Thibaut Cuvelier

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Applications of mathematical optimisation to machine learning and industrial issues
Research keywords: mathematical optimisation / operational research, reinforcement learning

Education

2017 – 2021: **PhD in Science and Technology of Information and Communication**, CentraleSupélec (Paris-Saclay university[1]).

PhD thesis: *Polynomial-time algorithms for combinatorial semibandits: computationally tractable reinforcement learning in complex environments*

2010 – 2015: **master's degree in Computer Science and Engineering[2]**, university of Liège (ULg), Belgium, magna cum laude (second year and master's thesis: summa cum laude).

Master's thesis: *Implementing and comparing stochastic and robust programming*.
Award: **best master's thesis in computer science and engineering, AIM, 2015.**

Electives:

- artificial intelligence (machine learning, intelligent robotics).
- applied mathematics (discrete and numerical optimisation, high-performance scientific computing).
- networks (advanced networking, information theory, telecommunications).

2004 – 2010: secondary education (CESS), Saint-Barthélemy, Liège, Belgium, magna cum laude. *Electives*: mathematics, Latin, ancient Greek. *Distinctions*: finalist for the Belgian round of the Olympics of Informatics (2010); top-3 contestant for the ancient Greek translation competition of the Rencontres Grecques, Institut du Sacré-Cœur de Mons, Belgium (2010). Student mentor in 2008-2009 and 2009-2010.

Research experience

Since September 2021: **software engineer** at Google Research.

October 2017-June 2021: **doctoral researcher** at Orange Labs and CentraleSupélec (université Paris-Saclay).
Keywords: mathematical optimisation, reinforcement learning, bandit algorithms, active learning, network routing.
Under the supervision of Dr. Zwi Altman, Dr. Éric Gourdin (Orange Labs), and Prof. Richard Combes (CentraleSupélec).

Machine-learning algorithms are often based on optimisation techniques, but do not always take the most of them. For example, combinatorial bandit algorithms tend to have exponential complexity, even when the deterministic combinatorial problem has a known polynomial-time algorithm (matching, shortest path, etc.): using more advanced tools from mathematical optimisation, **I reduce the bandit-learning time complexity to polynomial** in many useful cases, for two state-of-the-art algorithms

[1] Ranked 1st in mathematics in the world in 2020 and 2021 by Shanghai Ranking Consultancy.
[2] This master's degree has been awarded a EUR-ACE label by the French Commission des Titres d'Ingénieur (CTI).

(ESCB, based on the optimism principle; OSSB, based on the information-theoretic bound on the regret of Graves and Lai). Related publications: [C2], [C3], [T4]. The result of this work is available as open-source software: CombinatorialBandits.jl.
The combinatorial and nonsmooth optimisation algorithms are separately available: Kombinator.jl and NonsmoothOptim.jl.

Outside my thesis, I also worked on network routing problems, more specifically the relationships between routing under uncertainty (more specifically, oblivious routing) and fair routing. Related publications: [A5], [P2], [P3]. The result of this work is available as open-source software: Seleroute.jl.

Along with these topics, I contributed to RAL, a novel active-learning methodology that builds upon reinforcement learning. Related publications: [J2], [C1], [W2], [A7]. A Python implementation of the methodology is available as open-source software: RAL.

Full text: https://tel.archives-ouvertes.fr/tel-03296009v1

Grants: TMA 2018 student grant, ACM SIGMETRICS 2021 student grant.

January 2016-September 2017: **research engineer** at the university of Liège, Belgium.
Keywords: mathematical optimisation, data analytics.
In partnership with N-SIDE (project coordinator), UCL (ICTEAM and CRECIS), and ICEDD, within the InduStore project.

Industry may take advantage of the **increasing electricity price volatility**, by organising its production around price forecasts, and provide flexibility services to the grid. Moreover, respecting the well-being of the workforce is a requirement in this context. My responsibilities were to develop, apply, and evaluate mathematical **optimisation models** of plant operations, including HR concerns. Related publications: [A2], [A3], [P1], [J3]. The result of this work is available as open-source software: IndustrialProcessFlexibilisation.jl.

