Session 4:
Research is the Key PhD Degree Component

Thursday, October 21, 7pm ET
Learning Objectives

• Developing strong research skills
• Choosing graduate courses
• Choosing a research area, an advisor, and a research topic
• The research process and milestones
What Research Skills Do You Already Have?

Technical
• Programming skills
• ?

Soft Skills
• Time management
• ?

Enter into the chat: 1 technical skill and 1 soft skill you already have (ideally related to your research interest area)
Essential Research Skills You Will Need

Background & related work
• Performing literature search
• Reading papers critically
• Summarizing existing work

Tools & techniques
• Finding and learning needed technical material
• Discovering appropriate tools and techniques for topic
• Use of specific tools and techniques

Data collection, analysis, and visualization
• Mathematical argumentation
• Experimental design and data collection, including validation
• Generating and processing data
• Performing appropriate analysis and visualization of data

Communication
• Paper writing
• Presentation creation and delivery
• Research conversations, including asking/answering questions
• Managing advisor interactions
• Managing group dynamics
Practice: Elevator Speech

"Why do you want to get a PhD? What do you perceive as your strengths and weaknesses?"

(Breakout in Pairs: 1 Minute Speech Each)
Ways of Developing Research Skills

• Background and related work
  • Textbooks provide foundational skills
    • Find textbooks used at schools strong in a research area
  • Literature search
    • CRA-W/CDC "Identifying related literature" Exercise
  • Critically reading a research paper
    • CRA-W/CDC "Critically reading a research paper" Exercise
    • Griswold's "How to Read an Engineering Research Paper"
    • Shaw’s Organizing Your Research and Developing Your Research Skills
• Create annotated bibliography of papers read
  • Monmouth University's "Creating an Annotated Bibliography"
  • Consider using something like BibTeX
Ways of Developing Research Skills (2)

• Discovering and learning appropriate tools and techniques
  • Analyze related work for tools, techniques, input sets, data collected
  • Analyze related work for experimental framework
  • Find online tools/communities and textbooks
  • Find workshops or tutorials covering material
Ways of Developing Research Skills (3)

- Basic skills to improve efficiency
  - Missing Semester of Your CS Education
    - Shell
    - Shell tools and scripting
    - Editors (vim)
    - Data wrangling
    - Command-line environment
    - Version control (git)
    - Debugging and profiling
    - Metaprogramming
    - Security and cryptography
- Master LaTex beyond essential features and use Overleaf for collaborations
Ways of Developing Research Skills (4)

• Communication
  • Attend talks by outside speakers and critique
  • Attend practice talks to hear improvement suggestions
  • Practice elevator talk with peers
  • Join public speaking group (e.g., Toastmasters)
  • Present posters of your work
  • Try approaches for planning agenda for advisor meetings (e.g., topics, analyzed data, etc.) and establishing next steps
Choosing Coursework

- **Courses may serve different needs**
  - May be required
  - Course requirements vary greatly
  - May develop skills
  - May develop your knowledge of content related to your research area

- **Ugrad vs. grad vs. research courses**
  - Graduate: more independence expected, less guidance given, learning background material on your own
  - Research: more student initiative expected, problems may not have known solutions, some students produce research results
Example Breadth Course Requirements

**Purdue University**
- At least 6 grad-level CS courses
- Of those, one must be from the theory, one must be from the systems group

**University of Washington**
- At least 7 courses (quarter system)
- 5 courses must be from 3 of 4 groups (theory, systems, ML/AI, human-facing)
- 2 additional courses can be from related field

**Arizona State University**
- one course for each of 5 areas
- algorithms, arch & network systems, data & info systems, intelligent & interactive systems, software & info assurance
- 6 more credit hours in 1 core area

**Rice University**
- At least 6 courses
- 1 course from each of 3 core areas (algorithms, databases, software design)
- 3 additional elective courses
How To Choose Courses?

Courses ...

