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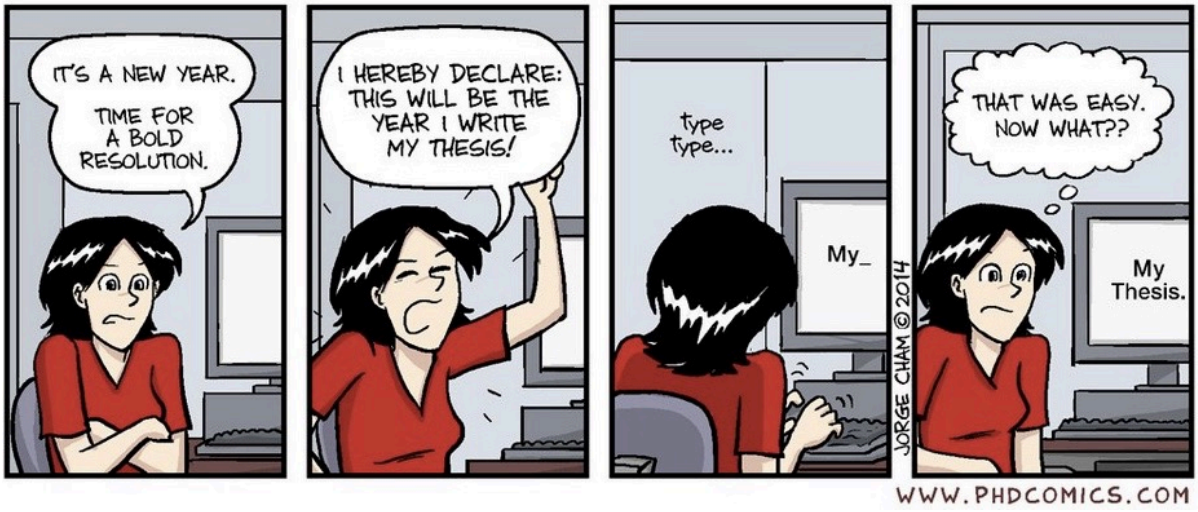
STADIUS
Center for Dynamical Systems, Signal Processing and Data Analytics

STADIUS Newsletter

JANUARY 2026



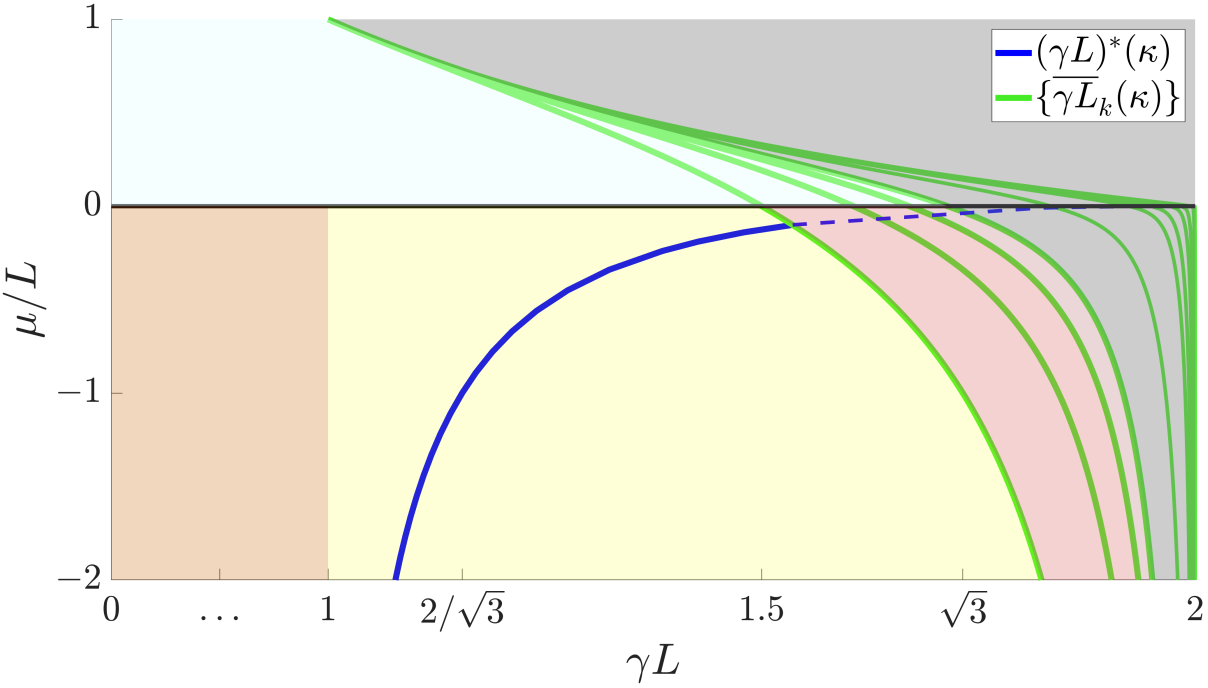
Research of the month by Teodor Rotaru

"Exact Performance Analysis of Fundamental First-Order Optimization Methods"
Work under the supervision of Panos Patrinos and François Glineur (UCLouvain)