September 2015-December 2015: **research engineer** at the university of Liège, Belgium.
Keyword: mathematical optimisation, mathematical modelling.
In partnership with the Walloon region and ULg (HECE).

Water reservoirs (such as dams) are usually managed using fixed rules or metaheuristics. However, these solutions are not always truly optimum for the sought objectives. My responsibility was to define **new operational rules** based on historical data using mathematical optimisation. Related publication: [J1], [A6]. The result of this work is available as open-source software: ReservoirManagement.jl.

September 2014-June 2015: master's thesis at the university of Liège, Belgium.
Keywords: mathematical optimisation, mathematical modelling under uncertainty.

Stochastic and robust programming are often used to model uncertainty. For the facility location and unit commitment problems, I conducted an **in-depth comparison** of the cost and the robustness of the obtained solutions.

Full text: http://hdl.handle.net/2268/197090. Related publications: [A5], [A1], [T3].
Award: best master's thesis in computer science and engineering, AIM, 2015.

Under the supervision of Prof. Quentin Louveaux.

July-August 2014: **intern** at N-SIDE (Louvain-la-Neuve, Belgium), working on the ENERTOP project.

Keywords: mathematical optimisation.

In the context of the **optimisation of energy costs** in a complex plant, my **responsibilities** were to make the solutions more **robust** to uncertain events, such as failures, and to handle the electricity-price uncertainty.

Under the supervision of Prof. Bertrand Cornélusse (N-SIDE, now ULg).

Communication experience

Journal articles

[J4] *Statistically Efficient, Polynomial-Time Algorithms for Combinatorial Semi-Bandits.*
Thibaut Cuvelier, Richard Combes, Éric Gourdin.
Proceedings of the ACM on Measurement and Analysis of Computing Systems, vol. 5, no. 9, pp. 1–31, February 2021.
https://hal.archives-ouvertes.fr/hal-03162127 and https://arxiv.org/abs/2002.07258

[J3] *Embedding Reservoirs in Industrial Models to Exploit their Flexibility*.
Thibaut Cuvelier.
SN Applied Sciences, vol. 2, no. 12, article 2171, December 2020.
https://hal.archives-ouvertes.fr/hal-03053322

[J2] *Adaptive and Reinforcement Learning Approaches for Online Network Monitoring and Analysis.*
Sarah Wassermann, Thibaut Cuvelier, Pavol Mulinka, Pedro Casas.
IEEE Transactions on Network and Service Management, vol. 18, no. 2, June 2021.
https://hal.archives-ouvertes.fr/hal-03110834

[J1] *Comparison Between Robust and Stochastic Optimisation for Long-term Reservoir Operations Under Uncertainty.*
Thibaut Cuvelier, Pierre Archambeau, Benjamin Dewals, Quentin Louveaux.
Water Resources Management, vol. 32, no. 5, pp. 1599–1614, March 2018.
http://hdl.handle.net/2268/219394 and https://arxiv.org/abs/1801.08892

Conference articles

[C3] *Asymptotically Optimal Strategies for Combinatorial Semi-Bandits in Polynomial Time.*
Thibaut Cuvelier, Richard Combes, Éric Gourdin.
Algorithmic Learning Theory (ALT), Paris (France), March 2021.
29% acceptance rate.
https://hal.archives-ouvertes.fr/hal-03162140 and https://arxiv.org/abs/2102.07254

[C2] *Statistically Efficient, Polynomial-Time Algorithms for Combinatorial Semi-Bandits.*
Thibaut Cuvelier, Richard Combes, Éric Gourdin.
ACM SIGMETRICS 2021, Beijing (China), June 2021.
12% acceptance rate.
https://hal.archives-ouvertes.fr/hal-03201526

[C1] *ADAM & RAL: Adaptive Memory Learning and Reinforcement Active Learning for Network Monitoring.*
Sarah Wassermann, Thibaut Cuvelier, Pedro Casas, Pavol Mulinka.
15th International Conference on Network and Service Management (CNSM) 2019, Halifax (Canada), October 2019.
16% acceptance rate.
https://hal.archives-ouvertes.fr/hal-02301393

