

## Faculty of Science and Engineering

**Profile report:** Topological Data Analysis and Data Science (Topologische Data-analyse en Data-Wetenschap)

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

### 1. Scientific discipline

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 (PT/dja/18/00153) as part of the new Center “Groningen Cognitive Systems and Materials”, which aims to develop systems and materials for cognitive computing. The position will be embedded in the Bernoulli Institute and falls within the framework of ‘Career Paths in Science 3’ (‘Bèta’s in Banen 3’). Please see link for [criteria and conditions](#).

### 3. Selection committee (BAC)

Prof.dr. J.B.T.M. Roerdink	Scientific director Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence (Chair), and professor Scientific Visualization and Computer Graphics
Prof.dr. B. Noheda	Director Groningen Cognitive Systems and Materials and Professor Nanostructures of Functional Oxides
Prof.dr. A. Telea	Program director bachelor Computing Science and professor Visual Analytics
Prof.dr. G. Vegter	Professor Geometry
Prof.dr. D. Karastoyanova	Professor Information Systems
M. Karlsen	Student member
Prof.dr. A.W. van der Vaart	Professor Stochastics, Leiden University

#### *Advisors:*

Prof.dr. T. Müller	Professor Combinatorics and Probability
Prof.dr. M. Biehl	Professor Machine Learning
Prof.dr. L.R.B. Schomaker	Professor Artificial Intelligence
Prof.dr.ir. C.H. van der Wal	Scientific director Zernike Institute for Advanced Materials and professor Nanostructures of Functional Oxides

Dr. J.H.M. van der Velde

Scientific Coordinator Groningen Cognitive  
Systems and Materials and secretary of the  
selection committee

*HR advisor:*

L.A. Boomsma

#### **4. Research area**

A position in the area of Topological Data Analysis (TDA) and Data Science (jointly referred to as TDA-DS) is in the interdisciplinary area of the mathematics of data analysis and data science. This position will be of great importance to strengthening connections between Mathematics, Computer Science, Artificial Intelligence and Materials Science.

Recent advances in computational topology have made it possible to actually compute topological invariants from data. Its aim is to reconstruct computationally the topological features of some low-dimensional set, only observed via a high-dimensional noisy point cloud. 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 (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, TDA-DS has found applications in a wide range of scientific disciplines, like Materials Science, Cosmology, Dynamics of Networks, Medical Imaging, Computational Physics and Chemistry.

#### **5. Embedding: institute (and base unit)**

The position will be embedded in one of the existing research units of the mathematics or computer science departments of the Bernoulli Institute, depending on the actual area of the selected candidate. If a full professor is selected and appointed, the candidate may also be offered to establish and lead a new research unit on Topological Data Analysis and Data Science 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. 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. The Bernoulli Institute aims to strengthen the current research portfolio in Mathematics, Computer Science and Artificial Intelligence by expanding both in fundamental areas that have a prominent role in education as well as in directions that are essential for new technological and societal developments.

## **6. Local and (inter)national position**

Locally, research on Topological Data Analysis and Data Science is embedded in several research lines in Mathematics (in particular, Computational Geometry & Topology, Dynamical Systems and Statistics & Probability), and in several research lines in Computer Science (in particular, Intelligent Systems and Visual Analytics). Within the Netherlands there are many initiatives in Data Science, but hardly any experts in the emerging field of Topological Data Analysis. Therefore, this position offers a unique opportunity to establish a leading role in TDA-DS for the Bernoulli Institute within the Netherlands.

Internationally, there is an increasing number of research teams working on TDA-DS, both on the theoretical and algorithmic underpinnings and on its applications in, e.g., Astronomy, Materials Science, Machine Learning, and Medical Image Processing. The Center for Data Science & Systems Complexity of the Faculty of Science & Engineering offers a natural environment for research in the field of 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.

At the national level the Bernoulli Institute participates in the Dutch mathematics Research Schools for Fluid Mechanics (J.M. Burgerscentrum) and the National Graduate School for Systems and Control (DISC). In Computer Science it participates in the Dutch Research School in Programming and Algorithmics (IPA), the Advanced School for Computing and Imaging (ASCI), the School for Information and Knowledge Systems (SIKS), and the Dutch Research School in Logic (OZSL). It is also involved in the 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) and in the national research school WONDER. 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).

Locally the Systems, Control and Applied Analysis research unit is part of the Jan C. Willems Center for Systems and Control, that furthermore consists of the control engineers in the Engineering institute ENTEG.

The Bernoulli Institute has a strong (inter)national position in mathematics and computer science, shown by regular publications in top journals and conferences, participation in NWO and EU projects, editorial board memberships of editorial boards (e.g. EJC, *Indagationes Mathematicae*, *J Stat Phys*, *IEEE TVCG*, *IEEE TPAMI*), boards of mathematical societies (e.g. IBS, Bernoulli) and conference committees and chairing (e.g. MTNS 2014, IWSM 2017, EuroVis 2016). Mathematics research in Groningen is strongly focused on mathematical systems, in particular, Nonlinear Dynamical Systems, Mathematical Physics and Systems & Control. In Computer Science, the Bernoulli Institute takes part in several international data-science-centered EU research projects (Human Brain Project, Remote Tower), and has cooperation and (under)graduate exchange programmes with many universities (e.g., Sao Paulo, Rio Grande do Sul, UniSap Rome, Birmingham, ENAC/Toulouse, Tampere).

## **7. Expected contributions to research**

The candidate is expected to initiate and develop an internationally leading research programme in the interdisciplinary field of Topological Data Analysis and Data Science. The research should have a visibility on the national and worldwide level and lead to publications in top journals. Further it is expected, that the new professor will take a leading role in the field of Mathematics / Computer Science 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 fields of Mathematics and Computer Science within the Bernoulli Institute and the Groningen Cognitive Systems and Materials center, and should lead to a strengthening of the international reputation of the group, the research center 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 within the Undergraduate and Graduate Schools of Science and Engineering. She/he is expected to participate in the teaching programme of specialized courses in relation to Topological Data Analysis and Data Science, and other related topics, e.g., Discrete Structures, 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 (BKO or Basis Kwalificatie Onderwijs), 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.