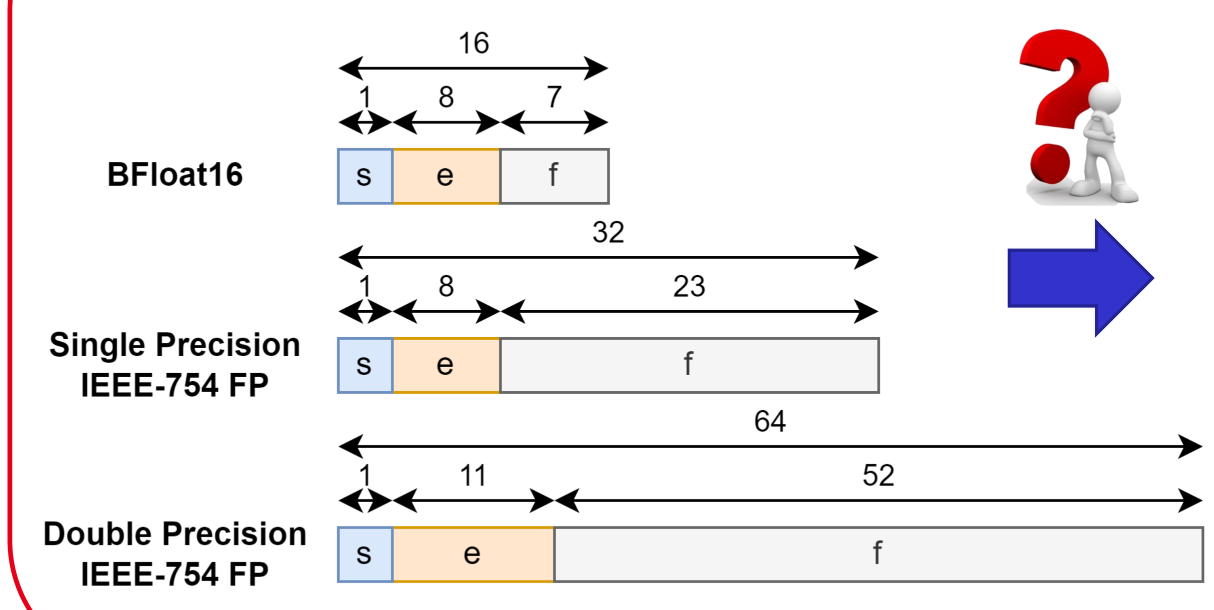
Hardware Support for Variable Precision Floating Point Formats Exploration

Riccardo Alidori*, Andrea Bocco*

Corresponding author: *riccardo.alidori@cea.fr*.

Context

Standard Floating Point (FP)



