# CS PhD Seminar Series

July 28th | 14:30-15:30 | Room 214

## Toward Scalable and Valid Conditional Independence Testing with Spectral Representations

Conditional independence (CI) is central to causal inference, feature selection, and graphical modeling, yet it is untestable in many settings without additional assumptions. Existing CI tests often rely on restrictive structural conditions, limiting their validity. Kernel methods using partial covariance operators offer a more principled approach but suffer from limited adaptivity and scalability. In this work, we explore whether representation learning can help address these limitations. Specifically, we focus on representations derived from the singular value decomposition of partial covariance operators and use them to construct a simple test statistic. We also introduce a bi-level contrastive algorithm to learn these representations. Our theory links representation learning error to test performance and establishes asymptotic validity and power guarantees. Experiments suggest that this approach offers a principled and statistically grounded path toward scalable CI testing, bridging kernel-based theory with modern representation learning.

Speaker: **Alek Fröhlich**

Alek Fröhlich received his BSc in Computer Science and MSc in Applied Mathematics from the Federal University of Santa Catarina, Brazil. Before starting his PhD, he was a visiting student at the Institute for Pure and Applied Mathematics and a research fellow at the University of São Paulo Medical School, where he worked at the interface of computational pathology and multiomics. He is now a PhD student in Computer Science at the University of Genoa and an ELLIS PhD student at the IIT and École Polytechnique. His research focuses on representation learning and spectral methods for nonparametric statistical inference, with a particular interest in causality and uncertainty quantification.

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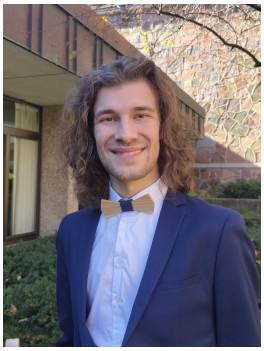
## Model-Based Reinforcement Learning for Olfactory Navigation: From Algorithmic Comparison to Sea Robin Behavior

Olfactory navigation is a fundamental problem faced by many organisms.Because odor signals are sparse, intermittent, and noisy, this task can be naturally formulated as a Partially Observable Markov Decision Process (POMDP), making model-based RL a powerful framework for studying navigation under uncertainty. In this seminar, I present a systematic comparison of several model-based RL approaches for olfactory navigation, including both classical search strategies and modern POMDP solvers. Using a unified benchmarking framework, I compare these methods in terms of navigation performance, computational efficiency, and scalability. I then show how these techniques can be applied to investigate biological behavior through a case study on sea robins. By combining realistic simulations with different sensory modalities, our results demonstrate that olfactory cues substantially enhance search performance compared with taste alone.



Speaker: **Arnaud Francois D Ruymaekers**

Arnaud Ruymaekers is a second-year PhD student in Computer Science at the University of Genova. He holds a BSc in Data Science and Knowledge Engineering from Maastricht University and a MSc in Data Science and Artificial Intelligence from the University of Genova. For his Master's thesis, he explored olfactory navigation within the PiMLB unit of the MaLGa Center under the supervision of Prof. Agnese Seminara and Prof. Alessandro Verri. He now continues this research with a focus on model-based reinforcement learning techniques.