PCC Proposal to Establish a Master of Science in Applied Machine Learning

PRESENTED BY	**Wendy Stickle, Chair, Senate Programs, Curricula, and Courses Committee**
REVIEW DATES	**SEC – October 20, 2023 | SENATE – November 1, 2023**
VOTING METHOD	**In a single vote**
RELEVANT POLICY/DOCUMENT	
NECESSARY APPROVALS	**Senate, President, USM Board of Regents, and the Maryland Higher Education Commission**

ISSUE

The College of Computer, Mathematical, and Natural Sciences proposes to establish a Master of Science in Applied Machine Learning. This program exists currently as an iteration of the Master of Professional Studies (MPS) program. The 30-credit MPS program (titled Machine Learning) has been in operation since the Winter 2019-2020 term. Master of Professional Studies programs were first approved in 2005, when the University System of Maryland Board of Regents and Maryland Higher Education Commission approved an expedited review process for master's and graduate certificate programs that respond quickly to the changing market needs of working professionals. Once a new iteration of the MPS is approved through campus PCC review, it only needs approval by the USM Chancellor to become official.

A limitation of offering this program as an MPS iteration is that all Professional Studies programs must use the same generic Federal Classification of Instructional Programs (CIP) code rather than a CIP code that accurately describes the program content. Those who search for academic programs by using the CIP codes related to Machine Learning will not find this program. Moreover, some CIP codes are designated as "STEM" eligible by the US Department of Homeland Security, and international students with F1 visas who graduate from STEM designated programs may continue to work in the United States for two years longer than students in non-STEM designated programs. The generic CIP code for Professional Studies programs does not qualify as STEM-designated, even if the academic content of the Professional Studies program is STEM-related, as is the case with this program.

Consequently, the college proposes to transition the current program from a Master of Professional Studies program to a stand-alone Master of Science program in order for the program to be classified more accurately. The 30-credit curriculum will remain the same.

The Master of Science in Applied Machine Learning will provide students with the opportunity to engage in cutting edge technical course work in machine learning and develop their problem-solving skills in the art and science of processing and extracting information from data with special emphasis on large amounts of data (Big Data). Students will build solid foundations in mathematics, statistics and computer programming, and explore advanced topics in machine learning such as deep learning, optimization, big data analysis, and signal/image understanding. The program

consists of 18 credits of required courses and 12 credits of electives. This program is a non-thesis program and will have both an in-person and distance education version. Graduates of the program will be able to understand the fundamental concepts of machine learning and explain applied mathematics and statistics necessary for the thorough understanding of machine learning algorithms and methods. Students will be able to implement problem-solving and analytical skills necessary to succeed in industry, including scripting and programming, and will be familiar with state-of-the-art machine learning tools and high-performance computing platforms. Students will be able to work in teams to solve problems and demonstrate written and oral communication skills appropriate to engineering professionals.

The proposal was approved by the Graduate School PCC committee on September 27, 2023, and the Senate Programs, Curricula, and Courses committee on October 6, 2023.

RECOMMENDATION(S)

The Senate Committee on Programs, Curricula, and Courses recommends that the Senate approve this new academic program.

COMMITTEE WORK

The committee considered this proposal at its meeting on October 6, 2023. Amol Deshpande, Amy Chester, and John Fourkas, from the College of Computer, Mathematical, and Natural Sciences, presented the proposal and answered questions from the committee. The committee unanimously approved the proposal.

ALTERNATIVES

The Senate could decline to approve this new academic program.

RISKS

If the Senate declines to approve this new degree program, the university will lose an opportunity to apply a more accurate Federal CIP code to an existing program thereby making the program more marketable.

FINANCIAL IMPLICATIONS

There are no significant financial implications with this proposal as the program already exists as a self-supported Master of Professional Studies program.

922: APPLIED MACHINE LEARNING

In Workflow

1. CMNS PCC Chair (jpresson@umd.edu; fourkas@umd.edu)
2. CMNS Dean (rinfanti@umd.edu)
3. Academic Affairs Curriculum Manager (mcolson@umd.edu)
4. Graduate School Curriculum Manager (jfarman@umd.edu)
5. Graduate PCC Chair (jfarman@umd.edu)
6. Dean of the Graduate School (jfarman@umd.edu; sroth1@umd.edu)
7. Senate PCC Chair (mcolson@umd.edu; wstickle@umd.edu)
8. University Senate Chair (mcolson@umd.edu)
9. President (mcolson@umd.edu)
10. Board of Regents (mcolson@umd.edu)
11. MHEC (mcolson@umd.edu)
12. Provost Office (mcolson@umd.edu)
13. Graduate Catalog Manager (bhernand@umd.edu; fantsao@umd.edu)

Approval Path

1. Thu, 01 Jun 2023 22:36:12 GMT
   John Fourkas (fourkas): Approved for CMNS PCC Chair
2. Tue, 06 Jun 2023 16:22:47 GMT
   Robert Infantino (rinfanti): Approved for CMNS Dean
3. Wed, 06 Sep 2023 18:17:56 GMT
   Michael Colson (mcolson): Approved for Academic Affairs Curriculum Manager
4. Fri, 29 Sep 2023 20:04:15 GMT
   Jason Farman (jfarman): Approved for Graduate School Curriculum Manager
5. Fri, 29 Sep 2023 20:08:44 GMT
   Jason Farman (jfarman): Approved for Graduate PCC Chair
6. Wed, 04 Oct 2023 20:48:32 GMT
   Stephen Roth (sroth1): Approved for Dean of the Graduate School
7. Sat, 07 Oct 2023 17:31:39 GMT
   Wendy Stickle (wstickle): Approved for Senate PCC Chair

New Program Proposal

Date Submitted: Mon, 29 May 2023 22:37:14 GMT

Viewing: 922 : Applied Machine Learning
Last edit: Tue, 10 Oct 2023 20:36:12 GMT

Changes proposed by: Sennur Ulukus (ulukus)

Program Name

Applied Machine Learning

Program Status

Proposed

Effective Term

Spring 2024

Catalog Year

2023-2024

Program Level

Graduate Program

Program Type

Master's

Delivery Method

On Campus

Departments

Department
Computer, Mathematical, and Natural Sciences

Colleges

College
Computer, Mathematical, and Natural Sciences

Degree(s) Awarded

Degree Awarded
Master of Science

Proposal Contact

Sennur Ulukus, Amol Deshpande, Amy Chester

Proposal Summary

Proposal to convert the MPS in Machine Learning to the MS in Applied Machine Learning with CIP code: 30.7101 (Data Analytics, General)

(PCC Log Number 23010)

Program and Catalog Information

Provide the catalog description of the proposed program. As part of the description, please indicate any areas of concentration or specializations that will be offered.

The Master of Science in Applied Machine Learning offers students the opportunity to engage in cutting edge technical course work in machine learning and develop their problem solving skills in the art and science of processing and extracting information from data with special emphasis on large amounts of data (Big Data). During their coursework, students will build solid foundations in mathematics, statistics and computer programming, and explore advanced topics in machine learning such as deep learning, optimization, big data analysis and signal/image understanding. The program consists of 30-credit course work and is a non-thesis MS program.

Catalog Program Requirements:

Course	Title	Credits
Core Requirements		
MSML601	Probability and Statistics	3
MSML602	Principles of Data Science	3
MSML603	Principles of Machine Learning	3
MSML604	Introduction to Optimization	3
MSML605	Computing Systems for Machine Learning	3
MSML606	Algorithms and Data Structures for Machine Learning	3
Elective Requirement (choose four of the following):		**12**
MSML612	Deep Learning	
MSML640	Course MSML640 Not Found (Computer Vision)	
MSML641	Natural Language Processing	
MSML642	Course MSML642 Not Found (Robotics)	
MSML650	Cloud Computing (Cloud Computing)	
MSML651	Course MSML651 Not Found (Big Data Analytics)	
Total Credits		**30**

Sample plan. Provide a term by term sample plan that shows how a hypothetical student would progress through the program to completion. It should be clear the length of time it will take for a typical student to graduate. For undergraduate programs, this should be the four-year plan.

