

**The advanced methods in computational Physics and simulation,
Fall semester 2024**

Lecturer: Prof. Movahed

TA: Mr. Aminreza Safarpour and Alireza Karamzadeh

Venue: Saturday and Monday, 8:30-10:30 am

**1) The course mark includes 10 Points for (Exercises+Project), 9 points for exams,
2 points for Quiz**

2) Main References:

- 1- Landau, Rubin H., Manuel J. Páez, and Cristian C. Bordeianu. Computational physics: Problem solving with Python. John Wiley & Sons, 2015.
- 2- Gould, Harvey, et al. "An introduction to computer simulation methods: applications to physical systems." Computers in Physics 10.4 (1996): 349-349.
- 3- Hartmann, Alexander K., and Heiko Rieger. Optimization algorithms in physics. Vol. 2. Berlin: Wiley-Vch, 2002.
- 4- Hartmann, Alexander K., and Heiko Rieger, eds. "New optimization algorithms in physics." (2004): 134411.
- 5- Mezard, Marc, and Andrea Montanari. Information, physics, and computation. Oxford University Press, 2009.
- 6- Bassett, Bruce A., et al. "Fisher matrix preloaded-Fisher4Cast." International Journal of Modern Physics D 20.13 (2011): 2559-2598.
- 7- Lewis, Antony. "GetDist: a Python package for analysing Monte Carlo samples." arXiv preprint arXiv:1910.13970 (2019).
- 8- Tejero-Cantero, Alvaro, et al. "SBI--A toolkit for simulation-based inference." arXiv preprint arXiv:2007.09114 (2020).

3) Other relevant References

- 9- Irvine, Kip R., and Lyla B. Das. Assembly language for x86 processors. Prentice Hall, 2011.
- 10- Giordano, Nicholas J., et al. "Computational physics." Computers in Physics 11.4 (1997): 351-351. Heermann, Dieter W. Computer simulation methods in theoretical physics. Springer Science & Business Media, 2012.
- 11- My lecture notes available via <http://faculties.sbu.ac.ir/~movahed/index.php/courses>
- 12- Pang, Tao. "An introduction to computational physics." (1999): 94 -95.
- 13- Sirca, Simon, and Martin Horvat. Computational methods for physicists: compendium for students. Heidelberg, New York: Springer, 2012.
- 14- Gao, Jianbo, et al. Multiscale analysis of complex time series: integration of chaos and random fractal theory, and beyond. John Wiley & Sons, 2007.
- 15- Williams, Christopher KI, and Carl Edward Rasmussen. Gaussian processes for machine learning. Vol. 2. No. 3. Cambridge, MA: MIT press, 2006.
- 16- Michael A. Nielsen & Isaac L. Chuang. "Quantum Computation and Quantum Information" (2000)
- 17- Maria Schuld · Francesco Petruccione. "Machine Learning with Quantum Computers ". (2021)
- 18- Santanu Pattanayak. "Quantum Machine Learning with Python"

4) Midterm will be held on 1403/08/24 at 9:00

5) Final exam will be held on 1 Bahman 1403

6) Overall necessities for doing exercises

- for each set of exercise, it should be a folder titled by the name of student including the set number of exercise.
- The folder must be included the source code and the results. The results must be illustrated in pdf or other type of figure. (Jpeg , eps, pdf is accepted)

7) Necessary operating system (Windows or GNU/ Linux) including the relevant things for Python, Mathematica, C++, matlab

8) I provided some scripts for plotting available via:

http://facultymembers.sbu.ac.ir/movahed/attachments/Python_plot.zip

http://facultymembers.sbu.ac.ir/movahed/attachments/Mathematica_plot.zip

9) Answers must be uploaded to Google Classroom (inviting link will be sent to your email)

10) Answers should include following 3 parts

1. Executed code
2. A brief report of code files
3. Theoretical answers.

Pay attention! Unreported code files are not acceptable.

Overall time table of training program

Subjects	Date/no.
Introduction, Scientific Methodology and Methods, Computational approach and Simulations مقدمه- جایگاه رویکردهای محاسباتی در روش شناسی علمی و علم داده	Lecture 1
Bash script and SBU-Clusters برنامه نویسی و نوشتن Bash و معرفی سیستم سرمد	Lecture 2
Error estimation 1 تخمین خطا ۱	Lecture 3
Error estimation 2 تخمین خطا ۲	Lecture 4
Probability Distribution 1: PDF Simple estimator تابع توزیع ۱ و PDF Simple estimator	Lecture 5
Probability Distribution 2: Probability Transformation, Joint PDF تابع توزیع ۲، تبدیل تابع چگالی احتمال، تابع چگالی احتمال همبسته	Lecture 6
Correlation functions: Two-point Correlation, Random walk- Simulations تابع همبستگی، تابع دونقطه‌ای، ولگشت تصادفی - شبیه‌سازی	Lecture 7
Langevin Equation and simulation معادله لانژون و شبیه‌سازی آن	Lecture 8
Numerical analysis1: Numerical derivative and Integration, Solving Systems of equations محاسبات عددی ۱: مشتق‌گیری و انتگرال‌گیری عددی، حل دستگاه معادلات	Lecture 9
Numerical analysis 2: Self-consistent method محاسبات عددی ۲: معرفی برخی از روشهای عددی برای حل معادلات دیفرانسیل - روش خودسازگار	Lecture 10
Chaos Theory نظریه آشوب (تولید)، نوسانگرهای جفت شده آشوبی، دیاگرام فاز	Lecture 11
Fractals and numerical algorithm to generation of Self-similar system فراکتالها (تولید)	Lecture 12
Monte-Carlo Simulation 1 اصول شبیه سازی مونته کارلو ۱	Lecture 13

Monte-Carlo simulation 2: Integration and Variational MC اصول شبیه سازی مونته کارلو ۲: انتگرال گیری، Variational MC	Lecture 14
Monte-Carlo simulations 3: Markov Chain Monte Carlo and Metropolis Hasting اصول شبیه سازی مونته کارلو ۳: روش متروپولیس، حلقه مارکوف مونت کارلو MCMC	Lecture 15
Monte-Carlo simulations 4: Hamiltonian Monte Carlo اصول شبیه سازی مونته کارلو ۴: HMC	Lecture 16
Monte-Carlo simulations 5: Ising model اصول شبیه سازی مونته کارلو ۵: Ising model	Lecture 17
Genetic Algorithm 1 الگوریتم ژنتیک ۱	Lecture 18
Genetic Algorithm 2 الگوریتم ژنتیک ۲	Lecture 19
Data modeling 1: Bayesian Inference مدل کردن داده ها ۱: (Bayesian Inference)	Lecture 20
Data modeling 2: Likelihood Analysis مدل کردن داده ها ۲ (Likelihood Analysis)	Lecture 21
Data modeling 3: Numerical Approach مدل کردن داده ها ۳ (Numeric Approach)	Lecture 22
Data modeling 4: Confidence Interval Inference مدل کردن داده ها ۴ (Confidence Interval)	Lecture 23
Data modeling 5: Fisher forecasts مدل کردن داده ها ۵ (Fisher Matrix)	Lecture 24
Simulation Based Inference (SBI)	Lecture 25
Quantum Algorithms الگوریتم های کوانتومی	Lecture 26
Topological Based Data Analysis 1	Lecture 27
Topological Based Data Analysis 2	Lecture 28

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