

Title: Mathematics of deep neural networks

Instruction style: Hybrid instruction (face-to-face & remote);

- Face-to-face: UNM students should attend class MWF 14.00 - 14.50 in DSH-227
- Remote: SNL and LLNL participants will access live lectures via Zoom
Zoom link: <https://unm.zoom.us/j/97126249789>
(Passcode will be provided to registered participants on 01/17/2023 via email)
- Recorded lectures will be available to all participants on [UNM CANVAS](#)

Instructor: Mohammad Motamed, Associate Professor of Computational Mathematics

Course webpage: <https://math.unm.edu/~motamed/Teaching/Spring2023/deepnn.html>

Contact: motamed@unm.edu (the title of your email must be **Math 579**)

Required Text: None. You will be provided with reading material such as notes and papers.

Description: We will study several concepts related to deep learning from an applied mathematics perspective. We will review recent articles on the subject. If needed, we will also be working with Python-Keras for implementation. We will be covering all or a portion of the following topics.

- Neural Networks: formalization and key concepts
 - What is a neural network? A parametric map with a compositional structure.
 - What is the use of a neural network? It solves regression and classification problems.
 - What is network training? It is an optimization problem.
 - How to solve the optimization problem? By (stochastic) gradient descent & back-propagation.
 - Convergence of (stochastic) gradient descent.
 - Choices of loss functions and activation functions.
 - Overfitting and regularization techniques.
 - Good practices for training neural networks.
- Approximation theory for neural networks
 - Density: the theoretical ability to approximate well (with very large number of parameters)
 - Approximation rates: how well is the approximation for a fixed number of parameters?
 - Complexity: how many parameters needed to achieve a desired accuracy?
 - Linear vs. nonlinear methods of approximation
- Residual networks (ResNets) and residual Fourier feature networks (ResFFNets)
- Convolutional networks
- Deep networks for solving high-dimensional PDEs

Required background: calculus, linear algebra, basic probability and numerical analysis.

Grading: Your grade will be determined based on in-class/zoom participation (10 points) and a final project (90 points). Letter grades will then be assigned according to the following scheme: A+/A, 98/90 points or above, B+/B, 88/80 points or above, C+/C, 78/70 points or above, F below 70 points. The instructor reserves the right to "curve" grades to offset unforeseen circumstances. The curving of grades will never decrease a student's letter grade below that given by the above formula.

Final project: A final project will be assigned to you about two months into class. I will propose several options and help you choose one that matches your interests and goals. The options include, but not limited to, reading and presenting some papers on particular topics, reading and presenting survey papers, reproducing some numerical results, working on a new project, etc. You are encouraged to work on the projects in groups of two. In the end of the semester, you will need to hand in a 6-15 page written report and make a 15-20 minute presentation of your work either in class or on Zoom. The last 3-4 classes will be assigned to project presentations.

Dishonesty Policy: Each student is expected to maintain the highest standards of honesty and integrity in academic and professional matters. The University reserves the right to take disciplinary action, including dismissal, against any student who is found responsible for academic dishonesty. Any student who has been judged to have engaged in academic dishonesty in course work may receive a reduced or failing grade for the work in question and/or for the course. Academic dishonesty includes, but is not limited to, dishonesty on quizzes, tests or assignments; claiming credit for work not done or done by others; and hindering the academic work of other students.

Accommodations: UNM is committed to providing equitable access to learning opportunities for students with documented disabilities. As your instructor, it is my objective to facilitate an inclusive classroom setting, in which students have full access and opportunity to participate. To engage in a confidential conversation about the process for requesting reasonable accommodations for this class and/or program, please contact Accessibility Resource Center (<https://arc.unm.edu/>) at arcsrvs@unm.edu or by phone at 505-277-3506.

Credit-hour statement: This is a three credit-hour course. Class meets for three 50-minute sessions of direct, hybrid instruction for fifteen weeks during the Spring 2023 semester. Please plan for a minimum of 3-4 hours of out-of-class work (or study, assignment completion, and class preparation) each week.

Title IX: Our classroom and our university should always be spaces of mutual respect, kindness, and support, without fear of discrimination, harassment, or violence. Should you ever need assistance or have concerns about incidents that violate this principle, please access the resources available to you on campus. Please note that, because UNM faculty, TAs, and GAs are considered "responsible employees" any disclosure of gender discrimination (including sexual harassment, sexual misconduct, and sexual violence) made to a faculty member, TA, or GA must be reported by that faculty member, TA, or GA to the university's Title IX coordinator. For more information on the campus policy regarding sexual misconduct and reporting, please see: <https://policy.unm.edu/university-policies/2000/2740.html>.

COVID-19 Health and Awareness: UNM is a mask friendly, but not a mask required, community. To be registered or employed at UNM, Students, faculty, and staff must all meet UNM's Administrative Mandate on Required COVID-19 vaccination. If you are experiencing COVID-19 symptoms, please do not come to class. If you have a positive COVID-19 test, please stay home for five days and isolate yourself from others, per the Centers for Disease Control (CDC) guidelines. If you do need to stay home, please communicate with me; I can work with you to provide alternatives for course participation and completion. UNM faculty and staff know that these are challenging times. Please let me, your

advisor, or another UNM staff member know that you need support so that we can connect you to the right resources. Please be aware that UNM will publish information on websites and email about any changes to our public health status and community response.

Support:

- [Student Health and Counseling](#) (SHAC) at (505) 277-3136. If you are having active respiratory symptoms (e.g., fever, cough, sore throat, etc.) AND need testing for COVID-19; OR If you recently tested positive and may need oral treatment, call SHAC.
- [LoboRESPECT Advocacy Center](#) (505) 277-2911 can offer help with contacting faculty and managing challenges that impact your UNM experience.

Citizenship and/or Immigration Status: All students are welcome in this class regardless of citizenship, residency, or immigration status. I will respect your privacy if you choose to disclose your status. As for all students in the class, family emergency-related absences are normally excused with reasonable notice to the instructor. UNM as an institution has made a core commitment to the success of all our students, including members of our undocumented community. The Administration's welcome can be found [here](#).

Disclaimer: I reserve the right to make reasonable and necessary changes to the policies outlined in this syllabus. Whenever possible, the class will be notified in advance of such changes. An up-to-date copy of the syllabus can always be found on [UNM CANVAS](#). You need to regularly check UNM CANVAS for possible updates. It is **your responsibility** to know and understand the policies discussed therein and to be up-to-date. If in doubt, ask questions.