Internship Proposal for 2026/2027

Lost in Precisions: Automatic Detection of Numerical Instabilities in Scientific Codes

Context

Safety-critical embedded systems increasingly rely on complex numerical computations to process large volumes of data. In domains such as aerospace, defense, telecommunications, energy, and transportation, numerical errors can compromise system behavior and lead to severe consequences [5]. Ensuring the reliability and correctness of floating-point computations is therefore a fundamental requirement.

IEEE754 floating-point arithmetic [3] provides several precision formats, whose selection affects numerical accuracy, memory footprint, and computational performance. Mixed-precision computing offers opportunities for optimization in resource-constrained environments, but safely reducing precision remains a challenging task.

Because floating-point arithmetic is inherently affected by rounding errors, precision loss can accumulate throughout a computation or arise abruptly due to numerical instabilities. Identifying and understanding these instabilities is therefore essential before adopting mixed-precision strategies in safety-critical applications.

Discrete Stochastic Arithmetic (DSA), as implemented in the CADNA library [2] (`https://cadna.lip6.fr/`), has proven particularly effective for the numerical validation of real-life applications [1, 2, 4, 6, 7]. It reveals hidden numerical issues (cancellations, unstable arithmetic operations, unstable branchings, and instabilities in mathematical library functions) in complex codes that would otherwise go unnoticed.

In [1], the authors leverage CADNA for a step-by-step numerical analysis of a complex real-world industrial application. To this end, they built a framework on top of CADNA to detect, quantify and characterize numerical instabilities at the level of individual computation steps, while estimating the number of correct digits in the intermediate results.

Goals

While the CADNA-based framework has been manually built around a specific industrial application, the approach is applicable to a wide range of scientific software. The internship therefore aims at formalizing and implementing an automated numerical analysis framework. This goal consists of multiple applied research and advanced engineering tasks:

- generalize and formalize the numerical analysis approach from [1] into an automated and reusable framework,
- design a source-to-source compilation architecture capable of instrumenting a scientific code with numerical analysis instructions and implement the architecture using Clang/LibTooling (`https://clang.llvm.org/docs/LibTooling.html`),
- design and implement a post-processing tool for producing actionable syntheses and visual representations of analysis results based on the foundations from [1],
- validate and test the framework on a series of scientific codes ranging from small-scale benchmarks, such as FPBench (`https://fptalks.org/spec/`), to complex real-world applications.

The work of the intern may result in publications and presentations in the team seminars.

Location

The internship will take place at Sorbonne Université, in the PEQUAN team (`https://pequan.team.lip6.fr/`) of the LIP6 computer science lab settled on the Pierre & Marie Curie Campus in the Latin Quarter of Paris, France.

Compensation

The internship is paid according to the French national regulations for internships.

Duration

6 months

Advisors

- Hanane Benmaghnia – post-doctoral researcher in numerical validation for scientifc computing in LIP6, Sorbonne Université – CNRS (`https://hanane-benmaghnia.github.io/`)
- Marek Felšöci – associate professor in computer science at LI-PaRAD, Université de Versailles–St. Quentin en Yvelines (`https://felsoci.sk`)
- Fabienne Jézéquel – associate professor in computer science, HDR, at University Paris-Panthéon-Assas and Sorbonne Université–CNRS/LIP6, (`https://perso.lip6.fr/Fabienne.Jezequel/`)

Profile

The internship is primarily intended for 2^{nd} year Master students in computer science, applied mathematics, or a related field. However, students from other disciplines are also welcome to apply, provided they can demonstrate a strong ability to work in an interdisciplinary environment.

The desired skills include:

- Ability to model problems using mathematical and computational tools.
- Familiarity with numerical analysis and floating-point arithmetic.
- Experience with source-to-source compilation and code instrumentation.
- Programming skills in C, as well as in software engineering.

Scientific curiosity, independence, rigor, and the ability to analyze experimental results will be particularly valued.

Applications

Applications should be sent to Hanane Benmaghnia (hanane.benmaghnia@lip6.fr), Marek Felšöci (marek.felsoci@uvsq.fr) and Fabienne Jézéquel (fabienne.jezequel@lip6.fr). They should include:

- a curriculum vitae,
- a cover letter describing the motivation for the internship,
- links to representative personal, professional or academic projects, e.g., Git repositories (if available).

References

[1] Hanane Benmaghnia, Marek Felšoci, Fabienne Jézéquel, and Stef Graillat. How many digits can you trust? numerical validation and instability localization in a real-world application. In *Proceedings of the 30th International Conference on Engineering of Complex Computer Systems (ICECCS)*, Brisbane, Australia, November 2026.

[2] Pacôme Eberhart, Julien Brajard, Pierre Fortin, and Fabienne Jézéquel. High performance numerical validation using stochastic arithmetic. *Reliable Computing*, 21:35–52, 2015.

[3] IEEE Computer Society. IEEE Standard for Floating-Point Arithmetic. Technical Report IEEE Std 754-2025, 2025.

[4] Fabienne Jézéquel, Jean Luc Lamotte, and Issam Said. Estimation of numerical reproducibility on CPU and GPU. In Maria Ganzha, Leszek A. Maciaszek, and Marcin Paprzycki, editors, *2015 Federated Conference on Computer Science and Information Systems, FedCSIS 2015, Lódz, Poland, September 13-16, 2015*, volume 5 of *Annals of Comput. Science and Information Systems*, pages 675–680. IEEE, 2015.

[5] Jacques-Louis Lions et al. Ariane 5 flight 501 failure: Report by the inquiry board. Technical report, European Space Agency, 1996.

[6] Roméo Molina, Vincent Lafage, David Chamont, and Fabienne Jézéquel. Investigating mixed-precision for AGATA pulse-shape analysis. In *EPJ Web of Conferences*, volume 295, page 03020, Norfolk, VA, United States, 2023.

[7] F. Stloukal, F. Jézéquel, S. Roiser, and F. Optołowicz. On numerical validation within madgraph5 for performance and efficiency enhancement. In *Proceedings of the 28th International Conference on Computing in High Energy and Nuclear Physics (CHEP 2026)*, Bangkok, Thailand, May 2026.