Abstracts Book

Understanding COMPLEXITY and CONCURRENCY through TOPOLOGY of DATA

2nd EATCS joint with TOPDRIM YOUNG RESEARCHERS SCHOOL & TOPDRIM WORKSHOP

Emanuela Merelli (Editor)

Camerino 13-22 July 2015

Contents

Introduction

TOPDRIM, Topology Driven Methods for Complex Systems has been funded by European Commission for envisioning a new mathematical and computational framework based on topological data analysis for probing data spaces and extracting manifold hidden relations (patterns) that exist among data. While pursuing this objective, a general program aiming to construct an innovative methodology to perform data analytics has been devised. This program proposes the realization of a *Field Theory of Data* starting from topological data analysis, passing through field theory and returning an automaton as a recognizer of the data language. TOPDRIM contributed mainly to the first stage of the program by giving evidence that topological data analysis is a viable tool to tame the wild collection of data and to detect changes in complex networks and going beyond the concept of networks by considering instead simplicial complexes, which allow the study of n-dimensional objects. The program rests on three pillars - Topological data analysis (Homology driven); Topological Field Theory for Data Space; Formal language (Semantic) - and pursues a general theory of structures one of which is “Category theory”, which has come to occupy a central position in contemporary mathematics and theoretical computer science, and has also successfully entered physics.

With the spirt to offer a wide spectrum of current research as well as applications on topological data analysis from one side and theoretical computer science for complex systems from the other, we organized a Workshop on Topology Driven Methods for Complex Systems, held in Camerino, Italy - July 18th & July 22nd, 2015. The program consisted of three keynote speakers by Seth Lloyd (MIT Boston) who spoke about a recent result he obtained in applying a quantum algorithm for topological and geometric analysis of big data, Samson Abramsky (Oxford University) showed by his talk that an important class of Contextuality arguments has a topological origin, and Mario Rasetti (ISI Foundation) whose talk introduced the topological field theory of data. Several thematic seminars complemented the program of the two days (available at bottom of the book) .

In the same context, TOPDRIM and the European Association for Theoretical Computer Science (EATCS), organized from July 13th - 22nd the 2nd EATCS Young Researchers School dedicated to Understanding COMPLEXITY and CONCURRENCY through TOPOLOGY of DATA. The aim was training a future generation of transdisciplinary researchers, Data Scientists, able to construct suitable methods that allow to extract, as much as possible, hidden patterns from data. The school offered two main streams of topics: (i) methods from topology and their application in data analysis, and (ii) methods from semantics and models of computation, and their applications in computer science. The topics of the lectures were enjoyed by wide range of the participants (the complete list in Section V) with a background in physics, mathematics and computer science.

The organizers express their thanks to all speakers for their interesting talks and inspiring contribution to the interdisciplinary discussions and all the participants for their contributions that made the event a success. A special acknowledge to the efforts of the UNICAM staff: Gian Vincenzo Lebboroni, Matteo Rucco, Michela Quadrini, Marco Piangerelli.

Emanuela Merelli
(TOPDRIM Coordinator)

Workshop + School website: http://camerino2015.topdrim.eu/

Part I

Workshop – Keynote Speakers

Quantum Algorithm for Topological and Geometric Analysis of Big Data

Seth Lloyd

Abstract

Extracting useful information from large data sets can be a daunting task. Topological methods for analyzing data sets provide a powerful technique for extracting such information. Persistent homology is a sophisticated tool for identifying such topological features connected components, holes, or voids and for determining how such features persist as the data is viewed at different scales. This paper provides quantum algorithms for calculating Betti numbers in persistent homology, and for finding eigenvectors and eigenvalues of the combinatorial Laplacian. The algorithms provide an exponential speedup over classical algorithms for topological data analysis.

Study material: Seth Lloyd, Silvano Garnerone and Paolo Zanardi. Quantum algorithms for topological and geometric analysis of data. Nature Communication, 7, 10138. 2016

Short Bio: Seth Lloyd is Professor of Mechanical Engineering at the Massachusetts Institute of Technology. He is the director of the WM Keck Center for Extreme Quantum Information Theory at MIT, the director of the Program in Quantum Information at the Institute for Scientific Interchange, and Miller Fellow at the Santa Fe Institute. Lloyd earned his A.B. degree in Physics from Harvard University, his Masters of Advanced Study in Mathematics and M.Phil. in History and Philosophy of Science from Cambridge University, and his Ph.D. in Physics from Rockefeller University. After postdoctoral fellowships at Caltech and at Los Alamos, he joined the MIT faculty in 1994. His research area is the interplay of information with complex systems, especially quantum systems. He has performed seminal work in the fields of quantum computation and quantum communication. He is the author of over 150 papers in refereed journals, and of a book, 'Programming the Universe,' as well as of numerous contributions to refereed proceedings, articles in Science, Nature, and Scientific American. Professor Lloyd has received awards for research and teaching, including the Lindbergh and Edgerton prizes. He is a fellow of the American Physical Society and Miller Fellow at the Santa Fe Institute. `http://meche.mit.edu/people/faculty/slloyd@mit.edu`

Non-Locality and Contextuality

Samson Abramsky

Abstract

Contextuality is a key feature of quantum mechanics that provides an important non- classical resource for quantum information and computation. Brandenburger and Abramsky used sheaf theory to give a general treatment of contextuality in quantum theory [New Journal of Physics 13 (2011) 113036]. However, contextual phenomena are found in other fields as well, for example database theory. In this talk, I shall develop this unified view of contextuality. Two main contributions were discussed: firstly, the exposition of a remarkable connection between contexuality and logical paradoxes; secondly, it was showed that an important class of contextuality arguments has a topological origin. More specifically, it was showed that All-vs-Nothing proofs of contextuality are witnessed by cohomological obstructions.

Study material: Samson Abramsky, Rui S. Barbosa, Kohei Kishida, Raymond Lal, Shane Mansfield. Contextuality, Cohomology and Paradox, arXiv:1502.03097v1, 2015

Short Bio: Samson Abramsky is Christopher Strachey Professor of Computing and a Fellow of Wolfson College, Oxford University. Previously he held chairs at the Imperial College of Science, Technology and Medicine, and at the University of Edinburgh. He holds MA degrees from Cambridge and Oxford, and a PhD from the University of London. He is a Fellow of the Royal Society (2004), a Fellow of the Royal Society of Edinburgh (2000), and a Member of Academia Europaea (1993). He is a member of the Editorial Boards of the North Holland Studies in Logic and the Foundations of Mathematics, and of the Cambridge Tracts in Theoretical Computer Science. He was General Chair of LiCS 2000-2003, and is currently a member of the LiCS Organizing Committee. His paper "Domain theory in Logical Form" won the LiCS Test-of-Time award (a 20-year retrospective) for 1987. The award was presented at LiCS 2007. He was awarded an EPSRC Senior Research Fellowship on Foundational Structures and Methods for Quantum Informatics in 2007.He has played a leading role in the development of game semantics, and its applications to the semantics of programming languages. Other notable contributions include his work on domain theory in logical form, the lazy lambda calculus, strictness analysis, concurrency theory, interaction categories, and geometry of interaction. He has recently been working on high-level methods for quantum computation and information. `http://www.cs.ox.ac.uk/people/samson.abramsky/home.html`

Topological Field Theory of Data

Mario Rasetti

Abstract

This talk aims to challenge the current thinking in IT for the Big Data question, proposing a program aiming to construct an innovative methodology to perform data analytics that goes beyond the usual paradigms of data mining rooted in the notions of Complex Networks and Machine Learning. The method developed at least as scheme that returns an automaton as a recognizer of the data language, is, to all effects, a Field Theory of Data. We discuss how to build, directly out of probing the data space, a theoretical framework enabling us to extract the manifold hidden relations (patterns) that exist among data as correlations depending on the semantics generated by the mining context. The program, that is grounded in the recent innovative ways of integrating data into a topological setting, proposes the realization of a Topological Field Theory of Data, transferring and generalizing to the space of data notions inspired by physical (topological) field theories and harnesses the theory of formal languages to define the potential semantics necessary to understand the emerging patterns.

