# The Applied and Computational Mathematics Program at The Johns Hopkins University

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T he Applied and Computational Mathematics Program emphasizes mathematical and computational techniques of fundamental importance and practical relevance. Students in the program acquire the skills to solve problems in diverse areas of engineering, business, science, health care, information technology, and public policy. The program emphasizes the strong connection between applied mathematics and modern computational methods, especially in the design and computer implementation of mathematical algorithms.

## OVERVIEW

There is a strong demand in the work world for people with training in applied mathematics and computation. Advances in areas such as biomedicine, communications networks, defense systems, and commerce all require people who are comfortable with basic mathematical tools and with methods for implementing those tools for efficient computation. The mathematical tools provide the fundamental building blocks and the ability to create representations of the world that can yield practical solutions to critical problems. The computational methods provide the means for using the mathematical tools to produce the fundamental output—numbers, graphics, rules, and so on—to allow designers and decision makers to solve their problems. With training in both the mathematical and computational aspects of modern analysis, an individual is prepared to both *understand* and *solve* the problem at hand. The Applied and Computational Mathematics (ACM)

Program at The Johns Hopkins University (JHU) is designed for working professionals with such interests. It is offered through the Engineering and Applied Science Programs for Professionals (EPP), which is the division of the JHU Whiting School of Engineering that is aimed at offering educational opportunities to working adults.

The ACM Program has a relatively long history, beginning as the Numerical Science Program in 1966 as part of the Johns Hopkins Evening College Center. The Numerical Science and other part-time programs were transferred to the Whiting School of Engineering in 1983 to foster a greater association with the full-time faculty of JHU. In 1988, the name was changed to Applied Mathematics to reflect the broader educational goals of the program. In 2000, it was again renamed as the Applied and Computational Mathematics Program to reflect the critical role of computing in modern

applied mathematics. Additional details on the history of the program can be found in Ref. 1.

The ACM Program has gone through a significant transformation in the last 8 years, resulting in an approximate tripling of student enrollments (Fig. 1). All courses have undergone extensive review, and many new courses have been introduced. A Program Committee of leading practitioners and academics oversees the program, making decisions about course offerings, faculty hiring, and degree requirements. The committee helps ensure that the program meets the needs of those in government, industry, and academia. Student and employer input is also a key part of the evaluation process.

## DEGREES AND CONCENTRATION AREAS

There are two levels of formal recognition for graduates of the ACM Program. The core level is the M.S. degree, representing the completion of 10 courses in ACM and related programs. For students already holding an M.S. (or equivalent) in ACM or in a closely related area, the option of an advanced certificate for post-master's study is available. The certificate requires six courses. At both levels, students work with a graduate advisor to choose courses that best suit their needs while fulfilling certain academic requirements. A thesis is not required for the M.S. or the certificate. Aside from pursuing one of these two levels of formal recognition in ACM, enrollees may also take selected courses of interest for which they are qualified as special students. Occasionally, students in the ACM Program will subsequently pursue a Ph.D. in the Department of Applied Mathematics and Statistics (AMS) at the Homewood campus of JHU or at another university.

The ACM Program allows degree seekers to choose an area of concentration from the following:

- Probability and Statistics
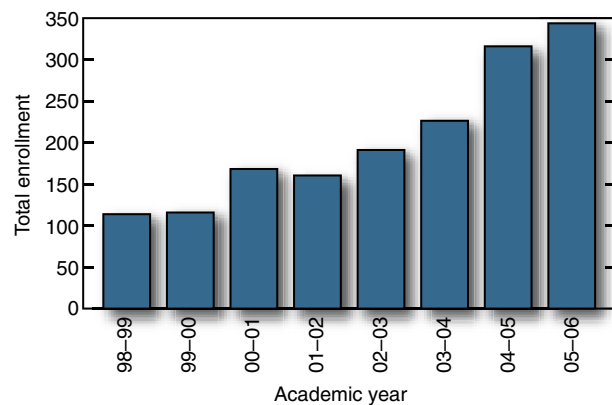- Applied Analysis
- Operations Research
- Information Technology and Computation
- Simulation and Modeling

Students pursuing one of these concentrations enroll in a selected subset of ACM courses. They are not required to choose one of the above concentrations; rather, they are free to select courses from different areas to meet their individual needs, subject to meeting general ACM graduation requirements.