• your adviser recommends
• in an area you are interested in
• taught by potential research advisor
• that teach you about research process
• that include a research project
• in a closely related research area
• that teach you skills
  • May be in another department (e.g., statistics)
  • May be non-technical classes (e.g., writing or speaking skills)
  • May be non-credit course (e.g., language course)
Most Important Decisions You'll Make

- Research area
- Research advisor
- Research topic
Common research areas

Security / Privacy / Information Assurance
Human-Computer Interaction
Software Engineering
Operating Systems
Scientific / Numerical Computing
Information Systems
Informatics: Bioinformatics / Other Science
Social Computing / Social Informatics
Artificial Intelligence / Machine Learning
Theory and Algorithms
High-Performance Computing
Programming Languages / Compilers
Information Science
Quantum Computing
Networking
Graphics / Visualization
Computing Education
Databases / Information Retrieval
Hardware / Architecture
Hardware / Architecture
Choosing a Research Area

• What research topics excite you and why?
• How much knowledge and experience do you already have in that area?
• How strong are the department and research groups in this area?
• How many faculty members work in this area? What are their academic ranks?
• Is interest in the research area existing and growing?
• Do the problems have "legs"?
Choosing a Research Advisor

- Renowned vs. beginning researchers
- Do your homework! Check the following information for a potential advisor’s Ph.D. students:
  - How many students and when they graduated?
  - How many papers (and where) students published with the advisor?
  - Where are those students now (academia, industry)?
- Talk to faculty during office hours, attend their talks
- Ask to attend research meetings of a group you are interested in joining
- Take a course with a faculty you consider as a possible adviser
Choosing a Research Advisor (2)

• Talk to students working with potential advisor
• What is the advisors collaboration style like?
  • How responsive are they to email or stopping by their office?
• What is the frequency and duration of group and 1:1 meetings?
• Do students work on individual projects or in groups? Are there post-docs?
• Do they have funding for students as RAs and conference travel?
• Are they taking on new students? Taking a leave?
• How do they decide to accept new students?
• Do they co-advice students with other faculty?
1-minute Reflection

Consider bosses you have worked with in the past. What aspects of their personalities and interaction style worked well for you? What didn't?

• Were they hands-off or did they micromanage?
• Did they focus on you developing your skills or did they expect you to learn skills on your own?
• Did they push you constantly because you needed that or did they rely on you being self-motivated?
• Did they have you work independently or in a group?
Choosing a Research Topic

- Want to be passionate about it
- Want advisor to be committed to it
- Want topic to still be of community interest (and funded) in 3-4 years
- Want a topic where you can make significant contributions over 3-4 years
  - avoid incremental or exceptionally difficult problems
  - potential for the future is important for an academic career
- Want a topic for which the needed resources are available
**A Typical Research Timeline**

**Foundational coursework to prepare for research.**
Join a lab with advisor & initial project.

**Year 1**

**Year 2**
Complete a majority of your coursework.
**Take qualifying exam.**
Identify research area. Potentially earn Master’s degree “along the way”.

**Year 3**
Obtain preliminary results and publish papers.
Formulate PhD research plan. Identify PhD committee. Begin writing proposal.

**Year 4**
Complete and defend PhD proposal.
Continue with research and publishing your results. Identify your future career path.

**Years 5-6**
Continue to publish.
**Write & defend dissertation.** Prepare and interview for next job.
Research Milestones

Details and timelines of required milestones vary by school. For example, the qualifying exam may be

- Entirely course based
- Oral or written examinations in multiple areas
- Writing and presenting a paper that synthesizes research in an area related to several papers provided to you
- Presentation of your own research

Departmental descriptions can be messy to parse.
Exploring Departments

Arizona State University (Tempe)
- School of Computing and Augmented Intelligence
- public R1, 53K student population

No department has a really easy to explore PhD milestone and requirement description.
Example: Arizona State University

Program description gives a good description for a potential PhD student looking for the overall requirements

- 28 courses
- a written comprehensive exam and an oral comprehensive exam
- a prospectus/prelim
- dissertation/defense