Study material: Mario Rasetti, Emanuela Merelli. Topological Field Theory of Data: a program towards a novel strategy for data mining through data language. Journal of Physics: Conference Series 626 (2015) 012005.

Short Bio: Mario Rasetti is Professor Emeritus of Theoretical Physics at the Politecnico, and President of the ISI Foundation in Torino, Italy. He holds degree (MSc) in Nuclear Engineering, a second one in Mathematics at the Politecnico of Torino in 1967/68 and a Ph.D. in Theoretical Physics at the CTH in Göteborg. From the very beginning, his scientific activity had an international profile (Yale, Coral Gables at Miami University, Princeton at the Institute for Advanced Studies). He has been awarded with the following prizes and honors Majorana Prize for Theoretical Physics, 2009, Volta Medal for Science, 2010 and Outstanding Referee, American Institute of Physics, 2009. His contributions to science were mostly in theoretical and mathematical physics, mathematics, information science and complexity science: solid state, statistical mechanics, theory of non-linear dynamical systems and chaos, quantum mechanics and quantum optics, quantization, quantum information and computation, topological quantum field theory, topological methods in data science, knot theory, quantum and super algebras. `http://www.isi.it/personal-profile/?pslug=mario-rasetti`

Part II

School – Lectures

Topology and Geometry of Data Analysis

Frederic Chazal

Abstract

Computational topology has recently seen an important development toward data analysis, giving birth to Topological Data Analysis (TDA). Persistent homology appears as a fundamental tool in TDA, particularly relevant to understand the topological structure of data. The goal of this mini-course was to give an introductory overview of persistent homology and illustrate some of its fundamental properties and its use in TDA.

The lectures were organized to present the following topics:

- Introduction and motivation: Persistent homology as a tool to extract topological features from data.
- Persistent homology for functions. Application to clustering.
- Multiscale topological signatures for (point cloud) data.
- Persistent modules, algebraic framework and stability.
- Statistical properties of persistence diagrams.
- Persistence landscapes and subsampling methods.

Study material: The slides of the lectures are available at
`http://camerino2015.topdrim.eu/materials/CHAZAL.pdf`

Short Bio: Frederic Chazal is Directeur de Recherche (DR1) at INRIA Saclay-Ile-de-France. He holds his PhD in Pure Mathematics at Universit de Bourgogne. He is a member of editorial board of Discrete and Computational Geometry (Springer), SIAM Journal on Imaging Sciences and Graphical Models (Elsevier). His main research interests are in the fields of Topological and Geometric Data Analysis: statistical methods, inference and learning Topological persistence; Geometric inference and geometric learning; Computational Geometry, Geometry processing and Solid Modeling and Geometry and Topology. He published many papers in leading international journals and books.

Category Theory underpins Computation

Samson Abramsky

Abstract

The aim of these lectures was to provide a succinct, accessible introduction to some of the basic ideas of category theory that support the computation. Why study categorieswhat are they good for? A range of answers for readers coming from different backgrounds were offered: *For mathematicians:* category theory organises your previous mathematical experience in a new and powerful way, revealing new connections and structure, and allows you to think bigger thoughts. *For computer scientists:* category theory gives a precise handle on important notions such as compositionality, abstraction, representation-independence, genericity and more. Otherwise put, it provides the fundamental mathematical structures underpinning many key programming concepts. *For logicians:* category theory gives a syntax-independent view of the fundamental structures of logic, and opens up new kinds of models and interpretations. *For philosophers:* category theory opens up a fresh approach to structuralist foundations of mathematics and science; and an alternative to the traditional focus on set theory. *For physicists:* category theory offers new ways of formulating physical theories in a structural form. There have inter alia been some striking recent applications to quantum information and computation.

Study material: Lecture notes are available at
`http://camerino2015.topdrim.eu/materials/ABRAMSKY.pdf`

Short Bio: Samson Abramsky is Christopher Strachey Professor of Computing and a Fellow of Wolfson College, Oxford University. He is a Fellow of the Royal Society (2004), a Fellow of the Royal Society of Edinburgh (2000), and a Member of Academia Europaea (1993). He has played a leading role in the development of game semantics, and its applications to the semantics of programming languages. Other notable contributions include his work on domain theory in logical form, the lazy lambda calculus, strictness analysis, concurrency theory, interaction categories, and geometry of interaction. He has recently been working on high-level methods for quantum computation and information.

Formal Languages and Automata Theory

Alexandra Silva

Abstract

The aim of these lectures was to introduce basic concepts of formal languages and automata. The course had a particular focus on techniques to show equivalence of languages, using coinduction, a proof principle arising in coalgebra and category theory. It was reviewed several automata constructions using category theory and show that such an abstract perspective provides means to uniformly extend know constructions to different kinds of automata.

The lectures were organized to present the following topics:

- Regular languages and expressions
- Regular languages and Deterministic Finite Automata
- Non-Deterministc Finite Automata
- Automata as Coalgebra

Study material: Lecture notes recommended during the lectures are available at `http://camerino2015.topdrim.eu/materials/SILVA.pdf`

Short Bio: Alexandra Silva is a theoretical computer scientist whose main research focuses on semantics of programming languages and modular development of algorithms for computational models. A lot of her work uses the unifying perspective offered by coalgebra, a mathematical framework established in the last decades. Alexandra is currently an assistant professor at the Institute for Computing and Information Sciences, Radboud University Nijmegen, The Netherlands. Previously, she was a post-doc at Cornell University, with Prof. Dexter Kozen, and a PhD student at the Dutch national research center for Mathematics and Computer Science (CWI), under the supervision of Prof. Jan Rutten and Dr. Marcello Bonsangue.

Introduction to Process Theory

Rocco De Nicola

Abstract

Process Algebras are mathematically rigorous languages with well defined semantics that permit describing and verifying properties of concurrent communicating systems. They can be seen as models of processes, regarded as agents that act and interact continuously with other similar agents and with their common environment. The goal of these lectures was to introduce the main concepts concurrency theory lies on among which structural operational semantics and behavioural equivalences.

