

## Homework 1 (CSM1)

Due: April 15, 2019.

The purpose of these exercises is that of learning to treat numerical data that have been generated in Monte Carlo or Molecular Dynamics simulations.

**DATA SETS:** Two data files are provided: `data1.txt`, `data2.txt`. On each line there are three numbers: the first number is the Monte Carlo time, the second number and third number correspond to measurements.  $U_1$  and  $U_2$  are the two quantities reported in `data1.txt` (second and third column, resp.) and  $U_3$  and  $U_4$  are the two quantities reported in `data2.txt`.

Data in: <http://elearning2.uniroma1.it/course/view.php?id=2878>

**Data are thermalized: check by looking at  $U_i(t)$  versus Monte Carlo time  $t$ .**

- 1) **Blocking analysis.** First, compute the average and error on  $\langle U_i \rangle$  neglecting correlations, i.e., assuming that data are independent.

Second, generate blocked data. If  $U_i(t)$ ,  $t = 1, 120000$  are the original data define

$$U^{(1)}(t) = \frac{1}{2}[U_i(2t-1) + U_i(2t)]$$

$$U^{(k)}(t) = \frac{1}{2}[U_i^{(k-1)}(2t-1) + U_i^{(k-1)}(2t)]$$

Compute average and error on the blocked variables for increasing values of  $k$  till the error stabilizes.

Repeat the analysis for all four observables  $U_1, U_2, \dots$ . Show your results for the error in a graph (error versus  $k$ ) and report in a table the best estimate of the error for each observable.

- 2) **Autocorrelation analysis.** Compute the autocorrelation function for the four observables and the corresponding integrated autocorrelation time (report  $\tau_{\text{int}}$  in a table for each observable). Use the estimates of the autocorrelation times to estimate the error on the sample mean of  $U_i$ . Compare the results with those obtained in the blocking analysis (report the results for the error in the same table).
- 3) **Jackknife.** Generate blocked variables with blocks of length 1500. They can be considered as essentially independent (is this consistent with previous results?). Define ( $i = 2, 3, 4$ )

$$R_i = \frac{\langle U_i \rangle}{\langle U_1 \rangle}.$$

Compute  $R_i$  and its error using the jackknife method applied to the blocked variables. Compare the error with those obtained by using the independent-error formula and the worst-error formula (use the errors computed with the autocorrelation analysis). Present the three different estimates in a table.