## COURSES

All students in the ACM Program take a blend of introductory and more advanced courses. Those working toward the M.S. may take two electives as part of the 10-course requirement. Electives are typically drawn from programs in Applied Physics, Computer Science, or Electrical and Computer Engineering, but other possibilities exist subject to student interest and advisor

**ACM PROGRAM COURSES**

Nongraduate credit
    Applied Mathematics I and II
    General Applied Mathematics
    Linear Systems

Graduate credit
    Combinatorics and Discrete Mathematics
    Complex Variables
    Computational Complexity and Modern
        Computing
    Computational Methods
    Cryptography
    Data Mining
    Fourier Analysis
    Graph Theory
    Independent Study Project
    Introduction to Optimization
    Linear Statistical Models
    Mathematics of Finance
    Matrix Theory
    Measure-Theoretic Probability
    Modern Algebra
    Neural Networks
    Nonlinear Differential Equations and Dynamical
        Systems
    Operations Research: Probabilistic Models
    Ordinary Differential Equations
    Partial Differential Equations
    Queuing Theory
    Real Analysis
    Signal Processing and Spectral Analysis
    Simulation and Monte Carlo Methods
    Statistical Methods and Data Analysis
    Stochastic Differential Equations
    Stochastic Optimization and Control
    Stochastic Processes I and II
    Theory of Statistics I and II
    Time Series Analysis and Dynamic Models



**Figure 1.** Course enrollments for the ACM Program.

approval. All electives must have significant mathematical content. Most of the ACM courses are taught at APL, but some are offered at the Dorsey Center near BWI airport and the Montgomery County Campus in Rockville, Maryland. Courses offered within the ACM Program are listed in the boxed insert.

Courses are continuously monitored, both formally and informally, to ensure that they reflect the field at large, are academically rigorous, and serve the needs of local employers and students. Nearly half of the courses have been introduced within the last 6 years. All of the remaining courses have been significantly updated in the same time period. Several new courses are being considered in areas such as nonlinear programming, systems theory, and statistical model building.

Some of the courses in the ACM Program are not commonly found in applied mathematics and related programs at other universities. They include Time Series Analysis and Dynamic Models, Computational Complexity and Modern Computing, Stochastic Differential Equations, and Stochastic Optimization and Control.

## FACULTY

The ACM Program has approximately 25 faculty members. Most hold a doctorate and are experienced practitioners working in government, research laboratories, or area companies. Several members also serve on the full-time faculty of the AMS Department of JHU. All members of the faculty are committed to the mission of the ACM Program: to instruct working professionals pursuing education on a part-time basis. They have significant accomplishments in mathematics and computational methods within their work environment, and most have been active in the broader research and development community through conference participation and publishing. Aside from refereed journal and conference publications, some members of the faculty have had books published within the last several years (Fig. 2).

## STUDENTS

There are approximately 140 active students in the ACM Program, almost all of whom are working full time (or nearly full time) at area employers. While most students are candidates for the M.S. degree or the advanced certificate for post-master's study, many others are simply taking selected courses to satisfy specific personal interests or an employer's needs.

The nature of the student body tends to differ from that of the full-time programs at the Homewood campus. Often, students in the ACM Program have
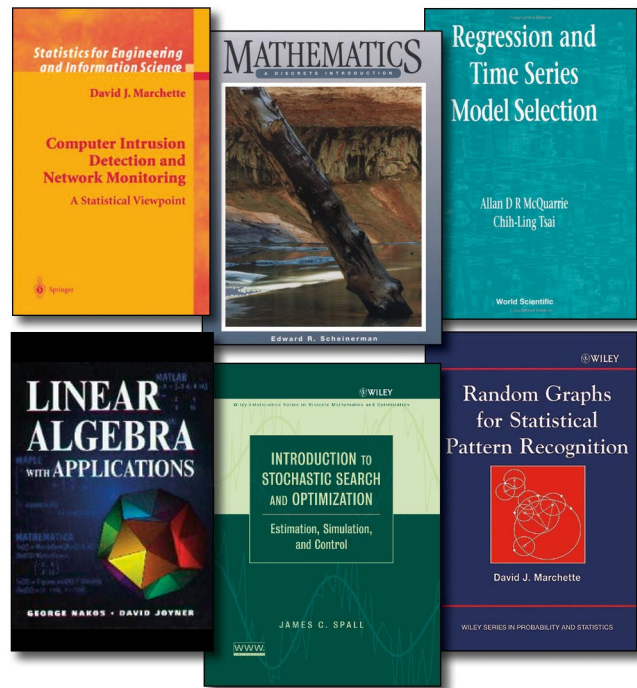


**Figure 2.** Recent books by ACM faculty. *Computer Intrusion Detection and Network Monitoring* by D. J. Marchette (2001); *Mathematics: A Discrete Introduction* by E. R. Scheinerman (2000); *Regression and Time Series Model Selection* by A. D. McQuarrie and C-L. Tsai (1998); *Linear Algebra with Applications* by G. Nakos (1998); *Introduction to Stochastic Search and Optimization* by J. C. Spall (2003); and *Random Graphs for Statistical Pattern Recognition* by D. J. Marchette (2004).

specific job-related goals in their choice of courses. Many are "older" and have been out of school for some time. In fact, many are apprehensive about their likelihood of success given the time that has elapsed since they were last in a formal class setting. To ease apprehension, ACM offers several noncredit courses covering material that is commonly seen in undergraduate programs in science, engineering, and mathematics (see the course list). Some students choose to take one or more of these classes before taking classes for the degree, while others are required to take one or more when the Admissions Committee has identified particular weaknesses. Many faculty members are supportive of the students, lending assistance outside of normal class hours to help ensure success (Fig. 3).

