

COMPUTATIONAL MODELING AND DATA ANALYTICS

Our Website (<https://data.science.vt.edu/programs/cmda.html>)

Overview

The Computational Modeling and Data Analytics (CMDA) program is a collaborative effort of the departments of Mathematics, Statistics, and Computer Science. It resides in the College of Science's Academy of Data Science. CMDA courses teach the range of emerging concepts and techniques from mathematics and statistics, with a decidedly computational approach, that are most in demand by a data-driven world. The curriculum prepares students as quantitative scientists ready to engage data and modeling problems wherever they may occur. CMDA is Virginia Tech's Big Data degree.

In addition to the standard degree option, CMDA offers specialized options in: Biological Sciences, Cryptography & Cybersecurity, Economics, Geosciences, and Physics. After graduation, CMDA majors can deploy their skills across many domains, from climate science to sports analytics, from financial modeling to cybersecurity. Diverse job opportunities abound.

During senior year, CMDA majors undertake a major Capstone Project (CMDA 4864), collaborating with a team of students to tackle an open-ended modeling or analytics challenge from a client in industry, government, academia, or the non-profit sector.

Each Spring the CMDA program awards approximately \$50,000 in Hamlett Scholarships, primarily to continuing students. Majors are also eligible to apply for CMDA Undergraduate Research Grants, awarded for Fall, Spring, and Summer research.

Bachelor of Science in Computational Modeling and Data Analytics

Please direct advising inquiries to cmda-advising@vt.edu.

Satisfactory Progress

University policy requires that students who are making satisfactory progress toward a degree meet minimum criteria toward the General Education (Curriculum for Liberal Education or Pathways to General Education) (see "Academic Policies (<https://catalog.vt.edu/undergraduate/academic-policies/>)") and toward the degree.

Satisfactory progress requirements toward the B.S. in Computational Modeling and Data Analytics can be found on the major checklist by visiting the University Registrar website at <https://www.registrar.vt.edu/graduation-multi-brief/checksheets.html>.

Computer Literacy

Most CMDA courses involve the use of statistical and/or mathematical software, typically including (but not limited to) Python, R, C, Java, and MATLAB. Previous experience with these languages is not expected; students will learn the necessary tools throughout the CMDA curriculum.

- Computational Modeling and Data Analytics Major with Biological Sciences Option (<https://catalog.vt.edu/undergraduate/college-science/computational-modeling-data-analytics/computational-modeling-data-analytics-bs-biological-sciences/>)
- Computational Modeling and Data Analytics Major with Cryptography and Cybersecurity Option (<https://catalog.vt.edu/undergraduate/college-science/computational-modeling-data-analytics/computational-modeling-data-analytics-bs-cryptography-cybersecurity/>)
- Computational Modeling and Data Analytics Major with Economics Option (<https://catalog.vt.edu/undergraduate/college-science/computational-modeling-data-analytics/computational-modeling-data-analytics-bs-economics/>)
- Computational Modeling and Data Analytics Major with Geosciences Option (<https://catalog.vt.edu/undergraduate/college-science/computational-modeling-data-analytics/computational-modeling-data-analytics-bs-geosciences/>)
- Computational Modeling and Data Analytics Major with Physics Option (<https://catalog.vt.edu/undergraduate/college-science/computational-modeling-data-analytics/computational-modeling-data-analytics-bs-physics/>)

Division Leader: M. Embree

Program Manager: H. Caldwell

Undergraduate Advisor: J.S. Whitehead

Principle Faculty: N. Abaid, C. Beattie, P. Cazeaux, L. Childs, J. Datta, E. de Sturler, X. Deng, F. Faltin, R. Gramacy, S. Gugercin, A. Habibnia, P. Haskell, D. Higdon, L. House, L. Johnson, I. Kim, S. Leman, C. Lucero, D. Lucero, M. Liu, G. Matthews, S. Merkes, A. Miedlar, J. P. Morgan, C. North, A. Patterson, L. Pillonen, M. Pleimling, N. Ramakrishnan, C. Ribbens, J. Rudi, E. Smith, E. Ufferman, T. Warburton, J. Wilson, X. Xing, and L. Zeitsman

Undergraduate Course Descriptions (CMDA)

CMDA 1634 - Discovering Computational Modeling and Data Analytics (3 credits)

An introduction to the practice and profession of Computational Modeling and Data Analytics. Acquaints students with foundational computational tools, solving problems with modeling and data, visualization, ethical considerations in data science, professional opportunities in the field, and advising resources at Virginia Tech.

Instructional Contact Hours: (3 Lec, 3 Crd)

CMDA 1984 - Special Study (1-19 credits)

Instructional Contact Hours: Variable credit course

CMDA 2005 - Integrated Quantitative Sciences (6 credits)

2005: Integrated topics from quantitative sciences that prepare students for advanced computational modeling and data analytics courses. Topics include: probability and statistics, infinite series, multivariate calculus, linear algebra. 2006: Intermediate linear algebra, regression, differential equations, and model validation.