Training neural networks, processing signals, and solving control problems all rely on **first-order optimization methods** that follow gradients. We know these methods work, but exactly how fast do they converge in the **worst-case**?
Standard results give rates like O(1/N), but this hides the **constants** that often matter in practice. Two algorithms with the same O(1/N) rate can perform very differently. Our research derives **tight, non-improvable bounds** with explicit constants for three core methods: **gradient descent**, **proximal gradient descent**, and **Douglas-Rachford splitting**.
Most theory focuses on smooth convex problems. This work goes beyond that to cover**smooth weakly convex problems**, where the function can have negative curvature and multiple local minima. To find exact worst-case limits, we use the **Performance Estimation Problem (PEP)** framework, which formulates the search for worst-case performance as a semidefinite program. This identifies the worst-case numerically and provides a proof certificate, which we then prove analytically.

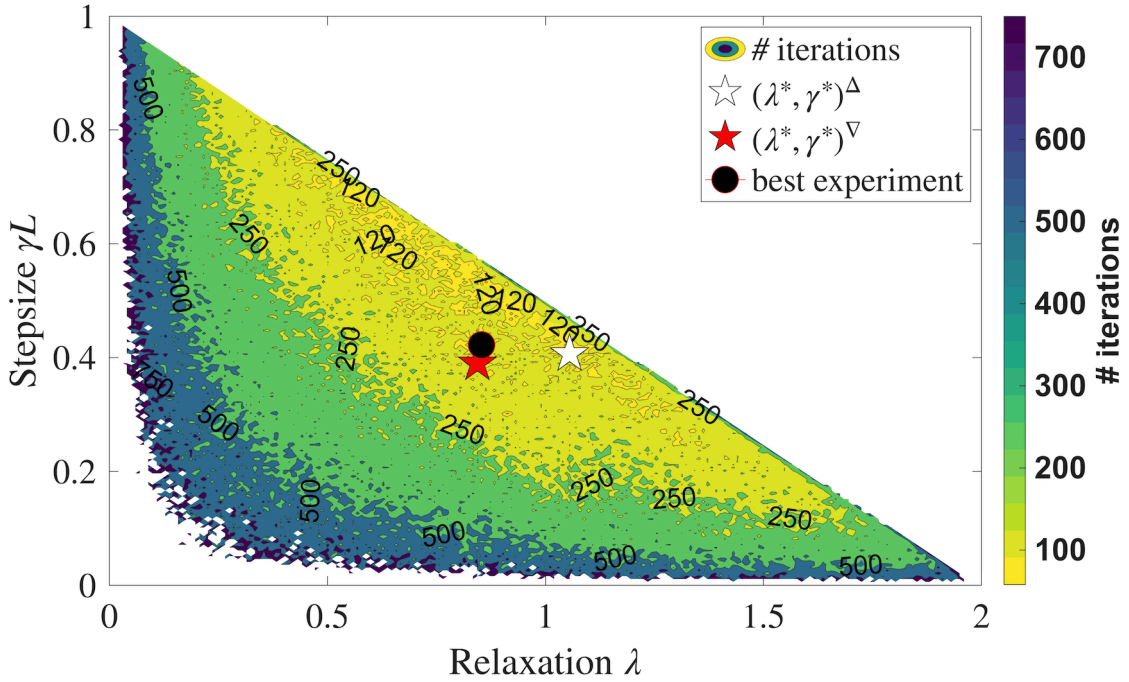
For **gradient descent**, we provide the first complete analysis covering any **constant stepsize** across weakly convex, convex, and strongly convex functions. Our analysis reveals**multiple convergence regimes** depending on stepsize and curvature (see figure),

each requiring distinct proof techniques. We also derive the **optimal constant stepsize** and propose a novel **horizon-free stepsize sequence** that outperforms it.



