

Bio-inspired deep learning workshop 2024

Bio-inspired deep learning

**Simulation-based inference
workshop 2024**

Who are we?



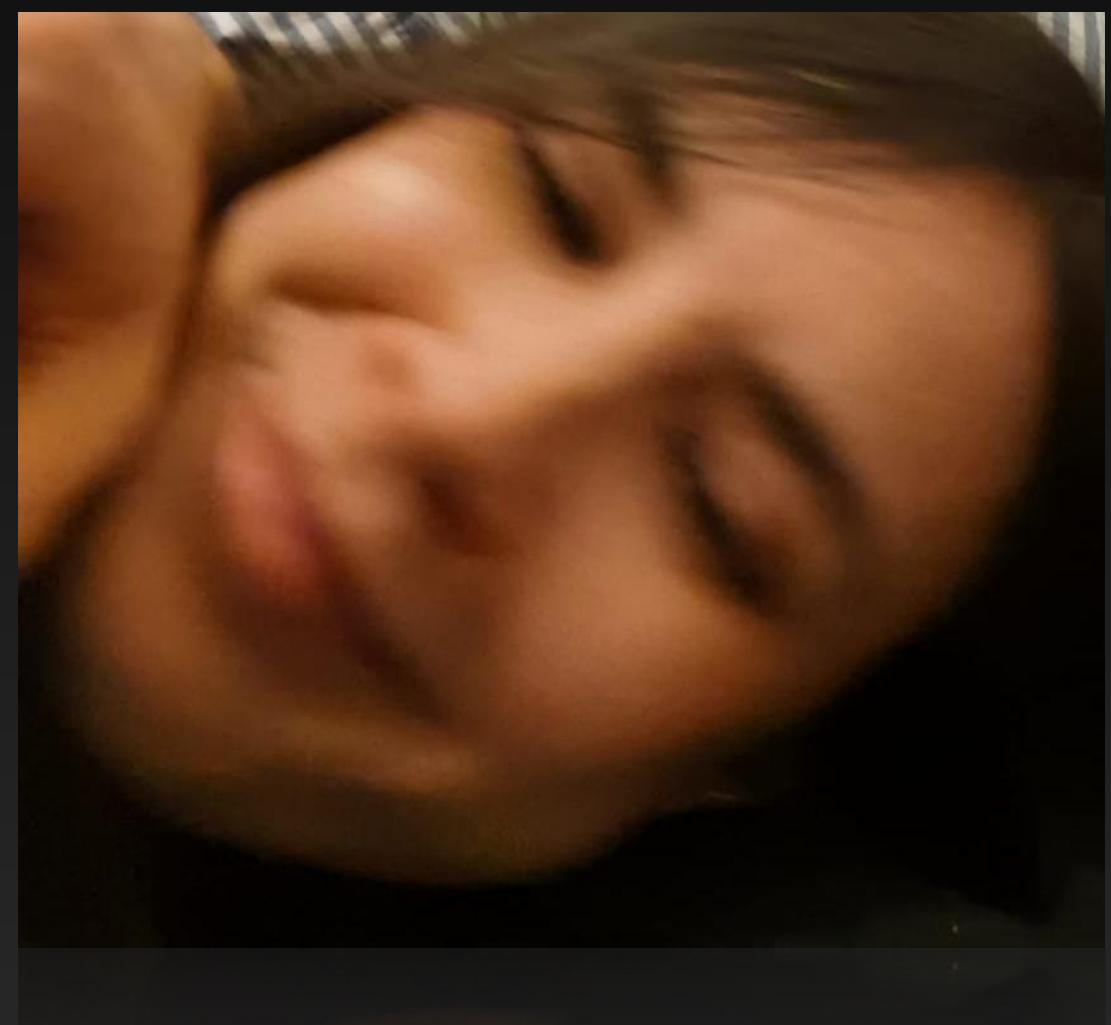
Max

- Emerging PI at institute of Neuroscience Alicante
- Background in mathematics
- Experience in fluid dynamics, control theory and computational neuroscience and



Laura

- Head of business development, Mimotype tech.
- Background in medtech & Comp. near
- Interested in innovation and how to spin-out scientific ideas



Let's back up The inspiration



- Young ERCOFTAC Spring School in Montestigliano - a series of workshops for graduate students

“... instead encourage a more active engagement of student, with hands-on examples, teamwork and learning-by-doing, rather than a passive exposure to scientific methodology.”

