



**Offre n°2024-07754**

## **PhD Position F/M Distributed Dimensionality Reduction for Large-Scale Physical Simulations**

**Type de contrat :** Fixed-term contract

**Niveau de diplôme exigé :** Graduate degree or equivalent

**Fonction :** PhD Position

### **A propos du centre ou de la direction fonctionnelle**

The Inria Grenoble research center groups together almost 600 people in 23 research teams and 7 research support departments.

Staff is present on three campuses in Grenoble, in close collaboration with other research and higher education institutions (University Grenoble Alpes, CNRS, CEA, INRAE, ...), but also with key economic players in the area.

Inria Grenoble is active in the fields of high-performance computing, verification and embedded systems, modeling of the environment at multiple levels, and data science and artificial intelligence. The center is a top-level scientific institute with an extensive network of international collaborations in Europe and the rest of the world.

### **Contexte et atouts du poste**

While artificial intelligence is growing at a fast pace, the bulk of the world's computing power remains targeted at modeling and predicting physical phenomena,

such as climate models, weather forecasting, or nuclear physics.

These simulations are run on highly parallel supercomputers on which both the hardware and the software are optimized for the task at hand. While the computing power of each processing unit is still increasing, the communication networks and the storage capabilities in these clusters do not follow such fast trends.

As a result, computing nodes produce outputs faster than what can be stored or sent to process elsewhere: These simulations are IO bound.

To reduce the communication burden, a promising venue is **is situ computations**, meaning that most of the data is processed locally by the nodes, and only meaningful aggregates are stored or sent over the network.

However, this is a difficult problem in general since meaningful information for the global simulation depends on the other nodes' output. The goal of this PhD is to **leverage machine learning techniques to bypass IO bottlenecks in the context of physics simulation on high-performance computing (HPC) clusters**. This work is thus placed in a broader "Machine Learning for Science" context, which aims at using ML to solve key problems arising in traditional sciences.

More specifically, we will focus on distributed dimensionality reduction techniques, which critically reduce the communication and storage needed to retain most of the information.

**Environment.** The PhD will take place at Inria Grenoble, in the Thoth team. This is a large team focused on machine learning, and in particular computer vision. Particular topics of interest include visual comprehension, hyperspectral imaging, numerical and parallel optimization, and unsupervised learning. A particular emphasis is put on interdisciplinary projects. The PhD will include frequent visits to the MIND team, at Inria Saclay. The two supervisors are young Inria researchers, with a strong track record in optimization and machine learning.

This project also takes place in the PEPR NumPEX, an initiative to improve the use of supercomputers for physical simulations. The results from the PhD will thus be integrated into the software stack for these applications. This PhD thus provides the unique opportunity to discuss with scientists from other fields and to improve their workflows through IA research. Interaction with scientists developing computational simulations in various fields will be encouraged, in particular with the Gysela code, which is part of the ITER project.

## Mission confiée

The project will first focus on dimensionality reduction techniques, and in particular the standard PCA method. To fit the requirements imposed by the HPC setting, we will consider distributed incremental PCA methods [8], that work with streaming data split over many computing nodes. An important consideration in our context is that, unlike classical data stream, the data is not i.i.d. on the nodes, but stems from the domain partitioning imposed by the physics of the problem. The two

main objectives are the following:

- **Benchmark existing methods:** This will require a thorough state-of-the-art review, as well as defining the relevant metrics for evaluating data compression in physics simulations (communication/computation time/cost, quality of the solution...). The benchmark will be realized with benchopt [3] and will benefit from the distributed coding expertise of both supervisors.
- **Designing new efficient methods:** To account for the structure of physics simulations, we propose to investigate how to efficiently leverage the inter-node communication to improve existing distributed PCA methods [5, 4]. The convergence of the proposed methods will be analyzed and we will provide tight convergence bounds.

While the initial focus will be on PCA, more advanced compression methods will be considered throughout the project, in particular with spatial compression [1, 2], mesh-based wavelets [7], or auto-encoders [6].