The lectures were organized to present the following topics:

- Introduction and motivation: Concurrent Programming topological features from data.
- Process algebra approach
- Labelled Transition Systems as Concurrency Models
- Behavioural Equivalences for Process Algebras
- Process Calculi and their Semantics

Study material: Lecture notes and slides are available at
`http://camerino2015.topdrim.eu/materials/DENICOLA_1.pdf`
`http://camerino2015.topdrim.eu/materials/DENICOLA_2.pdf`

Short Bio: Rocco De Nicola is full professor of Computer Science since 1990 and is among the ISI HiglyCited researchers for Computer Science. He has over 150 published papers, with important contribution to process algebras equivalences, temporal logics, languages for net- work aware programming, and quantitative analysis of systems. De Nicola is a member of the advisory boards of CITI-Lisbon and MT-Lab Lyngby and in the steering committee of important series of conferences. He has been invited speaker, PC chair and PC member for many inter- national conferences and workshops in the last twenty years. He is a member of the Academia Europaea, and of Working Group 2.2 and 1.9 of IFIP. In 2005 he was appointed "Commander of the Order of Merit of the Italian Republic" by the President of the Italian Republic. In the last 10 years De Nicola has been Principal Investigator and site coordinator for the FET projects: AGILE, MIKADO, SENSORIA. Currently he is the site coordinator and WP leader for the ASCENS and QUANTICOL project.

Behavioural Modelling and Equivalences & HDA

Rob Van Glabbeek

Abstract

These lecture had the goal to compare the expressiveness of several models of concurrency that could be thought of as formalisations of higher dimensional automata: cubical sets, presheaves over a category of bipointed sets, automata with a predicate on hypercube-shaped subgraphs, labelled step transition systems, and higher dimensional transition systems. A series of counterexamples were illustrated the limitations of each of these models. Additionally I presented results relating higher dimensional automata to ordinary automata, Petri nets, and various kinds of event structures. I compared the expressive power of these models of concurrency based on their ability to represent causal dependence. To this end, I translated these models, in behaviour preserving ways, into a model of higher dimensional automata. In particular, I proposed four different translations of Petri nets, corresponding to the four different computational interpretations of nets found in the literature. I also reviewed various equivalence relations for concurrent systems on higher dimensional automata. These include the history preserving bisimulation, which is the coarsest equivalence that fully respects branching time, causality and their interplay, as well as the ST-bisimulation, a branching time respecting equivalence that takes causality into account to the extent that it is expressible by actions overlapping in time. Through their embeddings in higher dimensional automata, it is well-defined whether members of different models of concurrency are equivalent.

Study material: Lecture Notes recommended during the lectures are available at `http://camerino2015.topdrim.eu/materials/VANGLABBEK_1.pdf`

Short Bio: Rob van Glabbeek has a strong international reputation in the study of the theory of concurrent computation, having made particular contributions to the conciliation of the interleaving and the true concurrency communities by codeveloping the current view of branching time and causality as orthogonal but interacting dimensions of concurrency. Together with Peter Weijland he invented the notion of branching bisimulation. With Ursula Goltz he proposed the notion of action refinement as a useful tool for evaluating semantic equivalences and implementation relations. With Peter Rittgen he initiated the application of process algebraic methods in the formal description and analysis of economic production processes. Together with Vaughan Pratt he initiated the now widespread use of higher dimensional automata and other geometric models of concurrency. With Gordon Plotkin he integrated various causality respecting models of concurrency, including Petri nets, event structures and propositional theories. He is editor-in-chief of Electronic Proceedings in Theoretical Computer Science.

Part III

Workshops & School – Seminars

Shape and Proximity

Riccardo Piergallini

Abstract

The talk speculated on the two terms shape and proximity, comparing their meaning in the abstract context of "pure mathematics" with the concrete interpretation they have in the analysis of data and complex systems.

Shape theory was introduced in the late 1960's by the polish topologist K. Borsuk as a variation of homotopy theory. The main motivation was to extend some good properties of homotopy theory to a larger class of spaces than complexes. This gives a classification of such spaces coarser than the homotopical one, in that it is only affected by the global shape and not by the local details.

The birth of proximity theory dates back to the early 1950's, with the work of the Russian topologist V.A. Efremovič. Proximity structures were intended to generalize the notion of metric, in order to study spaces where some notion of nearness is given, even if not quantifiable in terms of real numbers.

It is wonderful and quite surprising, that the classical ideas beyond these theories can be found, in a very similar form, in applicative fields like persistent homology independently developed several decades later.

Some specific example is discussed, showing that this observation could be exploited, in order to let applications benefit from well established theoretical results, avoiding the job of rediscovering known things.

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/PIERGALLINI.pdf`

Short Bio: Riccardo Piergallini is Full Professor of Geometry at University of Camerino. The main field of his scientific activity is low-dimensional topology. In particular, he is interested in the theory of branched coverings, as a tool for representing manifolds and studying various topological and geometric structures on them. Recently, he started to consider computational applications of topology and geometry, specially the ones concerning spatial modelling, image processing, computer graphics and artificial vision.

Algebraic and Computational Topology for Data Analytics

Francesco Vaccarino

Abstract

The statistical mechanical approach to complex networks is the dominant paradigm in describing natural and societal complex systems. The study of network properties, and their implications on dynamical processes, mostly focus on locally defined quantities of nodes and edges, such as node degrees, edge weights and more recently correlations between neighboring nodes. However, statistical methods become cumbersome when dealing with many-body properties and do not capture the precise mesoscopic structure of complex networks. Moreover, real-world networks usually display intricate patterns of redundant links with edge weights and node degrees usually ranging over various orders of magnitudes, which makes it very hard to extract the significant network structure from the background. In our lectures, we will give account of the way we attacked this problem via the calculation of the persistent homological features of complex weighted network, without the need to impose an ad-hoc metrical structure. Indeed, it is possible to define a filtration, which effectively returns the topological strata of the link-weight organization of a given network.

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/VACCARINO.pdf`

Short Bio: Francesco Vaccarino is Research Leader at the ISI foundation where is the PI of the EU funded FET Proactive Project TOPDRIM and leads, together with Mario Rasetti, the "Mathematics of Complex Systems Lab". Is also a tenured researcher and aggregate Professor of Geometry at Politecnico di Torino, where he is coordinating the EU ESF Funded - Master Degree in Big Data Engineering and where he is member of the University Board for Lifetime Education, cofounder and member of the scientific board of the BigDataLab@Polito facility. He is an expert in geometric invariant theory, computational topology and their application. As a scientific journalist, he is regularly publishing on major Italian newspapers and magazines. His major scientific achievement is the founding of generators and relations of the ring of multisymmetric functions, solving a problem open since the 19th century. He had his Ph.D. in Mathematics at University of Torino in 1994 and has been a post doc at Institut Fourier, Grenoble and La Sapienza, in Rome. After that, he worked at Fiat Auto where he became the CKO of the R&D Division. In 2001 he left Fiat and founded a consultancy firm devoted to support technology transfer from universities to industries. In 2007 he won a permanent position at Politecnico di Torino. He has been collaborating with ISI since 2009.

Getting to Topology for RNA

Chris Barrett

Abstract

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Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/BARRETT.pdf`

Short Bio: Chris Barret is member of the Science Board of the ISI Foundation, University Distinguished Professor at Virginia Tech, head of VBI, Virginia Bioinformatics Institute, Network Dynamics & Simulation Science Laboratory, specialized in Biomathematics and world leader in this topic.

