Fourier Methods: classical and quantum

1. *Introduction*

The goal of this practice project is for students to become familiar with one of the most used data analysis methods in engineering: Fourier analysis.

This method quantifies the vibrational modes in airframes (flutter analysis), automotive, ball-bearings, radio frequency spectrum analysis, radar and sonar engineering, interference in coherent optics and holography, etc.

2. *Project description*

The training provides a jump-start into C++ project-style coding [1,2], focusing on Fourier analysis to relevate the problems encountered and the solutions to those, rather than on the coding technicalities (which can be rather advanced [2]).

The aspects approached will be thus centered on the mathematical background, its discretisation and the problems arising, the solutions that exist, and of course hands-on experience with simulated data. The last part will give an introduction to quantum-computing and work a Quantum-FFT algorithm on IBM's Q-Experience quantum-chips.

3. *Description of the work on the project*

The students will have access to an internet Linux account, but they may also use their own laptops, or connect to their home computers. The approximate schedule is the following:

- review the mathematical background of Fourier series
- learn the particularities of discreet Fourier methods (Cooley-Tukey algorithm [3])
- become familiar w/ the underlying problems (spectrum-leakage, Gibbs satellite lobes)
- ... and w/ the solutions for those (apodisation, FoxLima series, Phase-Enhanced Smoothing)
- work some hands-on examples in C++ [1]
- introduction to quantum-algorithms
- IBM Q-Experience quantum-chips hands-on Quantum-FFT

4. *Desirable preliminary knowledge*

- basics of mathematical analysis, linear algebra
- basics of computer knowledge (Linux and C++)
- an IBM Q-Experience account

5. *References*

[1] M.O. Dima – *C++ course*, IFIN-HH, Romania (2018-2019) – http://cern.ch/modima/WXX
[2] M. Dima, V. Korenkov, *AFM Modules* https://dx.doi.org/10.24412/2500-1000-2022-6-1-136-140
[3] C++ code: https://rosettacode.org/wiki/Fast_Fourier_transform#C.2B.2B

6. *Number of students participating in the project*

The project can host 2 students.

7. *Project leader on behalf JINR*

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