First Year

Semester 1	Credits	Semester 2	Credits	Semester 3	Credits
MSML601	3	MSML604	3	MSML606	3
MSML602	3	MSML605	3	MSML612	3
MSML603	3	MSML641	3		
	9		**9**		**6**

Second Year

Semester 1	Credits
MSML640	3
MSML650	3
	6

Total Credits 30

Part Time

First Year

Semester 1	Credits	Semester 2	Credits	Semester 3	Credits
MSML601	3	MSML604	3	MSML606	3
MSML603	3	MSML605	3	MSML612	3
	6		**6**		**6**

Second Year

Semester 1	Credits	Semester 2	Credits
MSML602	3	MSML641	3
MSML640 (Computer Vision)	3	MSML650 (Cloud Computing)	3
	6		**6**

Total Credits 30

List the intended student learning outcomes. In an attachment, provide the plan for assessing these outcomes.

Learning Outcomes
Students will be able to understand the fundamental concepts of machine learning.
Students will be able to explain applied mathematics and statistics necessary for the thorough understanding of machine learning algorithms and methods.
Students will be able to implement problem-solving and analytical skills necessary to succeed in industry, including scripting and programming, and will be familiar with state-of-the-art machine learning tools and high-performance computing platforms.
Students will be able to demonstrate written and oral communication skills appropriate to engineering professionals.
Students will be able to work in teams to solve problems.

New Program Information

Mission and Purpose

Describe the program and explain how it fits the institutional mission statement and planning priorities.

The Computer Science (CS) and the Electrical and Computer Engineering (ECE) Departments at the University of Maryland, College Park propose launching a new Master of Science in Applied Machine Learning. This program will offer students the opportunity to engage in cutting-edge technical course work in machine learning and develop their problem solving skills in the art and science of processing and extracting information from data. During their coursework, students will build solid foundations in mathematics, statistics and computer programming, and explore advanced topics in machine learning such as deep learning, optimization, big data analysis and signal/image understanding. Students will also learn about applications of machine learning to computer vision, natural language processing, robotics, data science and other areas. The program will consist of 30-credit course work.

Artificial Intelligence (AI) has been an important aspect of Maryland's Computer Science department since the department's creation. Historically, and continuing at present, UMD has had strong groups in computer vision, natural language processing, and game theory. During the last several years, a strong presence has also emerged in two more areas, machine learning and robotics, in part due to intense faculty recruiting efforts supported by the campus administration.

The ECE Department offers one of the strongest and most highly-ranked programs in the nation in electrical and computer engineering. The ECE Department covers a wide spectrum of teaching and research activities in the areas of communications and networking, information and signal

processing, control, robotics and dynamical systems, computer engineering and electric, electronic and electromagnetic materials, devices and systems.

This document proposes the establishment of a new Master Science in Applied Machine Learning. This new degree program focuses on offering advanced education in the field of machine learning and aims to provide the skills and knowledge necessary to become a successful technologist in our information-based society. Its rigorous technical curriculum has been designed to prepare students for a career as an information engineer, data scientist, or data mining engineer. It will teach the methods and the techniques of creating models and algorithms that learn from, and make decisions or predictions based on data. The graduates of this program will be able to apply the learned tools and techniques to a wide variety of real world problems in areas such as marketing, finance, medicine, telecommunications, biology, security, engineering, social networking and information technology. Examples of such applications include the way email programs self-learn to distinguish spam from legitimate email, or how intrusion detection systems learn to differentiate between legitimate computer network traffic and malicious cyber-attacks, or how medical detection devices learn to distinguish healthy tissue and flag potentially dangerous tissue, or self-learning to detect stealth attacks in a smart grid; the number of applications of automated data-driven learning is growing at an ever increasing rate.

The MS in Applied Machine Learning program will contribute to the University of Maryland's vision in multiple ways. First, it will provide world-class graduate education and produce graduates who will become competent professionals in this new and constantly growing field. Their contributions and innovations will shape the future of our increasingly data-driven and information-driven society, and they will become well-trained leaders to meet the State of Maryland's future workforce needs. Second, this program will be a science, technology, engineering and mathematics (STEM) program, and it will enhance the University's STEM-related offerings and increase the number of students graduating with advanced STEM degrees. In addition, the program will be committed to creating an ethnically, culturally, and racially diverse community. This will be accomplished through diverse enrollment practices, through strategies for recruitment and retention of our faculty and staff, as well as implementing initiatives to build a greater sense of community among the students and alumni.

Program Characteristics

What are the educational objectives of the program?

The objective of the program is to provide highly technical, industry- and application-oriented education in the field of machine learning. The focus will be on teaching and training that provide our students with a solid understanding of the principles as well as the practical skill set to be able to start and maintain a successful career in industry after graduation. Furthermore, the course contents will also be of interest to professionals working in federal research labs and government organizations. While going through this program, the students will build a solid foundation in mathematics, statistics and programming, and these fundamental skills will form the core of their education. Then, while studying various electives, they will learn different methods and approaches to solve problems in machine learning and related technical fields concerned with automated data-driven learning, decision-making, and prediction.

Taking an industry-oriented approach, one of the program's goals is to teach the students how to use state-of-the-art tools and provide opportunities for hands-on experimentation and project-based learning.

Describe any selective admissions policy or special criteria for students interested in this program.

Any student applying for admission to a graduate program at the University of Maryland must meet the following minimum admission criteria as established by the Graduate School.
- Applicants must have earned a four-year baccalaureate degree from a regionally accredited U.S. institution, or an equivalent degree from a non-U.S. institution.
- Applicants must have earned a 3.0 GPA (on a 4.0 scale) in all prior undergraduate and graduate coursework.
- Applicants must provide an official copy of a transcript for all of their post-secondary work.

General Requirements:
- Statement of Purpose
- Transcript(s)
- TOEFL/IELTS/PTE (international graduate students)

Program-Specific Requirements:
- Graduate Record Examination (GRE) (optional)
- CV/Resume
- Description of research/work experience
- Prior coursework establishing quantitative ability (including calculus II, linear algebra, statistics, etc.)
- Proficiency in programming languages, demonstrated either through prior programming coursework or substantial software development experience

Summarize the factors that were considered in developing the proposed curriculum (such as recommendations of advisory or other groups, articulated workforce needs, standards set by disciplinary associations or specialized-accrediting groups, etc.).

The MS in Applied Machine Learning is based on the existing MPS in Machine Learning at UMD. The curriculum was inspired by similar, already existing programs at the Carnegie Mellon University, New York University, and Columbia University. Detailed descriptions of these programs and lists their most important characteristics are in the appendix. An ML Advisory Committee was formed from CS and ECE faculty members and the ENTS program staff, and the proposal was put together based on the suggestions and recommendations of the committee. The members of the Machine Learning Advisory Committee were: Prof. David Jacobs, Prof. Jordan Lee Boyd-Graber, Prof. Soheil Feizi, Prof. Dinesh Manocha, Prof. Sennur Ulukus, Prof. Rama Chellappa, Prof. Behtash Babadi, and Dr. Zoltan Safar.

Select the academic calendar type for this program (calendar types with dates can be found on the Academic Calendar page)

Traditional Semester

For Master's degree programs, describe the thesis requirement and/or the non-thesis requirement.

master's non-thesis

Identify specific actions and strategies that will be utilized to recruit and retain a diverse student body.

The primary recruitment activities will be via the CMNS Science Academy. The Science Academy uses a diverse, targeted approach when recruiting students. This digital strategy focuses on UMD alumni, current UMD graduating seniors, and working professionals in the DMV area. The admissions review process reviews for not only academic readiness but also diversity in experiences, industries, backgrounds, and career aspirations to recruit a diverse student body.

