Computer Science Graduate Research Orientation

Today's Discussion Leader:
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Assistant Professor, WPI CS

- Future Events:
  – Sept. 8: Techniques for Creating New Knowledge
  – Sept. 15: Making an Impact
  – Sept. 29: Creativity and Communicating with the Community
  – Oct. 6: Tools of the Trade

Professor Background

- **Prof. Craig A. Shue, Ph.D.**
  - Assistant Professor of Computer Science
  - Background:
    - Ohio University
      - Bachelor of Science: 2001 – 2004
    - Indiana University
      - Master of Science: 2006
      - Doctor of Philosophy (Ph.D.): 2009
    - Oak Ridge National Laboratory
      - Cyber Security Research Scientist: 2009 – 2014
    - Worcester Polytechnic Institute
      - Assistant Professor: 2011 – Present
  - Cyber Security Zealot
    - Club advisor, competition team coach, project center director

Welcome and General Advice

- New students
  - WPI is a great place to be
  - Work hard, play hard
  - Find your mentors and community
- Returning students
  - Welcome back
  - Mentorship can be it's own reward
  - Reach out if you feel adrift

What is original research?

- US Federal Government:
  - "*Research* means a **systematic investigation**, including research development, testing and evaluation, designed to develop or contribute to **generalizable knowledge**."
  - Code of Federal Regulations: Title 45, Part 46
- **Original** research indicates this investigation cannot simply be drawing from other sources.
- Almost all use of "research" you will hear in grad. school is shorthand for "original research"

Scientific Research

- Theory or experimentation that must be
  - Replicable
    - Others must be able to confirm your results
  - Falsifiable
    - There must be a means to prove the idea wrong
    - "A will be better than B"
      - Not falsifiable: no metrics to evaluate "better than"
    - "A will be twice as fast as B"
      - Falsifiable: test the speed of both
  - Unbiased
    - Yes, you want the work to succeed, but you must be distanced enough to give it a chance to fail.
    - To do otherwise is, well, fraud.

"Failure" is Learning

"I have not failed. I've just found 10,000 ways that won't work."
— Thomas Edison

"If we knew what it was we were doing, it would not be called research, would it?"
— Albert Einstein

Activity: Is it scientific research?

- Divide into small groups
  - Preferably of people you don't already know
- Briefly introduce yourselves to each other
- Consider the scenarios on the hand out and determine whether the described actions are scientific research or not.

Scenario 1: Web Browser Exploit

While building his new Web site, Joe notices that a popular Web browser hangs when he includes a particular Javascript code snippet. After a few tweaks, he finds he can make the browser crash. Joe creates a tool to exploit the vulnerability and contributes a patch to fix it to the browser manufacturer, who expresses their gratitude.

Scenario 2: Web Insecurity

Aanya noticed her state's department of motor vehicles asked for her private details without using proper encryption. She decides to find out how many web sites make the same mistake by downloading a web crawler data set and searching for prompts for personal information. Of the millions of sites in the data set, 5% make the same mistake.

Scenario 3: Mobile Application

While Aiden liked his phone's fitness application, it could not record his swimming activity (because the phone could not get wet). He decided to waterproof an existing sensor and built his own application and protocol for the sensor and application to communicate, allowing the application to record his swimming distance. He posted it online and the application has been downloaded over 50,000 times.

Scenario 4: Signal Processing

As she was building her robot, Ai noticed that its microphone picked up a background hissing noise in the robot's recorded MP3 file, which would be fed into a speech recognition program. Using the Fast Fourier Transform (FFT), she was able to eliminate the hissing noise from the MP3 file while preserving the speech.

First-class Work

"I have to get you to drop modesty and say to yourself, 'Yes, I would like to do first-class work.' Our society frowns on people who set out to do really good work. You're not supposed to; luck is supposed to descend on you and you do great things by chance. Well, that's a kind of dumb thing to say."

— Richard W. Hamming

Research is a Privilege

- Society invests in its "best and brightest" with the expectation they will do great things to advance society.

- We owe it to society to
  - do meaningful work
  - avoid wasting time (e.g., duplicative efforts)
  - share our accomplishments

How do **I** actually **do** research?

