UNIVERSITÀ DI TRENTO

PhD in Mathematics – Cycle 36
Research topics 2020

Bando 2020/Call 2020

Dipartimenti di Eccellenza/Departments of Excellence

Assegni di ricerca/Fellowship

A	Network inference for high-dimensional count data
B	Quaternionic and Clifford analysis and its applications
C	Geometric Analysis
D	Multilinear algebra for tensor decomposition

Fondazione Bruno Kessler - FBK

Borsa di studio/ Scholarship

E	Computational modeling of infectious diseases

TIM - TELSY

Borsa di studio/ Scholarship

F	Multi party Computation (MPC)

Assegno di ricerca/Fellowship A

Topic: **Network inference for high-dimensional count data**

P.I.: **Veronica Vinciotti**

Contacts: **veronica.vinciotti@unitn.it**

Synthetic description of the activity and expected research outcome

Graphical modelling approaches allow to infer the network of dependencies between a set of variables. In recent years, advanced computational approaches have been proposed for inference on high dimensional data, both in a frequentist and Bayesian paradigm. Most of these methods rely on an underlying assumption of Gaussianity. This project will focus on novel Copula graphical modelling approaches for high dimensional count data, with a focus on both methodological and computational aspects. In the applied context, these methods will take inspiration from the inference of biological networks from single cell genomic data. To this aim, specific bespoke extensions may be considered, such as accounting for zero inflation, different biological conditions and dynamic effects.

References

[1] L. Augugliaro, A. Abbruzzo and V. Vinciotti (2020) L1 penalized censored Gaussian graphical model. Biostatistics.

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[2] E. Tosetti and V. Vinciotti (2019) A computationally efficient correlated mixed probit model for credit risk inference. Journal of the Royal Statistical Society: Series C, 68, 4, 1183-1204.

[3] A. Peluso, V. Vinciotti and K. Yu (2019) Discrete Weibull generalised additive model: an application to count fertility data. Journal of the Royal Statistical Society: Series C, 68, 3, 565-583.

Ideal candidate (skills and competencies)

The ideal candidate is a student with a Master's degree (or similar) in mathematics, statistics, physics or computer science with excellent mathematical background and strong knowledge in probability and statistics. Good computer skills, such as knowledge of computer languages are a plus. Fluent English or Italian is compulsory.

Assegno di ricerca/Fellowship B

Topic: **Quaternionic and Clifford analysis and its applications**

P.I.: **Riccardo Ghiloni , Alessandro Perotti**

Contacts**:** alessandro.perotti@unitn.it

Synthetic description of the activity and expected research outcome

The activity of the PhD student will concern theoretical aspects of complex, quaternionic and Clifford Analysis, with particular interest towards methods of Functional Analysis that are part of the mathematical foundations of Quantum Mechanics. The selected candidate will collaborate with other PhD students and researchers on related topics.

References

[1] R. Ghiloni and A. Perotti. Slice regular functions on real alternative algebras. Adv. Math., 226(2):1662–1691, 2011.

[2] R. Ghiloni, V. Moretti, and A. Perotti. Continuous slice functional calculus in quaternionic Hilbert spaces. Rev. Math. Phys., 25(4):1350006, 83, 2013.

[3] R. Ghiloni, V. Moretti, and A. Perotti. Spectral representations of normal operators in quaternionic Hilbert spaces via intertwining quaternionic PVMs. Rev. Math. Phys., 29(10):1750034, 73, 2017.

[4] A. Perotti. Slice regularity and harmonicity on Clifford algebras. In Topics in Clifford Analysis – A Special Volume in Honor of Wolfgang Sproessig, Trends in Mathematics. Springer, 2019.

Ideal candidate (skills and competencies)

The ideal candidate should have obtained a Master degree in Mathematics, with a good basic theoretical formation in Mathematical Analysis of real and complex variables and in Geometry. Some knowledge in linear functional analysis in Hilbert spaces is a plus, not strictly necessary.

Assegno di ricerca/Fellowship C

Topic: **Geometric Analysis**

P.I.: **Lorenzo Mazzieri**

Contacts**:** lorenzo.mazzieri@unitn.it

Synthetic description of the activity and expected research outcome

The fellowship is meant for candidates with a solid background in Analysis and Geometry, and will be devoted to the study of the geometric aspects of elliptic partial differential equations, with special attention to methods and techniques coming from Riemannian geometry. The main focus will be on the following two aspects:

1) Extensions of the range of applicability of the present techniques, possibly with the introduction of new methods.
2) Applications to the study of the qualitative properties and to the classification of solutions to overdetermined elliptic boundary value problems arising in the field of shape optimization, in mathematical relativity (static metrics), and in the study of geometric flows (self-similar solutions).

