**Machine Learning for Time Series Analysis - UDel 2020**

## **Code of Conduct: Diversity is considered a resource that enriches us culturally and intellectually in this class. Be respectful and collaborate instead of competing. No instances of harassment or attempts to marginalize students will be tolerated in my class. If you have concerns please come talk to me** (details on the UDel code of conduct and ethical policies follow at the end of the syllabus)

## Course Description

Time series analyses appear in various subfields of the physical sciences, including astrophysics and cosmology, biophysics, and seismology, as well as in real-world problems including finance, policy, etc. The application of data-driven techniques to time series analysis has a long history (e.g. autoregressive methods), but the application of machine learning (ML) methods has recently emerged and demonstrated transformational potential.

This class will cover applications of ML methods to time series analysis of physical systems for inference and prediction. We will review traditional data-driven methods and explore applications of ML to time series analysis, including Bayesian approaches to template fitting, Gaussian Processes, Artificial Intelligence, Autoencoders, and Recurrent Neural Networks, through the lens of examples drawn from research in various physical disciplines including astrophysics, biophysics, and complexity.

Coding (in python), some knowledge of data handling, statistical analysis, and error analysis will be assumed. The class will include discussions of good practices for handling, processing, and analyzing data (including big-data) programmatically, as well as communication and visualization skills and good coding practices. The class will include live coding sessions and labs in python through cloud resources (no software or specific hardware is required but an internet connected device where it is easy to type, computer or tablet, will be used in class). Simpler algorithms will be explored in detail and implemented from scratch, others will be implemented through the use of dedicated python libraries.

Don't worry too much about how much you already know, especially do not compare it to what other students know. You may have the wrong perception of your skills, and of the skills of your classmates. Your strengths may lie in different aspects of the work: intuition, coding, being methodical….. Group work will allow you to leverage your own natural strengths and your background while improving on the other skills. The class assistants and I, are here to help you develop the skills you do not yet have and strengthen the skills you already have.

## Learning Outcomes

By the end of this class, students will be familiar with several – and fluent in a few – ML methods for time series analysis, should be able to recognize the most effective tools, create an analysis plan, choose models, prepare data, and perform analysis in python to answer questions in the time-domain.

The instructors is: Dr. **Federica Bianco** fbianco@udel.edu

oﬃce hours: TBD

The Class assistants TBD

## Resources

The primary textbooks are:

* **Elements of Statistical Learning,** Hastie,Tibshirani,Friedman, Springer 2001
* **Statistics, Data Mining, and Machine Learning in Astronomy,** Ivezic, Connoly, VanderPlas, Gray, Princeton Press 2nd edition

In addition, depending on your familiarity with coding, statistics, and visualization

* **ML in python: Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow** probably the book that is closer to the syllabus in terms of techniques, but don’t buy it, because the second edition is due to come out imminently and the deep learning chapters of the previous edition are out of date now
* **Python Data Science Handbook,** Jake VanderPlas, O'Reilly Media [<https://www.oreilly.com/library/view/python-data-science/9781491912126/>]
* computing and coding: **Beginning Python Visualization, 2009**
* **Interactive Data Visualization, S. Murray, O'Reilly Media**
* Visualizations: **Visualizations Analysis and Design, T. Munzer, 2014**

A few copies of these books are available in the Physics library.

Each week you will attend two classes, loosely structured as lecture and one lab session. **Attendance in lecture and lab is mandatory.**

Technology

***Google Collaboratory*** will be used for the class. Homework can be developed on any platform as long as the computational set up consistent the entire class: the class assistants and I need to be able to reproduce your work and obtain the same results. Modules and library used in your work need to be accessible to me, the graders, and your classmates. We may make a docker image and a virtual environment as well and instructions on how to set up your environment to allow you to work offline.

The course will be organized in a modular fashion, with some guest lectures. Each machine learning method will be studied as it is applied to a physical problem, based on open data and literature examples.

Homework will be exclusively received through [github](https://github.com).