- details of the exams (format, timing, etc) are relatively hidden in pdf files
ASU PhD Degree course requirement: 28 courses (84 cr)

Required Core Areas (6 courses)
- architecture and networked systems
- data and information systems
- foundations of computation and algorithms
- intelligent and interactive systems
- software and information assurance

Depth: two courses in one core area

Research (18 cr): CSE 792 Research

Electives and Additional Research (33 cr)

Culminating Experience (12 cr): CSE 799 Dissertation
Exploring Departments (2)

1. **Indiana University** (Bloomington)
   a. Luddy School of Informatics, Computing, and Engineering
   b. six departments, including CS and Informatics
   c. public R1, 45K student population

2. **University of Washington** (Seattle)
   a. Paul Allen School of Computer Science & Engineering
   b. public R1, 48K student population

3. **Northwestern University**
   a. Department of Computer Science
   b. private R1, 22K student population

4. **Tufts University**
   a. Department of Computer Science
   b. private R1, 12K student population
4 Breakout Rooms

Each room will explore the course requirements and PhD milestones for a specified department
Example: University of Washington

Milestones: Qualifying Evaluation, General Exam, Final Exam (defense)

The purpose of the Qualifying Evaluation ("Quals") is to demonstrate the potential to complete a high quality Ph.D.:

- completing at least five graduate level courses (see quals section)
- performing and presenting the results of a high quality research project.
- have a permanent research advisor before passing Quals.
- pass the Quals by the end of their 6th quarter in the program (excl. summer)

Descriptions are dense with details
University of Washington (2)

**General Exam** (Prelim)

- assigned thesis-related research papers or a thesis proposal
- preparation of a written report based on that work
- the presentation of findings to a select audience.

**Final Exam**

- intensive research and writing resulting in the dissertation
- Thesis Defense is a public oral presentation and defense of the research.
- At the successful conclusion, you will be awarded a Ph.D.
Example: **Northwestern University**

PhD student selects one of five academic tracks which determines some requirements.

Milestones common to all students:
- Choosing Advisor: Must have permanent academic advisor by end of first year
- Qualifying Exam: Details depend on academic track. Typically at end of second year.
- Admission to Candidacy: Granted after completing coursework for chosen track (minimum of 15 graduate courses) and passing qualifying exam
- Prospectus (Proposal)
- Dissertation Defense

Details described in a 46-page [Graduate Study Manual](#) (PhD program starts on page 24)
Northwestern University (2)

Academic tracks:
- Computer Systems
- Computer Engineering
- Theory
- Artificial Intelligence
- Graphics and Interactive Media
Example: **Tufts University**

**Summary**
- Course requirement: 20 courses, 2 must be regular 100-200 level courses.
- Community/residence requirement: attend 50% of dept. seminars in 4 sem.
- Teaching requirement: TA for at least one semester.
- Qualifying requirements: core competence, preliminary research project, oral presentation on the project, written qualifying exam, oral qualifying exam
- Prospectus/Prelim
- Dissertation and defense

More detail in a (readable) handbook
Example: Indiana University

Note: Requirement for CS are not the same as in other departments in the School. For example, Informatics has a higher course requirement.

Computer Science PhD curriculum

at least 8 CS courses:
  ● 6 of these courses from the areas of Foundations of Computing, Computer Systems, Programming Languages, and Intelligent Systems (with a breadth requirement)

Qualifying exam (written and oral)
Thesis proposal
Dissertation Defense
Does the PhD milestone structure matter?

Need/want more background and more breadth?
• Choose a curriculum with more required courses

Want to explore different research areas?
• choose a curriculum that gives flexibility on required breadth areas

Want to focus on research right away?
• Choose a curriculum with fewer required courses

Already have an MS?
• Can credits be transferred?

Don’t let the curriculum structure alone determine your choice of school!
Coming up next ...

Panel 2
What I wish I knew when I started graduate school
November 4, 7pm

4 panelists give their perspective (now: Post-doc, industry, assistant tenure-track faculty, assistant teaching faculty)