Automated Software Engineering Research Group @NCSU

Research Skills
(for career and life)

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Slides at
http://people.engr.ncsu.edu/txie/advice/researchskills.pdf

Motivation for This Talk

- Many students lack important (research) skills to succeed in academic or professional career
  - Many students don't realize that
  - Not to say that they know how to improve
- This talk intends to increase awareness of
  - Important research skills
  - (high-level) ways of improving these skills
- This talk is based on my own experience and observation while working with students
- Many skills described here applicable not only to research, but also to career and life

Important Research Skills

- Self-directed and motivated
- Problem solving skills
- Engineering skills
- Innovation skills
- Communication skills
- Learning skills
- …

Self-directed and Motivated

- If you need someone to push you to do your research, it often doesn't work well
- Research driven by passion:
  - Community/upper/peer recognition
  - Intellectual curiosity
  - Make impact (on the research field, practice, world)
  - Learning new things
  - Better understanding (of things)
  - …
  - Better career path
- Work hard and strategically
  - "strategically" related to engineering skills
  - effectively and efficiently

Research Ethics

- Absolutely follow (research) ethics
  - Responsible and responsive
  - Absolutely no fabrication or fraud of data
  - Absolutely avoid plagiarism
    - Plagiarism ex: copy a sentence from another source (even wiki) to your paper without citing the source
    - Plagiarism ex: copy a sentence from another source (even wiki) to your paper without rephrasing even when citing the source
  - http://www.acm.org/publications/policies/plagiarism_policy
  - http://www.ieee.org/web/publications/rights/ID_Plagiarism.html
  - …

http://en.wikipedia.org/wiki/Research_misconduct

http://www.chass.ncsu.edu/ethics/

Avoid Duplicate Submissions

http://www.acm.org/publications/policies/sim_submissions/
http://www.ieee.org/web/publications/rights/Multi_Sub_Guidelines_Intro.html
http://www.icse-conferences.org/sc/guidelines/duplicateSubmissions.html

"if there is substantial overlap in the technical content of the conference submission and any other work that is:

- under review at another publication,
- has been accepted by another publication, or
- has appeared in another publication, at any time before the conference review process is complete."

"publication": any peer-reviewed scientific archive such as a conference, journal, or technical book.

Also avoid LPU: Least Publishable Unit

http://en.wikipedia.org/wiki/Least_publishable_unit

Research Paper Lifecycle

W: Workshop position paper (4-7 pages)

[Note that some workshop accepts full research paper, which shall be viewed as conference full paper]

→ **C**: Conference full paper (10-11 pages)

→ **J**: Journal paper (15-20 pages)

[At least 30% new content over C]

C/J can treat W/C as a previous version of C/J, and claim contributions of W/C as C/J's contributions (need to explicitly state so and explain the main differences of two versions, e.g., in footnote)

But some PC members may evaluate C based on only the diffs of C and W → then publishing W is discouraged

Self-directed and Motivated cont.

- Try to improve external factors
  - Your assigned project idea may not be always promising
    - Try your best to improve the idea
    - Try your best to change to another idea
    - Ex. my past summer internship experience
- Try to do/try your best with the external factors
  - Sometimes you cannot change these factors
    - Ex. My past master thesis research
- Seemingly negative factors can turn out to be positive one (if you treat them right)
  - Ex. hands-off vs. hands-on advising style

