PhD Information Session

ICTEAM - INMA

Institute of Information and Communication Technologies, Electronics and Applied Mathematics

Division of Applied Mathematics - Mathematical Engineering

Tuesday, November 19th, 2024
Euler room a002, 12:50

What is a PhD?

Johnstone et al. eLife, 2021

What is a PhD?

both a **high-level degree** and a **full-time job!**

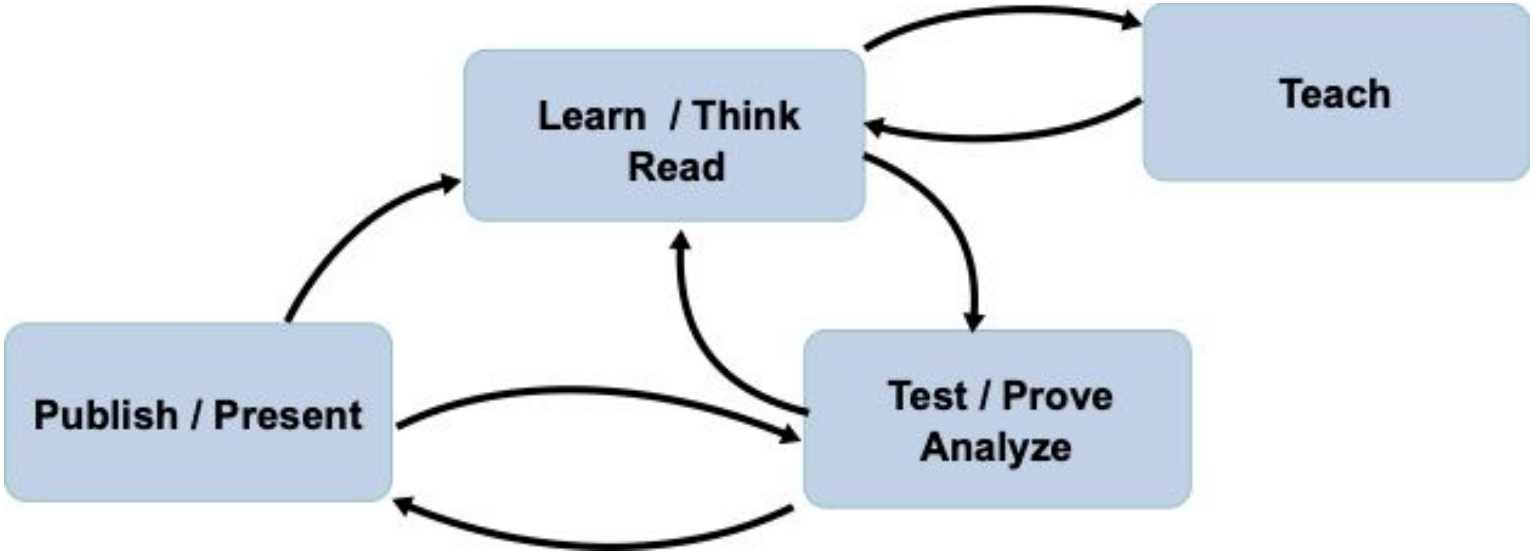
- A high-level degree dedicated to the creation of ***something new***
  New knowledge, new device, new algorithm with ***scientific validation***

- Expected to be completed in 4 years

- A full-time job at UCLouvain, with pay comparable to junior engineer position

- Main focus: scientific research, but also includes doctoral courses, collaborations, participation to teaching, conferences, travel, and infinite opportunities to learn!

What is a PhD?



Eligibility and first step

- Graduate with a *distinction*

- Motivation and research skills as important as grades, if not more

- First step: choose a potential supervisor (promoter), and contact them

    - to discuss a topic (no need to be fully defined)
    - to identify a source of funding

Contacting a potential supervisor is crucial (→ discussion, no commitment!)

Funding: several options

- Option 1 : you apply to a grant for doctoral position

  Mostly national funds, including: [see: www.frs-fnrs.be]

  - FNRS: “Aspirant”, written application in January
  - FRIA: written application in August + interview in October/November

- Option 2 : you apply to a UCLouvain teaching assistant position

  Application in May, 4 to 6 years (with ~50% teaching load)

- Option 3 : your promoter has secured some budget for a doctoral position

  project-based, national/EU → contact them to ask about possibilities !

