Course Change Request

New Course Proposal

Date Submitted: 04/25/21 4:41 pm

Viewing: MATH 663 : Mathematics of Machine Learning and Industrial Applications II

Last edit: 04/29/21 7:55 am

Changes proposed by: csausvil

In Workflow

1. **MATH Chair**
2. **SC Curriculum Committee**
3. SC Associate Dean
4. Assoc Provost-Graduate
5. Registrar-Courses
6. Banner

Approval Path

1. 04/25/21 10:36 pm David Walnut (dwalnut): Approved for MATH Chair

Are you completing this form on someone else's behalf?

No

Effective Term: Fall 2021

Subject Code: MATH - Mathematics

Course Number: 663

Bundled Courses:

Is this course replacing another course? No

Equivalent Courses:

Catalog Title: Mathematics of Machine Learning and Industrial Applications II

Banner Title: Math of ML and Indust App II

Will section titles vary by semester? No

Credits: 2

Schedule Type: Lecture

Hours of Lecture or Seminar per week: 2

Repeatable:

May be only taken once for credit, limited to 3 attempts (N3)

Max Allowable Credits: 6

Default Grade Mode: Graduate Regular

Recommended Prerequisite(s):

Recommended Corequisite(s):

Required Prerequisite(s) / Corequisite(s) (Updates only):

Math 662

Registrar's Office Use Only - Required Prerequisite(s)/Corequisite(s):

And/Or	(	Course/Test Code	Min Grade/Score	Academic Level	)	Concurrency?

Registration Restrictions (Updates only):

Registrar's Office Use Only - Registration Restrictions:

Field(s) of Study:

Class(es):

Level(s):

Degree(s):

School(s):

Catalog Description:

Basic mathematical and probabilistic models and derivations for convolutions, stability, regularization, inverse and optimal control problems, and dynamical systems in the context of semi-supervised learning. Mathematical and numerical aspects of stochastic descent methods, Nesterov accelerated gradient, AdaGrad, Adam, with applications to convolutional, deep, and ODE networks. Further applications include imaging and computer vision, saliency maps, segmentation, satellite Imagery, and physics informed learning.

Justification:

This course is being created to meet the ever changing needs of the department. Data Science is a growing domain of study that spans many fields, including Mathematics. This course will allow our students to better prepare for industry, research or acadmic positions where a solid understanding of the mathematics of data science is desired. It will also help support the university's initiative regarding the Tech Talent Investment Program (TTIP) created by the Commonwealth of Virginia.

Does this course cover material which crosses into another department? Yes

Impacted Departments:

Department
CDS - Computational & Data Sciences
CS - Computer Science
STAT - Statistics

Learning Outcomes:

Stated in attached syllabus.

Attach Syllabus

math663_4282021.pdf

Additional Attachments

Staffing:

H. Antil, M. Emelianenko, T. Berry, T. Sauer, E. Sander, I. Griva, C. Rautenberg, P. Seshaiyer

Relationship to Existing Programs:

This course will supplement our current graduate offerings for our Master and PhD students.

Relationship to Existing Courses:

We have successfully run previous special topics courses that cover much of the content of this course. We would like to make these topics into a permanent class for our graduate students and industry partners.

Additional Comments:

Reviewer Comments

Key: 17204

Math 663 : Mathematics of Machine Learning with Industrial Applications - II

- **Required Prerequisites:** Math 662 or permission of the instructor.
- **Office:** TBA
- **Office hours:** TBA
- **Course Website:** TBA
- **Possible Textbooks:**
  George Lan, "First-order and Stochastic Optimization Methods for Machine Learning"
  Gilbert Strang, "Linear Algebra and Learning from Data"
  Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning"
- **Classroom:** TBA

Overview: The course covers the mathematics behind deep learning. It has both analytical and computational components. Graduate version of the course will include additional assignments that require a higher degree of mathematical maturity. **This graduate course will include additional assignments and mathematical proofs (not needed for Math 463) that require a higher degree of mathematical maturity.**

Learning Outcomes: Students will gain a deep understanding of the topics listed below and mathematical connections between them. Graded assignments will be testing students' ability to produce rigorous mathematical proofs, synthesize methods and develop codes using computational and analytical methods discussed in class. Independent reading and open ended exploration projects will be given. Students will be expected to develop their own computational routines to explore the numerical performance and limitations of specific algorithms.

Tentative Schedule:

(1) Week 1: *Applications of Machine Learning:* Scientific computing algorithms, Physics-based modeling and learning, Imaging science (satellite imagery, SAR etc.), Inverse and optimal control problems.

(2) Weeks 2-3: *Optimization:* Stochastic descent methods, mini-batch and momentum approaches, Nesterov accelerated gradient, AdaGrad, AdaDelta, Adam.

(3) Week 4: *Computer vision:* Binarize images, Morphological operators (Erosion, Dilation, Interpolation, etc.), Image filtering, Convolutions, Padding, Gaussian filter, Sharpening filter, Gradient filter, Sobel operator, Image denoising.

(4) Weeks 5-6: *Deep Learning:* Brief history, Introduction to Tensorflow, Training/testing/overfitting, Batch normalization, Dropout, Vanishing/Exploding gradients, Pooling: Fourier transform and convolution theorem, AlexNet, ResNets, DenseNets, Ensamble behavior, Convolution neural networks, U-Net, Neural ODEs/PDEs, Coding your own Deep neural network, Overview of stability of neural networks via dynamical systems approach.

(5) Weeks 7-7.5: *Applications:* You only look once (YOLO), You only look twice (YOLT), Saliency maps, Semantic segmentation, Satellite imagery, VDSR (very deep super resolution), Synthetic aperture radar (SAR) imagery, Physics based neural networks (PINNs) with applications in inverse problems and parameterized PDEs, Data driven modeling, and optimal control.

Grading: Grades will be based on

- Homework exercises
- Computational projects

- Mathematical proofs

Tentative grading scale:

- Homework assignments and group projects: 60%
- Take-home final exam: 30%
- Class participation: 10%

Academic Integrity: Academic Policies: Mason is an Honor Code university; please see the Office for Academic Integrity for a full description of the code and the honor committee process. With collaborative work, names of all the participants should appear on the work. Collaborative projects may be divided up so that individual group members complete portions of the whole, provided that group members take sufficient steps to ensure that the pieces conceptually fit together in the end product. Other projects are designed to be undertaken independently. In the latter case, you may discuss your ideas with others and conference with peers on drafts of the work; however, it is not appropriate to give your paper to someone else to revise. You are responsible for making certain that there is no question that the work you hand in is your own. If only your name appears on an assignment, your professor has the right to expect that you have done the work yourself, fully and independently.

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In this class we welcome and value individuals and their differences including race, economic status, gender expression and identity, sex, sexual orientation, ethnicity, national origin, first language, religion, age, and disability.