Prerequisite(s): MATH 1226

Corequisite(s): MATH 2114 or MATH 2114H or MATH 2405H

Instructional Contact Hours: (6 Lec, 6 Crd)

- Computational Modeling and Data Analytics Major (<https://catalog.vt.edu/undergraduate/college-science/computational-modeling-data-analytics/computational-modeling-data-analytics-bs/>)

CMDA 2006 - Integrated Quantitative Sciences (6 credits)

2005: Integrated topics from quantitative sciences that prepare students for advanced computational modeling and data analytics courses. Topics include: probability and statistics, infinite series, multivariate calculus, linear algebra. 2006: Intermediate linear algebra, regression, differential equations, and model validation.

Prerequisite(s): CMDA 2005 and (MATH 2114 or MATH 2114H or MATH 2405H)

Instructional Contact Hours: (6 Lec, 6 Crd)

CMDA 2014 - Data Matter (3 credits)

This course develops fundamental analytical and programming skills to complete the “analytic pipeline”, including specifying research questions, selecting/collecting data ethically and responsibly, processing and summarizing datasets, and stating findings, while considering all assumptions made. Students will identify vulnerabilities in analyses, including sources of bias and ethical implications. Some programming skills recommended, but not required. Some prior use of data recommended, but not required.

Prerequisite(s): MATH 1014

Pathway Concept Area(s): 5A Quant & Comp Thnk Adv., 10 Ethical Reasoning

Instructional Contact Hours: (3 Lec, 3 Crd)

CMDA 2974 - Independent Study (1-19 credits)

Instructional Contact Hours: Variable credit course

CMDA 2984 - Special Study (1-19 credits)

Instructional Contact Hours: Variable credit course

CMDA 2984E - Special Study (1-19 credits)

Pathway Concept Area(s): 5A Quant & Comp Thnk Adv.

Instructional Contact Hours: Variable credit course

CMDA 2994 - Undergraduate Research (1-19 credits)

Instructional Contact Hours: Variable credit course

CMDA 3274 - Introduction Sports Analytics (3 credits)

Introduction to sports analytics, sources of sports analytics data and data collection methods, visualization techniques, game performance statistics, inferential statistics and predictive modeling techniques for sports data. Role and applications of data analytics in the sports industry.

Prerequisite(s): CMDA 2006 or STAT 3006

Corequisite(s): CMDA 3654 or CS 3654 or STAT 3654.

Instructional Contact Hours: (3 Lec, 3 Crd)

Course Crosslist: STAT 3274

CMDA 3605 - Mathematical Modeling: Methods and Tools (3 credits)

3605: Mathematical modeling with ordinary differential equations and difference equations. Numerical solution and analysis of ordinary differential equations and difference equations. Stochastic modeling, and numerical solution of stochastic differential equations. 3606: Concepts and techniques from numerical linear algebra, including iterative methods for solving linear systems and least squares problems, and numerical approaches for solving eigenvalue problems. Ill-posed inverse problems such as parameter estimation, and numerical methods for computing solutions to inverse problems. Numerical optimization. Emphasis on large-scale problems.

Prerequisite(s): (CS 1114 or CS 1064 or MATH 1454) and (MATH 2114 or MATH 2114H or MATH 2405H) and (MATH 2204 or MATH 2204H or MATH 2406H or CMDA 2005) and (MATH 2214 or MATH 2214H or MATH 2406H or CMDA 2006)

Instructional Contact Hours: (3 Lec, 3 Crd)

CMDA 3606 - Mathematical Modeling: Methods and Tools (3 credits)

3605: Mathematical modeling with ordinary differential equations and difference equations. Numerical solution and analysis of ordinary differential equations and difference equations. Stochastic modeling and numerical solution of stochastic differential equations. 3606: Concepts and techniques from numerical linear algebra, including iterative methods for solving linear systems and least squares problems, and numerical approaches for solving eigenvalue problems. Ill-posed inverse problems such as parameter estimation, and numerical methods for computing solutions to inverse problems. Numerical optimization. Emphasis on large-scale problems.

Prerequisite(s): CMDA 3605

Instructional Contact Hours: (3 Lec, 3 Crd)

CMDA 3634 - Computer Science Foundations for Computational Modeling & Data Analytics (3 credits)

Survey of computer science concepts and tools that enable computational science and data analytics. Data structure design and implementation. Analysis of data structure and algorithm performance. Introduction to high-performance computer architectures and parallel computation. Basic operating systems concepts that influence the performance of large-scale computational modeling and data analytics. Software development and software tools for computational modeling. Not for CS major credit.

Prerequisite(s): CS 2114

Instructional Contact Hours: (3 Lec, 3 Crd)

Course Crosslist: CS 3634

CMDA 3654 - Introductory Data Analytics and Visualization (3 credits)

Basic principles and techniques in data analytics; methods for the collection of, storing, accessing, and manipulating standard-size and large datasets; data visualization; and identifying sources of bias.