As the standard extension of gradient descent for constrained optimization, we analyze**proximal gradient descent (PGD)** through its equivalence to the **difference-of-convex (DC) algorithm**. A key novelty is extending the DC framework to allow **weak convexity** in the subtracted function, yielding bounds for larger PGD stepsizes beyond the **classical 1/L threshold**. We identify six distinct regimes in each of the two metrics: the residual gradient and the gradient mapping. Three regimes are proven tight, while the remaining three are conjectured based on strong numerical evidence.

For **Douglas-Rachford splitting**, we derive exact worst-case bounds across the full range of stepsizes and relaxation parameters, improving worst-case constants by **10-46%** compared to existing work. This enables theoretical hyperparameter tuning, confirmed by numerical experiments (see figure).



While worst-case scenarios are rare in practice, understanding these limits helps us design better algorithms.

For more detailed reading:

👉 Gradient descent complete analysis (accepted in Math. Program.): https://arxiv.org/abs/2406.17506
👉 Proximal gradient descent & Difference-of-convex algorithm study (AISTATS 2025): https://proceedings.mlr.press/v258/rotaru25a.html
👉 Full thesis: (available from 9th of February) https://lirias.kuleuven.be/4280924?&lang=en

News



Bart De Moor announces the creation of his 12th spin off company.

Prof. Bart De Moor is happy to announce the creation of his 12th spin-off company, which is a direct spin-out of the **Flanders AI Research Program**, and more specifically, its **Smart Grid** use case.

As a spin-off company of KU Leuven, VITO, Energyville, and Orion Grid Technologies focuses on Low Voltage (LV) distribution grids—the last mile of the electricity system—which is under **growing pressure from the energy transition.**
More than 3,000 European Distribution System Operators are struggling to keep pace with the rapid growth of solar panels, heat pumps, electric vehicle charging, and home batteries. To cope with this, they are seeking **tools that help them plan, operate, and invest more efficiently,** while the digitalization of LV grids is still very much in its infancy.
At the crossroads of power system engineering and AI, Orion designs **data-driven tools** that **turn grid data into actionable insights** for Distribution Grid Operators. Its solutions reconstruct LV grid connectivity, identify which households and assets are connected where, analyze the behavior of electric vehicles and heat pumps, assess available grid capacity, and determine how to reconfigure the grid to maximize that capacity. Orion also identifies which cables need reinforcement, supports regulatory reporting, forecasts congestion risks, and calculates mitigation actions.

Events @ STADIUS

5/02/2026 – PhD defense – Rosa Friesacher
Title: Uncertainty Quantification for Trustworthy Drug-Target Interaction Predictions
Supervisor: Yves Moreau
When: 14:00 to 15:00
Where: ESAT, Auditorim C (B91.300)

9/02/2026 – PhD defense – Teodor Rotaru
Title: *Exact Performance Analysis of Fundamental First-Order Optimization Methods*
Supervisor: Panos Patrinos & François Glineur
When: 16:00 to 18:00
Where: Aula van de Tweede Hoofdwet (TI 01.02)

11/02/2026 – PhD defense – Bram De Cooman
Title: *Het opleggen van beperkingen aan modelvrije versterkende leeralgoritmes met als toepassing autonoom rijden*
Supervisor: Johan Suykens
When: 13:30 to 15:30
Where: Aula van de Tweede Hoofdwet (TI 01.02)

For more information about STADIUS events please visit the STADIUS Event webpages.

Don't forget to check the website of VAIA for a wide choice of courses on (aspects of) AI: www.vaia.be

12/02/2026 What Matters: Scalable Data Mixing for LLMS
When: 12/02/2026 – 14:00 to 15:00
Where: B00.35
Speaker: Francesco Tonin

STADIUS Colloquium Series

An introduction to tensor methods
When: 23/02/2026; 16:15 -17:15
Speaker: Lieven De Lathauwer
Location: Aula L

In recent years, an important trend in research has been the generalization of "linear algebra and its applications" to "multilinear algebra and its applications". Whereas linear algebra relies on vectors and matrices, multilinear algebra additionally involves higher-order tensors. Multilinear methods are nonlinear, but in a relatively manageable (indeed "multi-linear") way. The tensor framework provides scientists and engineers with several new mathematical tools, opening up new possibilities in data analysis, systems modeling, prediction, completion, pattern recognition, data fusion, scientific computing, and more. This lecture is intended as a gentle introduction.



For more information go to STADIUS Colloquium Website

We wish the best of luck to the researchers who are leaving STADIUS

Best of luck!

Over the past weeks, several colleagues have reached important milestones and are starting new chapters beyond STADIUS.

- **Nithin Govindarajan,** a postdoctoral researcher from the group of Lieven De Lathauwer will be leaving STADIUS.
- **Sofie Buyckx**, our financial officer, moves to the Civil Engineering department to take a similar role there.