Workshop articles

[W2] *RAL: Improving Stream-Based Active Learning by Reinforcement Learning*.
Sarah Wassermann, Thibaut Cuvelier, Pedro Casas.
European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML-PKDD) Workshop on Interactive Adaptive Learning (IAL), Würzburg (Germany), September 2019.
https://hal.archives-ouvertes.fr/hal-02265426/

[W1] *NETPerfTrace — Predicting Internet Path Dynamics and Performance with Machine Learning.*
Sarah Wassermann, Pedro Casas, Thibaut Cuvelier, Benoît Donnet.
ACM SIGCOMM Workshop on Big Data Analytics and Machine Learning for Data Communication (Big-DAMA), Los Angeles (USA), August 2017.
http://hdl.handle.net/2268/211667

Abstracts

[A8] *ConstraintProgrammingExtensions: MathOptInterface gets broader usage.*
Thibaut Cuvelier.
JuMP-dev 2021.
https://hal.archives-ouvertes.fr/hal-03306211v1

[A7] *Improving Stream-Based Active Learning with Reinforcement Learning*.
Sarah Wassermann, Thibaut Cuvelier, Pedro Casas.
Workshop for Women in Machine Learning (WiML) 2019.
https://hal.archives-ouvertes.fr/hal-02375296

[A6] *Operation rules of the Vesdre reservoir revisited*.
Benjamin Dewals, Thibaut Cuvelier, Pierre Archambeau, Sébastien Erpicum, Michel Pirotton, Quentin Louveaux.
6th International Symposium on Hydrological Modelling of the Meuse basin, September 2019.
http://hdl.handle.net/2268/239415

[A5] *Comparing Oblivious and Robust Routing Approaches.*
Thibaut Cuvelier and Éric Gourdin.
Programme Gaspard Monge pour l'optimisation, la recherche opérationnelle et leurs interactions avec les sciences des données (PGMO Days) 2018, November 2018.
http://hdl.handle.net/2268/229784

[A4] *Retour d'expérience sur Julia pour la recherche et l'enseignement en recherche opérationnelle.*
Thibaut Cuvelier.
Congrès de la Société française de recherche opérationnelle et d'aide à la décision (ROADEF) 2018, February 2018.
http://hdl.handle.net/2268/220267

[A3] *Optimising workforce and energy costs by exploiting production flexibility.*
Thibaut Cuvelier and Quentin Louveaux.
21st Conference of the International Federation of Operational Research Societies (IFORS), Québec (Canada), July 2017.
http://hdl.handle.net/2268/207330

[A2] *Modelling the industrial flexibility from the electricity consumption and HR points of view.*
Thibaut Cuvelier and Quentin Louveaux.
22nd Belgian Mathematical Optimization Workshop, COMEX (combinatorial optimisation: metaheuristics and exact methods), La Roche-en-Ardenne (Belgium), April 2017.
http://hdl.handle.net/2268/209469

[A1] *Optimisation and uncertainty: comparing stochastic and robust programming.*
Thibaut Cuvelier.

30th Annual Conference of the Belgian Operational Research Society (ORBEL), Louvain-la-Neuve (Belgium), January 2016.
http://hdl.handle.net/2268/197081

Posters

[P4] *RAL — Reinforcement Active Learning for Network Traffic Monitoring and Analysis*.
Sarah Wassermann, Thibaut Cuvelier, Pedro Casas.
Proceedings of the ACM SIGCOMM Conference Posters and Demos, online, August 2020.
https://hal.archives-ouvertes.fr/hal-02932839

[P3] *Oblivious Routing: Static Routing Prepared Against Network Traffic and Link Failures*.
Thibaut Cuvelier and Éric Gourdin.
Network Traffic Measurement and Analysis (TMA) PhD School 2019, Paris (France), June 2019.
https://hal.archives-ouvertes.fr/hal-02161708/

[P2] *Oblivious Routing: Worst-Case Routing is not Breaking the Internet's Legs*.
Thibaut Cuvelier.
Network Traffic Measurement and Analysis (TMA) PhD School 2018, Vienna (Austria), June 2018.
http://hdl.handle.net/2268/227128

[P1] *Characterising Industrial Sites' Flexibility with Reservoir Models.*
Thibaut Cuvelier.
DS3 Data Science Summer School (École Polytechnique), Paris (France), August 2017.
http://hdl.handle.net/2268/212703

Books

[B3] *Créer des applications graphiques en Python avec PyQt5*, published by D-BookeR, March 2017.
Thibaut Cuvelier, Pierre Denis.
ISBN-13: 978-2-8227-0518-9.