- Invite **one** leading expert in the field, and let them talk in-depth about **one** topic.
- Students are provided research level projects that they will attempt to solve in groups throughout the workshop

Abstract

This work considers two different methods for the creating Reduced Order Models (ROM) of non-linear systems. The first method is based on Weakly Nonlinear Expansions (WNE) about a fixed point of the system. The second approach employs Proper Orthogonal Decomposition (POD) with Galerkin projection to extract the kinetic information of the dynamical system as a comparatively small number of modes and then form a ROM by projecting the full system onto these modes. The supercritical flow past a two-dimensional, circular cylinder is used for the comparison. The results show that the method based on WNE fails at reconstructing the behaviour of the system even at a small distance from criticality. The POD-based methods, on the other hand, prove to be more robust and are adequate for the reconstruction of the flow dynamics even at a considerable distance from the bifurcation.

1 Introduction

The high computational expense of simulating numerically time-varying fluid flows, coupled with the need to develop effective and efficient control strategies has sparked a plethora of research into new techniques to capture the essential flow dynamics of the full simulation, but at a much lower cost. These techniques generally fall under the umbrella of Reduced Order Models (ROMs), and are considered remarkably useful for both theoretical understanding and practical applications.

The majority of ROMs are based on the creation of low-dimensional basis on which the initial field can be projected. As a consequence of the strictly mathematical nature of this procedure, the initial field can be represented by any physical quantity. The most renown ROM approach is the Proper Orthogonal Decomposition (POD) [5] with the Galerkin projection [4, 6, 7]. The shortcomings of ROMs based on POD have been analysed, and a number of open issues still exist [1, 3].

The scope of this report is to detail the work done regarding the application of POD-Galerkin to a well-documented case: the supercritical flow around a cylinder, i.e. at a Reynolds number higher than the Re_c of its first Hopf bifurcation. The results are compared against a theoretical approach to the same conditions: the method of Weakly Nonlinear Expansions (WNE) [8]. The idea is to study and quantify how far from criticality the WNE fails to accurately predict the behaviour of the system, expecting such distance to be low, as to justify the use of more computationally expensive POD/Galerkin techniques.

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Why here?

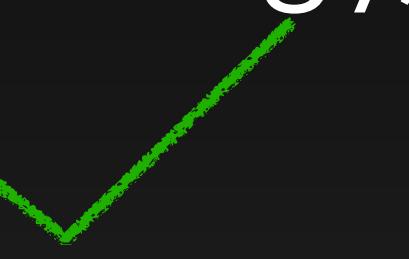
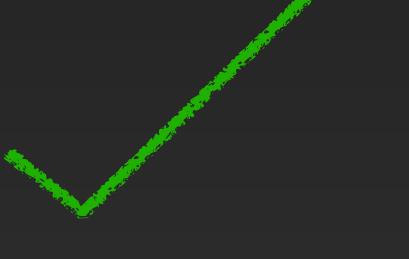
Gotta stay somewhere, innit?

- Be somewhere without any distractions for maximum work
- Easy to get to
- Nice wine
- Everything we need will happen here because:
 - There is nothing else
 - Breakfast, lunch and dinner all in the same place



The money

Someone has gotta pay for it all

- Interdisciplinary topics, with an emphasis on the sciences (biology, chemistry, physics)
- PhDs and Postdocs and give them the opportunity to get meet established scientists