We warmly thank them all for their contributions and wish them every success in the next steps of their careers.

Recently defended PhDs

Congratulations to the new PhD graduate!

- **29/022/2026 - Sibren Lagauw** *"Global Solution to Problems in System Identification and Model Order Reduction"*
  Promotor: Bart De Moor,

Thesis

New projects starting in January

With the start of the year, there are many projects kicking off:

ELEVATE - Event-based LEarning, Vision, and AcTuation for Edge applications
📌 EU - MSCA DN Project
🎓 Rodolphe Sepulchre (as coordinator)

THUNDER - Fostering Trust in AI driven Healthcare: SecUre and uNbiased knowleDge guided gEneRative AI
📌 EU - MSCA DN Project
🎓 Maarten De Vos (as beneficiary)

JustHealth Ensuring Social Justice in AI for Healthcare
📌 EU - MSCA DN Project
🎓 Bart Vanrumste (as beneficiary)

Methusalem-BiomedAI - Explainable and generative AI for accelerating biomedical discoveries: from genome to function
📌 Methusalem
🎓 Maarten De Vos
🎓 Pedro Gonçalves

Modelling Stimulus-Related Confounds in Naturalistic Brain-Computer Interface
📌 FWO Fundamental Project
🎓 Alexander Bertrand

SKYCATCH: Ultra-efficient and trustworthy distributed intelligence in the sky
📌 FWO Project: Junior
🎓 Jona Beysens

Co-Cultures and Network Modeling to Discover Convergent Therapies in Genetic DEEs
📌 GSKE-INTEGRATING IPS
🎓 Pedro Gonçalves

GENz-trials Revolutionizing Clinical Trials to Optimize Assessment of Healthcare Innovations
📌 EU Project: HORIZON-JU-IHI
🎓 Maarten De Vos

Publications

Here's the monthly STADIUS Publications Digest, including new reports that have been added to the publications database. Please remember to have your own reports added in the publications database and make sure your entries are kept up to date (status submitted/accepted/published) at all times.

Contact Ida for new additions and updates; do not add/update database content yourself.

25-196
Roebben A., Bernardi G., Wouters J., van Waterschoot T., Moonen M., ``HIDVAS: A Hearing Instrument Dataset in Various Acoustical Scenarios for Algorithm Evaluation and Training", Technical Report 25-196, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2025.
25-197
Epure A., Dietzen T., van Waterschoot T., ``Multi-channel processing for patient identification and audio analysis in the context of group music therapy", in *Proc. of the*

Forum Acusticum 2025, Malaga, Spain, Jun. 2025, pp. 4275-4281. Lirias number: 4392147.

25-198

van Waterschoot T., ``Deep, data-driven modeling of room acoustics : literature review and research perspectives'', in *Proc. of the Forum Acusticum 2025*, Malaga, Spain, Jun. 2025, pp. 4065-4072. Lirias number: 4392222.

25-199

Masad Y., Vitolo G., Sakr M., Tornila J.D., Hussein Y., Lorenzoni V., van Waterschoot T., ``A mobile Wi-Fi and IMU head-tracking system for auralization in XR'', in *Proc. of the 2025 IEEE 6th International Symposium on Internet of Sounds (IS2)*, L Aquila, Italy, Oct. 2025, pp. 1-10. Lirias number: 4392253.

26-01

Sajjadifar Z., Yperman J., Agudelo M., Hernandez Espin A., Becker T., Vanthournout K., De Moor B., ``Non-Intrusive Residential Electric Vehicle Detection Using Positive-Unlabeled Contrastive Learning'', *Proc. of the Deployable AI workshop in AAAI 2026 conference (DAI)*, Singapore, Republic of Singapore, Jan. 2026, 7 p. Lirias number: 4396934.

26-02

Epure A., Dietzen T., van Waterschoot T., ``Multi-channel Processing for Patient Identification and Audio Analysis in the Context of Group Music Therapy'', in *Proc. of the 11th Convention of the European Acoustics Association Forum Acusticum / EuroNoise 2025*, Malaga, Spain, Jan. 2026, pp. 4275-4281. Lirias number: 4392147.

26-03

Teuwen M., Schuurmans M., Patrinos P., ``Probabilistic Safety under Arbitrary Disturbance Distributions using Piecewise-Affine Control Barrier Functions'', Technical Report 26-03, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2026.

26-06

Lagauw S., *Global Solution to Problems in System Identification and Model Order Reduction*, PhD thesis, Faculty of Engineering, KU Leuven (Leuven, Belgium), Jan. 2026, 307 p. Lirias number: 4271675.