[B2] *Créer des applications avec Qt 5 – les essentiels*, published by D-BookeR, November 2013.
Guillaume Belz, Thibaut Cuvelier, Ilya Diallo, Louis du Verdier, Vincent Meyer, Florent Renault.
ISBN-13: 978-2-8227-0108-2.

[B1] *Web sémantique : méthodes et outils pour le Web de données*, published by Pearson, May 2012.
Translated by Thibaut Cuvelier, Julien Plu, Antoine Seilles.
Original title: *Linked Data: Evolving the Web into a Global Data Space*.
Tom Heath and Christian Bizier.
ISBN-13: 978-2-7440-2519-8.

Talks

[T4] *Polynomial-Time Combinatorial Bandits: Computationally Tractable Reinforcement Learning in Complex Environments*, March 2021, Amazon Transport Services, Luxembourg (Luxembourg)

[T3] *Voyage incertain : découvrir l'optimisation stochastique et robuste,* February 2018, Orange Labs, Châtillon (France).
http://hdl.handle.net/2268/219824

[T2] *A Journey through Julia*, May 2017, IEEE Student Branch Liège (Belgium).
http://hdl.handle.net/2268/210211

[T1] *A Journey through Julia*, November 2016, Geeks anonymes, Liège (Belgium).
http://hdl.handle.net/2268/203491

Open-source contributions

Research codes:

- Main developer of CombinatorialBandits.jl (2020-2021), [C2], [C3].
- Main developer of Seleroute.jl (computer-network routing, 2020), [A5], [P2], [P3].
- Main developer of IndustrialProcessFlexibilisation.jl (flexible industrial operations, 2017-2018), [A2], [A3], [P1], [J3].
- Main developer of ReservoirManagement.jl (for water-reservoir operations, 2016-2018), [J1], [A6].
- Co-developer of RAL (for stream-based active learning, 2019-2020), [J2], [C1], [W2], [A7].

Libraries used for research:

- Main developer of NonsmoothOptim.jl, a nonsmooth-optimisation Julia package (2020-2021).
- Main developer of Kombinator.jl, a combinatorial-optimisation Julia package (2020-2021).
- Main developer of a generic interface for constraint programming in Julia [A8]: ConstraintProgrammingExtensions.jl (2020-2021), JuCP.jl (2020-2021), CPLEXCP.jl (2020-2021), Chuffed.jl (2021).
- Regular contributor to several optimisation-oriented Julia packages (access to infeasibility information from the solvers, export to LP format): JuMP.jl (2019-2020), MathOptInterface.jl (2019-2020), MathOptFormat.jl (2019, since then merged with the latter), MathOptFormat.
- Developer of the CPLEX.jl optimisation-solver wrapper (since 2021; contributor in 2019-2021).
- Regular contributor to several optimisation-solver wrappers: Gurobi.jl (2019-2021), SCS.jl (2019), Xpress.jl (2019).
- Occasional contributor to several Julia packages: TimeSeries.jl (2015-2016), Distributions.jl (2016), Nemo.jl (2017), Hungarian.jl (2018), LightGraphsMatching.jl (2018), SimpleWeightedGraphs.jl (2018), JavaCall.jl (2020-2021).