To attract a diverse student population, we will engage in the following activities:
• Representing the program in educational fairs, conferences and events, e.g. the National Leadership Conference of the National Society of Black Engineers, GEM Grad Labs.
• Advertising the program to the National Society of Black Engineers (NSBE), the Society of Women Engineers (SWE), and the Association for Women in Computing (AWC).
• Direct mailing and email campaigns to domestic and international colleges
• Outreach to UMD Campus organizations and clubs
• Holding online (virtual) open houses, information sessions and career panels
• Outreach to US Military to attract veterans
• Social media and online advertising
• Establishing graduate scholarships to provide financial aid to underrepresented minority applicants

Once enrolled, the Science Academy staff, and faculty are committed to creating and fostering a supportive environment for all students to thrive. We regularly share resources and opportunities for counseling, support, and funding. All students are expected to complete and honor the TerrapinSTRONG orientation and initiatives. Students are encouraged to take part in Grad School programs that address diversity and inclusion in higher education, build communities of support and success, and create meaningful dialogue among graduate students. Such programs include"Cultivating Community Conversations" and the "Annual Office of Graduate Diversity and Inclusions Spring Speaker Services." Faculty that are involved in the Science Academy represent many departments, have a diversity of appointments (both tenure track, professional track, and adjunct) exposing students to many future career paths. The Science Academy and faculty provide student advising, academic support, and career guidance to students to retain all students and support timely graduation.

Our student retention efforts will consist of:
• Holding "Women in Engineering, Computing and STEM" seminars to addresses the obstacles faced by women in today's technical workplace and guide our women students to maneuver through the internship and job application process
• Requiring students to attend mandatory advising sessions with the program adviser to ensure that the students' study plans are in line with their interests and career goals, and that the students make satisfactory progress toward meeting the degree requirements
• Implementing an early warning system that detects students struggling with core courses and alerts the academic advisor, who meets with the students and designs a study plan to get them back on track

Relationship to Other Units or Institutions

If a required or recommended course is o#ered by another department, discuss how the additional students will not unduly burden that department's faculty and resources. Discuss any other potential impacts on another department, such as academic content that may significantly overlap with existing programs. Use space below for any comments. Otherwise, attach supporting correspondence.

Three of the proposed courses are to be co-listed versions of courses in common with the MPS programs in Data Science and Analytics, and Machine Learning: BIOI/DATA/MSML601, Probability and Statistics; BIOI/DATA/MSML602, Principles of Data Science; and BIOI/DATA/MSML603, Principles of Machine Learning. These three courses are foundational to modern quantitative and computational-based science, and thus are common to the existing programs and the proposed program. All the remaining core courses will be new to the program, and some electives may be accepted from other programs. All programs are managed by the Science Academy.

Accreditation and Licensure. Will the program need to be accredited? If so, indicate the accrediting agency. Also, indicate if students will expect to be licensed or certified in order to engage in or be successful in the program's target occupation.

No accreditation or licensure is required for the program.

Describe any cooperative arrangements with other institutions or organizations that will be important for the success of this program.

n/a

Faculty and Organization

Who will provide academic direction and oversight for the program? In an attachment, please indicate the faculty involved in the program. Include their titles, credentials, and courses they may teach for the program.

The CMNS Science Academy will work with the CS and ECE department chairs for oversight. Each department will also assign a faculty director each who will provide the academic and advising oversight to incoming and admitted students. In addition, the academic co-directors are responsible for all instructor selections and appointments and work with. Science Academy and OES will also have oversight.

Full list of faculty expected to participate in the program is available in one of the attached documents.

Indicate who will provide the administrative coordination for the program

The Science Academy in the College of Computer, Mathematics and Natural Science will provide administrative coordination for the program, in collaboration with the Office of Extended Studies. The Office of Extended Studies provides program development support (budget development and projections, in house marketing research, preparation of PCC document), program management (UMD policies and procedures compliance, program website, data requests), student and program services (admission support, scheduling, registration, billing and payment, graduation, appeals), and financial management (faculty contracts, payment processing, course charge processor, net revenue distribution),

Resource Needs and Sources

Each new program is required to have a library assessment prepared by the University Libraries in order to determine any new library resources that may be required. This assessment must be done by the University Libraries. Add as an attachment.

full assessment is attached.

Discuss the adequacy of physical facilities, infrastructure and instructional equipment.

No additional physical facilities, infrastructure and instructional equipment is required for this program. Existing facilities (e.g., classrooms) and resources (e.g., instructional equipment) will be used, and these are demonstrably adequate for the proposed program. It is anticipated that most of the instruction will be in the evenings, as befitting the target student population of working adults. Thus, the use of classrooms will be outside the hours used for instruction by most programs.

Discuss the instructional resources (faculty, staff, and teaching assistants) that will be needed to cover new courses or needed additional sections of existing courses to be taught. Indicate the source of resources for covering these costs.

Instructional resources for the program will comprise current tenure track faculty, professional track faculty, and adjunct instructors. These instructional personnel will come from the Computer Science Department and the Electrical and Computer Engineering Department, outside the university (e.g., National Institutes of Health, ARLIS, industry). The funding source of covering instructional costs will come from tuition both from the program and the Science Academy if needed. No state resources will be used to support the program.

Discuss the administrative and advising resources that will be needed for the program. Indicate the source of resources for covering these costs.

The CMNS Science Academy will provide the academic and advising oversight to incoming and admitted students. Revenue generated from the program will be used to support administrative and advising resources including a Program Manager. No state resources will be used to support the program.

Use the Maryland Higher Education Commission (MHEC) commission financial tables to describe the program's financial plan for the next five years. See help bubble for financial table template. Use space below for any additional comments on program funding.

Based on the attached proposed budget the program projects to bring in revenue during the first year and to cover all start up costs. This program will not use any state funds and will be revenue generating. All expenses will be paid for by the tuition revenue for this program. See attached document.

Implications for the State (Additional Information Required by MHEC and the Board of Regents)

Explain how there is a compelling regional or statewide need for the program. Argument for need may be based on the need for the advancement of knowledge and/or societal needs, including the need for “expanding educational opportunities and choices for minority and educationally disadvantaged students at institutions of higher education.” Also, explain how need is consistent with the Maryland State Plan for Postsecondary Education.

See support document attachment, Market Analysis, for a full analysis of the market as of March 2023. Our research indicates a much faster than average growth in computer and information research scientist positions nationally in the next 10 years. As more jobs become available in this area, it is our responsibility to respond to this need by preparing the workforce. Our graduates will complete the program with the skills and knowledge to fill the open positions in the market. Our program directly aligns with the Maryland State Plan for Postsecondary Education and the principles of public education in the State of Maryland. This program in the Science Academy increases access to higher education (specifically graduate level education) and increases the diversity of graduate students. Lastly, the program is an example of creativity and collaboration- a true partnership across departments and colleges on campus.

Present data and analysis projecting market demand and the availability of openings in a job market to be served by the new program. Possible sources of information include industry or disciplinary studies on job market, the USBLS Occupational Outlook Handbook, or Maryland state Occupational and Industry Projections over the next five years. Also, provide information on the existing supply of graduates in similar programs in the state (use MHEC's Office of Research and Policy Analysis webpage for Annual Reports on Enrollment by Program) and discuss how future demand for graduates will exceed the existing supply. As part of this analysis, indicate the anticipated number of students your program will graduate per year at steady state.

See attached for a full analysis of the market as of March 2023. Our research indicates a much faster than average growth, 21%, in computer and information research scientist positions in the field nationally in the next 10 years. Our program will be attractive to the professional learner because of its applied and experiential nature. Lastly, following the enrollment trends at other Maryland programs, our successful enrollments in other related programs, coupled with the projected job growth in this area, the program anticipates enrollment greater than 20 students per year.

