Faculty of Science and Engineering

Profile report: Topological Data Analysis /Stochastic Geometry and Topology / Statistical Data Analysis

- Discipline: Mathematics
- Level: tenure-track Assistant professor/Associate professor/Full professor
- Fte: Full time (1.0)

1. Scientific discipline
Stochastic Geometry (SG), the study of random point objects, finds a fast growing number of applications in for example Astronomy, Random Heterogeneous Materials, Random Graphs and Wireless Networks, and more. Topological Data Analysis (TDA) refers to a collection of methods for extracting and analysing shape from data, based on techniques from computational topology. It complements and extends inference methods from Data Science (DS), such as Machine Learning, Statistics, and Visual Analytics.

2. Vacancy
This position is opened by the Board of the Faculty of Science and Engineering FSE (PT/gl/21/00625) as part of the Center "Groningen Cognitive Systems and Materials" (CogniGron), which aims to develop systems and materials for cognitive computing. The position will be embedded in the Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence and falls within the framework of 'Career Paths in Science 4' ('Bèta's in Banen 4'). Please see link for criteria and conditions. (An update is expected in early 2022.)

3. Selection committee (BAC)

Prof. dr. N.A. Taatgen	Scientific director Bernoulli Institute and Professor, Cognitive Modeling
Prof. dr. ir. R.W.C.P. Verstappen	Program director Mathematics & Applied Mathematics; Professor, Computational Science
Prof.dr. B. Noheda	Director CogniGron; Professor, Nanostructures of Functional Oxides
Prof.dr. T. Müller	Professor, Combinatorics and Probability
Prof. dr. M.A. Grzegorczyk	Associate Professor Computational Statisticss
M.J. (Marit) Onstwedder	Student member
Dr. W.M. (Wioletta) Ruszel	Assistant Professor Stochastics, University of Utrecht

Advisors:

Prof.dr. J. Top	Department head of Mathematics;
	Professor, Number Theory & Algebraic Geometry
Dr. P. Trapman	Associate Professor, Probability Theory
Dr. J. H. M. van der Velde	Scientific Coordinator Groningen Cognitive Systems and
	Materials and secretary of the selection committee

HR advisor:
N.F. Clemencia-Lokai

4. Research Area

A position in the interface of Stochastic Geometry (SG), Topological Data Analysis (TDA) and Data Science (DS) is in the interdisciplinary area of the mathematics of random networks, point patterns, data analysis and data science. This position is of great importance towards strengthening connections between Mathematics and Materials Science within CogniGron. CogniGron is a unique research center, where researchers from materials science, physics, chemistry, mathematics, computer science and artificial intelligence work together to create self-learning materials that will perform the tasks that are now assigned to thousands of transistors and complex algorithms.

Recent advances in (computational) stochastic geometry and topology have made it possible to actually compute topological and other invariants from data. The aim is to reconstruct properties including the topological features of some low-dimensional set, only observed via a high-dimensional noisy point cloud. SG- and TDA-techniques relate to well-known approaches in Data Science (in particular Machine Learning, Statistics, Data Analytics and Visual Analytics), including clustering, feature extraction, manifold learning, nonlinear dimension reduction, multidimensional projections, information geometry, and distinguishing a (topological) signal from (topological) noise.

Other topics of interest are the analysis of data sets using techniques from topology and geometry; and large-scale data science for analyzing very large and complex data sets.

During the last decade, the research field found applications in a wide range of scientific disciplines including Materials Science, Cosmology, Dynamics of Networks, Epidemic Models, Medical Imaging, Computational Physics and Chemistry.

5. Embedding: institute (and base unit)

The position will be embedded in the research unit Probability and Statistics of the mathematics department of the Bernoulli Institute. If a full professor is selected and appointed, the candidate may also be offered to establish and lead a new research unit within the Bernoulli Institute. The position will play a crucial role within the Center "Groningen Cognitive Systems and Materials" (CogniGron).

The Groningen Cognitive Systems and Materials Center is a joint venture between FSE-institutes Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence, and the Zernike Institute for Advanced Materials. It comprises researchers from materials science, physics, chemistry, mathematics, computer science and artificial intelligence. The center provides structure, coherence, and visibility for a joint research program in the direction of cognitive systems and materials. The main goal of the Groningen Cognitive Systems and Materials Center is to create self-learning materials that will perform the tasks that are now assigned to thousands of transistors and complex algorithms in a more efficient and straightforward manner, hence, forming the basis for a new generation of computer platforms for cognitive applications, such as pattern recognition and analysis of complex data.

The Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence is part of the Faculty of Science and Engineering (FSE). The profile of the institute centers around modelling, computation, and cognition with a focus on science and technology, keeping a balanced mix of fundamental and applied aspects. The Bernoulli Institute comprises five mathematics programmes, six computer science programmes, and four artificial intelligence programmes. Each of these programmes contributes to one or more of the three research themes of the Bernoulli Institute: Computing & Cognition, Geometry and its Applications, Systems, Data and Society. The constituting programmes participate in various national research schools and most of the PhD students are enrolled in an educational programme and take part in other activities offered by these schools.

6. Local and (inter)national position

Locally, research on Stochastic Geometry and Topological Data Analysis (with applications to, as well as inspiration from Data Science) is embedded mostly in the Statistics & Probability programme of Mathematics, with connections to the programme Dynamical Systems, Geometry & Mathematical Physics (Mathematics) as well as to Scientific Visualization & Computer Graphics (Computer Science). Within the Netherlands there are many initiatives in Data Science. An approach via one of the fields Stochastic Geometry or specifically Topological Data Analysis offers a unique opportunity to establish a leading role in SG-DS or TDA-DS for CogniGron and the Bernoulli Institute within the Netherlands. Through its natural and prominent role in the Institute's research theme Systems, Data and Society as well as Geometry and its Applications, the position provides a great opportunity for further strengthening the cohesion within CogniGron and the Bernoulli Institute.

Internationally, there is an increasing number of research teams working on SG-DS and TDA-DS, both on the theoretical and algorithmic underpinnings and on its applications in Astronomy, Materials Science, Machine Learning, and Medical Image Processing, and other areas.

The Center for Data Science & Systems Complexity (DSSC) of the Faculty of Science & Engineering offers a natural environment for research in the field of SG-DS and TDA-

DS, in which also several scientists from the Kapteyn Astronomical Institute and the Engineering and Technology institute Groningen (ENTEG) are involved as co-supervisors of joint PhD projects.

The mathematics programmes within the Bernoulli Institute participate in the Dutch mathematics Research Schools for Fluid Mechanics (J.M. Burgerscentrum) and the National Graduate School for Systems and Control (DISC), as well as in the national master's and graduate courses programme Mastermath. They actively participate in each of the four NWO research clusters "Discrete, Interactive and Algorithmic Mathematics, Algebra and Number Theory" (DIAMANT), "Geometry and Quantum Theory" (GQT), "Nonlinear Dynamics of Natural Systems" (NDNS+) and "Stochastics – Theoretical and Applied Research" (STAR). The Bernoulli Institute also cooperates at the national level with the Data Science Center Eindhoven (DSC/e), the Data Science Institute of Philips Research, and IBM, and several institutes involved in data science (Astron, TNO, NLR, SARA, ECN, CWI).

The Bernoulli Institute and CogniGron has a strong (inter)national position, shown for example by regular publications in top journals and conferences, participation in NWO and EU projects, memberships of editorial boards, boards of mathematical societies, and international conference committees and chairing.

7. Expected contributions to research

The candidate is expected to initiate and develop an internationally leading research programme in at least one of the interdisciplinary fields Stochastic Geometry or Topological Data Analysis, in each case with strong connections to Data Science. The research should have a visibility on the national and worldwide level and lead to publications in top journals. The new professor will take a leading role in the field of Mathematics within the Netherlands. Obtaining substantial external funding for PhD projects is crucial. Supervision of PhD students is an important part of the research activities. The research is expected to strengthen the existing efforts in the field of Mathematics within the Bernoulli Institute and the Groningen Cognitive Systems and Materials center, and should lead to a further strengthening of the international reputation of the research programme, the field, and the institute.

8. Expected contributions to teaching

The candidate is expected to contribute to the teaching programmes in the bachelor and master degree programs of the Faculty of Science and Engineering. She/he is expected to participate in the teaching programme of specialized courses in relation to Stochastic Geometry, Topological Data Analysis and Data Science, and other related topics, e.g., Discrete Mathematics, Metric Spaces, Statistics, Geometry, Machine Learning, Visual Analytics. Furthermore, the candidate will be involved in supervising bachelor, master and PhD students. Upon appointment, depending on experience and formal qualifications to date, the candidate may be required to enter a nationally standardized tertiary teaching skills certification trajectory (University Teaching

Qualification UTQ), successful completion of which is a condition for extensions and tenure.

9. Expected contributions to the organization
The candidate is expected to have an active interest and to provide a positive contribution to the management and organizational tasks of the institute. At the level of the FSE, the candidate will contribute to the organization of the faculty, for example by participating in working groups and committees, in the fields of teaching, research and management. The candidate will participate in relevant national and international organizations.