

# CAAM454 / 554 Numerical Analysis II - Spring 2019

**Course content.** Iterative methods for linear systems of equations including Krylov subspace methods; Newton and Newton-like methods for nonlinear systems of equations; Gradient and Newton-like methods for unconstrained optimization and nonlinear least squares problems; techniques for improving the global convergence of these algorithms; linear programming duality and primal-dual interior-point methods.

**Course Web-Page.** <http://maartendehoop.rice.edu/caam-454/>.

Check the course web-page regularly for assignments, handouts, etc.

**Time and Room.** T/Th 2:30PM-3:45PM, Room: George R. Brown hall W212

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**Course Objectives.** Students should learn about the construction, analysis, and application of iterative methods for linear systems of equations including Krylov subspace methods, of Newton and Newton-like methods for nonlinear systems of equations, and of gradient and Newton-like methods for unconstrained optimization and nonlinear least squares problems.

For CAAM 454 students, the analysis of the iterative methods above will be limited to simpler cases and these iterative methods will be applied to simpler examples.

CAAM 554 students should learn how to carry out rigorous mathematical convergence analyses, and apply the iterative methods above in more advanced settings.

**Outcomes.** For both CAAM 454 and 554:

- Describe basic iterative methods, the conjugate gradient (CG) method, and GMRES for the solution of linear systems, and their convergence properties.
- Derive Newton's method and prove local convergence.
- Describe and apply line-search methods to globalize the convergence of gradient and of Newton-type methods.

- Develop Matlab programs of basic iterative methods, CG, GMRES, and Newton-type methods with line-search, and apply them to example problems.

Additional outcomes for CAAM 554:

- Carry out rigorous mathematical convergence analyses for basic iterative methods as well as for the Krylov subspace methods CG and GMRES.
- Carry out rigorous mathematical convergence analyses for line search globalizations.

**CAAM454 or 554?** CAAM 454 or 554 meet for the same T/Th lectures, but CAAM 554 will include more theoretical homework and exam problems. CAAM PhD students must enroll in CAAM 554; other graduate students comfortable writing rigorous mathematical proofs may also consider this option. Students cannot take both CAAM 454 and 554 for credit.

**Textbooks and References.** Lecture notes will be made available through the course web-page. In addition to the notes, I recommended the following books.

- J. E. Dennis, Jr., and R. B. Schnabel: *Numerical Methods for Unconstrained Optimization and Nonlinear Equations*, Prentice Hall 1983. Reprinted by SIAM, Philadelphia, 1996.
- C. T. Kelley: *Iterative Methods for Linear and Nonlinear Equations*, SIAM, Philadelphia, 1995. A free PDF version of this book is available at <http://www.siam.org/books/textbooks/download.php>.
- C. T. Kelley: *Iterative Methods for Optimization*, SIAM, Philadelphia, 1999. A free PDF version of this book is available at <http://www.siam.org/books/textbooks/download.php>.
- J. Nocedal and S. J. Wright: *Numerical Optimization (second edition)*, Springer Verlag, 2006. <https://doi.org/10.1007/978-0-387-40065-5>
- Y. Saad: *Iterative methods for sparse linear systems (2nd edition)*, SIAM, Philadelphia, 2003. A free PDF version of this book is available at <http://www-users.cs.umn.edu/~saad/books.html>.
- Lloyd N. Trefethen and David Bau, III: *Numerical Linear Algebra*, SIAM, 1997.

**Grading.** Problem sets will be assigned in the course web-page. There will be two exams/pledged homework assignments. The final grade will be determined from unpledged problem sets (60%) and pledged problem sets/exams (40%).

On unpledged assignments you may collaborate, but your write-up must be your own independent work. Exams/pledged homework assignments may be timed and ‘closed book’, and you are not allowed to discuss exams/pledged assignments with anyone but your instructor. Transcribed solutions are unacceptable; you may not consult solutions from previous sections of this class.

You may turn in two unpledged problem sets one class period late without penalty. Subsequent late assignments will be penalized 20% each. Homework will not be accepted more

than one class period late without a written excuse. This implies that you may not use two 'lates' on one assignment. Pledged assignments/exams must be turned in on time.

**Absence Policies.** Regular and active class participation is expected.

**Programming.** Homework assignments will require some MATLAB programming. Your solutions should adhere to good programming standards, and must not be copied from other students.

**Rice Honor Code.** In this course, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated at this institution. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at <http://honor.rice.edu/honor-system-handbook/>. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process.

**Disability Support Services.** If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with Disability Support Services (Allen Center, Room 111 / [adarice@rice.edu](mailto:adarice@rice.edu) / x5841) to determine the accommodations you need; and 2) talk with me to discuss your accommodation needs.

**Syllabus Change Policy.** This syllabus is only a guide for the course and is subject to change with advanced notice.