  More general information from ICTEAM website (also about administrative steps)
  https://uclouvain.be/en/research-institutes/icteam/phd.html

List of INMA supervisors

Absil, Pierre-Antoine

Bianchin, Gianluca

Crevecoeur, Frédéric

Delhaye, Benoît

Delvenne, Jean-Charles

Glineur, François

Hendrickx, Julien

Jacques, Laurent

Jungers, Raphaël

Lefèvre, Philippe

Legat, Benoît

Massart, Estelle

Nunes Grapiglia, Geovani

Blondel, Vincent

RESEARCH TOPICS OVERVIEW

L2C Learning to control:

Towards a Paradigm shift in Control theory

Raphael Jungers

Classical applications made the golden age of systems and control

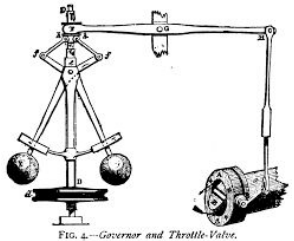


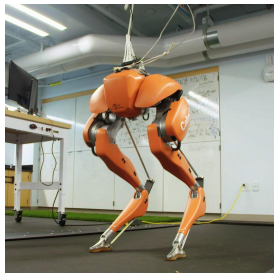
FIG. 4.—*Governor and Throttle-Valve.*

State space representation unleashed analytic approaches

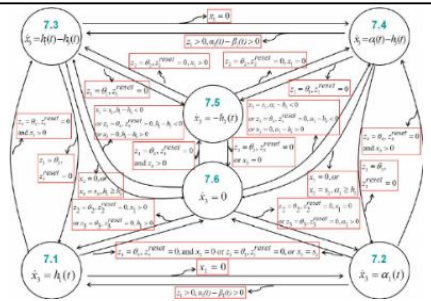
$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix} = \begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -5 & -26 & -5\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix} + \begin{bmatrix}0\\ 0\\ 1\end{bmatrix} u$$

$$y = \begin{bmatrix}1 & 0 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$$

However, modern applications are increasingly complex...



... and so are their models



a hybrid automaton

New challenges

Learning-based methods

Safety-critical applications

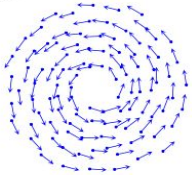
Human in the loop

Logical reasoning

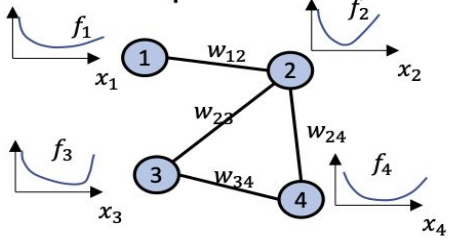
Dionysos

Networks and interconnected systems

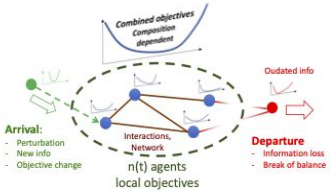
- Learning on problem with network structure
- Analysis of multi-agent systems



- Identification in networked systems
- Decentralized optimization



- Open Multi-agent Systems

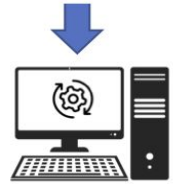


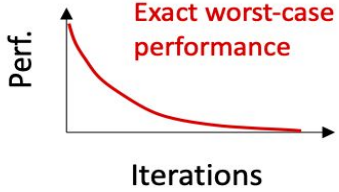
Tools: Graph theory, dynamical systems, probabilities, optimization, …
and new methods to be created

Performance Estimation Problems

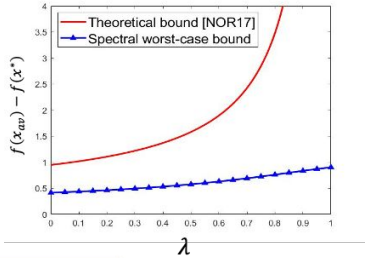
```
function MyDecentralizedAlgo()
    N = 10; % number of agents
    x0 = init(N); % Initial point
    x = x0;

    for i=1:niter
        % any local computations
        % and local communications
        x = update(x,N);
    end
end
```