Prerequisite(s): (CS 1114 or CS 1044 or CS 1054 or CS 1064) and (MATH 2204 or MATH 2204H or MATH 2406H or CMDA 2005) and (STAT 3006 or STAT 4105 or STAT 4705 or STAT 4714 or CMDA 2006)

Instructional Contact Hours: (3 Lec, 3 Crd)

Course Crosslist: CS 3654, STAT 3654

CMDA 3900 - Bridge Experience (0 credits)

Application of academic knowledge and skills to in a work-based experience aligned with post-graduation goals using research-based learning processes. Satisfactory completion of work-based experience often in the form of internship, undergraduate research, co-op, or study abroad; self-evaluation; reflection; and showcase of learning. Pre: Department approval of 3900 plan.

Instructional Contact Hours: (0 Crd)

CMDA 4274 - Sports Analytics Statistical Research (3 credits)

Statistical analysis of sports data. Game performance statistics and expected scores. Analysis of player performance, player tracking, team performance, and sports betting. Bayesian methods and prediction models applied to sports data. Decision-making. Assessing sports analytics research and literature.

Prerequisite(s): (STAT 4214 and STAT 4444) or (CMDA 4654 or CS 4654 or STAT 4654) or (STAT 3274 or CMDA 3274)

Instructional Contact Hours: (3 Lec, 3 Crd)

Course Crosslist: STAT 4274

CMDA 4314 - Big Data Economics (3 credits)

Applied econometrics dealing with big data. Theoretical, computational, and statistical underpinnings of big data analysis. The use of econometric models and deep machine learning algorithms to analyze the high-dimensional data sets. Implications in research focusing on economic questions that arise from rapid changes in data availability and computational technology. Materials are hands-on tutorials that come with Python codes and real-world data sets.

Prerequisite(s): ECON 3254 or ECON 4304 or CMDA 3654 or STAT 3006

Instructional Contact Hours: (3 Lec, 3 Crd)

Course Crosslist: ECON 4314

CMDA 4604 - Intermediate Topics in Mathematical Modeling (3 credits)

Introduction to partial differential equations, including modeling and classification of partial differential equations. Finite difference and finite elements methods for the numerical solution of partial differential equations including function approximation, interpolation, and quadrature. Numerical solution of nonlinear systems of equations. Uncertainty quantification, prediction.

Prerequisite(s): CMDA 3606

Instructional Contact Hours: (3 Lec, 3 Crd)

CMDA 4634 - Scalable Computing for Computational Modeling and Data Analytics (3 credits)

A focused study of concepts and tools that accelerate computational and data science at scale. Design, analysis, optimization, and modeling of application-driven algorithms suitable for state-of-the-art scalable computing platforms. Software development and engineering for scalable computational science.

Prerequisite(s): (CMDA 3634 or CS 3634 or CS 4234) and (CMDA 3654 or CS 3654 or STAT 3654) and (CMDA 3605 or CS 3414 or MATH 3414 or MATH 4445)

Instructional Contact Hours: (3 Lec, 3 Crd)

CMDA 4654 - Intermediate Data Analytics and Machine Learning (3 credits)

A technical analytics course. Covers supervised and unsupervised learning strategies, including regression, generalized linear models, regularization, dimension reduction methods, tree-based methods for classification, and clustering. Upper-level analytical methods shown in practice: e.g., advanced naive Bayes and neural networks.

Prerequisite(s): (STAT 3654 or CMDA 3654 or CS 3654) and (CMDA 2006 or STAT 3104 or STAT 4106 or STAT 4706) and (MATH 2114 or MATH 2114H or MATH 2405H)

Instructional Contact Hours: (3 Lec, 3 Crd)

Course Crosslist: CS 4654, STAT 4654

CMDA 4664 - Computational Intensive Stochastic Modeling (3 credits)

Stochastic modeling methods with an emphasis in computing are taught. Select concepts from the classical and Bayesian paradigms are explored to provide multiple perspectives for how to learn from complex, datasets. There is particular focus on nested, spatial, and time series models.

Prerequisite(s): (STAT 4106 or CMDA 3605) and (CS 1114 or CS 1064 or STAT 2005)

Instructional Contact Hours: (3 Lec, 3 Crd)

Course Crosslist: STAT 4664

CMDA 4864 - Computational Modeling and Data Analytics Capstone Project (3 credits)

Capstone research project for Computational Modeling and Data Analytics majors. Cultivates skills including reviewing the literature, creative problem solving, teamwork, critical thinking, and oral, written, and visual communications. Quantitative and computational thinking, informed throughout by ethical reasoning.

Prerequisite(s): CMDA 3605 and CMDA 3634 or CS 3634 and CMDA 3654 or CS 3654 or STAT 3654

Pathway Concept Area(s): 5A Quant & Comp Thnk Adv., 10 Ethical Reasoning

Instructional Contact Hours: (3 Lec, 3 Crd)

CMDA 4964 - Field Study (1-19 credits)

Instructional Contact Hours: Variable credit course

CMDA 4974 - Independent Study (1-19 credits)

Instructional Contact Hours: Variable credit course

CMDA 4984 - Special Study (1-19 credits)

Instructional Contact Hours: Variable credit course

CMDA 4994 - Undergraduate Research (1-19 credits)

Instructional Contact Hours: Variable credit course