- Ask a good question
- Find out if it has already been answered
- Develop a way to answer it
- Answer it
- Tell others

systematic investigation
generalizable knowledge
original   **replicable**
falsifiable   **unbiased**

Asking a Good Question

- Good research questions must:
  - have answers that yield generalizable knowledge
  - matter to somebody
  - not have already been answered
- Ask yourself: "What does humanity need to know and why?"

Has it Been Answered?

"A month in the laboratory can often save an hour in the library."

— Frank Westheimer

"If I have seen further it is by standing on the shoulders of Giants."

— Isaac Newton

Answering the Question

- Design experiments or theory that would conclusively answer the question.

- This is often non-trivial.

- Resist the urge to jump right in.
  - Blind action is usually wasted.

Getting Around the Lamppost

Story Courtesy of Bernard Roth

If you can't answer the question, perhaps your question is wrong

- Let's use a fictitious example:
  - "How might I find a spouse?"
    - Transforms into: "Find a spouse."
  - It's a loaded question that assumes an outcome.
  - Why is this the question? What is really to be solved here?

Example Courtesy of Bernard Roth

Second Order Questions

- How might I get companionship?
- How might I get taken care of?
- How might I stop working?
- How might I have (more) intimacy?
- How might I get my parents to stop nagging me?
- How might I improve my economic situation?
- How might I have a better social life?
- How might I "keep up with" my friends?

Third Order Question

- "How might I find a spouse?"
  - "How might I get companionship?"
    - "How might I feel less lonely?"

- Focus on the true goal.

- Breaking down questions can lead to tractable, testable experiments.

Answering the Question

- Now we have a good question and a good experiment that may answer the question…

- What are our metrics?
  - A study on baseball pitcher throwing speed?
  - A comparison between monitor crispness?
  - Whether Chrome is better than Firefox?

Telling Others

- Tweet about it!
- Create a web page about it
- Poster presentation
- Workshop paper
- Conference paper
- Journal article

- Leadership requires the "soft skills"
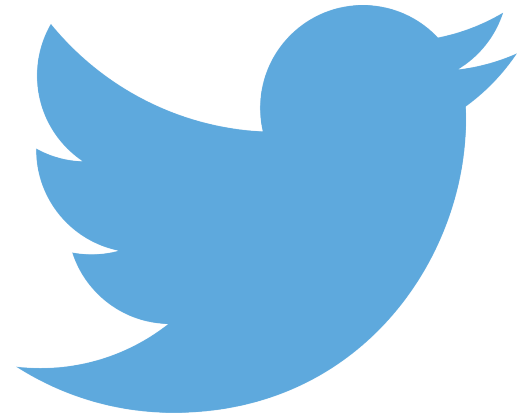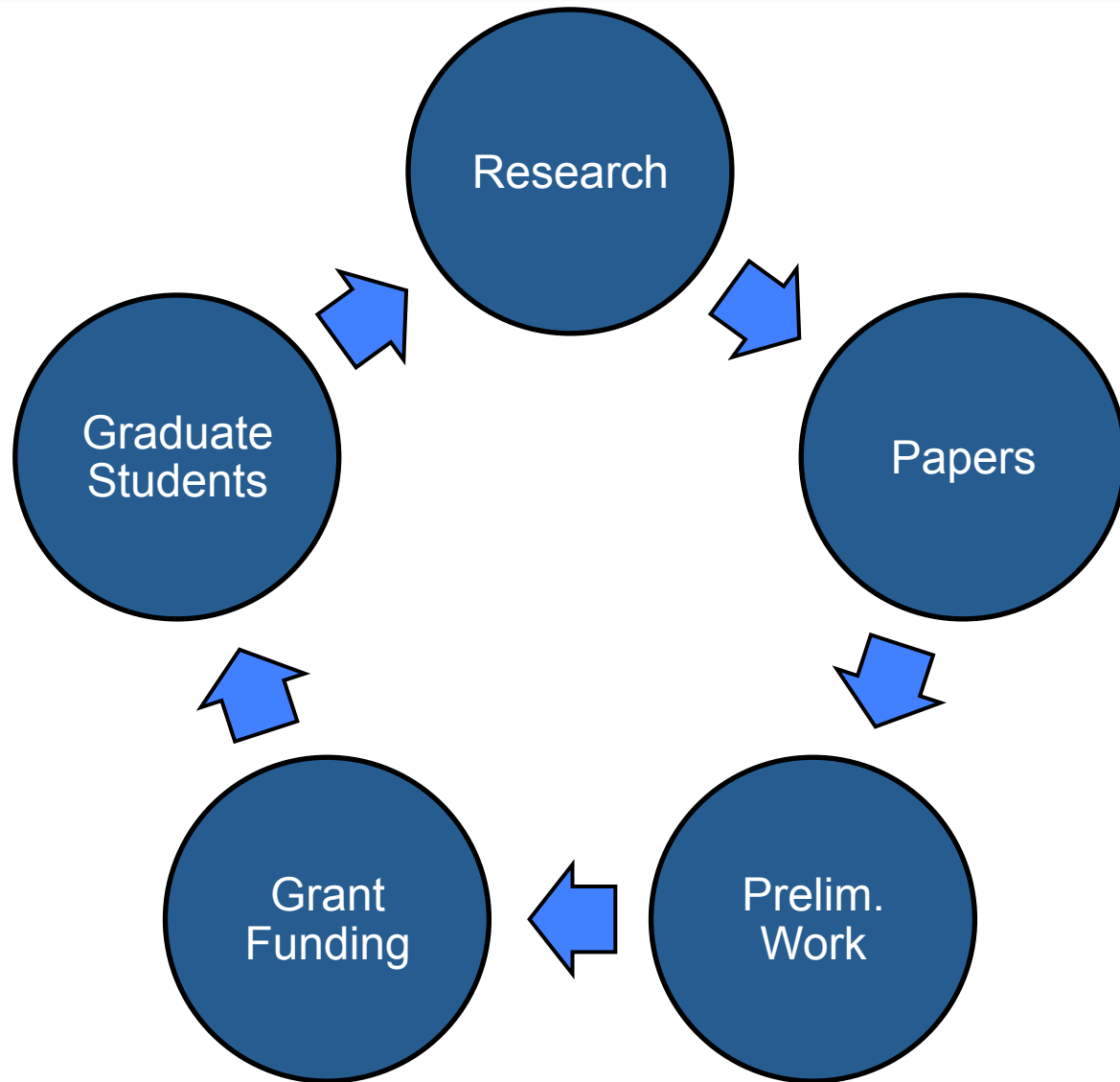
Having an Impact

