Professional Activities for Research Scientists

AMSC/CMSC 663
Fall 2016

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Outline

1. Comments on how to conduct research
2. Writing
3. Presenting results
4. Professional activities
5. Ethical issues
1. How to Conduct Research

How do I identify a research problem?
How do I begin doing research?
How do I know if what I’m doing is any good?
How do I know when I’ve actually accomplished something?
MS with thesis vs. PhD

Much more

• independence
• depth
• work

for doctoral project than for masters
How do I Identify a Research Problem?

Learn a discipline:
  • Coursework
  • Read papers
  • Talk to people

Ask questions:
  • No question is too stupid
  • Look for what is not said and ask (yourself) about it
  • Talk to other people (faculty, students) who might know

Read critically:
  • Again: look for what is not said
  • Ask yourself: Are these results clean & elegant?
    Can they be made more so?
    Can they be made simpler?
How do I Begin Doing Research?

Perform simple tests

• You’ve identified something that wasn’t said
• Design an experiment to see why it wasn’t mentioned

  Does the idea in the paper fail? Why?

• Be playful
• Talk to people who might know, follow their suggestions

  Don’t think you have to come up with all the ideas

• Do simple things
• Build on previous results:

  Most research is incremental
How do I Know if What I’m Doing is Any Good?
How do I Know When I’ve Accomplished Something?

This is a *social* enterprise
You are not a solitary scientist
Talk to people, get their feedback
+
Sell it
Critical Components of the Research Life

Writing

Presenting

Ideas are hard to come by

To be successful, you need to communicate your ideas so people understand them

For writing: it’s very difficult to start with a blank page
Strategy: Put something down on paper

Then: it’s also very difficult to make your ideas clear
Strategy: on the next day, or later: edit
    then edit again
    then edit again
    then edit again
2. Writing

Step 0: Staring at a blank page
Writing

Step 1: Start with something

It is a truth universally acknowledged that a single man in possession of a good fortune, must be in want of a dog.

Happy families are all alike; unhappy families are exceedingly

is unhappy in its own way.

(Leo Tolstoy, Anna Karenina)

When he was nearly thirteen my brother Jem got his arm badly broken at the elbow.

(Harper Lee, To Kill a Mockingbird)

The point: it’s hard to get it right the first time but easier to get it right when you have something other than a blank page.
bounded by the much less stringent relative tolerance
\[ \frac{\|r_{n+1}\|}{\|A\|_{\infty} \cdot \|x_{n+1}\|} \gg \delta. \]

This larger relative tolerance implies that the inner iterations required for solving the correction equation can be considerably smaller than those needed to solve the original equation directly.

3.3. Linear solvers with subspace recycling for the correction equation.

Step 2 of Algorithm 2 can be further refined by the use of linear solvers with subspace recycling to further reduce the number of inner iterations. This methodology has proved efficient for solving a long sequence of slowly-changing linear systems. When the iterative solution of one linear system is done, a small set of vectors from the current subspace for the candidate solutions is selected and “recycled,” i.e., used for the solution of the next system in the sequence. Subspace recycling usually reduces the cost of solving subsequent linear systems, because the iterative solver does not have to build the candidate solution subspace from scratch. A popular solver of this type is the Generalized Conjugate Residual with implicit Orthogonalization and Deflated Restarting (GCRO-DR) [27] developed using ideas of special truncation [7] and restarting [23] for solving a single linear system.

Reference [27] makes a general assumption that the preconditioned system matrix changes from one linear system to the next, and thus the recycled subspace taken from the previous system must be transformed by matrix-vector products involving the current system matrix to fit into the solution of the current system. In the setting of solving the sequence of correction equations in Algorithm 2, fortunately, this transformation can be avoided, because the preconditioned system matrix without tuning is the same for the correction equation in all Arnoldi steps.

It is suggested in [27] that the harmonic Ritz vectors corresponding to smallest harmonic Ritz values can be chosen to span the recycled subspaces. These vectors are approximate eigenvectors of the preconditioned system matrix corresponding to smallest eigenvalues. If the harmonic Ritz vectors are good approximate eigenvectors, this strategy tends to reduce the duration of the initial latency of GMRES convergence typically observed when the system matrix has some eigenvalues of very small magnitude; see [11]. Our subspace recycling also includes dominant Ritz vectors, as suggested in [27]. In Section 5, our numerical experiments show that the set of dominant Ritz vectors is an effective choice for subspace recycling if the use of harmonic Ritz vectors fails to reduce the inner iteration counts.

