SIAM Book Proposal

Please help us evaluate your proposal fairly and accurately by providing careful, complete responses. This form will be read by non-technical people and applied mathematicians who may work in areas different from your own.

In addition to the information outlined in this form, please provide:

- a **preface** that describes the scope and aims of the book
- a **table of contents** with a short description of each chapter
- a list of **sample references**

These materials and this form will be given to reviewers. Be sure to convey exactly what you are trying to do and whom you are trying to reach. Assume that reviewers know little about the importance of your topic.

Author Information

Please provide preferred contact information for all authors of this project.

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Book Information

Title: PETSc for Partial Differential Equations

Projected # of Pages: 250--350 (attached PDF is 123)
Projected # of Chapters: 11 or 12
Projected # of Figures: 50

- # of Line drawings (b&w only): 40
- # of Halftones (b&w photos or line drawings w/grayscale): 10
- # of 2-color figures (black + 1 color): 0
- # of 4-color figures (black + 2 or more colors): 0

Composition: LaTeX with tufte-book class for now
Software Used to Create Art: LaTeX/tikz and python

Percentage of Manuscript Completed: 40%
Expected Date of Completion: August 2016

Book Content

Provide a brief non-technical description of your book.

This book is about numerically solving linear and nonlinear partial differential equations (PDEs) by writing C code that directly calls PETSc. It both explains the ideas embodied in PETSc and illustrates them through example codes. These codes come with enough background information and context so that readers can easily use them as a basis for further developments. Demonstrated performance and scalability are goals, so runtime options are explained and compared, and explored in the exercises.

What is the scope of your book?

The scope in terms of software used is: C and PETSc.

The scope in terms of PDEs is a selection of specific linear and nonlinear PDEs, including some systems of PDEs, but especially nonlinear elliptic PDEs and nonlinear variational inequalities. (See the proposed inside-back-cover chart in the PDF.)

The scope in terms of scientific computing and numerical analysis topics: Krylov methods, preconditioning, Newton method, multigrid, structured finite difference schemes, structured and unstructured finite element schemes.

List three distinctive features of your book and give reasons why your colleagues will want to purchase it.

1. PETSc is the most important scientific software layer right now that does not have good introductory documentation. It is the part of the software stack upon which major FEM libraries (e.g. firedrake and moose), and many other kinds of software suitable for supercomputers, are being built. This book is in the big documentation gap, though it does not fill it.

2. Serious high-performance-computing is increasingly a domain where linear and nonlinear systems must be solved, not just explicit time steps taken, where codes must work on parallel hardware, and where preconditioning really matters. This book introduces that world.

3. Existing PETSc example codes are hap-hazardly designed and maintained. The codes in this book are better-designed and simpler, and match explanatory text, although their scope is much less than the full existing PETSc example collection.

Are any topics omitted? If so, why? What topics are emphasized and why?

Umm ... lots of topics are omitted!

Some places I do not plan to go: serious discussion of hyperbolic systems, "field-split"-type preconditioners, serious discussion of performance tuning, scaling beyond ~500 processes.

Lots of nice nonlinear PDE examples will not appear, unfortunately. (I hope to expose a few nice ones, that's all.)

What applications are covered?

I do not plan to include real science/engineering "applications" at all, because my book is about the software and the mathematical ideas that make it work. The audience definitely includes scientists and engineers who need to use the software/library, but I won't try to teach them their applications.

List new methods or special techniques not discussed in other books.

PETSc itself is not in other texts, other than Smith et al. [1996; see references in PDF draft] which is very dated. My book will be more modern for preconditioning and Newton's method than other books of which I am aware and which are at the same level of accessibility.

What previous knowledge is the reader assumed to have?

As stated in the preface, the reader has to have a fair amount of background. On the programming side, exposure to C, though expert-level programming is definitely not needed. On the mathematical side, some numerical linear algebra (at the level of Trefethen & Bau) is assumed.

Moreover, this cannot be the first PDE book the reader has seen; it won't make sense. I am trying to write a book targeting the same (roughly) level of reader as Elman et al's FEM book, LeVeque's FVM book, and Trefethen's spectral methods book--see my references--but such readers need to be living in a unix/C world already, not exclusively in a Matlab world.

How will this book benefit the reader?

The reader will come away with a powerful tool well in hand: PETSc. Big projects can be built on this tool.

What software is used in your book?