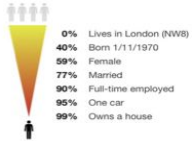


Extension to
- Data-Based control
- Optimized control



Other topics

Privacy



Opinion dynamics

Inverse Problems in Computational Sensing and Data Science

Inverse Problem Solving:

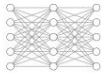
Prior, Structure → regularization

$$\mathcal{Y} \approx \Phi(\mathcal{X}) \rightarrow \mathcal{X} \approx \mathcal{A}(\mathcal{Y})?$$

"Sensing"

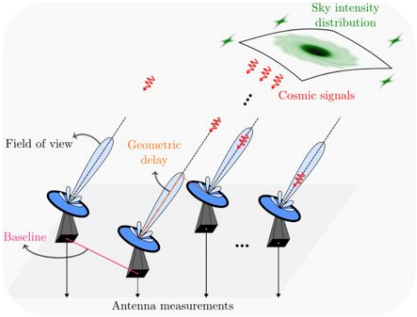
Signal, Image, Datasets, ...

Algorithm, Neural Network



Inverse Problems in Computational Sensing and Data Science

Radio-astronomy



Self-supervised learning

No access to $\mathcal{X}$?

Equivariance ?

Inverse Problem Solving:

Prior, Structure → regularization

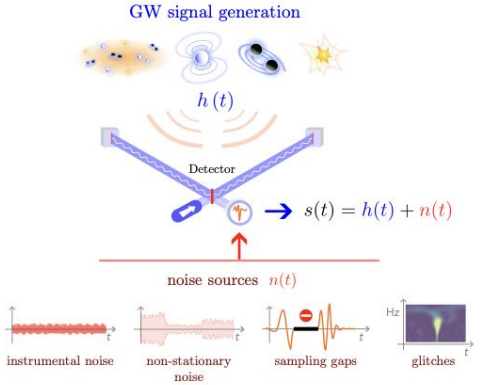
$$\mathcal{Y} \approx \Phi(\mathcal{X}) \rightarrow \mathcal{X} \approx \mathcal{A}(\mathcal{Y})?$$

"Sensing"

Signal, Image, Datasets, ...

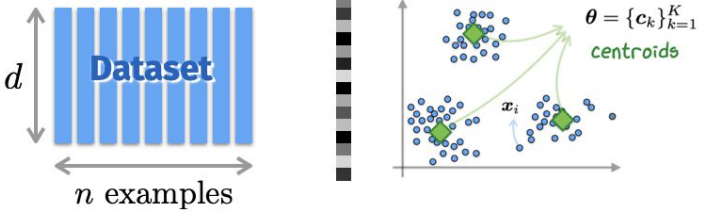
Algorithm, Neural Network

Gravitational wave detection

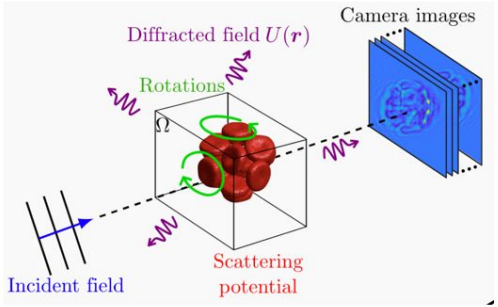


Compressive Learning

$$\mathcal{X} = \{\boldsymbol{x}_i \in \mathbb{R}^d\}_{i=1}^n \quad \mathcal{Y}$$