Topology and Algebra of Multilevel Systems

Jeffrey Johnson

Abstract

Most systems have many levels of description. Can highly entangled multilevel systems be separated into well-defined levels, and can the dynamics of multilevel systems be integrated between well-defined levels? Part-whole aggregation provides one fundamental vertical arrow for multilevel systems, where the parts are mapped upwards to the whole. The conventional micro- meso- macro- distinction is inadequate since most systems have many more than three levels. Instead it is proposed to number the levels. However, there are no absolute micro or macro levels, so the numbering is defined with respect to an arbitrary Level N. If the set of parts exists at Level N then the whole exists at Level N+1. Often the Level N+1 whole is then aggregated into a higher level whole at Level N+2, and so on to the highest levels. Assembling a set of n parts into a whole requires an n-ary relation, R. The simplices and hypersimplices representing a system form its backcloth. Simplices have a q-connectivity structure that constrains the behaviour of the traffic. This has many subtle topological properties. Multilevel systems can then be represented as commutative cubic lattices where, horizontally the traffic arrows map the Level N+k backcloth into numbers and the backcloth arrows representing the algebraic and topological connectivity. Vertically the arrows represent multilevel aggregation and disaggregation. The commutativity is necessary for consistency: hierarchical aggregation of traffic on the lower level backcloth must equal the traffic on the higher level hierarchically aggregated backcloth. This then provides a formalism to integrate the dynamics of systems at all levels. Establishing the algebra and topology of hypernetworks is a necessary step towards fulfilling the objectives of the DYM-CS programme.

Study material: Jeffrey Johnson, Hypernetworks in the Science of Complex Systems, Imperial College Press, 2013. The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/JOHNSON.pdf`

Short Bio: Jeff Johnson is Professor of Complexity Science and Design at the Open University. His PhD is in mathematics and he is a chartered mathematician and a chartered software engineer. His research involves developing new mathematical methods for the design and management of complex systems. He has worked in many areas including road traffic systems, market systems, organisational structure, intelligent systems, pattern recognition, robotics, and machine vision. He has extensive experience of projects funded by industry, national research councils, and the European Commission. His European projects have included leading a number of coordination actions and through these he has established an extensive network of complex systems scientists in Europe and around the world. He is author or editor of five books and he has published many papers applying structures from algebraic topology to complex multilevel systems to complex multilevel systems.

Topological electrodynamical interactions among biomolecules

Marco Pettini

Abstract

In the context of ICT exciting research domains on biocomputers and wet computing are now under way. Beyond the present silicon-bound reality, molecular computers are expected to lead to new and unknown scenarios by resorting to biomolecules and the knowledge of their functions in living cells. This stems from the observation that it is hardly conceivable that the astonishingly high efficiency, rapidity and robustness against environmental disturbances of the complex networks of biochemical reactions in living cells be only driven by random encounters between cognate partners. There are reasons based on physical first principles and experimental evidence to assign an essential role, in this highly efficient pattern of interactions, to an electromagnetic long-distance communication among biomolecules leading to a complex information processing activity implemented by heteropolymers (DNA and RNA), homopolymers (microtubules, actin), and proteins. This talk highlighted many aspects of the current research whose development implies also the use of topology-based measurements of complexity.

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/PETTINI.pdf`

Short Bio: Marco Pettini is Professor of Theoretical Physics at the Physics Department of AMU. He received the Laurea in Physics in 1978 from the University of Firenze, Italy, and the Habilitation Diriger des Recherches (HDR) from the former University of Aix-Marseille II. Leader of the Nonlinear Dynamics Team at CPT, has published more than 90 papers on scientific journals and one book [M.Pettini, Geometry and Topology in Hamiltonian Dynamics and Statistical Mechanics, IAM Series n.33, Springer, NY (2007), pp.456]. Among other original contributions in nonlinear dynamics and its applications (as an open-loop theory of control of chaos in dissipative and Hamiltonian systems; the definition of a non-conventional model to explain anomalous transport in magnetized thermonuclear fusion plasmas; the discovery of a transition between weak and strong chaos in large Hamiltonian systems), he has formulated a new theoretical approach to explain the origin of Hamiltonian chaos in terms of Riemannian geometry and a new theory of phase transitions resorting to differential topology (Morse theory). He has been working in: Atomic Physics, Statistical Mechanics and Nonlinear Dynamics, Nonlinear Systems Theory, Mathematical Physics, Biophysics.

Information Geometry

Stefano Mancini

Abstract

In this lecture I will introduce basic notions of information geometry, namely Riemannian geometry applied to probability theory, with the aim of using such a framework to characterize complex systems, like complex networks. To this end I will then put forward geometric entropy corresponding to the volume of a statistical manifold which may serve as a measure of complexity, discuss some of its properties and applications. As a more sophisticated scenario I will finally look at the entropic dynamics arising from inductive inference (Maximum Entropy Methods) and consider there, as complexity measure, the time averaged statistical volume explored by geodesic flows.

Study material: Domenico Felice, Carlo Cafaro and Stefano Mancini. Information Geometric Complexity of a Trivariate Gaussian Statistical Model. Entropy 16, 2944-2958, 2014

Short Bio: Stefano Mancini earned the PhD in Physics from the University of Perugia in 1998 and then began his academic career at University of Milan. Subsequently he obtained a lecturer position at University of Camerino where he is currently professor of theoretical physics and mathematical methods. His interests are in the fields of open dynamical systems, quantum information theory and information geometry where he published more than 180 papers in leading international journals. He has a lot of international collaborations and he has contributed to several projects funded under international umbrellas as well as by Italian Institutions.

Information Processing

Rick Quax

Abstract

Emergent behaviour is the process where a large collection of elements (termed agents) generate a complex systemic behaviour. Examples include human cognition emerging from a network of neural cells, ecosystems from food webs, and cellular regulatory processes from protein-protein interactions. A first important question is: which agents are the 'drivers' of the systemic behaviour? A second question is: can we detect emergent phenomena, particularly 'criticality' (susceptibility to small perturbations)? We address these questions using the concept of 'information dissipation' which we are developing. This is the idea that Shannon information is first stored in an agent's state, and then percolates through the network due to the agent-agent interactions. I will present recent work on addressing the above questions through analytical results, computational modeling, and real data-analysis of financial derivatives data around the Lehman Brothers collapse.

Study material: The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/QUAX.pdf`

Short Bio: Rick Quax is currently a postdoctoral researcher in the Computational Science in the Faculty of Science of the University of Amsterdam. I am particularly interested in the emergence of complex, systemic behavior from the interactions of relatively simple elements, such as human cognition from neurons and synapses, cell regulatory processes from gene-gene interactions, and social unrests and protests through person-person communication. Supervised by Prof. Dr. Peter M.A. Sloot, I am specifically formulating a theoretical framework of information processing in complex systems, more specifically, systems with complex networks of interactions. My goal is to use information theory as a universal language to describe the emergent behavior of such systems. In particular, I believe it may provide a bridge between microscopic and macroscopic information, and may express causal relations. This can be used to characterize the behavior of a system as a whole in terms of local dynamics. I obtained the Ph.D. in Computational Science at the University of Amsterdam in 2013, the M.Sc. ("Full GPA") in Computer Science from the Georgia Institute of Technology, U.S.A., and the B.Sc. ("cum laude") in Computer Science from the University of Amsterdam, The Netherlands.

Information Geometry and Algebraic Statistics on a finite state space

GIOVANNI PISTONE

Abstract

It was shown by C. R. Rao in a paper published 1945 that the set of positive probabilities on a finite state space is a Riemannian manifold in a way which is of interest for Statistics because the metric tensor equals the Fisher information matrix. It was later pointed out by Sun-Ichi Amari, that it is actually possible to define two other affine geometries of Hessian type on top of the classical Riemannian geometry. Amari gave to this new topic the name of Information Geometry. The term Algebraic Statistics was introduced to denote the use of Commutative Computational Algebra in Statistical Design of Experiments and in Statistical Models. Information Geometry and Algebraic statistics are deeply connected because of the central place occupied by exponential families in both fields. The present talk is a tutorial and rigorous introduction the topic.