Documentation and technical-writing tools:

- Main developer of QtDocTools (management of the translation of Qt's documentation, including tooling to work with DocBook documents, since 2014).
- Developer of LyX (C++/Python, since 2018, responsible for DocBook and ePub output formats).
- Occasional contributor to Apache POI (Java, 2019-2020).
- Occasional contributor to Qt (C++, 2019-2020, export from qdoc to DocBook).
- Occasional contributor to LilyPond (Python, 2021, DocBook fixes)
- Occasional external contributor to the DocBook OASIS standard (2016-2021).

Miscellaneous (related to my other activities on Developpez.com):

- Contribution to the translation into French of Qt Creator (2012-2013).
- Occasional contributor to PHP libraries: GeSHi (2014), Silex (2012).

Service to the community

Session co-chair at IFORS 2017.

Reviewer for the following conferences:

- 16th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2018)
- JuliaCon 2019
- 7th International Conference on Water Resource and Environment conferences (WRE 2021)

Reviewer for the following journals:

- Journal of Hydrology (2019-2020)
- Journal of Water Resources Management (2019-2021)
- International Journal of Mining Science and Technology (2021)

Trainings

First aid: European first aid certificate (BEPS, Belgian Red Cross, May 2015); workplace first aider (UNASS, December 2018 and February 2020).

IEEE compliance trainings: anti-bribery and corruption, antitrust and fair competition, conflicts of interest, GDPR, discrimination and harassment prevention (2020).

Graduate school trainings:

- STIC: law and intellectual property, European projects Horizon 2020, ethics and technology (2019).
- SOCN: algorithmic convex optimisation (2016).

PhD schools:

- HIM School on modern directions in discrete optimization 2021.
- Combinatorial Optimization at Work (CO@W) 2020.
- TMA 2019 PhD school.
- ECML PKDD 2019 Summer School, quality-of-experience track.
- 2018 school on column generation.
- TMA 2018 PhD school.
- IPCO 2016 summer school.

Other trainings: open-channel flows (ULg GCIV2034, 2015) and fluvial hydrodynamics (ULg GCIV2035, 2016).

Pedagogical training

Several courses at the *Institut de Formation et de Recherche en Enseignement Supérieur* (IFRES, ULg):

- Design multimedia material for face-to-face teaching
- Competency-based approach
- Motivate my students
- Introduction to evaluation: principles and quality criteria
- Customising teaching by considering students' characteristics
- Triple concordance between objectives, methods, and evaluation
- Organising practical lessons in science and applied science courses
- Introduction to the Blackboard Learn platform
- Using Blackboard Learn to create tests
- Evaluate and regulate one's teaching activities

Leaders of Learning, HarvardX, edX, September 2021.

Online courses

- Deep learning specialisation, Andrew Ng, Coursera, March 2018 (overall score: 100%).
- Reinforcement Learning Explained, Microsoft DAT257x, edX.
- Artificial Intelligence A-Z™: Learn How To Build An AI, SuperDataScience, Udemy, April 2020.
- Advanced AI: Deep Reinforcement Learning in Python, Lazy Programmer, Udemy, August 2020.
- Unsupervised Deep Learning in Python, Lazy Programmer, Udemy, May 2021.
- Comprendre la 4G, IMT Atlantique, Fun MOOC, December 2020.
- Explorer la 5G, IMT Atlantique, Fun MOOC, May 2021.
- Understanding Artificial Intelligence through Algorithmic Information Theory, edX, July 2021.

Non-research work experience

2018–now: book-review manager for **Developpez.com**. Partnership management and development (7 new publishers).

August 2015: development of a real-time car-sharing prototype application for the **ULg**. This prototype evolved into the UGo platform (https://ugo.be/).
Technologies: Python, Django.
Under the supervision of Prof. Bertrand Cornélusse (ULg).

July 2015: translation into English of a 100-page numerical-analysis textbook (2nd year students) for the **ULg**.
Under the supervision of Prof. Quentin Louveaux (ULg).

2011–2017: officer for the ULg **IEEE Student Branch**. Event organisation, website and server maintenance, poster design.
Technologies: Joomla!, CentOS.

2009–now: section manager for **Developpez.com** (Qt since 2009, project hosting in 2010 and 2011, semantic Web between 2011 and 2013, HPC since its creation in 2018, algorithms and mathematics since 2018). Team management, website maintenance, application development.