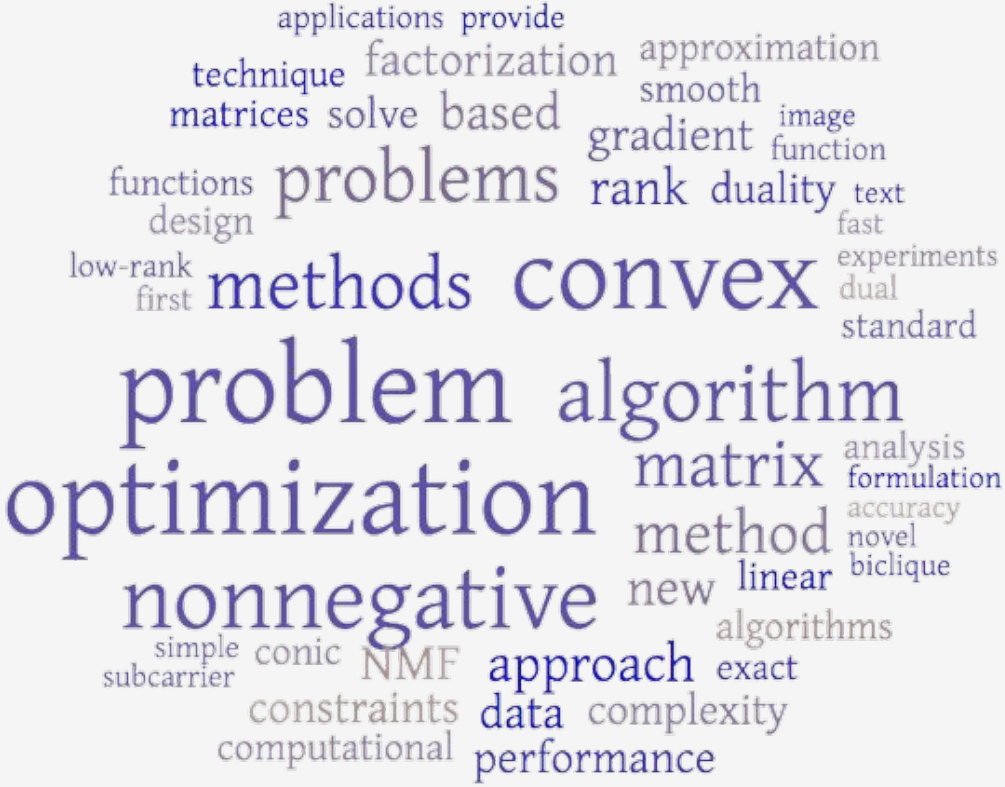


Optical Diffraction Tomography



L. Jacques, R. Delogne, N. Mil-Homens Cavaco + collaborators (UCLouvain, ENS Lyon, WashU, ...)

François Glineur



Website
Google scholar

François Glineur

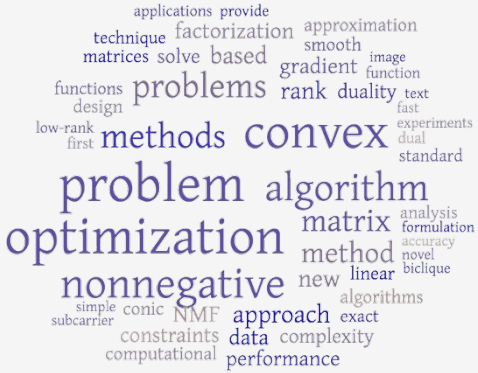
Algorithmic optimization

- Design of efficient algorithms, usually for specific classes of problem
- Analysis of existing methods (optimal choice of parameters, impact of inexactness, empirical evaluation, AI to improve performance)

Convex and increasingly non-convex

Key tool: Performance Estimation[1]
= computer assisted methodology to automatically compute convergence rates

[1] collaboration with J. Hendrickx



Applications

Project-oriented: topics include energy, predictive maintenance, organology

Data analysis

Focus on Nonnegative Matrix Factorization to obtain part-based decompositions with nonnegative features (images, texts)

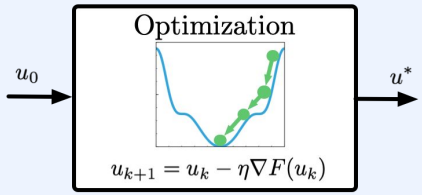
- Design of efficient algorithms
- Extensions to more general settings (continuous signals, tensors)

Website
Google scholar

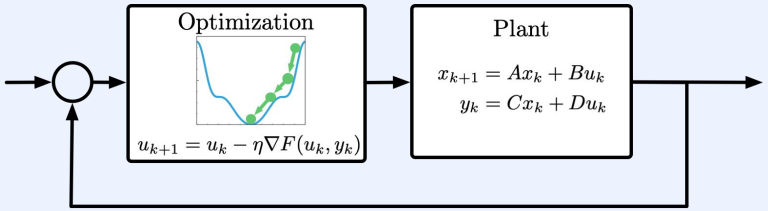
Note: currently no project-based open position – interested in some topics? Contact me!

