Computational Quantum Physics

Week 3

Due on Week 5

Slides template Starting from this week, it is mandatory to submit a report of the exercises in the presentation format (slides). The maximum length is six slides, including:

1. First slide: heading with your name, the date, exercise number and course name and year.
2. Different sections, such as (if applicable)
   * THEORY: Explain very briefly the theory you have based your solution on.
   * CODE DEVELOPMENT: Introduce strategies, tests, and report debugging problems, compilations options.
   * RESULTS: Present data and explain your results.

(a) Upload the slide report in Moodle under the correspondent exercise.

(b) File names must include your name, exercise number and codewords SLIDES, and CODE. Example: Ex3-Rossi-SLIDES.pdf

Exercise 1: **Scaling of the matrix-matrix multiplication**

Consider the program developed in Exercise 3 of Week 1 (matrix-matrix multiplication).

(a) Write a python script that changes N between two values N_{min} and N_{max}, and launches the program.

(b) Store the results of the time needed in different files depending on the multiplication method used.

(c) Fit the scaling of the time needed for different methods as a function of the input size. Consider the biggest possible difference between N_{min} and N_{max}.

(d) Plot the results for the different multiplication methods.

Exercise 2: **Eigenproblem**

Consider a random Hermitian matrix A of size N.

(a) Diagonalize A and store the N eigenvalues λ_i in crescent order.

(b) Compute the normalized spacings between eigenvalues
$s_i = \Delta\lambda_i / \bar{\Delta\lambda}$ where

$$\Delta\lambda_i = \lambda_{i+1} - \lambda_i,$$

and $\bar{\Delta\lambda}$ is the average $\Delta\lambda_i$.

Exercise 3: **Random Matrix Theory**

Study $P(s)$, the distribution of the s_i defined in the previous exercise, accumulating values of s_i from different random matrices of size at least $N = 1000$.

(a) Compute $P(s)$ for a random HERMITIAN matrix.

(b) Compute $P(s)$ for a DIAGONAL matrix with random real entries.

(c) Fit the corresponding distributions with the function:

$$P(s) = a s^{\alpha} \exp(-b s^{\beta})$$

and report α, β, a, b.

Hint: if necessary neglect the first matrix eigenvalue.