Identify similar programs in the state. Discuss any di#erences between the proposed program and existing programs. Explain how your program will not result in an unreasonable duplication of an existing program (you can base this argument on program di#erences or market demand for graduates). The MHEC website can be used to find academic programs operating in the state: http://mhec.maryland.gov/institutions_training/pages/HEPrograms.aspx

While there are programs in the State that cover similar content areas, this will be the only program focused specifically on Machine Learning. Other state programs are in computing and systems engineering and are heavily focused on research. Other programs are offered online only whereas our program is offered both in-person and online.

Discuss the possible impact on Historically Black Institutions (HBIs) in the state. Will the program affect any existing programs at Maryland HBIs? Will the program impact the uniqueness or identity of a Maryland HBI?

We do not foresee any negative impacts on the uniqueness or identity of any Maryland HBIs. Rather, we see our program complementary in several ways. First, most HBIs in the state do not have related degree programs, and thus our program provides HBI students more opportunities for an advanced degree in an area not presently offered at their current institution. Second, there is distinct differentiation between the somewhat related programs at Maryland HBIs. The Computer Science MS program at Bowie State and the Advanced Computing MS program at Morgan State University, although listed in our market research document, are fundamentally different in subject matter coverage from the Applied Machine Learning MS covered by this proposal. The Bowie State and Morgan State programs are more broadly computer science-focused (sans theoretical aspects of the field). These degree programs are geared toward students who would be employed in various areas of computer science. Our degree program is geared toward data-informed or data-driven employment opportunities and emphasizes the interdisciplinary nature of machine learning.

Supporting Documents

Attachments

Faculty List Template- ML.docx
MachineLearningBenchmark2_23.xlsx
MS in Applied Machine Learning.xlsx
Library Assessment.pdf
Appendix 2 Summary of Learning Outcome Assessments 7-31-2023.pdf
Appendix 6 Course Descriptions.pdf

Key: 922

Faculty Information- Applied Machine Learning

The following faculty members are projected to teach in the program. All faculty are full-time unless otherwise indicated.

Name	Highest Degree Earned, Program, and Institution	UMD Title (indicate if part-time)	Courses
Babak Azimi-Sadjadi	Ph.D., ECE, UMD	Visiting Lecturer	DATA/MSML 603: Principles of Machine Learning
Sandra Cerrai	Ph.D., Mathematics, Scuola Normale Superiore of Pisa	Prof & Assoc Chair	DATA/MSML 601: Probability and Statistics
Manoj Franklin	Ph.D., Computer Science, University of Wisconsin- Madison	Associate Professor	MSML 605: Computing Systems for Machine Learning
Mohammad Taghi Hajiaghayi	Ph.D., Computer Science, MIT	Professor	DATA/MSML 602: Principles of Data Science
Leonid Koralov	Ph.D., Mathematics, SUNY at Stony Brook	Prof & Assoc Chair	DATA/MSML 601: Probability and Statistics
Yuntao Liu	Ph.D., ECE, UMD	Asst Research Scientist	MSML604: Introduction to Optimization
Alejandra Mercado	Ph.D., ECE, UMD	Associate Director	DATA/MSML 603: Principles of Machine Learning
Arefeh A Nasri	Ph.D., Transportation Engineering, UMD	Visiting Lecturer	DATA/MSML 602: Principles of Data Science
Paul Rodrigues	Ph.D., Linguistics, Indiana University Bloomington	Visiting Assoc Res Scientist, ARLIS	MSML:651: Big Data Analytics
Zoltan Safar	Ph.D., ECE, UMD	Director	DATA/MSML650: Cloud Computing
Shabnam Tafreshi	Ph.D., Computer Science, George Washington University	Asst Research Scientist, ARLIS	MSML641- Natural Language Processing
Jerry Wu	Ph.D., RF MEMS, George Washington University	Lecturer	MSML642: Robotics

OES In-House Market Research: Other Institution Comparison								
Program Name = Machine Learning, MS								
Institution	Website	Delivery Method	Degree Name & Type (MPS, MA, MS, MPH, etc.)	# of Credits	Tuition (course or credit)		Target Population	Prior Education/ Pre-Requisites
					Resident	Non-Resident		
Big Ten Institutions								
Northwestern University	https://www.mccormick.northwestern.edu/artificial-intelligence/	F2F	Artificial Intelligence, MS	Five-quarter sequence	$20,314/quarter (students pay for 4 quarters of tuition)		The program targets ambitious students who seek to become architects of intelligent systems as well as developers.	Bachelors degree in Computer Science or a related field.
University of Michigan	https://masters.engin.umich.edu/degree/robotics-ms/	F2F	Robatics, MS	30 credits	$1,926/credit	$3,286/credit	Our students come to the field with a variety of backgrounds, particularly in mechanical engineering, electrical engineering, and computer science. They learn to work in teams to accomplish the man tasks necessary to build and operate an autonomous system, including mechanical design, electronics, programming and integrating all the parts. Students graduate the program as independent researchers and engineers, and many will go on to become leaders in robotics research in academia, industry and governmen	An engineering background is recommended but not required for the Roboti Program, although we have found that the lack of an engineering background puts students at a disadvantage as they begin their graduate studies. In general, our Admissions Committee is most interested in undergraduate and graduate academic performance, research experience, letters of recommendation (with particular attention to letters coming from faculty in relevant fields) and the academic statement of purpose.
Penn State University Park	https://www.worldcampus.psu.edu/degrees-and-certificates/penn-state-online-artificial-intelligence-masters-degree/overview	Online	Artificial Intelligence, MS	33 credits	$1,046/credit		This online program is designed to provide technical education that empowers graduates to drive the design, development, and deployment of AI and ML products and services across a broad array of applications. Professionals working in the field of AI are responsible for identifying and acquiring relevant data sets, developing scalable algorithms based on state-of-the-art AI/ML (including deep learning) natural language processing, reinforcement learning, and computer vision. Their work also includes applying findings to smart consumer devices, medical imaging diagnostics, autonomous vehicles, and weapons systems.	For admission to the Graduate School, an applicant must hold either (1) a baccalaureate degree from a regionally accredited U.S. institution or (2) a tertiary (postsecondary) degree that is deemed comparable to a four-year bachelor's degree from a regionally accredited U.S. institution. This degree must be from an officially recognized degree-granting institution in the country in which it operates. Students should hold a bachelor's degree in computer science, engineering, o mathematics to be considered for admission to the program. Students from other disciplines will be considered based on prior course work (including th entrance requirements for mathematics and programming) and standardized test scores. Students should have earned at least a 3.00 junior/senior GPA (o a 4.00 scale) in their baccalaureate program. Entrance to Major Mathematics entrance requirement Applicants must complete Calculus I equivalent to Penn State's MATH 140 and 1 semester of probability or statistics. Programming entrance requirement Applicants must complete two introductory-level programming courses whe both courses used the same language. If an applicant believes his/her work experience satisfies the background, he/she should include a recommendatio letter from a technical colleague describing the applicant's coding contributions at work.
Rutgers University New Brunswick	https://www.cs.rutgers.edu/graduate/ms-program-in-computer-science/#section32	F2F	Computer Science, MS-Machine Learning Track	36 credits	$779/credit	$1,325/credit	Students who: *Hold professional positions in the development and design of computer systems and software applications *Teach computer science *Interested in future study and research at the doctorate level.	The department requires that applicants to the M.S. program have completed an undergraduate program in Computer Science, or taken the following prerequisite courses for the undergraduate degree: calculus, linear algebra, finite mathematics, probability/combinatorics, numerical analysis, high level languages, data structures, computer architecture, assembly language, algorithm design and analysis, programming languages and compilers, operating systems, distributed systems, information systems, networks.
University of Wisconsin–Madison	https://www.wisc.edu/	F2F or Online	Electrical Engineering: Machine Learning & Signal Processing, MS	30 credits	$1,200/credit		Designed for students looking for a jump start on a career in data science with a passion for quantitative thinking, practical problem-solving, and computer programming. The Electrical Engineering MLS master's degree is an accelerated program intended to prepare student to excel in the data science workforce in just one year.	All applicants must: Have a Bachelor of Science in electrical or computer engineering from an accredited institution, however bachelor's degrees in other fields of engineering, computer science, mathematics, statistics or a related discipline will be considered. Have a minimum undergraduate GPA o 3.0 on the last 60 credits of degree. Submit GRE test scores using code 1846 (optional). Submit evidence of English language proficiency, if applicable. The required proficiency scores are: TOEFL IBT 92, PBT 580; or IELTS 7.0. Application materials required: Online application; Resume/CV; Statement of purpose; Transcripts; Three letters of recommendation
State of Maryland System Institutions: Overseen by MHEC (http://mhec.maryland.gov/publications/Pages/research/index.aspx)								
Bowie State University	https://www.bowiestate.edu/academics/colleges/college-of-arts-and-sciences/departments/computer-science/graduate/masters-degree/	F2F	Computer Science, MS- Artificial Intelligence/Machine Learning Specialization	36 credits	$439/credit	$723/credit	Students interested in knowledge representation and logical reasoning, robotics, machine learning, probabilistic modeling and inference, natural language processing, cognition, and applications.	Bachelors degree from an accredited institution and completion of specific mathematics (Calc I and Calc 2 and one course beyond Calc) and computer science (Software Design and Development)