Algorithms for Optimization-based Control

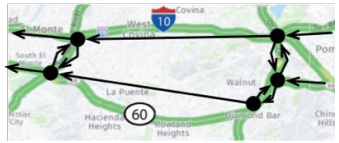
Basic optimization (as in OPT courses)



Optimization-based control

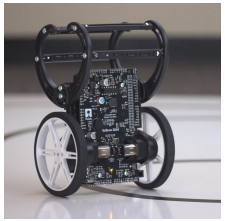


Applications of interest:

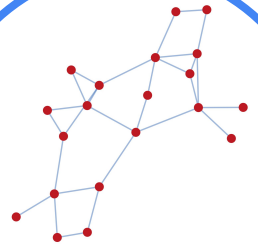


Transportation

Epidemics



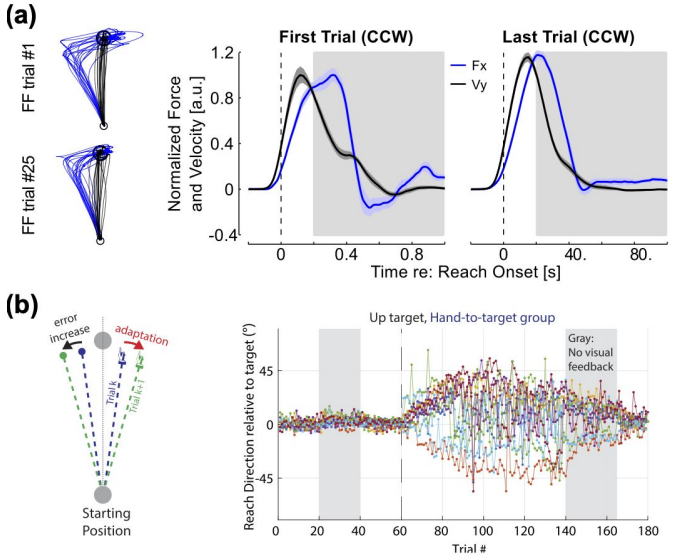
Robotics

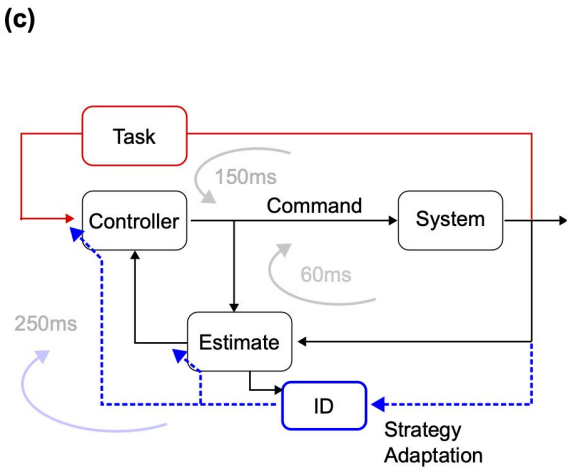


Networks

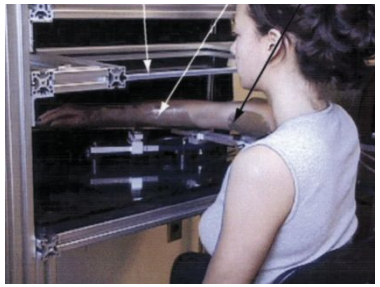
Prof. Gianluca Bianchin
gianluca.bianchin@uclouvain.be
https://gianlucabi.github.io

Motor Control - Systems Neuroscience





Kalidindi and Crevecoeur, 2023, https://doi.org/10.1016/j.conb.2023.102810



Singh & Scott, 2003

Img: https://bradentonresearch.com

- Behavioural experiments: eye and arm movements, locomotion
- Computational models: control theory, probabilistic models, ANN
- Application to understand movement disorders in clinical populations (e.g. Essential Tremor, Parkinson's disease).

frederic.crevecoeur@uclouvain.be

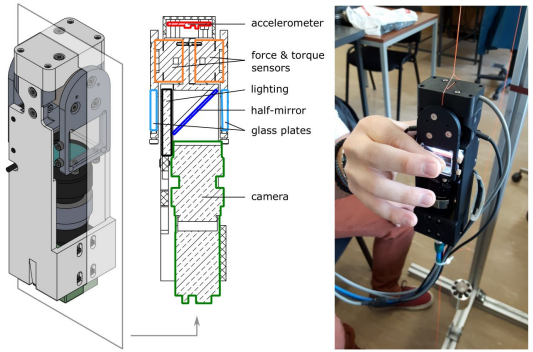
Sensorimotor Neuroscience
Touch and Grip Control