High-precision Applications

- Computational Chemistry
- Computational Physics
- Mathematical models
- …

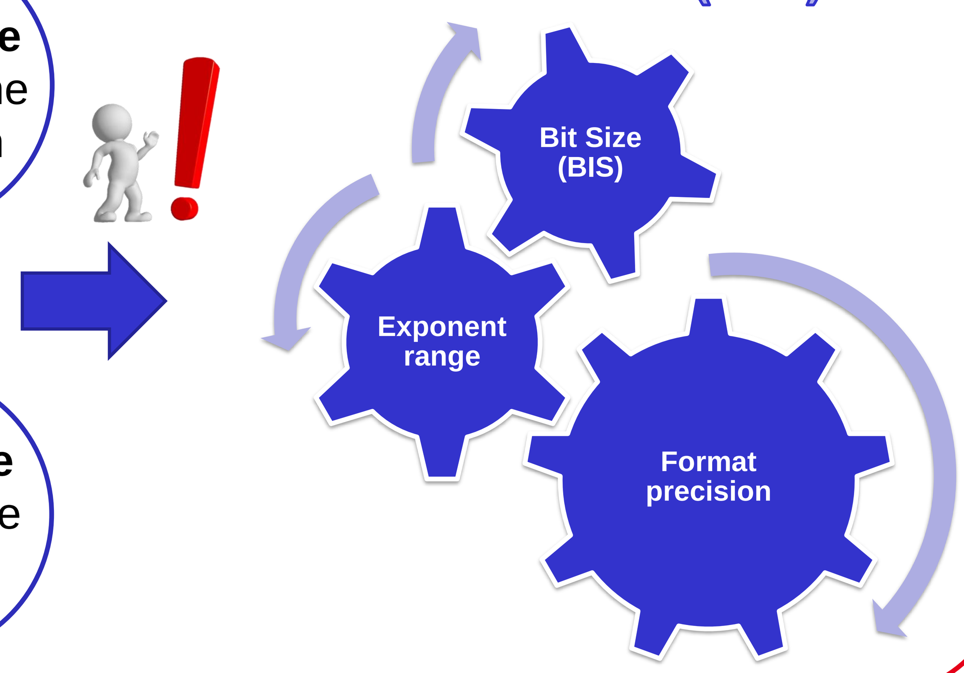
Challenge Enlarge the precision

Low-precision Applications

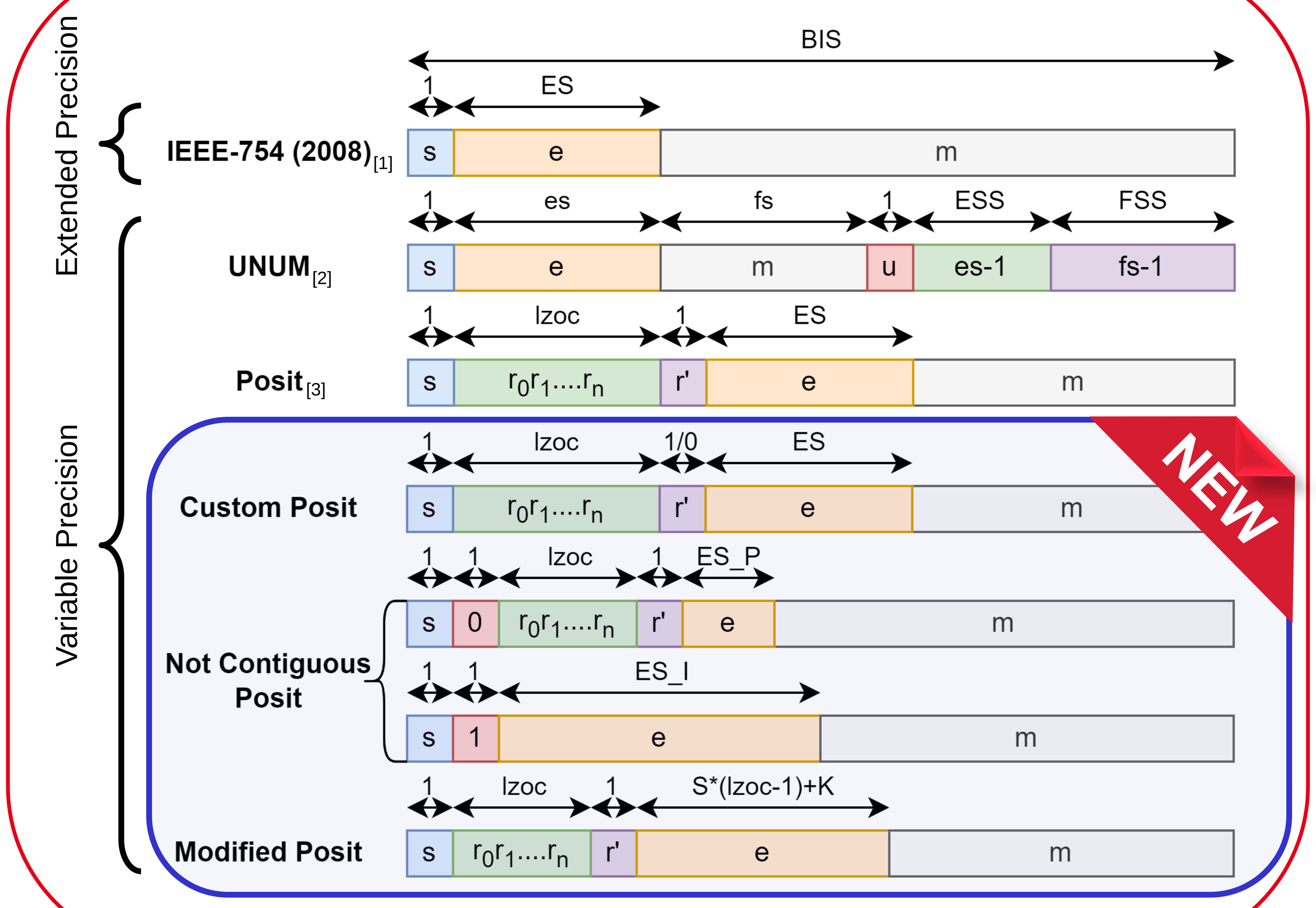
- Embedded digital signal processing
- DNN: deep neural networks
- Computational geometry
- …

Challenge Reduce the precision

Variable Precision (VP) FP



SOA & Proposed VP FP Formats



VaRiable Precision Core (VRP[4])

The VRP is a RISC-V CVA6 based accelerator for extendable FP computation [4]. It aims to facilitate the use of variable extended precision in order to improve the numerical stability of big linear algebra algorithms.