2008–now: author (30+ articles), translator (100+ articles), proofreader, columnist (750+ news articles), and technical book critic (85+ books) for **Developpez.com**.
http://tcuvelier.developpez.com/ and https://tcuvelier.wordpress.com/

Pedagogical experience

Spring 2019: exercise sessions for the **combinatorial optimisation** course (master's students), in French, with a 20-student class. University of Paris-Sud (Paris-Saclay university).
Lecturer: Prof. Abdel Lisser.

Winter 2018: instructor for the introduction to **object-oriented programming and Java** (bachelor's students), in French, with a 20-student class. University of Paris-Sud (Paris-Saclay university).
Lecturer: Prof. Guillaume Wisniewski.

Winter 2018: exercise sessions for the introduction to **probabilities** course (bachelor's students), in French, with a 30-student class. University of Paris-Sud (Paris-Saclay university).
Lecturer: Prof. Abdel Lisser.

Spring 2017: project supervision for the **intelligent robotics** course (master's students), in English, with a 50-student class. University of Liège.
Lecturers: Prof. Bernard Boigelot, Philippe Latour, Antoine Lejeune, Dr. Raphaël Marée, Prof. Marc Van Droogenbroeck, Prof. Louis Wehenkel.

Winter 2016: exercise sessions and project supervision for the **discrete optimisation** course (master's students), in English, with a 50-student class. Includes the design of a complete exercise book. University of Liège.
Lecturer: Prof. Quentin Louveaux.

Spring 2016: project supervision for the **intelligent robotics** course (master's students), in English, with a 50-student class. University of Liège.
Lecturer: Dr. Renaud Detry.

Winter 2015: exercise sessions and project supervision for the **discrete optimisation** course (master's students), in English, with a 50-student class. University of Liège.
Lecturer: Prof. Quentin Louveaux.

Spring 2015: student instructor for the **numerical analysis project** (1st year students), in French, with a 20-student class. University of Liège.
Lecturer: Prof. Quentin Louveaux.

Open course material

Discrete optimisation: development of an exercise book with solutions and Julia source-code examples, available at https://github.com/dourouc05/OptimisationTeachingKit.
Intelligent robotics: contributions to the TRS project (*teaching robotics with a simulator*), including updates of the webpages and video making. Official website: https://github.com/ULgRobotics/trs

Language skills

French	Mother tongue
English	Cambridge FCE (B2 level) in 2010, English-taught master (2013-2015), British Council EnglishScore (C1) in 2020
German	B1-level training from 2014 to 2017

Technical skills

Programming

Programming languages	Julia, Python, C++, Java, C, PHP, Scala
Mathematical modelling	JuMP (Julia), AMPL
Optimisation solvers	Gurobi, CPLEX, Bonmin, Couenne
Data analytics	scikit-learn
Data visualisation	Mathematica, Plotly and Dash, MATLAB
Query languages	SQL, SPARQL
Database systems	Microsoft SQL Server, MySQL, SQLite
XML technologies	XSLT, XPath, RELAX NG
Development environments	Visual Studio Code (Julia), PyCharm (Python), Mathematica, MATLAB, IntelliJ IDEA (Java), CLion and Visual Studio (C++)
Graphical user interfaces	Qt (especially Qt Quick), PyQt
Version control	Mercurial (Hg), Git, SVN

Wolfram Technology Certified Level I in Mathematica (May 2021).

Office software

Word processors	LyX (LaTeX), Microsoft Word
Spreadsheet	Microsoft Excel
Technical documentation	DocBook
Technical-writing tools	Oxygen XML Author, XMLmind
Technical drawing	Microsoft Visio, Adobe Illustrator
Photo editing	Adobe Photoshop (with Nik Collection)

Personality

Detail-minded, results-driven, autonomous, energised by challenges.
Sports: climbing (since 2002, both indoor and outdoor, including competitions), walking.
Hobbies: reading novels (thrillers); listening to music (progressive rock, electronica).
Active contribution to the *Revue des Ingénieurs* at the ULg (satiric play; 2013, 2016).