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/PISTONE.pdf`
`http://www.giannidiorestino.it/Papers/Papers.html`

Short Bio: Giovanni Pistone has been professor of Probability of the Politecnico di Torino to the year 2009 when he retired. Previously he was professor at the Università di Genova, where he served as Head of the Department of Mathematics for 3 years. He obtained his "Laurea" (Master degree) from the Università di Torino in 1969, and the degree "docteur de 3me cycle" from the Université de Rennes (France) in 1975. He has worked as high school teacher and as postdoc, assistant professor, associate professor for the universities of Turin, Nice (France), Genoa. Contributions to Probability and Mathematical Statistics cover various topics, e.g. Stochastic Partial Differential Equations, Industrial Statistics, Information Geometry, Algebraic Statistics. He holds un undergraduate degree in Theology from the Facoltá Valdese di Teologia, Rome. He is local preacher and member of the Chiesa Valdese di Torino. Currently he is affiliate of the Statistics Initiative of the Collegio Carlo Alberto, Moncalieri, Italy.

Multidimensional Persistence and Noise

Martina Scolamiero

Abstract

Multidimensional persistence is a method in topological data analysis which allows to compare various measurements on a data set. Within this method a dataset is represented by a functor from the poset of r-tuples of non negative rational numbers to the category of vector spaces. Such functors are well behaved and we call them tame and compact. In this talk I will explain a way of comparing tame and compact functors based on the notion of a noise. This approach is based on the idea that in multidimensional persistence it is possible not only to choose properties of a dataset we want to study, for example by using filter functions, but also what should be neglected. I will also introduce an invariant for tame and compact functors we call the basic barcode. Finally, stability properties of the basic barcode and computational aspects will be addressed. This is a joint work with W. Chachólski, A. Lundman, S. Öberg and R. Ramanujam.

Study material: The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/SCOLAMIERO.pdf`

Short Bio: Martina Scolamiero started a postdoctoral researcher position at École Polytechnique fédéral de Lausanne. Her work is focused on studying psychiatric diseases using topological methods. She received a PhD in Production Systems and Industrial design from Politecnico di Torino. During this period she has been working on applications of computational topology to network theory with emphases on social and managerial networks under the supervision of Prof. F. Vaccarino. Subsequently she earned a Phd in mathematics from the Royal Institute of Technology in Stockholm under the supervision of Prof. W. Chachólski. Her thesis was focused on multidimensional persistence, a method in topological data analysis which allows to study topological properties of data using more than one parameter. Her main research interests are in the field of topological data analysis and in particular generalizations of persistent homology.

Geometric Entropy Revealing Complex Network structures

Domenico Felice

Abstract

A central issue of the science of complex systems is the quantitative characterization of complexity. The talk aimed to address this issue by resorting to information geometry. Actually it was proposed a constructive way to associate to a - in principle any - network a differentiable object (a Riemannian manifold) whose volume is used to define an entropy. The effectiveness of the latter to measure networks complexity is successfully proved through its capability of detecting a classical phase transition in random graphs, as well as of characterizing small Exponential random graphs, Configuration Model and real networks.

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/FELICE.pdf`

Short Bio: Domenico Felice is currently a postdoctoral researcher in Theoretical Physics and Mathematical Models at University of Camerino, School of Science and Technology. In 2007, he received his M. Sc. in Mathematics, specializing in Riemannian Geometry, from University of Pisa. In 2012, he earned his PhD in Mathematics at University of Florence. At University of Camerino, his primary research focus concerns the application of Information Geometry Methods to both classical and quantum complex systems.

Graphical homology

Reza Rezazadegan

Abstract

A goal of topological data analysis is to use topological invariants such as homology to obtain qualitative information about a graph. This graph can represent a network of interacting agents or may be the proximity graph of a dataset. The homology of the clique complex of the graph is arguably the most widely used such invariant.In recent years new homology theories of graphs have emerged such as discrete homology or path homology which are defined in an intrinsic way without constructing a simplicial complex. Graphical homology is an attempt at bringing all these theories under the same roof and develop a framework for defining graph homology theories based on special types of neighborhoods (subgraphs). As an example I present a homology theory based on star shaped subgraphs. Joint work with Christian Reidys.

Study material: The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/REZA.pdf`

Short Bio: Please insert here.

A new Stochastic context-free grammar for topological RNA structures

Fenix Huang

Abstract

We introduce a new context-free grammar (CFG) for the analysis of RNA structures including pseudoknots (pk-structures). RNA structures are considered in a fatgraph model and classified by their topological genus, in particular, secondary structures have exactly genus zero. The grammar considers an arc-labeled RNA secondary structure, called λ-structures, that correspond one-to-one to pk-structures together with additional information, called blueprint, which is about its construction from a secondary structure. The blueprint can be viewed as a specific sequence of transpositions of the backbone by which a pk-structure can be made cross-free. The grammar is then designed as an extension of the classic CFG for secondary structures employing an enhancement by labelings of the symbols as well as the production rules. A stochastic context-free grammar (SCFG) is further developed by assigning probabilities to the production rules. The SCFG allows for fast sampling and analysis on pk-structures based on data-bases of RNA sequences and structures.

Study material: The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/FENIX.pdf`

Short Bio: Fenix Huang received his PhD under the supervision of Professor Christian Reidys at the Center for Combinatorics, Nankai University, China, a Key Laboratory for Pure Mathematics and Combinatorics. After two years of post doc at Institute of mathematics and computer science, University of Southern Denmark (SDU), he is promoted as an assistant professor at the same department, 2014. He is now an research assistant professor at Virginia Bioinformatic Institute (VBI), Virginia Tech, USA. The core theme of his research is the discrete maths and algorithms in the context of pseudoknot RNA structures. He did a lot of work on the framework of algorithms predicting RNA pseudoknot structures as well as RNA-RNA interaction structures based on combinatorial and topological classification. Currently he is working on extracting information from the RNA structures based on a topological model, inverse folding problem, and the topological model of permutations that relates to the reversal and transposition distance problem of genome.

Boons and banes of topological tools: too much or too little information?

Giovanni Petri

Abstract

Over the last decade network theory has emerged as the foremost tool for the understanding of complex systems. This success is due the ability of networks to simplify and capture non-trivial interaction patterns, in terms of pairwise relations. Higher order interaction patterns however remain elusive under this lens. Topological methods for data analysis have recently attracted large attention due to their capacity to capture mesoscopic features which are lost under standard network technique. The talk focused on persistent homology, a technique able to identify robust topological features underlying the structure of high-dimensional data and complex dynamical systems (such as brain dynamics, molecular folding, distributed sensing). In the first part, it was presented a few applications of persistent homology to a variety of datasets, e.g. a urban mobile phone activity dataset, complex weighted networks and brain functional data of patients in different states of consciousness. Finally, it has been showed how the persistent topological features can be summarised in terms of the Laplacian structure of the filtration used to approximate the datasets, and discuss ongoing work regarding temporal datasets and dynamical processes

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/PETRI.pdf`

Short Bio: Giovanni Petri is a Principal Researcher in the "Mathematics of Complex Systems Lab" of ISI Foundation. His research focuses on the development and application of topological methods for complex systems, in particular networks and biological systems, in which he recently obtained promising results on mesoscale structures within functional brain networks. He holds a PhD from Imperial College London, where he worked in the Complexity and Networks group on information and dynamics of traffic networks.