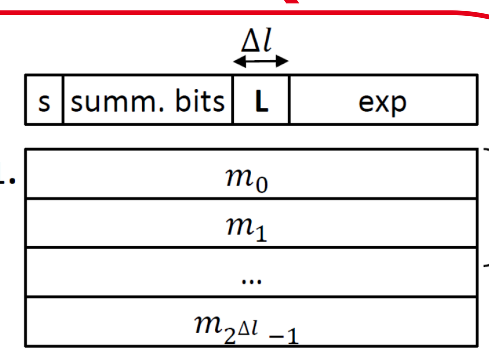


Fig 2. The custom internal FP format "P"

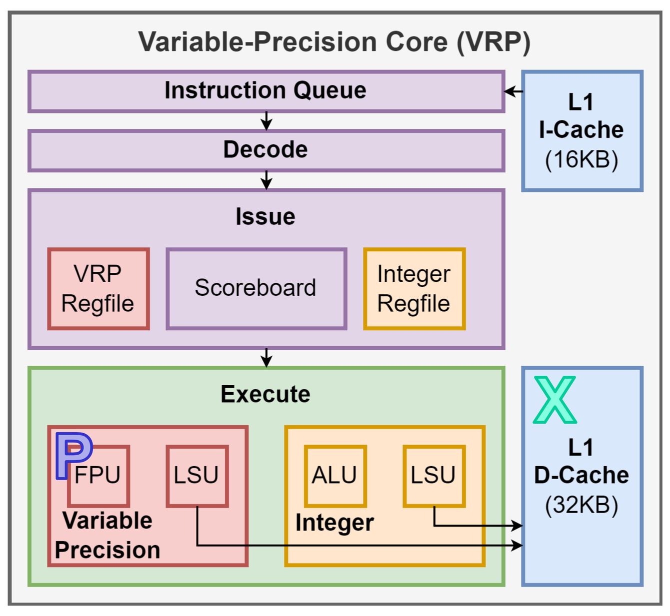
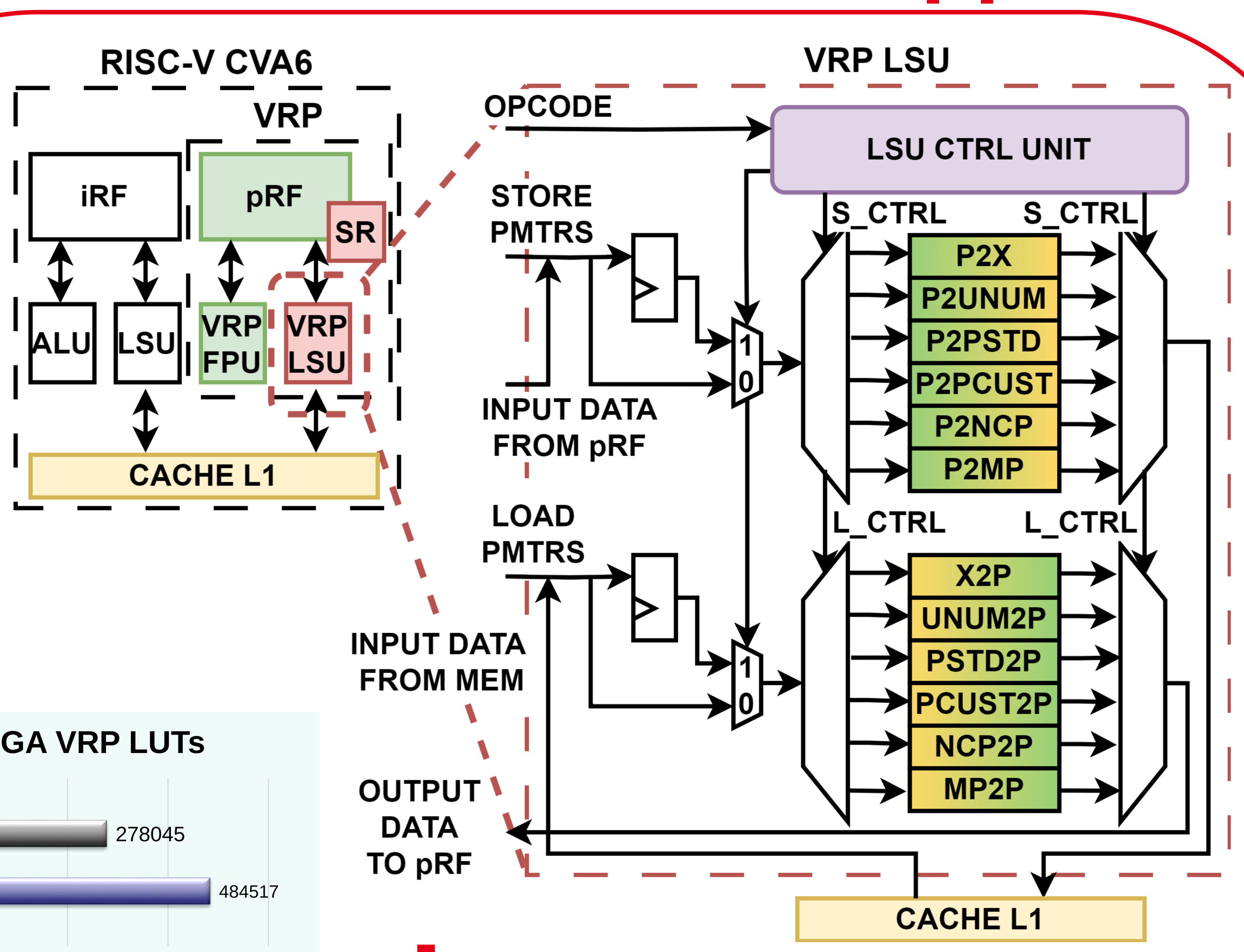