4. A refined analysis of allowable errors in Arnoldi steps. Reference [4] is one of the earliest papers on inexact Krylov subspace eigenvalue algorithms, where a large number of numerical tests were carried out for the ordinary Arnoldi method (without restarting). It was observed empirically that matrix-vector products involving \( A \) must be computed with high accuracy as the Arnoldi iterations progress. A similar phenomenon is also observed in [18] for an inexact Lanczos method. An analysis based on matrix perturbation theory given in [30] shows that the allowable errors in the matrix-vector product can be related to a quantity inversely proportional to the eigenvalue residual norm of the current desired approximate invariant subspace with the quality of the approximate invariant subspace is still under control (and is expected to improve) after these exact Arnoldi steps. This relaxation strategy is extended in [18] to the inexact IRA method, where a practical estimate of the allowable tolerance is proposed.

In this section, we give a refined analysis of allowable errors in Arnoldi steps and an alternative estimate of allowable tolerances for the linear systems.

Suppose the matrix-vector product involving \( A = A^{-1}B \) is applied inexactly for
bounded by the much less stringent relative tolerance \( \frac{\delta \| B_{u_k}^{(i)} \|}{\| B_{u_{k+j+1}} - A \|} = \frac{\delta}{O(s_p^{(i)})} \gg \delta \).

This larger relative tolerance implies that the inner iterations required for solving the correction equation can be considerably smaller than those needed to solve the original equation directly.

### 3.3. Linear solvers with subspace recycling for the correction equation.

Step 2 of Algorithm 2 can be further refined by the use of linear solvers with subspace recycling to further reduce the number of inner iterations. This methodology has proved efficient for solving a long sequence of *slowly-changing* linear systems. When the iterative solution of one linear system is done, a small set of vectors from the current subspace for the candidate solutions is selected and “recycled,” i.e., used for the solution of the next system in the sequence. Subspace recycling usually reduces the cost of solving subsequent linear systems, because the iterative solver does not have to build the candidate solution subspace from scratch. A popular solver of this type is the Generalized Conjugate Residual with implicit inner Orthogonalization and Deflated Restarting (GCRO-DR) [27] developed using ideas of special truncation [7] and restarting [23] for solving a single linear system.

Reference [27] makes a general assumption that the preconditioned system matrix changes from one linear system to the next, and thus the recycled subspace taken from the previous system must be transformed by matrix-vector products involving the current system matrix to fit into the solution of the current system. In the setting of solving the sequence of correction equations in Algorithm 2, fortunately, this transformation can be avoided, because the preconditioned system matrix without tuning is the same for the correction equation in all Arnoldi steps.

It is suggested in [27] that the harmonic Ritz vectors corresponding to smallest harmonic Ritz values can be chosen to span the recycled subspaces. These vectors are approximate eigenvectors of the preconditioned system matrix corresponding to smallest eigenvalues. If the harmonic Ritz vectors are good approximate eigenvectors, this strategy tends to reduce the duration of the initial latency of GMRES conver-
It is suggested in [27] that the harmonic Ritz vectors corresponding to smallest harmonic Ritz values can be chosen to span the recycled subspaces. These vectors are approximate eigenvectors of the preconditioned system matrix corresponding to smallest eigenvalues. If the harmonic Ritz vectors are good approximate eigenvectors, this strategy tends to reduce the duration of the initial latency of GMRES convergence typically observed when the system matrix has some eigenvalues of very small magnitude; see [11]. Our subspace recycling also includes dominant Ritz vectors, as suggested in [27]. In Section 5, our numerical experiments show that the set of dominant Ritz vectors is an effective choice for subspace recycling if the use of harmonic Ritz vectors fails to reduce the inner iteration counts.