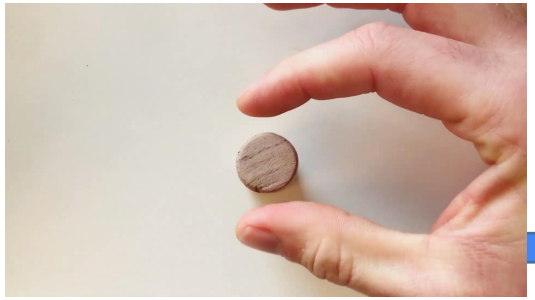
SensMoTion Lab

benoit.delhaye@uclouvain.be
https://perso.uclouvain.be/benoit.delhaye

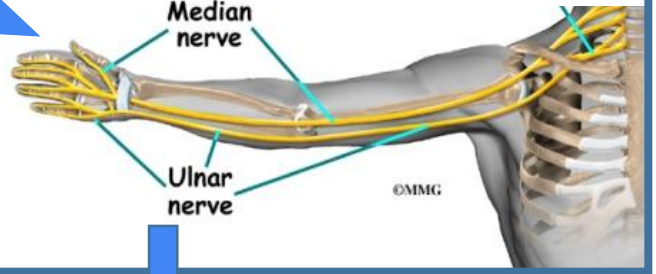
philippe.lefevre@uclouvain.be
https://perso.uclouvain.be/philippe.lefevre

1. Sensory input





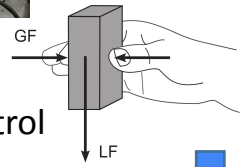
2. Neural coding



3. Sensorimotor behavior

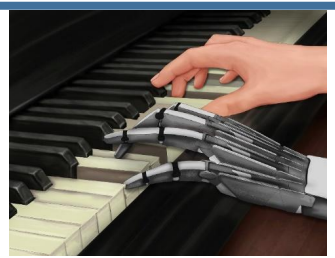
Perception

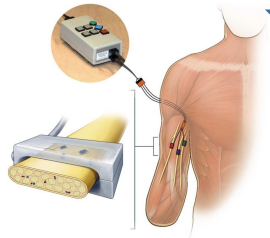
Adaptation



Closed-loop control

4. Conveying **sensory feedback** in **hand neuroprostheses** using a **neural interface**



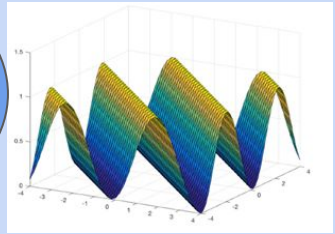


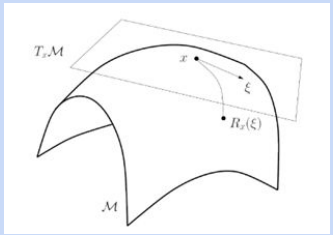
Estelle Massart

Exploiting invariances for optimization

(Design of algorithms and complexity analysis for overparametrized problems)

Tools:
- Diff. geometry
- Dimensionality reduction





More applied projects:

- ML for physics
- Biomedical applications (epilepsy detection, biomedical imaging)

Maths for Deep Learning

"Machine learning has become a form of alchemy"

