Session 4:
Research is the Key PhD Degree Component

Thursday, October 21, 7pm ET

CSGRAD4US & mentoring program

Computer and Information Science and Engineering Graduate Fellowships

CRA-WP Computing Research Association Widening Participation

NSF

CRA-E Computing Research Association Education

Learning Objectives

- Developing strong research skills
- Choosing graduate courses
- Choosing a research area, an advisor, and a research topic
- The research process and milestones

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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)

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Essential Research Skills You Will Need

Background & related work

- Performing literature search
- Reading papers critically
- Summarizing existing work

Data collection, analysis, and vis

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

Tools & techniques

- Finding and learning needed technical material
- Discovering appropriate tools and techniques for topic
- Use of specific tools and techniques

Communication

- Paper writing
- Presentation creation and delivery
- Research conversations, including asking/answering questions
- Managing advisor interactions
- Managing group dynamics

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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)

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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

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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

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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

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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

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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

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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

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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)

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Most Important Decisions You'll Make

- Research area
- Research advisor
- Research topic

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Common research areas

Security / Privacy / Information Assurance

Social Computing / Social Informatics

Human-Computer Interaction

Artificial Intelligence / Machine Learning

Robotics / Vision

Networking

Theory and Algorithms

Software Engineering

Quantum Computing

Graphics / Visualization

Operating Systems

High-Performance Computing

Computing Education

Scientific / Numerical Computing

Programming Languages / Compilers

Information Systems

Databases / Information Retrieval

Information Science

Informatics: Bioinformatics / Other Science

Hardware / Architecture

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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"?

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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

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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-advise students with other faculty?

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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?

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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

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A Typical Research Timeline

Year 1

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

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.

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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.

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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

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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

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4 Breakout Rooms

Each room will explore the course requirements and PhD milestones for a specified department

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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

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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.

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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)

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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

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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!

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Coming up next ...

Panel 2
What I wish I knew <u>when I started</u> graduate school
November 4, 7pm

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

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