*Homework* projects **must be turned in as iPython notebooks by checking them into your github account in a**

**MLTSA\_<fistinitialLastname>/HW<hwnumber>\_<fistinitialLastname>** repo (unless otherwise stated).

## Assessment

**Grades are based on**

* **10% pre-class questions**
* **15% labs performance and participation**
* **20% homework**
* **20% midterm (project proposal)**
* **35% ﬁnal (project)**

Weekly assignments will be handed out at the end of the class, and will be due **strictly** before the first class of the following week (no submissions at all can be accepted after that as the homework may be reviewed in class). Please come to class on time: at the beginning of each class you will be handed a sheet of “Pre-class Questions” to be answered **before each lecture and before each lab**. You will have up to 5 minutes after the official start time of the class to answer them. The later you arrive at the class, the less time you will have to answer the questions. This will affect your homework grade as described above. The questions will cover

* the material in the previous classes, and
* the reading assignments.

**Late homework will not be accepted.** A single 72-hour exception is allowed throughout the semester, explicitly declare that you are going to use it *before the deadline*, and do use it wisely. The lowest grade in the first half of the course (before midterm), and the lowest grade in the second half will be disregarded in assigning you a final grade. If you fail to turn in an assignment that will be a 0, and (likely) the lowest grade. This means you will lose the chance to disregard your worst performance.

You are encouraged to work in groups of up to 5 people, but as a collaborative project. Individual notebooks must be returned for each homework. Different group members should lead different aspects of the work. A statement **must be included in the README** explaining each team member’s contribution (similar to an acknowledge of contribution you would find in a *Nature* letter see, for example [these contributions](https://www.nature.com/articles/s41586-018-0443-1#author-information)). *Midterm* and *Final* will include aspects of the work developed in the homework sessions. Failing to actively participate in the homework will result in not being able to get the Midterm and Final done.

*Midterm* and the *Final* will be 2 phases of a group project: a proposal need to be delivered as the midterm, and presented in class, and the project will be delivered and presented as a final. Each student need to contribute to a specific aspect of the project, as described in the midterm/proposal.

## Course Calendar

**Lecture and reading schedule (details subject to change):**

Week 1

Historical context of time series analysis. Regression

 Week 2

Autoregressive methods for TSA

 Week 3

 Bayes theorem and Monte Carlo Markov Chain methods

 Week 4

 Probabilistic and Bayesian Event Detection

 Week 5

Template Fitting in Bayesian context

 Week 6

 Gaussian Processes

 Week 7

 Midterm Presentations

 Week 8

 Neural Networks

 Week 9

 Autoencoders

 Week 10

 Recurrent convolutional neural networks

 Week 11

Recurrent convolutional neural networks

 Week 12

 Final Presentations

Datasets will include: Atmospheric data, Financial Time Series, Gravitational Waves, Kepler exoplanet, Geoseismic data, Molecular diffusion time series (and others)

## Course Expectations and Policies

Attendance

Absences on religious holidays listed in university calendars are recognized as excused absences. Nevertheless, students are urged to remind the instructor of their intention to be absent on a particular upcoming holiday. Absences on religious holidays not listed in university calendars, as well as absences due to athletic participation or other extracurricular activities in which students are official representatives of the university, shall be recognized as excused absences when the student informs the instructor in writing during the first two weeks of the semester of these planned absences for the semester. All unexcused absences will result in loss of participation credit for the session in question.

Late assignments

Late homework will not be accepted. A single 72-hour exception is allowed throughout the semester

Professional Conduct

● Adhere to the ​University of Delaware Code of Conduct​.

● Be punctual.

● Complete all reading and homework assignments.

● Be respectful of your peers and instructor.

● Hold yourself accountable for your own academic performance.

Academic Integrity

Please familiarize yourself with UD policies regarding academic dishonesty. To falsify the results of one's research, to steal the words or ideas of another, to cheat on an assignment, to re-submit the same assignment for different classes, or to allow or assist another to commit these acts corrupts the educational process. Students are expected to do their own work and neither give nor recieve unauthorized assistance. Complete details of the university's academic integrity policies and procedures can be found at [http://www1.udel.edu/studentconduct/policyref.html​](http://www1.udel.edu/studentconduct/policyref.html) ​Office of Student Conduct, 218 Hullihen Hall, (302) 831-2117. E-mail: ​student-conduct@udel.edu

**Policies concerning plagiarism, in particular, will be strictly followed.** Please consult the [Chicago Manual of Style](https://www.chicagomanualofstyle.org/home.html) for guidelines on citations. Do not hesitate to ask if you have any questions regarding writing style, citations, or any academic policies.