- Who are you going to help?

- What are their needs? Pain points?

- What is your approach going to be?
  - What's your "golden nugget" or secret sauce?

- What benefits will your approach bring?

- Who is your competition?

Need, Approach, Benefit, Competition (NABC)

The Research Enterprise

Graduate Student Life

"Being a graduate student is like becoming all of the Seven Dwarves. In the beginning, you're Dopey and Bashful. In the middle, you are usually sick (Sneezy), tired (Sleepy), and irritable (Grumpy). But at the end, they call you Doc, and then you're Happy."

— Ronald T. Azuma

Being a Graduate Student is a Job

- ## Supported Students
  - Stipend: $2,100/month: $18,900 for 9 months
  - Tuition: 18 credits at $1,407 a piece: $25,326
  - Health Insurance: $1,082
  - Total Compensation: $45,308
    - For 9 months of the year at 20 hours per week
    - $45,308 x 1.333   x 2   = $120,791 annually
      (12 months)   (full time)

- ## Unsupported Students
  - Much like college's full time or part time study

The Hours are Long

- Classes meet for 9 hours a week
- Outside class expectation: 3 times as much as in class (27 hours/week)
- TA/RA responsibilities (20 hours/week)

                    Total: 56 hours/week

- Caveat: Unstructured research generally takes longer to do.

You are not alone

- Form a community with other graduate students at WPI
- The faculty cares and wants to help you.
  - We invest time and resources in you. We have already bet on your future.
- The faculty work just as hard as you.
  - And we went through the same experience.
- The academic research model is essentially an apprenticeship.

Doing is Everything

"For the things we have to learn before we can do them, we learn by doing them."

— Aristotle

"Let me tell you the secret that has led me to my goal. My strength lies solely in my tenacity."

— Louis Pasteur

Success

- Base intelligence helps
  - Congrats! You're good to go.
- Hard work and determination
  - But, work smarter, not harder
- Good computer scientists are efficient
  - Design, rather than build blindly

Question and Answer

Upcoming Sessions

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- Sept. 15: Making an Impact

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