JOACHIM
HERZ

STIFTUNG



Begegnungszonen

Förderung von interdisziplinären
Veranstaltungen in den
Naturwissenschaften

Advertisement for the JH foundation

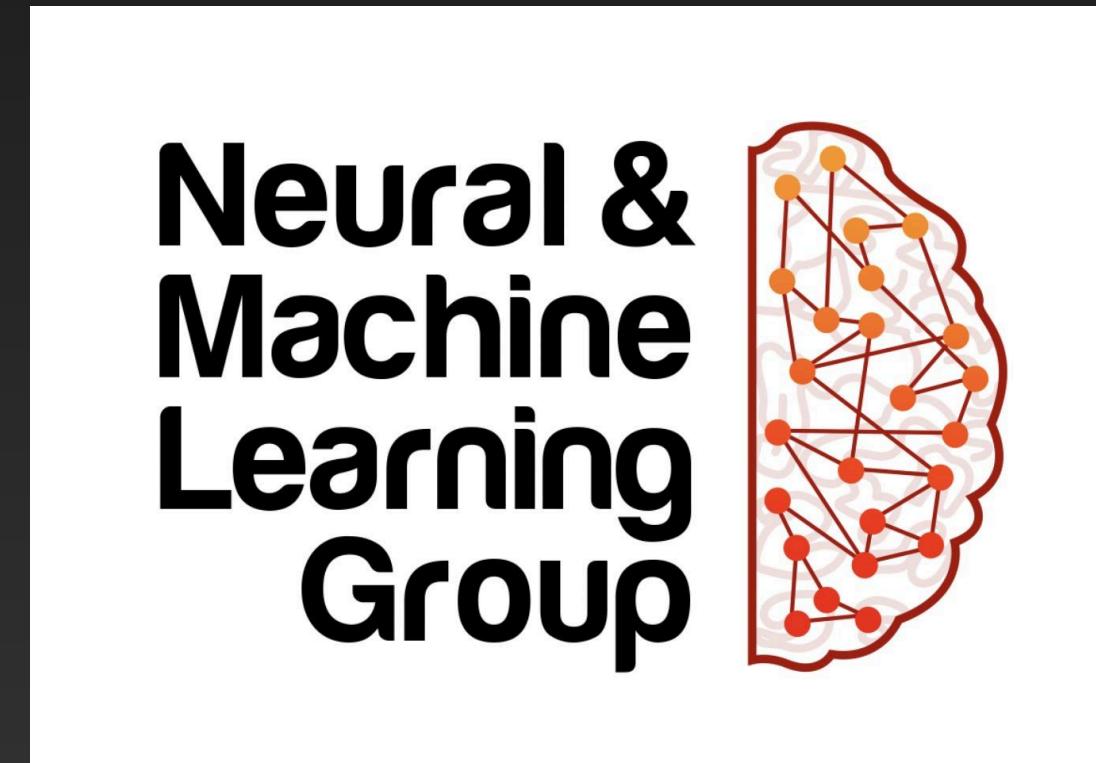
A brief interlude



- Young foundation that really provides a lot of funding to young scientists to undertake new and cool ideas
- Flagship fellowship: Add-on fellowship which provides 12.5k euros **just for you**
- 50 fellowships
- Deadline: 04.06.2024

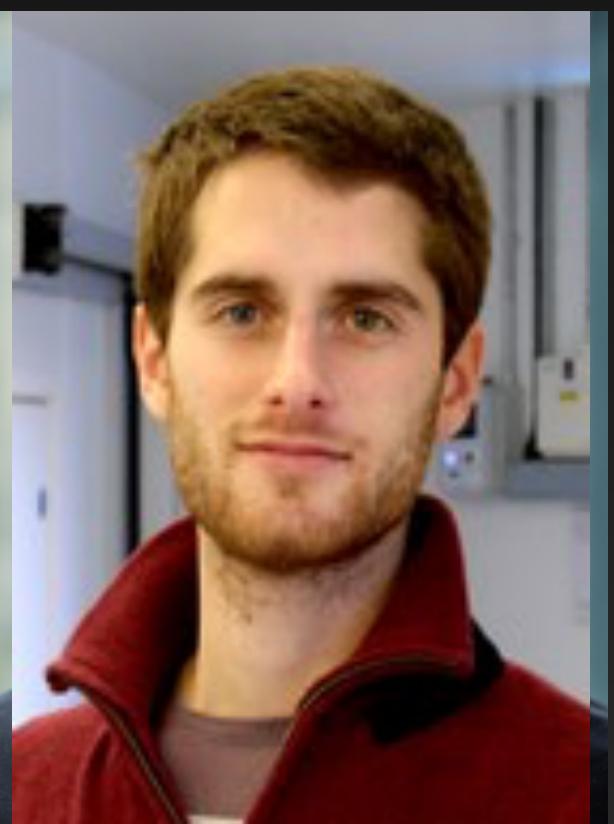
The expert from last year

- Dr. Rui Ponta Costa: Neural and Machine learning group at the University of Bristol (now oxford). His group works to understand the principles underlying learning in the brain.



