G. Arioli, *Symmetric boundary value problems and non-symmetric solutions*

10:00–10:50 Z. Galias, *On periodic windows for the Hénon map close to the classical case*

12:00 LUNCH

POSTER SESSION ON TUESDAY, 16 JUNE, STARTING AT 18:00

- D. Lima *Smale's cancellation theorem: birth and death of connections*
- B. Garda *An efficient method to find all low-period windows for the logistic map*
- M. Scolamiero *Invariants for multidimensional persistence*
- M. R. da Silveira *Continuation detected through a spectral sequence analysis.*
- J. Duda *Maximal entropy random walk - when topology is not enough*
- A. Gierzkiewicz *Integrability of the Szekeres system*
- I. Makarenko *3D morphology of a random field from its 2D cross-section*
- K. Soga *Numerical methods of weak KAM theory*
- A. Czechowski,
P. Zgliczyński *Rigorous numerics for PDEs with indefinite tail: existence of a periodic solution of the Boussinesq equation with time-dependent forcing*
- M. Moczurad, P. Zgliczyński *New lower bound estimates for quadratures of bounded analytic functions*
- G. Jabłoński *Persistence of generalized eigenspaces of self-maps*