References

[1] V. Agostiniani and L. Mazzieri. Riemannian aspects of potential theory. J. Math. Pures Appl. (9), 104(3):561–586, 2015.
[2] V. Agostiniani and L. Mazzieri. On the Geometry of the Level Sets of Bounded Static Potentials. Comm. Math. Phys., 355(1):261–301, 2017.
[3] V. Agostiniani and L. Mazzieri. Monotonicity formulas in potential theory. 2016. ArXiv Preprint Server https://arxiv.org/abs/1606.02489.
[4] L. Ambrozio. On static three-manifolds with positive scalar curvature. 2015. ArXiv Preprint Server https://arxiv.org/abs/1503.03803.
[5] S. Borghini and L. Mazzieri. On the mass of static metrics with positive cosmological constant-I. 2017. ArXiv Preprint Server https://arxiv.org/abs/1710.10990.
[6] T. H. Colding. New monotonicity formulas for Ricci curvature and applications. I. Acta Mathematica, 209(2):229–263, 2012.
[7] T. H. Colding and W. P. Minicozzi. Monotonicity and its analytic and geometric implications. Proceedings of the National Academy of Sciences, 110(48):19233–19236, 2013.
[8] T. H. Colding and W. P. Minicozzi. Ricci curvature and monotonicity for harmonic functions. Calculus of Variations and Partial Differential Equations, 49(3):1045–1059, 2014.
[9] G. Crasta, I. Fragala`, and F. Gazzola. On a long-standing conjecture by P´olya-Szeg˙o and related topics. Z. Angew. Math. Phys., 56(5):763–782, 2005
[10] Farina, L. Mari, and E. Valdinoci. Splitting theorems, symmetry results and overdetermined problems for Riemannian manifolds. Comm. Partial Differential Equations, 38(10):1818–1862, 2013.
[11] G. Huisken and T. Ilmanen. The inverse mean curvature flow and the Riemannian Penrose inequality. J. Differential Geom., 59(3):353–437, 2001.

Ideal candidate (skills and competencies)
The ideal candidate should have obtained a Master degree in Mathematics, or in another scientific field (Physics, Engineering...) but with a solid mathematical background, especially in the area of differential equations, and a strong interest in modelling applied problems. A good knowledge of probability and statistics, and experience in scientific programming are a plus.

Assegno di ricerca/Fellowship D

Topic: **Multilinear algebra for tensor decomposition**

P.I.: **Edoardo Ballico, Alessandra Bernardi**

Contacts**:** edoardo.ballico@unitn.it; alessandra.bernardi@unitn.it

Synthetic description of the activity and expected research outcome:
The problem of the decomposition of structured tensors is currently of the highest interest in many areas of research both in terms of pure mathematics and for applications. For example, in phylogenetics, computational complexity, signal processing for telecommunications, the problem of the complexity of P vs NP, the study entanglement in quantum physics.
The geometric point of view on the tensors allows to insert the questions coming from the various areas of applied research in a wide-ranging mathematical context. It allows to interpret results in terms of multilinear algebra, commutative algebra and algebraic geometry. Between the most effective and commonly used geometric methods are techniques such as apolarity and secant varieties.
The background required to the student who intends to deal with these arguments is rather modest because the knowledge of linear algebra already allows already to tackle research topics related to very advanced problems in tensor decomposition. Some familiarity with commutative algebra, classical algebraic geometry are desirable but not mandatory.