4. A refined analysis of allowable errors in Arnoldi steps. Reference [4] is one of the earliest papers on inexact Krylov subspace eigenvalue algorithms, where a large number of numerical tests were carried out for the ordinary Arnoldi method (without restarting). It was observed empirically that the matrix-vector products involving $A$ must be computed with high accuracy in the initial Arnoldi steps, whereas the accuracy can be relaxed as the Arnoldi method proceeds. A similar phenomenon is also observed in [18] for an inexact Lanczos method. An analysis based on matrix perturbation theory given in [30] shows that the allowable errors in the Arnoldi steps can be relaxed to a quantity inversely proportional to the eigenvalue residual norm of the current desired approximate invariant subspace. While the quality of the approximate invariant subspace is still under control (and is expected to improve) after these inexact Arnoldi steps. This relaxation strategy is extended in [16] to the inexact IRA method, where a practical estimate of the allowable tolerance is proposed for the linear systems in Arnoldi steps. Ideally, accurately estimated allowable tolerances can help reduce the inner iteration counts to the best extent possible without compromising the convergence of the IRA method to the desired invariant subspace. In this section, we give a refined analysis of allowable errors in Arnoldi steps and an alternative estimate of allowable tolerances for the linear systems.

Suppose the matrix-vector product involving $A = A^{-1}B$ is applied inexact for
Critical Components of the Grad Student’s Life

Writing a thesis

How will I ever do this?

Most important thing (or one of them):
Put one foot in front of the other
2. Presenting results

A main topic of this class

Issues to consider:

• How much material to put on a displayed page
• How technical should the presentation be
• Use of figures, tables, other things to present data
• Other tools: movies, colors, transition (in PowerPoint)
• Personal components: posture, loudness of speech, standing position
4. Professional Activities

Submitting papers to journals and conferences

The process:

• Get the results (!) and write them up (edit, edit, edit)
• Decide on a place to submit
  Requires critical self-evaluation
• Wait for some time (seems interminable)
• Get comments back
  These come from reviewers and editors
• Are the comments favorable? If so:
  • Respond to editor’s and reviewers’ requests
    Generally speaking: don’t argue with them
  • Revise: edit, edit, edit
Submitting grant proposals and requests for funding

The process:

• Generate some ideas (sounds easy, right)
• Generate some preliminary results: the aim here is to demonstrate “proof of concept”
• Write them up (edit, edit, edit)
• Leave enough time to meet deadlines

Much of the time (NSF, NIH): peer review
Sometimes: you can establish relationships with funding agencies
Salesmanship

You need to convince
  the world
  your advisor
  listeners
  readers

that your ideas are worth listening to

How:
Do you have a faster algorithm?    Show timings
Do you have a provably faster algorithm?  Provide the proof
Are your ideas comprehensible?
  Say them clearly, write them clearly, provide graphical
evidence that is easy to see
5. Some Ethical Issues in Research

I. Plagiarism
   a. Unacknowledged use of other work
   b. Unacknowledged use of one’s own work

Every paper submitted to SIAM journals is checked for plagiarism with a program called Crosscheck

approximately 5% (171 in a recent year) of submissions are flagged

Of these:

- approximately 50% are flagged for self-plagiarism
- approximately 50% are flagged for other reasons

118/171 = 62% are rejected outright

In some (other) cases: papers about to be accepted were later rejected after duplication was discovered
Some Ethical Issues in Research

I. Plagiarism

c. Use of proprietary material:

You receive a paper/proposal to review
Don’t like most of it, reject
Like one part of it, use it yourself
Completely inappropriate
Some Ethical Issues in Research

II. Reproducibility of experimental results
   a. Serious problems have arising in medical research
      Statements about safety of experimental results
      have been shown to be invalid and not reproducible,
      led to very bad outcomes
      One example: Patients suffered collapsed lungs due
      to errors in MATLAB codes
   b. At least one journal, Biostatistics, has criteria
      “reproductibility” to which papers are subjected.
      Papers meeting the criteria are marked R
   c. Can’t use only “good” outcomes of experiments
Some Ethical Issues in Research

III. Improper statement of one’s record
   a. Paper under review cited in a CV as having been accepted
   b. More generic overstatement of accomplishments, record
      Exaggeration of teaching record, responsibilities, class sizes

Makes you look bad

Makes University of Maryland look bad
Some perks of the research life:

• The opportunity to study interesting questions

• Independence:
  You have considerable flexibility in deciding what to work on

• Travel
  This is an exciting endeavor of worldwide interest

• Meet interesting people