Capitol Technology University	https://www.captechu.edu/degrees-and-programs/masters-degrees/systems-engineering-mres	Online	Systems Engineering, MS	30 credits	$630/credit		The M.Res. in Systems Engineering program is structured for those with experience, or established professionals, in the Engineering field with an appropriate degree. During the program, students will conduct original research in an approved area of Systems Engineering.	Not Noted
University of Maryland, Baltimore County	https://umbc.edu/admissions/graduate/graduate-degree-programs/#engineering-IT	F2F	Human-Centered Computing, MS	30 credits	$679/credit	$1,166/credit	The program has two tracks: a Practitioner Track for those who wish t become user experience, information architecture, or usability professionals and a Research Track for those who are interested in pursuing a Master's Thesis and possibly apply to a PhD program. Graduates from our program have moved on to be UX directors in bot government and industrial positions, and graduates from the research track have joined top HCC PhD research programs.	Most accepted students meet the following minimum criteria: Applicants must include a Goal Statement summarizing their interests and experience in the field of Human-Centered Computing (Recommend 1-2 pages) Applicants must submit three letters of recommendation. We recommend these be from individuals who know the applicant professionally and can speak about their past professional accomplishments and potential as a graduate student. The majority of successful applicants have an undergraduate GPA well above 3.2 (on a 4.0 scale). All applicants are expected to read, speak, write, and understand the English language fluently. Those whose native language is not English are required to take the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS), unless they have earned a post-secondar degree from an accredited university in the United States. Admitted applicants must have a combined TOEFL score of 550 (written), 213 (computer based) or 80 (iBT-Internet based), a score above 6.5 with the IELTS (International English Language Testing System), or a score of 105 and above through DuoLingo. The code for UMBC is 5835 While not required for consideration to the MS program, we encourage interested applicants to include a resume (or CV), any samples of high-quality past work, and/or a UX portfolio or link to one. If online UX courses have been taken (e.g. through CourseEra), we encourage applicants to uploa certificates of completion. GRE scores are not required for the MS degree program. When entering in contact details for referees, use institutional or corporate email addresses. References provided to us should be completed on headed notepaper and signed by the referee
Morgan State University	https://www.morgan.edu/advanced-computing-ms/ms_advancedcomputing	F2F or Online	Advanced Computing - Artificial Intelligience Area, MS	30	$464/credit	$912/credit	This new program is designed for students who have recently completed a bachelor's degree program in Computer Science or a related field and wish to enhance their career, explore research opportunities in Computer Science, and apply their acquired skills in multi-disciplinary teams or for specific focus. The program also meets the needs of students who are already in the workforce and wish to update or improve their knowledge of current computer science.	Only students with an undergraduate cumulative grade-point average of 3.0 will be considered for admission. Students with an undergraduate cumulative GPA of between 2.5 and 2.99 may be considered for conditional admission Post-bachelor's undergraduate credits will not be used to enhance G.P.A. requirements for admission to graduate study.For admission to graduate stud an applicant must: Have earned a bachelor's degree from a regionally accredited college or university. The undergraduate record must be of such quality as to promise successful achievement at the graduate level.
Johns Hopkins University	https://ep.jhu.edu/programs/artificial-intelligence/masters-degree-requirements/	Online	Artificial Intelligence, MS	10 Courses	$4,920/course		With the expertise of the Johns Hopkins Applied Physics Lab, we've developed one of the nation's first online artificial intelligence master programs to prepare engineers like you to take full advantage of opportunities in this field. The highly advanced curriculum is designed to deeply explore AI areas, including computer robotics, natural language processing, image processing, and more.	You must meet the general admission requirements that pertain to all master's degree candidates. Prior education must include the following prerequisites such as: (1) three semesters or five quarters of calculus, which includes multivariate calculus; 625.108 – Calculus I 625.109 – Calculus II 625.250 – Multivariable Calculus and Complex Analysis (2) one semeste of Linear Algebra 625.252 – Linear Algebra and Its Applications (3) one semeste of Probability and Statistics 625.240 – Introduction to Probability and Statistics (4) one semester/term of Java or Python. 605.201 – Introduction to Programming Using Java OR 605.206 – Introduction to Python (5) one semester/term of advanced programming such as Data Structures. 605.202 – Data Structures If prior education does not include the prerequisites listed above, you may still be admitted under provisional status followed by full admission once you have completed the missing prerequisites. Missing prerequisites may be completed with Johns Hopkins Engineering (all prerequisites are available) or at another regionally accredited institution. When reviewing an application, your academic and professional background will be considered. If you are an international student, you may have additional admission requirements.