Harassment and Discrimination

The University of Delaware works to promote an academic and work environment that is free from all forms of discrimination, including harassment. As a member of the community, your rights, resource and responsibilities are reflected in the non-discrimination and sexual misconduct policies. Please familiarize yourself with these policies at ​www.udel.edu/oei​ . You can report any concerns to the University’s Office of Equity & Inclusion, at 305 Hullihen Hall, (302) 831-8063 or you can report anonymously through UD Police (302) 831-2222 or the EthicsPoint Compliance Hotline at ​[www1.udel.edu/compliance​](http://www1.udel.edu/compliance%E2%80%8B).​ You can also report any violation of UD policy on harassment, discrimination, or abuse of any person at this site: [sites.udel.edu/sexualmisconduct/how-to-report/](http://sites.udel.edu/sexualmisconduct/how-to-report/)

Faculty Statement on Disclosures of Instances of Sexual Misconduct

If, at any time during this course, I happen to be made aware that a student may have been the victim of sexual misconduct (including sexual harassment, sexual violence, domestic/dating violence, or stalking), I am obligated to inform the university’s Title IX Coordinator. The university needs to know information about such incidents in order to offer resources to victims and to ensure a safe campus environment for everyone. The Title IX Coordinator will decide if the incident should be examined further. If such a situation is disclosed to me in class, in a paper assignment, or in office hours, I promise to protect your privacy--I will not disclose the incident to anyone but the Title IX Coordinator. For more information on Sexual Misconduct policies, where to get help, and how to reporting information, please refer to ​www.udel.edu/sexualmisconduct​. At UD, we provide 24-hour crisis assistance and victim advocacy and counseling. Contact 302-831-1001, UD Helpline 24/7/365, to get in touch with a sexual offense support advocate.

For information on various places you can turn for help, more information on Sexual Misconduct policies, where to get help, and reporting information please refer to [​www.udel.edu/sexualmisconduct](http://www.udel.edu/sexualmisconduct)

Inclusion of Diverse Learning Needs

Any student who thinks he/she may need an accommodation based on a disability should contact the Office of Disability Support Services (DSS) office as soon as possible. The DSS office is located at 240 Academy Street, Alison Hall Suite 130, Phone: 302-831-4643, fax: 302-831-3261, DSS website (​[www.udel.edu/DSS/](http://www.udel.edu/DSS/)​). You may contact DSS at ​dssoffice@udel.edu

Non-Discrimination

The University of Delaware does not discriminate against any person on the basis of race, color, national origin, sex, gender identity or expression, sexual orientation, genetic information, marital status, disability, religion, age, veteran status or any other characteristic protected by applicable law in its employment, educational programs and activities, admissions policies, and scholarship and loan programs as required by Title IX of the Educational Amendments of 1972, the Americans with Disabilities Act of 1990, Section 504 of the Rehabilitation Act of 1973, Title VII of the Civil Rights Act of 1964, and other applicable statutes and University policies. The University of Delaware also prohibits unlawful harassment including sexual harassment and sexual violence.

For inquiries or complaints related to non-discrimination policies, please contact:

Interim Director, Institutional Equity & Title IX Coordinator - Fatimah Stone ​titleixcoordinator@udel.edu​, 305 Hullihen Hall Newark, DE 19716 (302) 831-8063

For complaints related to Section 504 of the Rehabilitation Act of 1973 and/or the Americans with Disabilities Act, please contact: Director, Office of Disability Support Services, Anne L. Jannarone, M.Ed., Ed.S. - ajannaro@udel.edu​ Alison Hall, Suite 130, Newark, DE 19716 (302) 831-4643 OR contact the U.S. Department of Education - Office for Civil Rights ​(​[wdcrobcolp01.ed.gov/CFAPPS/OCR/contactus.cfm](http://wdcrobcolp01.ed.gov/CFAPPS/OCR/contactus.cfm)​)