Students must hold an undergraduate degree from an accredited college or university. Each student's undergraduate degree program (or subsequent study) must have included at least one mathematics course beyond multivariate calculus (e.g., advanced calculus, differential equations, linear algebra). All students are expected to have a working knowledge of at least one language for technical computing (MATLAB, MATHEMATICA, Fortran, C, or C++).

The ACM Program draws students from a diverse range of undergraduate backgrounds, reflecting the broad applicability of mathematics in society. Areas of

**Figure 3.** ACM faculty member Stacy Hill (center) meets with students outside of class to discuss a mathematical problem.

study for the undergraduate degrees of ACM students include mathematics, all major fields of engineering, physics, chemistry, biology, business, economics, statistics, and computer science. While most students do not pursue a degree beyond the M.S., some use their ACM studies as a springboard to doctoral studies at JHU or another university.

## INTERACTIONS WITH FULL-TIME FACULTY OF JHU

Significant interactions occur between the ACM Program and the AMS Department at JHU, which focuses on full-time students. ACM students are free to take graduate courses in the AMS Department, two of which may count toward the M.S. degree in ACM. The Program Chair for ACM has a Research Professor appointment in the AMS Department and has taught several of the department's courses. The ACM Program Committee (which, as noted earlier, reviews and approves all significant changes to the program) includes one faculty member from the AMS Department. Furthermore, several ACM faculty members come from the AMS or Electrical and Computer Engineering departments at JHU-Homewood.

Other occasional interactions between faculty members in ACM and Homewood include joint proposals to NASA and NSF and joint APL/Whiting School of Engineering committee appointments. These interactions provide additional opportunities for faculty and students and help ensure that the academic standards for the ACM Program are commensurate with the standards of the full-time programs of JHU. There is also an ongoing evaluation of the feasibility of introducing a doctoral program catering to EPP students; this has involved close interaction between JHU-Homewood and certain faculty members in EPP (the Program Chair for ACM is the Chair of the EPP Committee evaluating the feasibility of such a doctoral program). As of this writing, no decision has been made regarding the doctral program.

## CONCLUDING REMARKS

Mathematics and computation are fundamental to modern society. Many of the historically important areas in applied mathematics—including analysis, probability, statistics, optimization, discrete math, and numerical methods—remain essential in modern problem solving. In addition, newer areas of application in fields such as network computing, genomics, and financial mathematics require new algorithms and implementations for various branches of mathematics. The ongoing shift toward the integration of computing into a greater fraction of activities in society provides a good opportunity for those well versed in mathematics and computation.

The ACM Program of Johns Hopkins has long served the needs of area students and employers and will continue to do so. The strengths of the program are centered on enthusiastic and technically strong faculty members, the personalized academic advising and faculty support offered to all students, the close interaction with the AMS Department at the main campus, and a unique combination of standard and nonstandard course offerings that are highly relevant to people using mathematics in the work world. Recent developments in the program have led to significant growth in student enrollments. Near- and long-term plans have the program continuing to adapt to the changing environment and to meet the needs of current and future students.

REFERENCE

[1]Rich, R. P., and Stadter, J. T., "The Master's Degree Program in Applied Mathematics," *Johns Hopkins APL Tech. Dig.* **10**, 135–139 (1989).

## THE AUTHOR

**James C. Spall** is a member of the Principal Professional Staff at APL, the Chair of the Applied and Computational Mathematics Program within the JHU School of Engineering, and a Research Professor in the JHU Department of Applied Mathematics and Statistics. Dr. Spall has published extensively in the areas of control systems, optimization, and statistics (including two books) and holds two U.S. patents for inventions in control systems. Among other appointments, he is an Associate Editor at Large for the *IEEE Transactions on Automatic Control* and a Contributing Editor for the *Current Index to Statistics*. Dr. Spall has received numerous research and publications awards and is a Fellow of IEEE, a member of the American Statistical Association, and a Fellow of the engineering honor society Tau Beta Pi. His e-mail address is james.spall@jhuapl.edu.

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