Colleges & Universities in the Washington DC - Baltimore MD area								
Catholic University of America	https://engineering.catholic.edu/eecs/graduate-programs/index.html	F2F	Computer Science, MS- Robotics and Artificial Intelligence Concentration	30 credits	$1,910/credit		The program focuses on teaching how to enhance automation in motic planning and provide assistance in human-machine cooperative tasks i complex domains such as robotic-assisted surgery, robot manipulatior mobile robotics, and air-traffic control.	Students seeking admission to a graduate program in the School of Engineering must have received a bachelors degree in engineering, science mathematics, or a related field from an accredited institution
Columbia University- Video Network	https://cvn.columbia.edu/program/columbia-university-computer-science-masters-degree-machine-learning-masters-science	Online	Computer Science, MS- Machine Learning Track	30 credits	$2,362/credit		The Machine Learning Track is intended for students who wish to develop their knowledge of machine learning techniques and applications. Machine learning is a rapidly expanding field with many applications in diverse areas such as bioinformatics, fraud detection, intelligent systems, perception, finance, information retrieval, and oth areas.	Have a bachelor's degree from a regionally accredited U.S. institution with a 3.3 GPA. Most candidates have completed an undergraduate degree in computer science. Applicants with degrees in other disciplines and a record excellence are encouraged to apply; these applicants are required to have completed at least six prerequisites: 4 computer science courses covering the foundations of the field and 2 math courses.
George Mason	https://cs.gmu.edu/current-students/ms-students/ms-in-computer-science/machine-learning-concentration/	F2F	Computer Science, MS- Machine Learning Concentration	30 credits	$679/credit	$1,474/credit	Designed for students interested in research and professional practice in computer science and related technologies.	Have a bachelor's degree from a regionally accredited U.S. institution.
Virginia Tech	https://www.vt.edu/innovationcampus/masters-degrees/meng-cpe.html	F2F	Computer Engineering, MEng - Machine Learning and Applications Track	30 credits	$16,060/year (no credit breakdown available)	$31,298/year (no credit breakdown available)	The master of engineering in computer engineering offers graduate students a strong academic foundation in core technological areas with a culminating project-based learning experience, preparing students to begin or to advance their professional careers.	We are looking for applicants with a strong math background. Ideally applicants will have completed up to Calculus III, but some completion of Calculus is needed. Complete applications include Transcript, Strong GPA (minimum 3.0 cumulative), No GRE required, 2-3 Letters of recommendation
Howard University	https://gs.howard.edu/computer-science-mcs	F2F	Computer Science, MCS- Algorithms and Machine Learning Specialization	33 credits	$35,556/year (no credit breakdown available)		Designed for students with interest in a comprehensive knowledge of contemporary computer science through training that combines both theory and practice.	Have a bachelor's degree from a regionally accredited U.S. institution with a 3.0 GPA.
Other Major Institutions Offering Similar Programs								
Carnegie Mellon University	https://www.ml.cmu.edu/academics/primary-ms.html	F2F	Machine Learning, MS	30 credits	$27,250/semester		Students who have good analytic skills and a strong aptitude for mathematics, statistics, and programming.	Incoming students must have a strong background in computer science, including a solid understanding of complexity theory and good programming skills, as well as a good background in mathematics. First-year courses assume at least one year of college-level probability and statistics, as well as matrix algebra and multivariate calculus.
Drexel University	https://drexel.edu/cci/academics/graduate-programs/ms-in-artificial-intelligence-machine-learning/	F2F or Online	Artificial Intelligence and Machine Learning, MS	45 credits	$1,342/credit		Students interested in exploring the artificial intelligence and machine learning field's fundamental mathematics to develop related tools and apply AI and ML to various real-world problems.	A four-year bachelor's degree or Master's degree from a regionally accredited institution with a 3.0 GPA in Computer Science, Software Engineering or related STEM degree plus work experience equal to Drexel CS Post-Baccalaureate certificate. Those without the above will have to complete the Post-Baccalaureate Certificate in Computer Science program (with grade B or better in each course) prior to admission to the AI masters degree.
Duke University	https://ece.duke.edu/masters/degrees/ms	F2F	Electrical & Computer Engineering- Data Analytics & Machine Learning Concentration	30 credits	Master's students are required to enroll in and pay tuition for at least three semesters of full-time study ($30,110). After that, they will be charged at an estimated rate of $3,478 per credit.		Specialized preparation for industry, research careers or doctoral study	Have a bachelor's degree from a regionally accredited U.S. institution with a 3.0 GPA.

OES In-House Market Research: Projected Enrollment Information				
Program Name = Machine Learning, MS				
Occupation	**# of Jobs in the Field**	**Where Professionals are Employed**	**Professional Salary Information**	**Projected Job Growth**
Information from U.S. Bureau of Labor Statistics' Occupational Outlook Handbook (https://www.bls.gov/ooh/)				
Computer and Information Research Scientists	33,500 (2021)	31% - Federal government, excluding postal service 20% - Computer systems design and related services 16% - Research and development in the physical, engineering, and life sciences 6% - Software publishers 5% - Colleges, universities, and professional schools; state, local and private	$131,490 (2021)	2021-2031 Projected to grow 21% (much faster than average)
Information from State of Maryland's Occupational and Industry Projections (http://www.dllr.state.md.us/lmi/iandoproj/)				
Computer and Information Research Scientists	2,873 (2021)	**Top 12** - Computer systems design and related services; - Management and technical consulting services; - Architectural and engineering services; - Scientific research and development services; - Colleges and universities; - Management of companies and enterprises; - Commercial equip. merchant wholesalers; - Wired telecommunications carriers; - Other financial investment activities; - Elementary and secondary schools; - Insurance carriers; - Data processing, hosting and related services;	Annual Mean Wage: $123,324 Annual 10th Percentile: $87,880 Annual 75th Percentile: $142,438	2018-2028 Increase by 7%

Five-Year Enrollment Trends					
Year	Bowie State University	Capitol Technology University	University of Maryland, Baltimore County	Morgan State University	Johns Hopkins University
	Computer Science, MS- Artifical Intelligence/Machine Learning Specialization	Systems Engineering, MS	Human-Centered Computing, MS	Advanced Computing - Artificial Intelligience Area, MS	Artificial Intelligence, MS
2017	32	Starting Spring 2023	35	0	0
2018	31		37	0	0
2019	30		37	0	0
2020	25		30	2	60
2021	36		44	10	191

Five-Year Degree Recaps					
Year	Bowie State University	Capitol Technology University	University of Maryland, Baltimore County	Morgan State University	Johns Hopkins University
	Computer Science, MS- Artifical Intelligence/Machine Learning Specialization	Systems Engineering, MS	Human-Centered Computing, MS	Advanced Computing - Artificial Intelligience Area, MS	Artificial Intelligence, MS
2018	12	Starting Spring 2023	16	0	0
2019	12		14	0	0
2020	15		21	0	0
2021	6		14	0	0
2022	8		21	2	4

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http://mhec.maryland.gov/publications/Pages/research/index.aspx

Enrollment Trends: Go to "Enrollment Reports" then "Trends in Fall Enrollment by Program"
Degree Recaps: Go to "Student Outcomes" then "Trends in Degrees and Certificates by Program"

The learning outcomes for the program will be assessed using a combination of formative and summative assessments during and at the completion of each semester. Each course in the program will have homework assignments, practice sets, and other assessments that will be graded with feedback to help assess the student's learning. Midterms and final exams or projects will be cumulative assessments to determine if and to what level the student mastered the learning outcomes for each course.

The assessments will be appropriate to the nature of the course content and the course learning objectives. Both individual assessments and group assessments will be required in the program. This type of variation best mimics the work and industry expectations. The assessments of the program will mirror work products in the industry and prepare students for jobs in industry. For example, many of the elective courses include final projects, presentations and assignments where students have to work with real data sets. Students will be expected to process the data, and perform tasks and make recommendations that are expected of an entry level data scientist/AI engineer.

Lastly, students will also be challenged to complete reflective assessments to apply knowledge and skills in their future professional work. This work will assist students in the job search process and enable them to identify, apply to, and earn positions in this field. The assessments will all follow best practices for adult and professional students. As the student progresses through the curriculum and satisfies learning objectives, they will align with and accomplish the program-level learning outcomes.

MS in Applied Machine Learning					
Five-Year Program Budget					
Tuition Revenue	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
A. Total enrolled students	9	19	20	21	23
First year enrollment	9	10	10	11	12
Second year enrollment		9	10	10	11
B. Total # of 3-credit Courses (by enrollment year)	8	10	10	10	10
# of courses offered for students in year one of the program	8	8	8	8	8
# of courses offered for students in year two of the program		2	2	2	2
C. Per Course Rate	$4,000	$4,120	$4,244	$4,371	$4,502
Total Tuition Revenue	$288,000	$403,760	$424,360	$472,058	$531,240
Direct Expenses	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
A. Instructor Salaries and Fringe	$134,927	$173,936	$179,154	$184,529	$190,065
1. Subtotal: Instructor salaries	$103,870	$133,900	$137,917	$142,055	$146,316
Average 3-credit course salary	$13,000	$13,390	$13,792	$14,205	$14,632
Program specific courses (100% FTE)	7	7	7	7	7
Shared courses (33% FTE)	3	3	3	3	3
2. Fringe Benefits: 29.9%	$31,057	$40,036	$41,237	$42,474	$43,749
Total Direct Expenses	$134,927	$173,936	$179,154	$184,529	$190,065
Total Annual Tuition Revenue	$288,000	$403,760	$424,360	$472,058	$531,240
Total Annual Direct Expenses	$134,927	$173,936	$179,154	$184,529	$190,065
Total Annual OES Administrative Fee	$28,800	$40,376	$42,436	$47,206	$53,124
Annual Distributable Revenue	$124,273	$189,448	$202,770	$240,323	$288,051