Detecting Causality in Event Data: a Coalgebraic Model

Ugo Montanari

Abstract

Event data are among the most important traces of process behavior, and their observation and analysis is essential in defining the semantics of models of computation. In particular, event causal dependencies form a relational (partial ordering) structure, which reveals key concurrency and non-interference properties. Modern treatment of causality relies on a presheaf coalgebraic model, where processes are indexed with (part of) their past event posets and where the operational semantics may employ various concurrent models, like causal trees or Petri nets. Efficient model checking is possible, thanks to a categorical construction which replaces presheaves with named sets as base category of the coalgebra.

Study material: The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/MONTANARI.pdf`

Short Bio: Ugo Montanari is Emeritus Professor of University of Pisa at the Department of Computer Science. He is presently member of the Editorial or Advisory Boards of the following international scientific journals: Fundamenta Informaticae, Mathematical Structures in Computer Science, New Generation Computing, Theoretical Computer Science, Computer Science Review. He was member of the Boards of Artificial Intelligence, IEEE Transactions on Software Engineering, Logic Programming, Science of Computer Programming and Theory and Practice of Logic Programming. He is presently member of the steering committees of the following international conferences: CALCO, CMCS, CONCUR, ICGT, TGC, WRLA. He was member of the steering committee of CP. His research involves Semantics of Concurrency, Process Description and Object Oriented Languages, Constraint Programming, Graph Rewriting Systems, Coordination Models, Algebraic and Categorical Models of Concurrency, Models and Languages for Open Distributed Systems, Network Aware Programming, Service Oriented Computing. He is the author of about 300 papers in international refereed journals and conference proceedings and three books. He also edited about 20 books and special issues. Pioneering papers in: picture recognition, graphics, graph grammars, heuristically guided search, networks of constraints, algebraic data types, logic unification and true concurrency.

Behavioural Types

Mariangiola Dezani

Abstract

During the 1990s, program semantics, in particular concurrency theory and especially the study of type disciplines for process calculi, has inspired notions of typing that are also able to describe properties associated with the behaviour of programs and in this way also describe how a computation proceeds. The behavioural type of a software component specifies its expected patterns of interaction using expressive type languages, so that types can be used to determine automatically whether the component interacts correctly with other components. The talk presented an overview of behavioural types for calculi modelling sequential and distributed computations.

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/DEZANI.pdf`

Short Bio: Mariangiola Dezani has been full professor of Foundations of Computer Science at the University of Torino since 1981. She is member of the editorial board of Information and Computation and of The Computer Journal, member of the IFIP Working Group 2.2, member of the Academia Europaea. In the 1980s she introduced with other researchers intersection type assignment systems, which were initially used as finitary descriptions of lambda-models. More recently, she studied type systems for communication centred calculi. In 2015 she was named EATCS Fellow.

From Automata Theory to Process Theory

Flavio Corradini

Abstract

This talk presented the solution to an open question posed in 1984 by Robin Milner. It has been introduced how a set of so-called well-behaved finite automata that, modulo bisimulation equivalence, corresponds exactly to the set of regular expressions, and showed how to determine whether a given finite automaton is in this set. As an application, we consider the star height problem. Finally the conjecture that this is the largest language for which bisimulation admits a finite equational axiomatization has been discussed.

Study material: The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/CORRADINI.pdf`

Short Bio: is Full Professor of Computer Science at the University of Camerino. Since November 2011, he is the Rector of the University of Camerino. He has been Prorector of International Research and the Transfer of Knowledge, Skills and Technology (2010-2011), and Director of the Mathematics and Computer Science Department (2006-2009), President of the center for digital services and information systems of the University of Camerino (2004-2010) and Coordinator of the Computer Science Studies of the University of Camerino (2004-2006). He is permanently invited member to the Technical Committee for the "Target Project to Research and Innovation" by National Industries Association (Confindustria). He is member in the tables of assessment at MIUR for the "Future Internet" IT Technology Platform and to set up the Italian perspective in the "Vision of the European Research". He was the co-founder and the President of the spin-off UniCam "e-Lios (e-Linking on line systems)". His main research activities are in the area of formal specification, verification of concurrent, distributed and real-time systems and in the area of e-government and information society.

On the expressiveness of Higher Dimensional Automata

Rob van Glabbeek

Abstract

In this talk I will compare the expressive power of several models of concurrency based on their ability to represent causal dependence. To this end, I translate these models, in behaviour preserving ways, into the model of higher dimensional automata, which is the most expressive model under investigation. In particular, I propose four different translations of Petri nets, corresponding to the four different computational interpretations of nets found in the literature. I also extend various equivalence relations for concurrent systems to higher dimensional automata. These include the history preserving bisimulation, which is the coarsest equivalence that fully respects branching time, causality and their inter- play, as well as the ST-bisimulation, a branching time respecting equivalence that takes causality into account to the extent that it is expressible by actions overlap- ping in time. Through their embeddings in higher dimensional automata, it is now well-defined whether members of different models of concurrency are equivalent.

Study material: The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/VANGLABBEEK_2.pdf`

Short Bio: Rob van Glabbeek has a strong international reputation in the study of the theory of concurrent computation, having made particular contributions to the conciliation of the interleaving and the true concurrency communities by codeveloping the current view of branching time and causality as orthogonal but interacting dimensions of concurrency. He has organised workshops on combining compositionality and concurrency, on logic, language and information, on the Unified Modelling Language, on workflow management, web services and business process modelling, on automatic and semi-automatic system verification, on structural operational semantics, and on formal methods for embedded systems. He is editor-in-chief of Electronic Proceedings in Theoretical Computer Science, a member of the editorial boards of Information and Computation and Theoretical Computer Science, and has been on several dozen program committees.

Topological characterization of complex systems

Matteo Rucco

Abstract

This talk presented a methodology for deriving a model of a complex system by exploiting the information extracted from topological data analysis. Central to the proposed approach is the S[B] paradigm in which a complex system is represented by a two-level model. One level, the structural S one, is derived using the newly-introduced quantitative concept of persistent entropy, and it is described by a persistent entropy automaton. The other level, the behavioral B one, is characterized by a network of interacting computational agents. The presented methodology is applied to a real case study, the idiotypic network of the mammalian immune system.

Study material: The slides of the seminar are available at `http://camerino2015.topdrim.eu/materials/RUCCO.pdf`

Short Bio: Matteo Rucco is currently a PhD candidate in the Computational Science, curricula "Information Science and Complex Systems" organized by the School of Advanced Studies at University of Camerino and supervised by Prof. E. Merelli. He obtained the M.Sc. in Computer Science from the University of Camerino and the B.Sc. in Physics from the University of Salento, Italy. The goal of his research activity is the formalization of a new methodology for modeling the behaviour of complex systems. The methodology is based on the application of topological-based techniques for data analysis, information theory, and automata theory.