A. Rahimi (Google, NeurIPS 2017 Test of Time Award)

Improve training? Architecture choices? Model compression

Tools:
- Optimization
- Diff./algebraic geometry

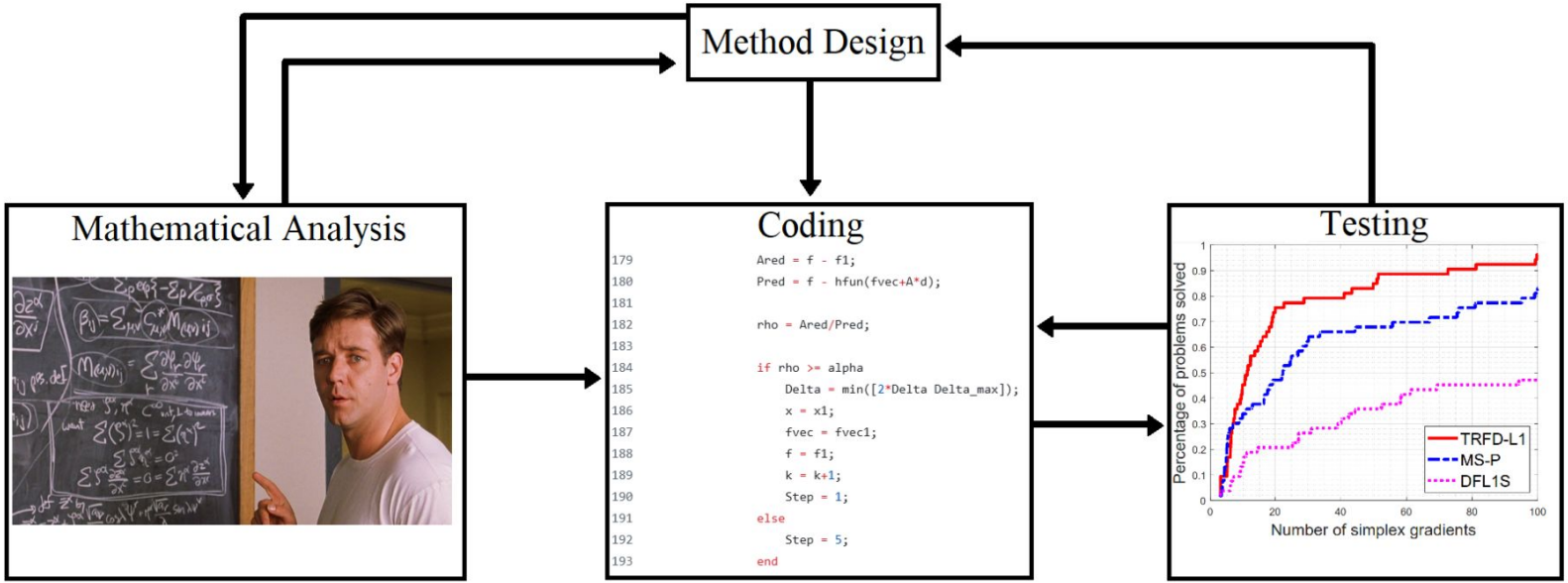
…

Interested?
Contact me!

Geovani Grapiglia (geovani.grapiglia@uclouvain.be)

Problem: Minimize $f(x)$, s.t. $x \in \Omega$

Research Topics: Derivative-Free Optimization; Lower-Order Implementation of High-Order Methods; Universal Methods for Convex and Nonconvex Optimization,...



Goal: Development of **efficient methods with strong theoretical guarantees!**

Hello! My name is Jean-Charles Delvenne.

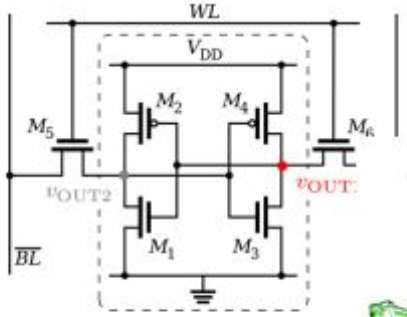
I like discrete mathematics, algorithms, probability, statistical physics, dynamical systems & control. For example, I love Markov Chains.

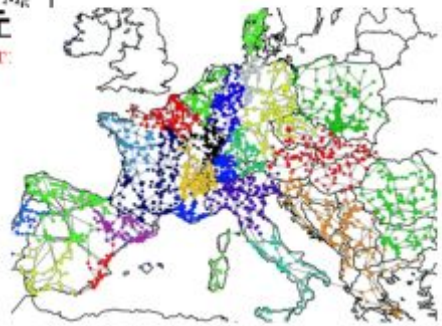
I apply all this to study complex systems (that is, many things interacting together).

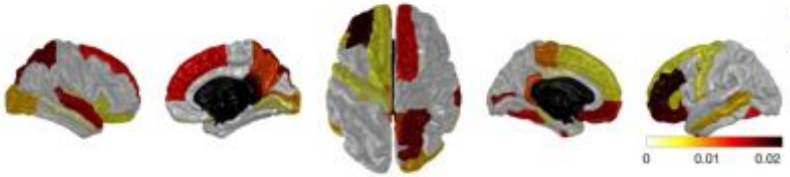
For instance social systems, biophysical systems and electronic devices.