Problem Solving Skills

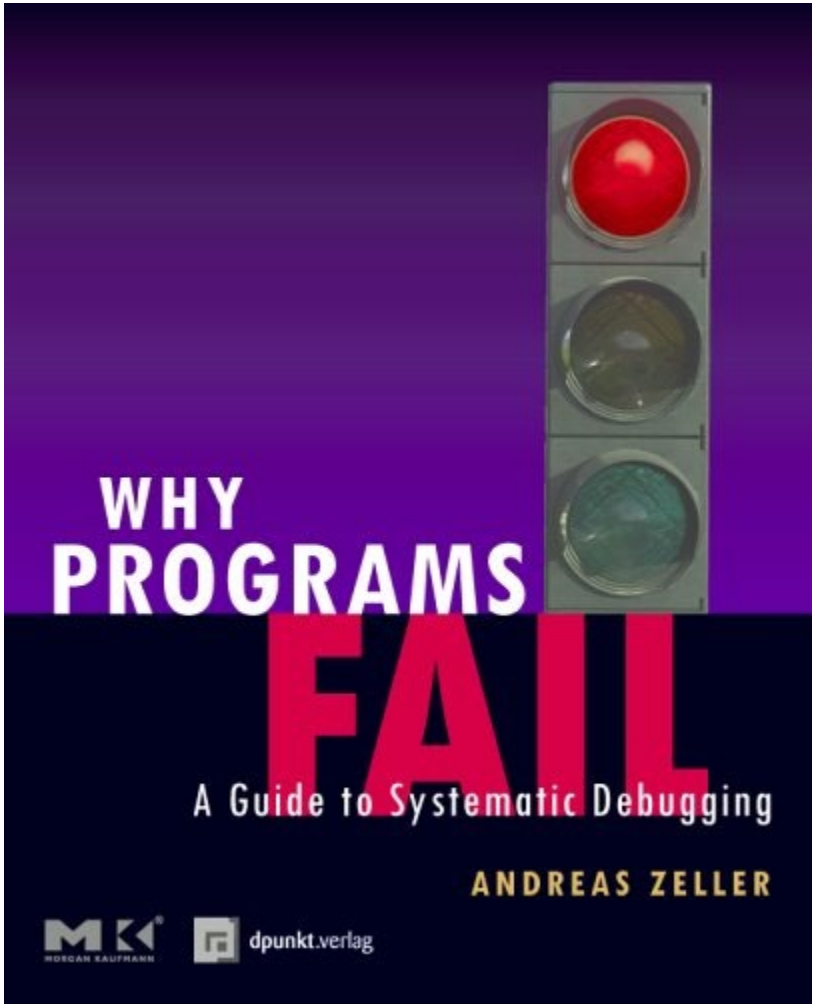
- Examples of lacking debugging skills
  - A student came to me informing me that the Java code doesn't compile, giving some error messages; I found out that the student didn't set classpath correctly for the required jar files
  - A student complained to a third-party tool's developers that the new release of the tool didn't work with an example input; I found out that the example input didn't even work with the old release
  - A student presented me a Java file telling me that the file cannot be processed by a tool whereas the tool can deal with other files; I had to narrow down the cause to specific constructs for the student.

Problem Solving Skills cont.

- Debugging skills
  - Having a passing case and a failing case → the failure-inducing input portion(s)
  - Having a passing old version and a failing new version → the failure-inducing change(s)
  - Delta debugging http://www.st.cs.uni-sb.de/dd/
  - Where to seek help?
    - Google the error message
    - Contact relevant people (tool authors, etc.) with "minimal" or "reduced" failure-causing inputs (cc. your advisor)
    - Seek upper/peer support
    - Tradeoff between "try hard yourself vs. ask others for help"

Problem Solving Skills cont.

- Improving debugging skills



http://www.whyprogramsfail.com/

Problem Solving Skills cont.

- Tool-development skills
  - Programming skills
  - Program understanding skills
  - Software reuse skills (sometimes you can reuse without requiring to understanding everything)
  - Think about alterative easier way of implemenation
- Searching skills ("Google" skills)
  - Which keywords to pick
  - How to find out what you want in query result sets
  - How to refine keywords based on query result sets
  - Options: "filetype:ppt", …
  - Ex: searching available NSF proposals on the web

Engineering Skills

- Cost-benefit analysis
  - Example cost:
    - How much development effort?
    - How much evaluation effort?
    - Any existing infrastructures to exploit or reuse?
  - Example benefit:
    - How much novelty of the work?
    - How much research/practical value of the work?
    - How much you accumulate infrastructures for next idea?
    - How much you get yourself skills to get into an area if you want? (real option value)
- Always think about alternative (easier) ways of implementation (especially in feasibility study)
- Help decide do it (or not) or do it now (or later)

Engineering Skills cont.

- Automate (or not) in experiment: I wrote my paper's LaTeX source files so that when I update my experimental data by redoing my experiment, my LaTeX source files are automatically updated
  - Cost: constructing macros (if you haven't done it, learning curve cost)
  - Benefit: when rerunning experiments, you don't need to do extra work
  - Analysis: benefit > cost?
- Remember your ultimate goal
  - Often you need to convince readers that you research idea works with prototype/evaluation
  - Indeed, sometimes evaluation or your research goal calls for a highly usable tool in practice

Engineering Skills cont.

- Risk-reduction skills (spiral model)
  - Research full of risk (just like software development)
    - Initial ideas/whole direction may not work
    - Choosing the wrong existing infrastructure
    - You misinterpret your advisor's ideas/mind
  - Counter-measures
    - (Heavy) manual feasibility study phase, e.g., mining code for bugs
    - At least you need to find out one convincing, motivating example before you go ahead
    - Prototype features iteratively and try subjects to get feedback
    - Formal writing of abstract, intro, example, approach sections sent to advisor before doing full tool development; experiment design section before doing full experiment

Engineering Skills cont.

- Deadline-making skills
  - Some people are last-minute persons and some are not
  - But many students are not good last-minute persons and finish work (or not) to the last minute before the deadline
    - Late submission to your advisor → no or insufficient help from your advisor to improve your submission
  - Many students don't have good sense of
    - Task selection/prioritization: which tasks to focus first given the limited time (acceptance chance/time spent)
  - Many students tend to postpone their writing to the last minute (they don't like writing; few does)
  - Goal: anytime you are stopped, you shall have a good-shape draft (incremental style towards the deadline)

Innovation Skills

- Critical thinking/questioning skills/assessment skills
  - Not every idea of your advisor or authority in your area is correct or the best
  - Questioning almost anything (not just questioning others and also yourself)
    - Ex. A student questions almost every idea that I gave him (not enough, need constructive solving skills)
  - Capability of judging research is not easy (Ex. reviewing papers)
    - Requiring the knowledge breadth and depth of the subarea, insights, …
    - Always think about whether and how the paper convinces the readers that the work is indeed useful.

