EUROPEAN MECHANICS SOCIETY

Colloquium n. 657 – Recent advances in non-smooth dynamics

Dates and location

8 December — 10 December 2025, Exeter, UK

Chairperson

Yang Liu

Co-chairperson

Aasifa Rounak, Petri Piiroinen, and Piotr Kowalczyk

Conference fees

- Registration fee regular: **300.00 €**

What other funding was obtained?

None

What were the participants offered?

8 coffee breaks, two lunches, and one gala dinner

Applicants (members)

1. Olivier Bruls
2. Meiyazhagan Jaganathan

Applicants (non members)

1. Viktor Avrutin
2. Dinesh Bandi
3. Kaidong Chen
4. Joseph Cusumano
5. Enora Denimal Goy
6. Volodymyr Denysenko
7. Chiara Gastaldi
8. Indranil Ghosh
9. Majdi Gzal
10. Seigan Hayashi
11. Mike Jeffrey
12. Kamil Khan
13. Huda Mahdi
14. Ekaterina Pavlovskaia
15. Petri Piiroinen
16. Loic Salles
17. Christoph Schwingshackl
18. Baiyang Shi
19. Rahil Valani
20. Tobias Weidemann

Scientific report

Background

Non-smooth dynamical systems arise naturally in a wide range of physical, engineering, biological, and socio-technical systems, where discontinuities, impacts, friction, switching, saturation, and threshold effects play a fundamental role. Such phenomena are ubiquitous in applications including mechanical systems with impacts or frictional contacts, power electronics, control and hybrid systems, structural dynamics, robotics, biomechanics, neuroscience, and increasingly in data-driven and machine-

learning-based models. While non-smooth formulations provide faithful representations of these systems, they pose deep theoretical, computational, and experimental challenges, particularly with respect to bifurcation analysis, numerical simulation, model reduction, identification, and control.

The EUROMECH Colloquium 657 aimed to bring together leading researchers and early-career scientists working on theoretical, numerical, experimental, and data-driven aspects of non-smooth dynamics, fostering cross-fertilisation between mathematics, mechanics, engineering, and applied sciences. A particular emphasis was placed on discontinuity-induced bifurcations, Filippov systems, piecewise-smooth maps and flows, vibro-impact systems, non-smooth control, and emerging links with machine learning, robotics, and biomechanics.

The colloquium was held over 2.5 days at the University of Exeter and hosted by the Exeter Small-Scale Robotics Laboratory. The programme included 9 keynote lectures and 42 invited and contributed talks, complemented by structured discussion sessions and informal scientific exchanges during coffee breaks, lunches, and social events. In total, the meeting featured more than 51 presentations delivered by internationally recognised experts and early-career researchers from 13 countries.

A defining feature of the meeting was the strong integration of fundamental theory, computational methods, and applications, highlighting both long-standing challenges and new research directions in non-smooth dynamics.

Scientific Themes and Topics

The presentations and discussions covered a broad spectrum of topics, including but not limited to the following themes:

Discontinuity-Induced and Grazing Bifurcations

Several keynote and contributed talks addressed the theory and applications of discontinuity-induced bifurcations, including grazing, border-collision, and impact-related bifurcations. New insights were presented on the subtle role of grazing events in mechanical systems, demonstrating how apparently benign non-smooth interactions can trigger complex transitions to chaos, sensitivity amplification, and loss of robustness. Analytical, numerical, and geometric perspectives were discussed, with emphasis on both local and global bifurcation structures.

Piecewise-Smooth and Filippov Systems

Filippov systems and piecewise-smooth dynamical models formed a central theme of the colloquium. Contributions examined synchronization phenomena, invariant sets, robust chaos, and discontinuous invariant curves in piecewise-smooth maps and flows. Novel computational techniques were introduced for analysing stable and unstable manifolds, as well as for understanding the global organisation of dynamics in high-dimensional non-smooth systems.

Numerical Methods for Non-Smooth Dynamics

A number of talks focused on numerical challenges associated with non-smooth systems, including time-integration schemes, harmonic balance methods, and generalized-α formulations for flexible multibody dynamics. Improvements in accuracy, efficiency, and robustness were reported, alongside discussions on excitation harmonisation and the faithful numerical treatment of impacts and switching events.

Vibro-Impact Systems and Mechanical Applications

Vibro-impact dynamics, impact oscillators, and friction-dominated systems were discussed extensively, reflecting their relevance to engineering applications such as turbomachinery,

drilling systems, vibration absorbers, and structural damping. New modelling approaches and reduced-order representations were presented, together with experimental validation and comparative studies between nonlinear energy sinks, tuned mass dampers, and vibro-impact absorbers.

Data-Driven, Bayesian, and Machine-Learning Approaches

An emerging and particularly vibrant theme concerned the integration of non-smooth dynamics with data-driven modelling and machine learning. Contributions explored physics-enhanced machine learning, Bayesian identification frameworks, observability of non-smooth systems, and the construction of smooth surrogate models for fundamentally non-smooth dynamics. These approaches demonstrated significant promise for system identification, uncertainty quantification, and control in complex engineering systems.

Control, Switching Logic, and Hybrid Systems

Several presentations addressed non-smooth control problems, switching logic, and conserved quantities in hybrid systems. The interplay between discontinuities and control design was examined, including retrospective perspectives on the control of discontinuity-induced bifurcations and modern approaches to stabilisation and performance enhancement in non-smooth mechanical systems.

Biomechanics, Robotics, and Bio-Inspired Systems

Non-smooth dynamics in biomechanics and robotics constituted an important application domain. Topics included discontinuous models of human locomotion, neural mass models exhibiting grazing and canard-like explosions, medical device dynamics, and the navigation and sensing capabilities of micro- and soft robots operating in confined environments. These studies highlighted the relevance of non-smooth modelling for understanding biological systems and developing next-generation medical and robotic technologies.

Non-Smooth Dynamics in Networks and Multi-Agent Systems

The dynamics of interacting agents, including autonomous vehicles and human-machine systems, were explored from a non-smooth perspective. Presentations demonstrated how switching, impacts, and contact constraints influence collective behaviour, stability, and emergent dynamics in complex networks.

Concluding Remarks

The EUROMECH Colloquium 657 successfully showcased the breadth, depth, and vitality of contemporary research in non-smooth dynamics. By bringing together experts from mathematics, mechanics, engineering, and applied sciences, the meeting fostered lively discussions and initiated new connections across disciplines. A recurring message throughout the colloquium was the growing importance of integrating rigorous theory with computation, experiments, and data-driven methods, particularly as non-smooth models continue to gain relevance in emerging applications.

The organisers gratefully acknowledge EUROMECH and the University of Exeter for their support, as well as all speakers and participants for their high-quality contributions and active engagement, which were essential to the success of the meeting.

Number of participants from each country

Country	Participants
United Kingdom	6
Germany	3
Belgium	2
Ireland {Republic}	2
India	1
Netherlands	1
United States	1
France	1
Poland	1
Italy	1
Israel	1
Canada	1
Sweden	1
Total	**22**