The expert from this year

- Criteria: At the intersection of ML and Neuroscience
- Portuguese and with three day stubble



GONÇALVES LAB

- Pedro Gonçalves is a group leader at NERF (Belgium)
- His lab is interested in building biologically constrained theoretical models
 - Guide new experiments
 - Gain further our understanding of neural systems in health and disease.



GONÇALVES LAB

- Group leader at Nerf and member of ELLIS
- PhD from Ecole normale superieure, Paris supervised by Christian Machens
- PostDoc with Mannish Sahani in UCL and Jakob Macke at Tuebingen
- Cool dude - you guys should talk to him

The expert's minions



- Use computational methods to investigate the role of different scales in conferring robustness to neural systems.
- Combining neural circuit modeling, and the development of machine learning methods to extract mechanistic insights from data



Simulation-Based Inference of Surface Accumulation and Basal Melt Rates of an Antarctic Ice Shelf from Isochronal Layers
[G Moss](#), [V Višnjević](#), [O Eisen](#), [FM Oraschewski](#), [C Schröder](#), [JH Macke](#), [R Drews](#)
arXiv preprint arXiv:2312.02997, 2023 • arxiv.org

- Actually PhD student the lab of Jakob Macke
- His interests lie in simulation-based inference, particularly in its application in analysing the history of ice sheets.

The topic

I mean we can't just drink wine all day

"Yes, a bio-inspired deep learning workshop can be useful for providing inspiration and insights into developing more advanced deep learning algorithms by studying the biological mechanisms behind how the brain works."

- Laura and I are both interested in machine learning and we both come from computational neuroscience.
- It is interdisciplinary topic
- It can be performed in the hackathon-style format we had envisaged.

The topic

Maybe we can drink wine all day?

- Simulation based inference:
 - a set of methods used in statistical inference where the probability distribution of the data is difficult to work with directly
 - Given a model you can do some simulations and try and infer the parameters
- machine learning + neuroscience
- It is interdisciplinary topic
- hackathon-style

Hows it going to work?

“... instead encourage a more active engagement of student, with hands-on examples, team-work and learning-by-doing, rather than a passive exposure to scientific methodology.”

- What does this mean?
 - There will be **some** expert lectures to give you an overview in the field
 - You will be presented research level projects that you will be asked to work on over the next couple days in groups
 - You will have your “minions” to help you
 - Present your findings at the end

The expert's minions



- Benchmarking
- Amortised regression



- Summary statistics
- Mining silver

When

Gotta know what to do, innit!

1st day:

- Introductions (hello)
- Introductory lectures on SBI and PyTorch
- Assignment in your groups
- Coding exercise
- Pizza dinner

2nd day

- Breakfast (from 7)
- Expert lecture (9:00)
- Expert lecture (10:30)
- Pre-lunch Project work
- Lunch (13:00)
- Project Work
- Dinner (18:30)
- Wine Tasting (20:30)

3rd day

- Breakfast (from 7)
- Expert lecture (9:00)
- Pre-lunch Project work
- Lunch (13:00)
- Expert lecture (14:30)
- Project Work
- Free time

4th day

- Breakfast
- Project work time
- lunch (13:00)
- Presentation preparation time
- Presentations
- Farewell :((17:00)

What do we want?

Outcome

- Have fun! (cliche I know)
- Make new scientific contacts (its really useful at conferences I promise)
- Learn a new technique
- Depending on how the project goes
 - maybe a paper? 
- More concretely:
 - At the end of the workshop a presentation
 - A month afterwards a report that we will compile into a bulletin



Questions?