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References

[1] Four Lectures on Secant Varieties, Enrico Carlini, Nathan Grieve, Luke Oeding. Connections Between Algebra, Combinatorics, and Geometry pp 101-146

[2] Joins and secant varieties, Chris Peterson and Hirotachi Abo
Note.This script is also available at: http://www.math.colostate.edu/~abo/Research/smi/smi-algebraic-geometry.html

Ideal candidate (skills and competencies)
The background required to the student who intends to deal with these arguments is rather modest because the knowledge of linear algebra already allows already to tackle research topics related to very advanced problems in tensor decomposition. Some familiarity with commutative algebra and classical algebraic geometry are desirable but not mandatory.
- Excellent knowledge of linear algebra; (preferably) some background in commutative algebra and algebraic geometry.
- Good computer skills
- Fluent English

Borsa di studio/ scholarship E

Topic: **Computational modeling of infectious diseases**

P.I.: **Andrea Pugliese**

Contacts: **andrea.pugliese@unitn.it**

Synthetic description of the activity and expected research outcome
Research activity conducted during the Ph.D. will focus on the development of computational tools aimed at providing insight into factors influencing the spatio-temporal spread of infectious disease in humans and reliable estimates of the expected impact of public health interventions. Envisioned approaches range from the study of mechanistic models mimicking the transmission processes underlying outbreak, epidemic, and pandemic situations to the use of statistical inference applied to epidemiological data.

References

[1] Ferguson NM, Cummings DA, Fraser C, Cajka JC, Cooley PC, Burke DS. Strategies for mitigating an influenza pandemic. Nature. 2006 Jul;442(7101):448-52.

[2] Cauchemez S, Donnelly CA, Reed C, Ghani AC, Fraser C, Kent CK, Finelli L, Ferguson NM. Household transmission of 2009 pandemic influenza A (H1N1) virus in the United States. New England Journal of Medicine. 2009 Dec 31;361(27):2619-27.

[3] Li S, Ma C, Hao L, Su Q, An Z, Ma F, Xie S, Xu A, Zhang Y, Ding Z, Li H. Demographic transition and the dynamics of measles in six provinces in China: A modeling study. PLoS medicine. 2017 Apr;14(4).

[4] Zhang Q, Sun K, Chinazzi M, y Piontti AP, Dean NE, Rojas DP, Merler S, Mistry D, Poletti P, Rossi L, Bray M. Spread of Zika virus in the Americas. Proceedings of the National Academy of Sciences. 2017 May 30;114(22):E4334-43

[5] Chinazzi M, Davis JT, Ajelli M, Gioannini C, Litvinova M, Merler S, y Piontti AP, Mu K, Rossi L, Sun K, Viboud C. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. Science. 2020 Mar 6.

[6] Marziano V, Trentini F, Poletti P, Ajelli M, Melegaro A, Merler S. Parental and Mandatory School Entry Vaccination to Reduce Measles Immunity Gaps in Italy: A Modelling Study. Available at SSRN 3299138. 2018 Aug 12.

Ideal candidate (skills and competencies)
Ideal candidates will have a degree in applied mathematics or related areas, some experience in mathematical modelling, and scientific programming; a good knowledge of basic statistical methods.

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Borsa di studio/ scholarship F

Topic: Multi party Computation (MPC)
P.I.: **Massimiliano Sala**
Contacts: massimiliano.sala@unitn.it
Synthetic description of the activity and expected research outcome Secure Multi-Party Computation (MPC) is a cryptographic technique that allows two or more parties to jointly calculate the result of a function while keeping the input values private, even without a relationship of mutual trust between the parties or relying a "trusted third party". The project is focused on the theoretical analysis and practical applications of secure MPC, identifying and developing efficient techniques according to different application scenarios. Special focus will be given to IoT applications on the 5G infrastructure and on the privacy in Big Data scenarios. A further objective of the project is the integration of secure MPC technology with blockchain solutions. The project will be developed in collaboration with Telsy cryptographers.
References *[1] Yao, A. C.-C. 1982. Protocols for Secure Computations (Extended Abstract), 23rd Annual Symposium on Foundations of Computer Science. IEEE Computer Society Press.* *[2] R. Canetti, Y. Lindell, R. Ostrovsky and A. Sahai. Universally Composable Two-Party and Multi-Party Computation. 34th STOC, 2002.* *[3] I. Damgard and J. Nielsen, Scalable and Unconditionally Secure Multiparty Computation, CRYPTO 2007.* *[4] D. Beaver. Efficient Multiparty Protocols using Circuit Randomisation. CRYPTO 2012.* *[5] I. Damgard, V. Pastro, N. P. Smart, and S. Zakarias. Multiparty computation from somewhat homomorphic encryption, CRYPTO 2012.*
Ideal candidate (skills and competencies) The ideal candidate should have a Master Degree in Mathematics with strong background in cryptography, both theoretical and practical. Good programming skills are also required.