Innovation Skills cont.

- Constructive invention skills (Not easy at all!)
  - Require months/years of accumulation, learning, training, thinking, exercising …
  - Need to force yourself to think
    - I got many new ideas when I stared at the blank research task portion in my proposal being written
    - New ideas generated while joggling, attending talks, even in dreams, …
  - Need to know about background and related work
    - WebMon: http://www.markwell.btinternet.co.uk/webmon/
  - Need to have the habits of (creative) thinking
    - Can I apply this idea from field A to my field B?
    - Can I address this solution for problem A to my problem B?
    - …

    My Advice on Getting a Start into Research

    http://people.engr.ncsu.edu/txie/adviceonresearch.html

Choose Research Problem/Idea

- Novelty: is the problem novel? Or is the solution novel?
- Utility: can the research produce practical impact? E.g., with help of industrial collaborators
- Risk: how likely the research could fail? Reduced with significant feasibility studies and risk management in the research development process
- Cost: how high effort investment would be needed? sometimes being able to be reduced with using tools and infrastructures available to us.

Choose Research Problem/Idea cont.

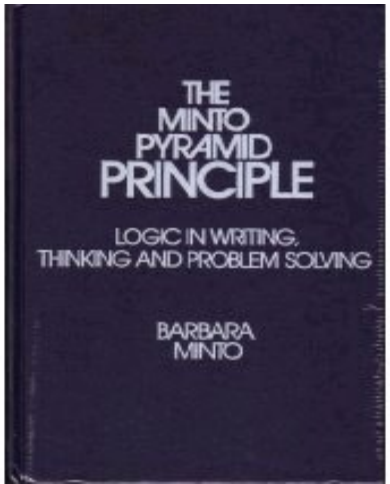
- Competitive advantages:
  - what is it that your group has that places you at an advantage with respect to others -- a particular tool, a particular technique, some colleagues, an insight, etc.
  - "secret weapon"
- Underlying assumptions and principles
  - core values that drive your research agenda in some broad way
  - "how do you choose what to pursue?"
  - can be problem-driven or solution-driven

Contributed by David Notkin

Communication Skills

- Technical writing
  - Avoid lacking of logical thinking, ex.
    - Use before define, define without explanation
    - No strong causal/transition relationships between sentences
  - Countering careless mistakes
    - Use spell check (or style check in MS Word)
    - Customize style-check with historical issue patterns
    - Ask for peer review before submitting to your advisor
  - Learn from patterns and anti-patterns

Advice on Writing Research Papers:
http://people.engr.ncsu.edu/txie/publications/writepapers.pdf
Common Technical Writing Issues:
http://people.engr.ncsu.edu/txie/publications/writeissues.pdf
Tools and Tips for Writing Papers:
http://people.engr.ncsu.edu/txie/publications/writingtools.html



Communication Skills cont.

- Oral communication
  - Presentation skills
  - Effective meeting with advisor (be prepared)
    - Bring in an agenda (discussion items listed)
    - Prepare backup discussion items in case you still have time in your allocated time
    - Use written materials to help oral communication
  - 5-mins elevator talk
    - Most students would start with low-level details of their research, forgetting about the motivation, problem domain
    - Lose the big picture due to being too familiar or excited about the solutions
    - Don't address "why do I care?" "how can you convince me that your work is useful?"

Learning Skills

- Traditional learning skills
- Be mindful and learn from your successful and failing experience
  - After you finish doing something, you shall be able to abstract and summarize your lessons learned and convey to others your tips
    - Studying for a course, preparing for your GRE, applying for grad schools, contacting professors during application, getting started in a new research area, working with your advisor, writing high-quality papers, preparing for job interviews and applying for jobs, negotiating your hiring packages, writing funding proposals, increasing visibility in community, …
  - Opportunities are visible to only people who keep their eyes wide open and think proactively

Summary

- Self-directed and motivated
- Problem solving skills
- Engineering skills
- Innovation skills
- Communication skills
- Learning skills
- …

Welcome additional skills that you feel important but are not described here! Let me know!

Automated Software Research Group Engineering @NCSU

What next?

- Now you know what skills are important
- Next you need to think about improving these skills in your professional and personal development
  - Not an easy task but you shall try and try hard
- Browse my advice collections at:
  - http://people.engr.ncsu.edu/txie/advice/

My research group/research web at:

https://sites.google.com/site/asergrp/

We always look for motivated students/researchers to collaborate with