Indirect Expenses					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Administrative Salaries and Fringe	$53,692	$55,303	$56,962	$58,671	$60,431
1. Administrative Salaries	$39,596	$40,784	$42,007	$43,268	$44,566
Director (20% FTE)	$25,846	$26,621	$27,420	$28,243	$29,090
Faculty Director Stipend	$15,000	$15,450	$15,914	$16,391	$16,883
Program Manager (33% FTE)	$13,750	$14,163	$14,587	$15,025	$15,476
2. Fringe Benefits: 35.6%	$14,096	$14,519	$14,955	$15,403	15,865
Hourly Wages	$38,736	$51,648	$52,552	$53,474	$54,414
1. Hourly Wages	$36,000	$48,000	$48,840	$49,697	$50,571
Graders for program specific courses ($6K per course)	30,000	42,000	42,840	43,697	44,571
Graders for shared courses ($2K per course)	6,000	6,000	6,000	6,000	6,000
2. Hourly Wages Benefits: 7.6%	$2,736	$3,648	$3,712	$3,777	$3,843
Marketing	$2,500	$2,575	$2,652	$2,732	$2,814
1. Marketing	2,500	2,575	2,652	2,732	2,814
Equipment	$1,500	$1,545	$1,591	$1,639	$1,688
1. Equipment	1,500	1,545	1,591	1,639	1,688
Travel & Recruitment	$1,500	$1,545	$1,591	$1,639	$1,688
1. Travel & Recruitment	$1,500	$1,545	$1,591	$1,639	$1,688
Total Indirect Expenses	$97,928	$112,616	$115,349	$118,155	$121,035

Net Revenue	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
OES Distribution to CMNS	$124,273	$189,448	$202,770	$240,323	$288,051
Indirect Expenses	$97,928	$112,616	$115,349	$118,155	$121,035
Balance	**$26,345**	**$76,832**	**$87,421**	**$122,169**	**$167,016**

Appendix E: Library Assessment

DATE: February 21, 2019

TO: Matthew M. Nessan

Associate Director, Programs; Office of Extended Studies

FROM: On behalf of the University of Maryland Libraries:

Nevenka Zdravkovska, Head, STEM Library

Maggie Saponaro, Director of Collection Development Strategies

Daniel Mack, Associate Dean, Collection Strategies & Services

RE: Master of Professional Studies in Machine Learning - Library Collection Assessment

We are providing this assessment in response to a proposal by the Computer Science Department (CMNS) and Electrical and Computer Engineering Department (A. James Clark School of Engineering) to create a Master of Professional Studies (MPS) in Machine Learning. This program asked that we at the University of Maryland Libraries assess our collection resources to determine how well the Libraries support the curriculum of this proposed MPS in Machine Learning.

Serial Publications

The University of Maryland Libraries currently subscribe to a large number of scholarly journals, with almost all in online format that focus on various specialties within Electrical and Computer Engineering, including Machine Learning.

The Libraries subscribe to several of the top ranked journals that are listed in the Computer Science, Artificial Intelligence category (which includes machine learning journals) in *Journal Citation Reports.** These journals include the following, all of which are available online:

- *International Journal of Machine Learning and Cybernetics*
- *Journal of Machine Learning Research*
- *Machine Learning*

Also, the Libraries have subscription to IEEE and ACM publications, which are numerous and can be accessed through the relevant databases, as discussed below.

Due the interdisciplinary research and instruction inherent in machine learning, there may be highly-ranked core journals to which the Libraries do not currently subscribe. However, articles in journals that we do not own likely will be available through Interlibrary Loan/Document Delivery.

*_Journal Citation Reports_ is a tool for evaluating scholarly journals. It computes these evaluations from the relative number of citations compiled in the _Science Citation Index_ and _Social Sciences Citation Index_ database tools.

Databases

The Libraries' _Database Finder_ (http://www.lib.umd.edu/dbfinder) resource offers online access to databases that provide indexing and access to scholarly journal articles and other information sources. Many of these databases cover subject areas that would be relevant to this proposed program, especially since due to the interdisciplinary applications of machine learning. Databases that would most be useful in the field of machine learning are

- IEEE Xplore
- ACM Digital Library
- Knovel
- ScienceDirect

In many and likely in most cases, these indexes offer full text copies of the relevant journal articles. In those instances that the journal articles are available only in print format, the Libraries can make copies available to graduate students through either the Libraries' Scan & Deliver Program (http://www.lib.umd.edu/access/scan-deliver) or via Interlibrary Loan (more details given below).

Monographs

The Libraries regularly acquire scholarly monographs in machine learning and allied subject disciplines. Monographs not already part of the collection can usually be added upon request. The Libraries has also acquired many eBooks and eBook collections, like:

- Springer eBooks in Computer Science and Springer eBooks (2005-2011)
- SIAM eBooks
- SPIE eBooks
- Synthesis Digital Library (Morgan & Claypool)
- IEEE/Wiley eBooks

A search of the University of Maryland Libraries' WorldCat UMD catalog was conducted, using a variety of relevant subject terms. This investigation yielded sizable lists of citations of books that we own over 700 monographs related to machine learning, including hundreds in areas relevant to proposed courses. In addition, we own dozens of monographs published within the last five to ten years, insuring the program has access to relevant and recent holdings.

A further search revealed that the Libraries' membership in the Big Ten Academic Alliance (BTAA) dramatically increases these holdings and citations with 694 results for "machine learning" and 221 results

for “deep learning.” As with our own materials, graduate students can request that chapters be copied from these BTAA books if the books are not available electronically.

Scan & Deliver and Interlibrary Loan

These services offer online delivery of bibliographic materials that otherwise would not be available online. As a result, remote users who take online courses may find these services to be helpful. Scan & Deliver and Interlibrary Loan are available free of charge.

The Scan & Deliver service scans and delivers journal articles and book chapters within three business days of the request--provided that the items are available in print on the UM Libraries' shelves or in microform. In the event that the requested article or chapter is not available on campus, Scan & Deliver will automatically refer the request to Interlibrary Loan (ILL). Interlibrary Loan is a service that enables borrowers to obtain online articles and book chapters from materials not held in the University System of Maryland.

Additional Materials and Resources

In addition to serials, monographs, and databases available through the University Libraries, students in the proposed program will have access to a wide range of media, datasets, software, and technology. Library Media Services (http://www.lib.umd.edu/lms) houses media in a variety of formats that can be utilized both on-site and via ELMS course media. GIS Datasets are available through the GIS Data Repository (https://www.lib.umd.edu/gis/data-and-resources). Statistical consulting and additional research support are available through the Research Commons (http://www.lib.umd.edu/rc), and technology support and services are available through the Terrapin Learning Commons (http://www.lib.umd.edu/tlc).

Additionally, although not likely to be highly used by this program, UMD does have a number of microform collections, which may be of use for interdisciplinary research. Finally, the STEM Library is a Patent and Trademark Resource Center and provides patent and trademark research consultation.

The subject specialist librarian for Computer Science is Nevenka Zdravkovska (Nevenka@umd.edu) and will also serve as an important resource to programs such as the one proposed.

Other Research Collections

Because of the University’s unique physical location near Washington D.C., Baltimore and Annapolis, University of Maryland students and faculty have access to some of the finest libraries, archives and research centers in the country vitally important for researchers in this discipline. These include the Library of Congress, the National Archives, the Smithsonian, and more available for research use.