In the end, it all boils down to pretty mathematics.

I you feel like-minded, contact me.

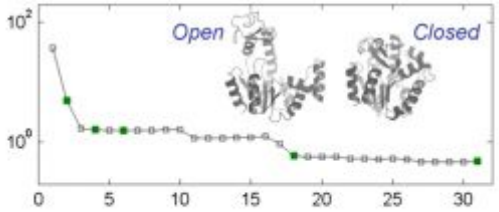




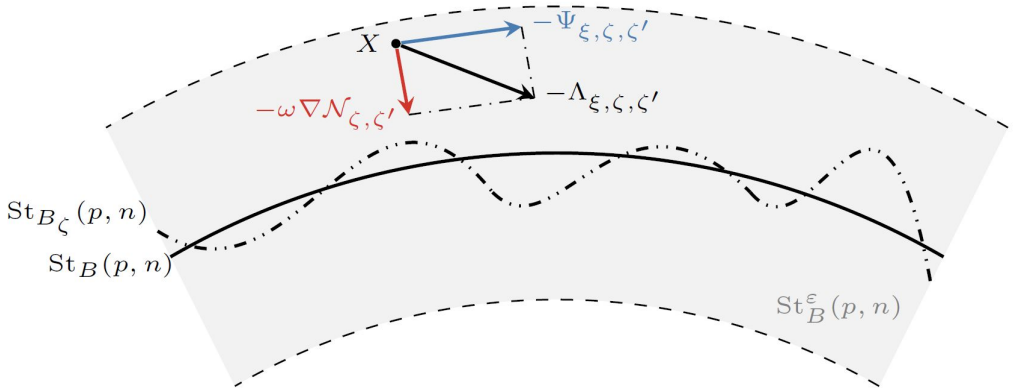


A few examples of end-results, with various co-authors, including PhD students

$$Lx = b$$



PA Absil - “Landing” methods for constrained optimization

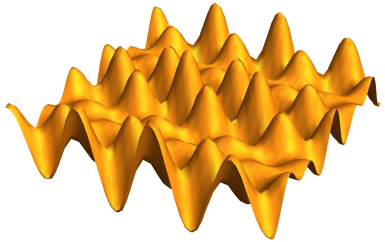


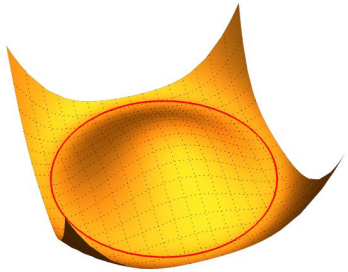
Webpage: https://sites.uclouvain.be/absil/

E-mail: pa.absil@uclouvain.be

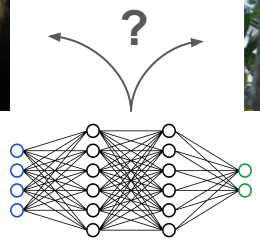
Benoît Legat

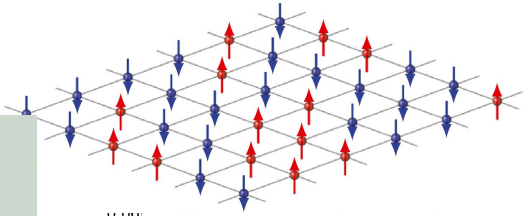
Open Ph.D. position for next year

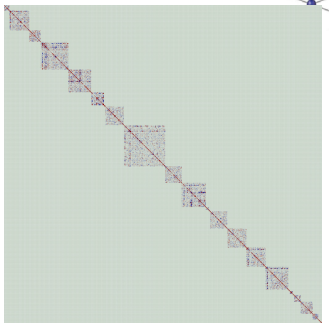


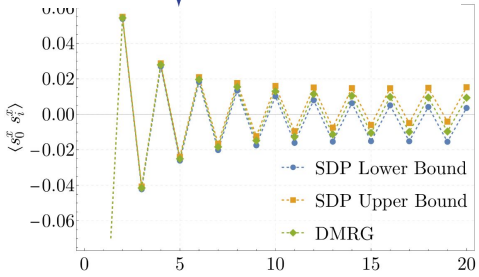


Explaining benign nonconvexity through
hidden convexity









Symmetry

Structure exploitation in large-scale optimization

Low-Rank

Sparsity

JUMP