26-07

Passemiers A., *Multimodal analysis of cell-free DNA for early and sensitive cancer detection*, PhD thesis, Faculty of Engineering, KU Leuven (Leuven, Belgium), Jan. 2026 Lirias number: 4243527.

26-08

Ding R., Hovine C., Callemeyn P., Kraft M., Bertrand A., ``A wireless, scalable and modular EEG sensor network platform for unobtrusive brain recordings'', *IEEE Sensors Journal*, vol. 25, no. 2, 2025, pp. 22580-22590. Lirias number: 4244209.

26-09

Ding R., Geirnaert S., Hovine C., Bertrand A., ``Synchronized EEG with two galvanically-separated miniature wireless behind-the-ear EEG sensors'', in *Proc. of the International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Copenhagen, Denmark, Jul. 2025, pp. 1-4. Lirias number: 4396938.

26-10

Elgendi M., Markov K., Liu H., De Vos M., Khalaf K., Khandoker A., Jelinek H.F., Goswami D., Menon C., ``Wearable devices for anxiety assessment : a systematic review'', *Communications medicine*, vol. 6, no. 20, 2026, pp. 1-16. Lirias number: 4394429.

26-11

Mouslech S., Wijnants S., van der Schagt A., Van Hoovels L., Deley R., Oyaert M., Neirinck J., Billen J., Frans G., De Vos M., ``Towards clinical integration of deep learning-based classification of urinary sediment particles from digital microscopy images : a prospective study'', *Clinical Chemisty*, 2026, pp. 1-11. Lirias number: 4394388.

26-12

Gistelinck L., Van den Broeck R., De Vos M., Wass S., Ortibus E., Bollen B., Naulaers G., Boets B., ``Regulation of stress physiology across social contexts in prematurely born toddlers'', *OSF Preprints*, 2026, pp. 1-27. Lirias number: 4395473.

26-13

Rousis G., Gistelinck L., Deferm W., Van den Broeck R., Bollen B., Wass S., Naulaers G., De Vos M., Boets B., ``When research does not synchronize : Comprehensive analyses show

no mother-child physiological coupling",*OSF Preprints*, Dec. 2025, pp. 1-29. Lirias number: 4395472.

26-14

Micheli C., Thelen A., De Vos M., Dereymaeker A., Haueisen J., Fiedler P., ``Validation of an automate seizure detection procedure for multi-channel neonatal EEG'', *Applied Sciences*, vol. 16, no. 52, 2026, pp. 1-21. Lirias number: 4394387.

26-15

Chatzichristos C., Chatzichristos G., Borremans I., Gruyaert S., De Vos I., De Vos M., De Backere F., ``Bridging the AI-literacy gap in healthcare : a qualitative analysis of the Flanders case-study'', Technical Report 26-15, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2026. Accepted for publication in *Journal of Medical Internet Research*, pp. 1-35. Lirias number: 4282259.

26-16

Bono M., Liu Z., Van Helleputte N., De Vos M., Van Den Bossche M., ``Multimodal sensing and machine learning for continuous monitoring of agitation in dementia'', *Alzheimer's Dementia*, vol. 21, no. 3, 2025, pp. 1-2. Lirias number: 4390500.

26-17

van der Schaft A., Sepulchre R., Chaffey T., ``Symmetry structures in linear physical systems'', *Systems & Control Letters*, vol. 206, 2025, pp. 106-287. Lirias number: 4280081.

26-18

Xiao Z., De Vos M., Chatzichristos C., Jiang Y., Zhao M., Ding F., Yang C., Li J., Liu C., ``Non-direct contact ECG signal classification using a hybrid deep learning framework with validation in bedside heart rate variability analysis'', *IEEE Journal Biomedical and Health Informatics*, 2026, pp. 1-13. Lirias number: 4280867.

26-19

Cecconi A., Bin M., Sepulchre R., Marconi L., ``Event disturbance rejection : A case study'', in *IFAC PapersOnline (13th IFAC Symposium on Nonlinear Control Systems (NOLOS))*, Reykjavik, Iceland, Jul. 2025, pp. 262-267. Lirias number: 4393770.

26-20

Pattyn E., Thammasan N., Davidoff H., De Raedt W., Eisele G.V., van Stiphout R., De Vos M., Kirtley O.J., Van Wambeke P., Morlion B., Vergaelen E., Van Hoof C., ``Exploring the relationship between stress-physiology and pain in the daily life of patients with chronic widespread pain'', *IEEE Transactions on affective computing*, vol. 16, no. 3, Jul. 2025, pp. 1903-1915. Lirias number: 4261354.



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