Fig 1. The VRP Core[4]

The VRP has two different FP formats

1. P : Custom **Internal** FP format
   - Fixed-size fields (64bit chunks)
   - Internal FP Operations (Add, Mul, …)
   - Tunable Mantissa length (8 to 512bits, 1 bit granularity)
2. X : IEEE-754 Extendable **Memory** format
   - Variable-size fields
   - Memory operation (Load/Store)
   - Tunable Bit Size (8 to 512bits, 1 bit granularity)

VP FP RISC-V HW Support



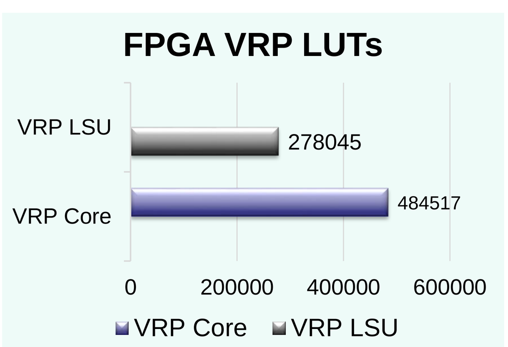


Fig 3. The Multiple VP FP formats support: extended VRP Load and Store Unit

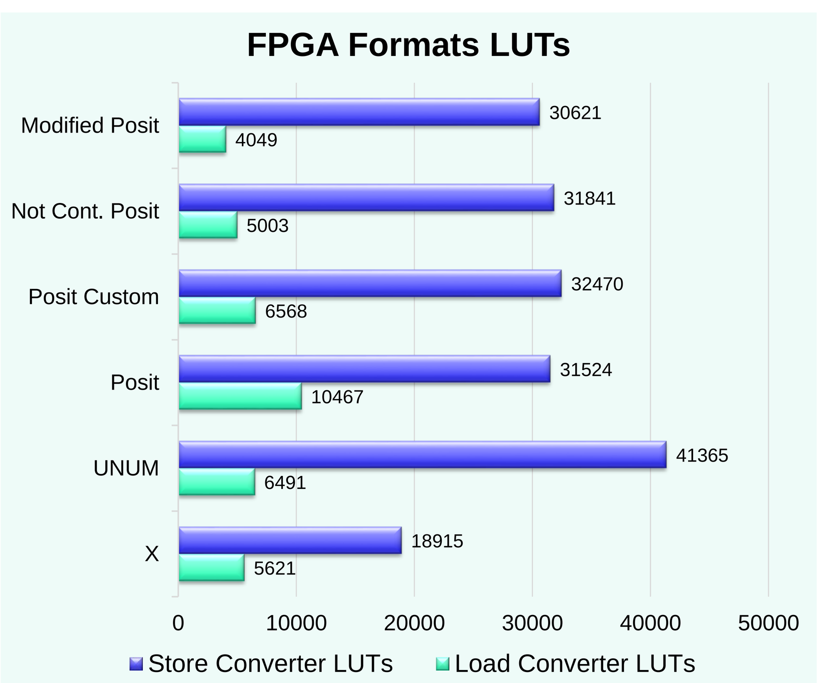


Fig 4. The VRP@50MHz into the Virtex UltraScale+ VCU128 Board

Benchmarking

Run applications for each parameter configuration of each format

High-precision application: Gauss Elimination on a 100x100 Hilbert Matrix

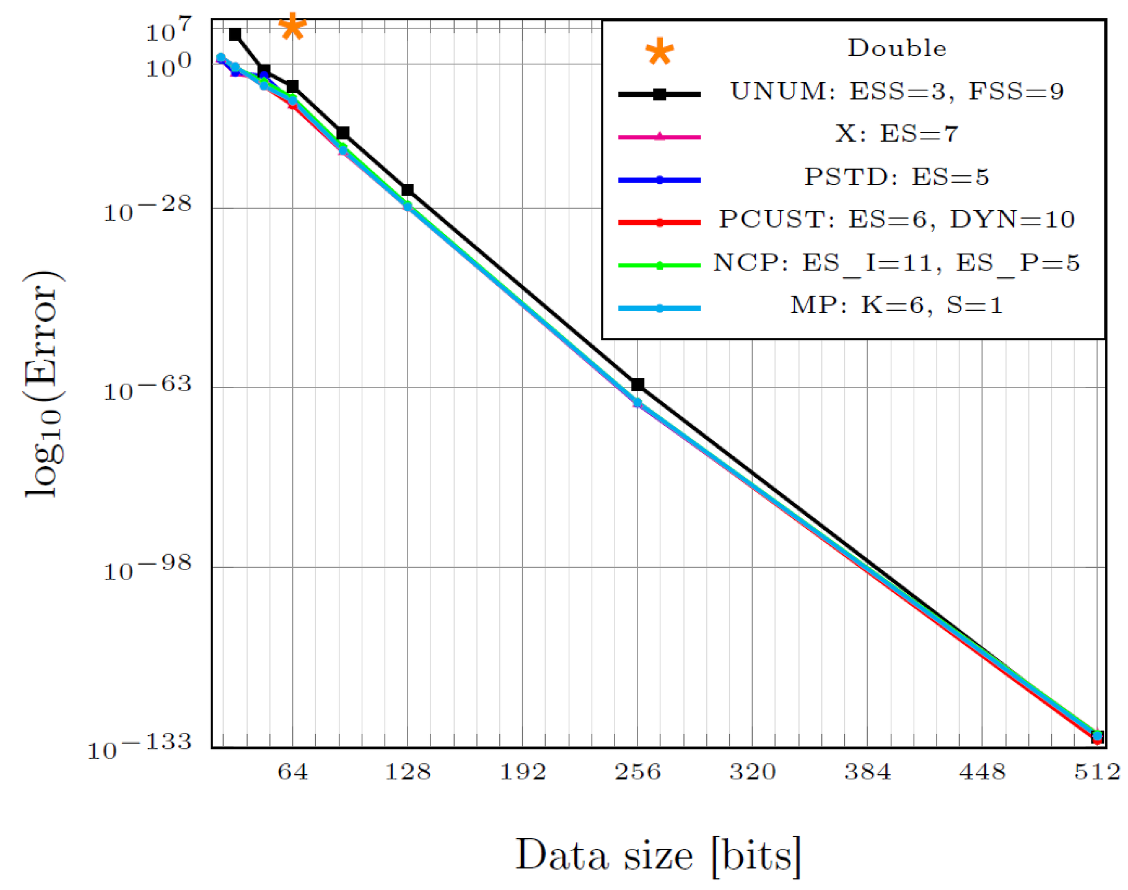


Fig 5. Gaussian Elimination residual error results. Best format configurations

Low-precision application: In-place FFT algorithm on a 8192 samples signal

Size [Bits]	UNUM %	X %	PSTD %	PCUST %	NCP %	MP %	Standard FP %
8		77.65	75.65	75.65	79.67	75.65	
16	99.85	98.82	99.43	99.43	99.43	99.42	94.54
24	99.42	99.94	99.99	99.99	99.98	99.98	
32	99.95	100	100	100	100	100	100

Fig 6. FFT accuracy results. Best format configurations

Conclusion: Choosing between VP FP formats may be irrelevant for high-precision applications, while it has some benefit when handling small-size variables.

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[1] *IEEE Standard for Floating-Point Arithmetic*. doi: 10.1109/IEEESTD.2008.4610935.
[2] John Gustafson. *The End of Error: Unum Computing*. doi:10.1201/9781315161532.
[3] Gustafson and Yonemoto. *Beating Floating Point at Its Own Game: Posit Arithmetic*. doi: 10.14529/jsfi170206.
[4] Yves Durand et al. *Accelerating Variants of the Conjugate Gradient with the Variable Precision Processor*. doi: 10.1109/ARITH54963.2022.00017.

* Univ. Grenoble Alpes, CEA, List, F-38000 Grenoble, France