C and PETSc

Textbooks

If your book is appropriate for classroom use, complete this section; otherwise skip to the next section on Competing and Similar Books.

What course or course topics are relevant to the topic of the book?

The book is suitable as a text for an advanced graduate course in scientific high-performance computing. This course can be aimed at students who have the equivalent of a Masters in Computational Science/Engineering or a Masters in Applied Mathematics. I will try such a course in Spring 2016 from this book, so I'll be providing some slides along with the text itself and the example codes.

What textbook(s) are you currently using?

None exist. The course described above would be a new one, though such "courses" have been attempted many times as tutorials at conferences, for example.

What is the level of the textbook?

☐ Undergraduate ☐ Advanced Undergraduate/First-Year Graduate ☒ Advanced Graduate

☒ Primary ☐ Supplementary

Competing and Similar Books

Please list the author(s), title, and publisher for any competing or similar books. Please tell us how your book compares.

- The only "comparable" book is

  B. Smith et al., 1996. Domain Decomposition: Parallel Multilevel Methods for Elliptic Partial Differential Equations, Cambridge University Press

  which is now very dated now relative to the ideas and API of the PETSc library software. My book will include significant material on Newton's method and nonlinear PDEs, plus material on multigrid and variational inequalities.

  Note that Barry Smith and other PETSc developers generally support my project to write a new PETSc book.

Market

SIAM uses the following subject areas to identify the special interests of its members. Please use an asterisk to mark the code most appropriate for your book.

(1) Linear algebra and matrix theory

(2) Real and complex analysis including approximation theory, integral transforms (including Fourier series and wavelets), integral equations, asymptotic methods, and special functions

(3) Ordinary differential equations including dynamical systems

(4) Partial differential equations including inverse problem

(5) Discrete mathematics and graph theory including combinatorics, combinatorial optimization, and networks

(6) Numerical analysis (theory)

* (7) Computational mathematics including scientific computing, parallel computing, and algorithm development

(8) Computer science including computer architecture, computer hardware, computational complexity, applied logic, database, symbolic computation

(9) Applied probability including stochastic processes, queueing theory, and signal processing

(10) Statistics including data analysis and time series analysis

(11) Control and systems theory including optimal control

(12) Optimization theory and mathematical programming including discrete and numerical optimization and linear and nonlinear programming

(13) Communication theory including information theory and coding theory

(14) Applied geometry including computer-aided design and related robotics

(15) Imaging science including computer graphics, computer vision, related robotics, and tomography

(16) Classical mechanics of solids including elasticity, structures and vibrations, and constitutive models

(17) Fluid mechanics including turbulence, aeronautics, and multiphase flow

(18) Quantum physics, statistical mechanics, and relativity

(19) Geophysical sciences including reservoir modeling, seismic exploration, and petroleum engineering

(20) Atmospheric and oceanographic sciences

(21) Chemical kinetics, combustion theory, thermodynamics, and heat transfer

(22) Life sciences including biophysics, biomedical engineering, and biomathematics
(23) Environmental sciences
(24) Economics and finance
(25) Social sciences
(26) Functional analysis and operator equations, and integral and functional equations
(27) Management sciences including operations research
culum, graduate study, and modeling courses)
(28) Mathematics education (K-12, undergraduate curriculum, graduate study, and modeling courses
(29) Astronomy, planetary sciences, and optics
(30) Simulation and modeling
(31). Materials science, polymer physics, and structure of matter
(32) Electromagnetic theory, semi-conductors, and circuit analysis
(40) Applications of mathematics and computation in industry
(43) Dynamical systems
(44) Nonlinear waves and coherent structures
(48) Data mining, information retrieval
Other

What engineers would read your book?
☒ Industrial ☒ Aeronautical ☐ Manufacturing ☒ Civil ☒ Mechanical ☒ Chemical ☒ Electrical ☐ Other

What other scientists would read your book?
☒ Astronomers ☒ Physicists ☐ Biologists ☒ Chemists ☐ Other

Series

Do you feel your book belongs in any of these series http://www.siam.org/books/series/index.php? You may choose more than one.
☐ Advances in Design and Control
☐ Classics
☒ Computational Science and Engineering
☐ Financial Mathematics
☐ Fundamentals of Algorithms
☐ Mathematics in Industry
☐ Mathematical Modeling and Computation
☐ MOS-SIAM Series on Optimization
☐ Other Titles in Applied Mathematics
☒ Software, Environments, and Tools
☐ Spotlights