Adaptability checking in complex systems

Luca Tesei

Abstract

A hierarchical approach for modelling the adaptability features of complex systems is introduced. It is based on a structural level S, describing the adaptation dynamics of the system, and a behavioural level B accounting for the description of the admissible dynamics of the system. Moreover, a unified system, called S[B], is defined by coupling S and B. The adaptation semantics is such that the S level imposes structural constraints on the B level, which has to adapt whenever it no longer can satisfy them. In this context, we introduce weak and strong adaptability, i.e. the ability of a system to adapt for some evolution paths or for all possible evolutions, respectively. We provide a relational characterisation for these two notions and we show that adaptability checking, i.e. deciding if a system is weakly or strongly adaptable, can be reduced to a CTL model checking problem. We apply the model and the theoretical results to the case study of a motion controller of autonomous transport vehicles.

Study material: Emanuela Merelli, Nicola Paoletti and Luca Tesei, "Adaptability checking in complex systems", Science of Computer Programming Volumes 115116, Pages 2346, 2016.
`http://www.sciencedirect.com/science/article/pii/S0167642315000659`
The slides of the seminar are available at
`http://camerino2015.topdrim.eu/materials/TESEI.pdf`

Short Bio: Luca Tesei took the PhD in Computer Science at the Department of Computer Science of the University of Pisa on 28/04/2004. He was then one-year post-doc at Dipartimento di Scienze dell'Informazione, Alma Mater Studiorum, University of Bologna. From 01/04/2005 he has been Assistant Professor of Computer Science at the School of Science and Technology of the University of Camerino. From 2002 to 2015 Luca Tesei participated to 5 National PRIN research projects, one National FIRB research project and one EU FP7 FET-Open Project. His main research interests are in Formal Methods for the specification and verification of complex systems: automata, timed automata, probabilistic automata, timed non-interference properties, timed and untimed process algebras, model checking. Moreover, he is interested in Systems Biology: modelling of biological systems, emergent behaviours, simulation of biological systems, membrane computing, modelling of ecosystems, modelling using multi-agent systems. Finally, he is active in the field of Abstract Interpretation: static analysis of programming languages, verification of security properties. Luca Tesei is author and peer reviewer of many papers published in proceedings of international workshops/conferences and in international journals in the sector of theoretical computer science.

Topological View of Behavioural Equivalences

Emanuela Merelli

Abstract

This talk discussed how behavioural equivalences, such as traces equivalence, usually encoded in a linear space (typically a vector space) and locally interpreted, can be interpreted in a global topological space. The global view offered by the topology may provide a way for a new interpretation of bisimulation equivalence. Starting from a topological representation of the states and processes involved in pursuing a mathematical framework able to capture the structure and dynamics of information manipulation that was recently developed focused mainly on data, three main ingredients were identified: 1) an information encoding space $\mathbf{P}$ as a topological space in the sense of Groethendieck topology; 2) a fiber bundle $\mathbf{F_b}$ extending the objects in $\mathbf{P}$ and leading to a Gauge group G, finitely presented; 3) a language whose syntax and semantics is fully represented by G. It has been noted that the nature of the objects in $\mathbf{P}$ endows the space naturally with a process algebra.

Study material: Mario Rasetti, Emanuela Merelli. Topological Field Theory of Data: mining data beyond complex networks. Cambridge University Press (March 2016).

Short Bio: Emanuela Merelli, PhD in Artificial Intelligent Systems, is Full Professor of Computer Science at the University of Camerino where she is the responsible of the Doctoral Program in Computer Science and the Coordinator of the FP7-FET Project TOPDRIM (Topology Driven Methods for Complex Systems) and leads the BioShape Laboratory. She has been also the Unit Coordinator of the Italian FIRB Project LITBIO (Laboratory for Interdisciplinary Technologies in Bioinformatics). Her research interests are formal methods and their application to computational biology. Currently, she is collaborating with Mario Rasetti for launching a new program on "topological field theory of data" where her contribution aims to pave the way to synthesize automata as recognizers of data languages by analysisng a topological data space. She published many papers, some of them with interdisciplinary character, in refereed international journals. She has been continuously involved in the organization of interdisciplinary events among which she conceived "From Biology to Concurrency and Back (FBTC)".

Part IV

Participants Contributions

On endofunctors modelling higher-order behaviours

Marco Peresotti

Poster - The abstract of the poster is available at
`http://camerino2015.topdrim.eu/materials/PERESOTTI.pdf`

Hypergraph Algebra for Big Data

Marco Bergami

Poster - The abstract of the poster is available at
`http://camerino2015.topdrim.eu/materials/BERGAMI.pdf`

Homotopic intersection form of a surface and positivity in the mapping class group

Alessandra Renieri

Poster - The abstract of the poster is available at
`http://camerino2015.topdrim.eu/materials/RENIERI.pdf`

Part V

Participants

List of Participants:

Abramsky	Samson	Oxford University	Samson.Abramskycs.Ox.Ac.Uk
Barrett	Christian	Biocomplexity Institute of Virginia Tech	CBarrett@Vbi.Vt.Edu
Belluccini	Sara	Msc - Unicam	Sara.Belluccini@Studenti.Unicam.It
Bergami	Giacomo	PhD - University of Bologna	Giacomo.Bergami@Unibo.it
Binchi	Jacopo	Msc - Unicam	Jacopo.Binchi@Studenti.Unicam.It
Carvalho	João	Royal Technical Institute	Jfpbdc@Kzth.se
Castagnari	Carlo	Msc - Unicam	Carlo.Castagnari@Studenti.Unicam.It
Chazal	Fedric	Inria Saclay	Frederic.Chazal@Inria.Fr
Corradini	Flavio	Unicam	Flavio.Corradini@Unicam.It
Cristalli	Cristina	Research Leader - Loccioni Group	C.Cristalli@Loccioni.com
D'Arienzo	Daniele	PhD - Bocconi University	Daniele.Darienzo@Libero.It
De Angelis	Francesco	Researcher - Unicam	francesco.deangelis@Unicam.It
De Berardinis	Jacopo	Msc - Unicam	Jacopo.Deberardinis@Studenti.Unicam.It
De Nicola	Rocco	IMT Lucca	Rocco.Denicola@Imtlucca.It
Dezani	Mariangiola	Unversity of Torino	Dezani@Di.unito.It
Felice	Domenico	PostDoc - Unicam	Domenico.Felice@Unicam.it
Fenix	Wenda Huang	Assistant Professor - Virginia Tech	Fenixh@Vbi.Vt.Edu
Ferrante	Andrea	Research Leader - Loccioni Group	A.Ferrante@Loccioni.com
Firsov	Denis	PhD - Tallinn University of Technology	Denis@Cs.Ioc.Ee
Forcina	Giorgio	Msc - Unicam	Giorgio.Forcina@Studenti.Unicam.It
Fornari	Fabrizio	PhD - Unicam	Fabrizio.Fornari@Unicam.It
Giuliodori	Paolo	PhD - Unicam	Paolo.Giuliodori@Unicam.It
Guidolin	Andrea	PhD - Unito	Andr.Guidolin@Gmail.Com
Jadanza	Riccardo	PostDoc - Isi Foundation	Riccardo.Jadanza@Isi.It
Jimezer-Romeno	Cristian	PhD - The Open University	Cristian.Jimenez-Romero@open.ac.uk
Johnson	Jeffrey	The Open University	Jeff.Johnson@Open.Ac.Uk
Karumachi	Siddharth	PhD - Unicam	siddharth.karumanchi@gmail.com
Lloyd	Seth	MIT Boston	Slloyd@Mit.Edu
Mamuye	Adane	PhD - Unicam	Adaneletta.Mamuye@Unicam.it
Mancini	Stefano	Unicam	Stefano.Mancini@Unicam.it
Merelli	Emanuela	Unicam	Emanuela.Merelli@Unicam.it
Moerman	Joshua	Radboud University Nijmegen	Moerman@Science.Ru.Nl
Montanari	Ugo	University of Pisa	Ugo@Di.Unipi.It
Morán Peláez	Manuel Eduardo	Msc - Universidad Complutense de Madrid	Edumoran@Ucm.Es
Nazem	Soroosh	PhD - Polito	Soroosh.Nazem@Polito.It
Neves	Renavo	PhD - HASLab and Minho University	Nevrenato@Gmail.Com
Patania	Alice	PhD - ISI Foundation and Polito	Alice.Patania@Isi.It
Peressotti	Marco	PostDoc - UniUd	marco.peressotti@Uniud.It
Petri	Giovanni	ISI Foundation	Giovanni.Petri@Isi.It
Pettini	Marco	Aix-Marseille University	Marco.Pettini@Gmail.Com
Piangerelli	Marco	PhD - Unicam	Marco.Piangerelli@Unicam.It
Piergallini	Riccardo	Unicam	Riccardo.Piergallini@Unicam.It
Pistone	Giovanni	Politecnico di Torino	Giovanni.Pistone@Gmail.Com
Polini	Andrea	Assistant Professor Unicam	Andrea.Polini@Unicam.It
Quadrini	Michela	PhD - Unicam	Michela.Quadrini@Unicam.It
Quax	Rick	PosDoc - Amsterdam University	R.Quax@Uva.Nl
Rasetti	Mario	ISI Foundation	Rasetti@Isi.It
Re	Barbara	Researcher - Unicam	Barbara.Re@Unicam.It
Renieri	Alessandra	PhD - Unicam	Alessandra.Renieri@Unicam.It
Reza	Rezazadegan	Assistant Professor Virginia Tech	Rezareza@Vbi.t.Edu
Riihimäki	Cheers	PhD - Tampere University of Technology	Henri.Riihimaki@Tut.Fi
Rilli	Samuele	PhD - Unicam	Samuele.Rilli@Unicam.It
Rossi	Lorenzo	Msc - Unicam	Lorenzo.Rossi@Studenti.Unicam.it
Rucco	Matteo	PhD - Unicam	Matteo.Rucco@Unicam.It
Scolamiero	Martina	PosDoc - École Polytechnique de Lausanne	Martina.Scolamiero@Gmail.Com
Silva	Alexandra	University College London	Alexandra.Silva@Ucl.Ac.Uk
Tesei	Luca	Assistant Professor - Unicam	Luca.Tesei@Unicam.It
Tiezzi	Francesco	Unicam	Francesco.Tiezzi@Unicam.It
Toller	Daniele	PostDoc - Unicam	Daniele.Toller@Unicam.It
Vaccarino	Francesco	Polito and ISI Foundation	Francesco.Vaccarino@Polito.It
Van Glabbeek	Robert	Stanford University	Robert.vanGlabbeek@Nicta.Com.Au
Varava	Anastasiia	PhD - the Royal Institute of Technology	Varava@Kth.Se

Workshop Program

	Saturday 18 July	Wednesday 22 July
9:00 - 9:50	*Quantum Algorithm for topological and geometric analysis of big data* ***Seth Lloyd, Keynote Speaker***	*Respecting Safety and Liveness Properties of Concurrent Systems* ***Van Glabbeek, Invited speaker***
9:50- 10:40	*Topological Field Theory of Data* ***Mario Rasetti, Keynote Speaker***	*Information Geometry and Algebraic Statistics on a finite state space* ***Giovanni Pistone, Invited Speaker***
	Coffee Break	***Coffee Break***
11:00- 11:50	*Non-locality and Contextuality* ***Samson Abramsky, Keynote Speaker***	*Multidimensional Persistence and Noise* ***Martina Scolamiero, Invited Speaker***
11:50- 12:25	*Proximity Spaces and Shapes* ***Riccardo Piergallini, Invited Speaker***	*Geometric Entropy Revealing Complex Network structures* ***Domenico Felice, TOPDRIM Speaker***
12:25-	*Open Discussion*	*Open Discussion*
	Lunch	***Lunch***
15:00- 15:30	*Getting to topology for RNA* ***Chris Barrett, Invited Speaker***	*Graphical homology* ***Reza Rezazadegan, TOPDRIM Speaker***
15:30- 16:00	*Topology and Algebra of Multilevel Systems* ***Jeffret Johnson, TOPDRIM Speaker***	*A new Stochastic context-free grammar for topological RNA structures* ***Fenix Huang, TOPDRIM Speaker***
	Coffee Break	***Coffee Break***
16:15- 16:45	*Topological electrodynamical interactions among biomolecules* ***Marco Pettini, TOPDRIM Speaker***	*Boons and banes of topological tools: too much or too little information?* ***Giovanni Petri, TOPDRIM Speaker***
16:45- 17:15	***Discussion***	*Topological characterization of complex systems* ***Mattero Rucco, TOPDRIM Speaker***
17:15- 17:45		*Adaptability checking in complex systems* ***Luca Tesei, TOPDRIM Speaker***
17:45	***Closing***	***Closing***

School Program

	I Week				II Week		
	Monday 13th	Tuesday 14th	Wednesday 15th	Thursday 16th	Friday 17th	Monday 20th	Tuesday 21st
9:00-9:45	Algebraic and Computational Topology for Data Analytics **Francesco Vaccarino**	Topology and Geometry of Data Analysis **Frederic Chazal**	Advanced Applied Topology **Frederic Chazal**	Introduction to Process Algebras and SOS **Rocco De Nicola**	Behavioural Equivalences **Rocco De Nicola**		
10:00-10:45			Information Geometry **Stefano Mancini**				Information Processing during Tipping Point **Rick Quax**
Coffe Break							
11:15-12:00	Topology and Geometry of Data Analysis **Frederic Chazal**	Categorial Underpinning of Computation **Samson Abramsky**	Coinduction for Automata **Alexandra Silva**	Categorial Underpinning of Computation **Samson Abramsky**	Categorial Underpinning of Computation **Samson Abramsky**	HDA and Other Models of Concurrency **Rob Van Glabbeek**	Behavioral Equivalences and Preorders **Rob Van Glabbeek**
12:15-13:00							A Topological view of behavioural equivalences **Emanuela Merelli**
Lunch							
15:00-15:45	Formal Languages and Equivalences **Alexandra Silva**	Formal Languages and Equivalences **Alexandra Silva**	Behavioural modelling **Rob Van Glabbeek**	Behavioural Types **Mariangiola Dezani**	From automata theory to process theory **Flavio Corradini**	Information Processing during Tipping Point **Rick Quax**	Poster Session 10 minutes talk
16:00-16:45			Detecting Causality in Event Data: a Coalgebraic Model **Ugo Montanari**	HDA and CHU space **Rob Van Glabbeek**	Tourist tour		
17:00-19:00	**Free Lab**	**Free Lab**	**Free Lab**	**Free Lab**	**Free Lab**	**Free Lab**	**Free Lab**


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