## References

- [1] Andrés Hoyos-Idrobo, Gaël Varoquaux, Jonas Kahn, and Bertrand Thirion. Recursive nearest agglomeration (ReNA): Fast clustering for approximation of structured signals. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 41(3):669–681, 2019.
- [2] Milan Klöwer, Miha Razinger, Juan J. Dominguez, Peter D. Düben, and Tim N. Palmer. Compressing atmospheric data into its real information content. *Nature Computational Science*, 1(11):713–724, November 2021.
- [3] Thomas Moreau, Mathurin Massias, Alexandre Gramfort, Pierre Ablin, Pierre-Antoine Bannier, Benjamin Charlier, Mathieu Dagr  ou, Tom Dupr   la Tour, Ghislain Durif, Cassio F. Dantas, Quentin Klopfenstein, Johan Larsson, En Lai, Tanguy Lefort, Benoit Mal  zieux, Badr Moufad, Binh T. Nguyen, Alain Rakotomamonjy, Zaccharie Ramzi, Joseph Salmon, and Samuel Vaiter. Benchopt: Reproducible, efficient and collaborative optimization benchmarks. In *Advances in Neural Information Processing Systems (NeurIPS)*, volume 36, New-Orleans, LA, USA, November 2022.
- [4] Kevin Scaman, Francis Bach, S  bastien Bubeck, Yin Tat Lee, and Laurent Massouli  . Optimal convergence rates for convex distributed optimization in networks. *Journal of Machine Learning Research*, 20:1–31, 2019.
- [5] Ohad Shamir, Nati Srebro, and Tong Zhang. Communication-efficient distributed optimization using an approximate newton-type method. In *International conference on machine learning*, pages 1000–1008. PMLR, 2014.
- [6] Lucas Theis, Wenzhe Shi, Andrew Cunningham, and Ferenc Husz  r. Lossy

Image Compression with Compressive Autoencoders. In International Conference on Learning Representations (ICLR), Toulon, France, 2017.

[7] S. Valette and R. Prost. Wavelet-based progressive compression scheme for triangle meshes: Wavemesh. IEEE Transactions on Visualization and Computer Graphics, 10(2):123–129, March 2004.

[8] Xiaolu Wang, Yuchen Jiao, Hoi-To Wai, and Yuantao Gu. Incremental aggregated riemannian gradient method for distributed pca. In International Conference on Artificial Intelligence and Statistics, pages 7492–7510. PMLR, 2023.

## Principales activités

Main activities :

- Read papers and state of the art
- Benchmark existing algorithms
- Write problem formulation, proofs of convergence.
- Adapt the formulation to the target scenario.
- Propose a new dedicated algorithm.
- Program, run and analyse simulation results.

Complementary activities

- Participate to the teams activities : scientific meetings, seminars, scientific presentations.

## Compétences

- Strong mathematical background. Knowledge in numerical optimization is a plus.
- Good programming skills in Python. Knowledge of a distributed computation framework is a plus.
- The candidate should be proficient in English. Knowing French is not necessary, as daily communication in the team is mostly in English due to the strong international environment.

## Avantages

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (90 days / year) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Complementary health insurance under conditions

## Rémunération

2 200 euros gross salary /month

## Informations générales

- **Thème/Domaine** : Optimization, machine learning and statistical methods  
Statistics (Big data) (BAP E)
- **Ville** : Montbonnot
- **Centre Inria** : [Centre Inria de l'Université Grenoble Alpes](#)
- **Date de prise de fonction souhaitée** : 2025-10-01
- **Durée de contrat** : 3 years
- **Date limite pour postuler** : 2025-05-26

## Contacts

- **Équipe Inria** : [THOTH](#)
- **Directeur de thèse** :  
Hendrikx Hadrien / [hadrien.hendrikx@inria.fr](mailto:hadrien.hendrikx@inria.fr)

## A propos d'Inria

Inria est l'institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 215 équipes-projets agiles, en général

communes avec des partenaires académiques, impliquent plus de 3900 scientifiques pour relever les défis du numérique, souvent à l'interface d'autres disciplines. L'institut fait appel à de nombreux talents dans plus d'une quarantaine de métiers différents. 900 personnels d'appui à la recherche et à l'innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 200 start-up. L'institut s'efforce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l'économie.

## L'essentiel pour réussir

We seek candidates strongly motivated by challenging research topics in machine learning for science. Applicants should have a strong mathematical background with knowledge of numerical optimization and machine learning. With regards to software engineering, proficiency in Python is expected and preliminary experience in a distributed computation library is a plus.

**Attention:** Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d'autres canaux n'est pas garanti.

## Consignes pour postuler

Applications must be submitted online on the Inria website.

Processing of applications sent by other channels is not guaranteed.

### Sécurité défense :

Ce poste est susceptible d'être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L'autorisation d'accès à une zone est délivrée par le chef d'établissement, après avis ministériel favorable, tel que défini dans l'arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l'annulation du recrutement.

### Politique de recrutement :

Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.