Conclusion

With our substantial journals holdings and index databases, as well as additional support services and resources, the University of Maryland Libraries have the resources to support teaching and learning in machine learning. These materials are supplemented by a strong monograph collection and additional holdings through the Big Ten Academic Alliance. Additionally, the Libraries Scan & Deliver and Interlibrary Loan services make materials that otherwise would not be available online, accessible to remote users. As a result, our assessment is that the University of Maryland Libraries are able to meet the curricular and research needs of the proposed MPS in Machine Learning to be offered from the Computer Science and Electrical and Computer Engineering departments.

Course Descriptions

MSML601 Probability and Statistics (3 Credits)
Provides a solid understanding of the fundamental concepts of probability theory and statistics. The course covers the basic probabilistic concepts such as probability space, random variables and vectors, expectation, covariance, correlation, probability distribution functions, etc. Important classes of discrete and continuous random variables, their inter-relation, and relevance to applications are discussed. Conditional probabilities, the Bayes formula, and properties of jointly distributed random variables are covered. Limit theorems, which investigate the behavior of a sum of a large number of random variables, are discussed. The main concepts random processes are then introduced. The latter part of the course concerns the basic problems of mathematical statistics, in particular, point and interval estimation and hypothesis testing.
Prerequisite: Undergraduate courses in calculus and basic linear algebra. Cross-listed with: DATA601, BIOI601.
Credit Only Granted for: BIOI601, DATA601 or MSML601.

MSML602 Principles of Data Science (3 Credits)
An introduction to the data science pipeline, i.e., the end-to-end process of going from unstructured, messy data to knowledge and actionable insights. Provides a broad overview of what data science means and systems and tools commonly used for data science, and illustrates the principles of data science through several case studies.
Restriction: Must be in one of the following programs: (Data Science Post-Baccalaureate Certificate, Master of Professional Studies in Data Science and Analytics, or Master of Professional Studies in Machine Learning). Cross-listed with: DATA602, BIOI602.
Credit Only Granted for: BIOI602, DATA602, MSML602 or CMSC641.
Formerly: CMSC641.

MSML603 Principles of Machine Learning (3 Credits)
A broad introduction to machine learning and statistical pattern recognition. Topics include: Supervised learning: Bayes decision theory, discriminant functions, maximum likelihood estimation, nearest neighbor rule, linear discriminant analysis, support vector machines, neural networks, deep learning networks. Unsupervised learning: clustering, dimensionality reduction, PCA, auto-encoders. The course will also discuss recent applications of machine learning, such as computer vision, data mining, autonomous navigation, and speech recognition.
Restriction: Must be in one of the following programs: (Data Science Post-Baccalaureate Certificate, Master of Professional Studies in Data Science and Analytics, or Master of Professional Studies in Machine Learning). Cross-listed with: DATA603, BIOI603, MSQC603.
Credit Only Granted for: BIOI603, DATA603, MSML603, MSQC603 or CMSC643.
Formerly: CMSC643.

MSML604 Introduction to Optimization (3 Credits)
Focuses on recognizing, solving, and analyzing optimization problems. Linear algebra overview: vector spaces and matrices, linear transformations, matrix algebra, projections, similarity transformations, norms, eigen-decomposition and SVD. Convex sets, convex functions, duality theory and optimality conditions. Unconstrained optimization: 1D search, steepest descent, Newton's method, conjugate gradient method, DFP and BFGS methods, stochastic gradient descent. Constrained optimization: projected gradient methods, linear programming, quadratic programming, penalty functions, and

interior-point methods. Global search methods: simulated annealing, genetic algorithms, particle swarm optimization.
Prerequisite: Undergraduate courses in calculus and basic linear algebra.
Recommended: DATA601.

MSML605 Computing Systems for Machine Learning (3 Credits)
Programming, software and hardware design and implementation issues of computing systems for machine learning. Topics in the programming/software domain will include: basic Python program structure, variables and assignment, built-in data types, flow control, functions and modules; basic I/O, and file operations. Classes, object-oriented programming and exceptions. Regular expressions, database access, network programming and sockets. Introduction to the Numpy, Scipy and Matplotlib libraries. Topics in the hardware domain include computer architecture, CPUs, single- and multi-core architectures, GPUs, memory and I/O systems, persistent storage, and virtual memory. Parallel processing architectures, multiprocessing and cluster processing.
Restriction: Must be in the MPS in Machine Learning program.

MSML606 Algorithms and Data Structures for Machine Learning (3 Credits)
Provides both a broad coverage of basic algorithms and data structures. Topics include sorting, searching, graph and string algorithms; greedy algorithm, branch-and-bound, dynamic programming and job scheduling; Arrays, linked lists, queues, stacks, and hash tables; Algorithm complexity, best/average/worst case analysis. Applications selected from machine learning problems.

MSML612 Deep Learning (3 Credits)
Provides an introduction to the construction and use of deep neural networks: models that are composed of several layers of nonlinear processing. The class will focus on the main features in deep neural nets structures. Specific topics include backpropagation and its importance to reduce the computational cost of the training of the neural nets, various coding tools available and how they use parallelization, and convolutional neural networks. Additional topics may include autoencoders, variational autoencoders, convolutional neural networks, recurrent and recursive neural networks, generative adversarial networks, and attention-based models. The concepts introduced will be illustrated by examples of applications chosen among various classification/clustering questions, computer vision, natural language processing.
Prerequisite: DATA603 or MSML603. Cross-listed with: DATA612.
Credit Only Granted for: DATA612 or MSML612.

MSML640 Computer Vision
An introduction to basic concepts and techniques in computer vision. Topics include low-level operations such as image filtering, correlation, edge detection and Fourier analysis. Image segmentation, texture and color analysis. Perspective, cameras and 3D reconstruction of scenes using stereo and structure from motion. Deep learning for object detection, recognition and classification in images and video.
Prerequisite: DATA603 or MSML603

MSML641 Natural Language Processing (3 Credits)
Introduces fundamental concepts and techniques involved in getting computers to deal more intelligently with human language. Focused primarily on text (as opposed to speech), the class will offer a grounding in core NLP methods for text processing (such as lexical analysis, sequential tagging, syntactic parsing, semantic representations, text classification, unsupervised discovery of latent

structure), key ideas in the application of deep learning to language tasks, and consideration of the role of language technology in modern society.
Prerequisite: DATA603 or MSML603. Cross-listed with: DATA641.
Credit Only Granted for: DATA641 or MSML641.

MSML642 Robotics
This course offers an introduction to the design and programming of robotics systems. Topics include kinematics, differential motion and velocity, dynamics and forces. Sensors, actuators and drive systems. Trajectory planning and motion control systems, open-loop and closed-loop controllers, state estimation and Kalman filters. It will also discuss recent applications of machine learning to motion planning, grasping, manipulation, and related areas.
Prerequisite: DATA603 or MSML603

MSML650 Cloud Computing (3 Credits)
Presents the state of the art in cloud computing technologies and applications. Topics will include: telecommunications needs, architectural models for cloud computing, cloud computing platforms and services. Data center networking, server, network and storage virtualization technologies, and containerization. Cloud operating and orchestration systems. Security, privacy, and trust management; resource allocation and quality of service; interoperability and internetworking.Cross-listed with: DATA650.
Credit Only Granted for: MSML650 or DATA650.

MSML651 Big Data Analytics
The course will focus on the challenges, tools and methods to design and implement machine learning algorithms for very large datasets, and the configuration and operation of distributed computing platforms to execute them. Topics include scalable learning techniques, data streaming and data flow analytics, machine learning on large graphs. Massively parallel computing models such as map-reduce, and techniques to reduce the memory, disk storage and/or communication requirements of parallel machine learning algorithms. SQL and no-SQL database systems, distributed file systems, key-value stores, document databases, graph databases and large dataset visualization.
Prerequistie: DATA601 or MSML602; and DATA603 or MSML603