Research elements for life

Methodology for Research in Networking

M2 — Networking
Sorbonne Université

2021-2022

I INSIST

Don't take this class as an academia-only topic

Many successful people in industry
follow a **similar** approach

3 QUESTIONS

What is research?

A definition

"Research is an organized and systematic way of finding answers to questions"

Lynn Henrichsen
https://linguistics.byu.edu/faculty/henrichsenl/ResearchMethods/RM_1_01

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Structure or method to do research. It is a planned procedure, not a spontaneous one. It is focused and limited to a specific scope.

A definition

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Definite set of procedures and steps to follow. Certain things in the research process are always done in order to get the most accurate results.

A definition

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End of all research, whether it is the answer to a hypothesis or even a simple question. Sometimes the answer is no, but it is still an answer.

A definition

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Central to research. If there is no question, then the answer is of no use. Research is focused on relevant, useful, and important questions.

A definition

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- In everyday life, this includes
  - Reading a factual book of any sort is a kind of research
  - Surfing the internet or watching the news is also a type of research
  - You do research when you have to solve a problem in your company without following a recipe

https://explorable.com/definition-of-research

In science

- Goal
  - Create knowledge
  - Discovery
- Strict protocols and long established rules
  - Structure
  - Formalism

https://explorable.com/definition-of-research

Why practice CS as science?

- Scientific practice provides a limited type of external verification that grounds our work in something other than mere consensual hallucination
- Scientific practice enables more rapid progress toward things we wish to produce
  - **Explanations** — *How does that IR system work? Why did the Internet behave in that way?*
  - **Guidance** — *What should we do if we want our data center to have a higher percentage of uptime?*
  - **Technologies** — *How can we build a better integrated development environment? What networking protocol offers the highest performance for real P2P networks?*

From: "Research Methods for Empirical Computer Science"
Class by David Jensen at University of Massachusetts, Amherst

Doing research in CS

Construct an algorithm or system

- Much of what we think of as "doing computer science" is about building the infrastructure to do computer science
- Examples include building new...
  - Compilers
  - Garbage collectors
  - Networking protocols
  - Machine learning algorithms
- But, of course, this isn't everything we do (or should do)

From: "Research Methods for Empirical Computer Science"
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The kinds of things CS researchers do

- Design an algorithm
- Design an experiment
- Run an experiment
- Gather data
- Identify an existence proof
- Make a conjecture
- Devise a research question
- Construct a theoretical proof
- Find flaws in previous experiment
- Identify an important exception to a theory
- Construct a general theory
- Use a theory to explain an observation
- Compare results from theory and experiment
- Devise a new measurement or technique
- Unify disparate theories
- Establish a relationship between variables

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The kinds of things CS researchers do

- Could you type a few more?

Identify a research question

- Identify a research question about which a hypothesis can be formulated
- These hypotheses are typically about
  - Algorithms, tasks, or environments
- Questions about
  - Individual elements (e.g., existence proofs)
  - How changes in one element affect another
  - Comparisons of two more elements holding others constant
- Often iterative and done by multiple researchers

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Do you want to do a doctorate?

What is a doctorate?

- A *long*, *in depth* research exploration of *one topic*
  - Long = 3+ years
  - In depth = you will be the world expert or close to it in your particular area
  - One = typically be working on only one narrow problem

From: M. Harchol-Balter, "Applying to Ph.D. Programs in Computer Science"
http://www-2.cs.cmu.edu/~harchol/gradschooltalk.pdf

Very different than taking classes

In class

- Homeworks have known answers
- Techniques for solving problems introduced in class
- Professor pick problems
- Close guidance: grades, professor tells you what to do next

In research

- Problems may not be solvable
- Invent techniques to solve problems
- You pick problems
- Some help from advisor, but need to be self-motivated and pro-active

From: J. Kurose, "10 pieces of advice I wish my PhD advisor had given me" (now 15 :-))
http://www-net.cs.umass.edu/kurose/talks/

Life after a doctorate

Academia

- Teaching schools
- Research-1 schools
- Research institutes
- In France, INRIA, CNRS
- Big vs. small; public vs. private
- Do you like to teach?

Industry

- Many different types of industry settings
- Startup
- "Big industry"
- Research labs

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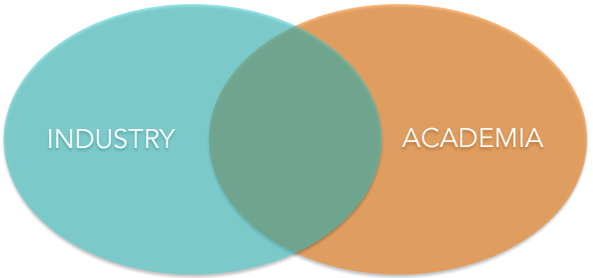
In reality, specifically for advanced areas...



Academia: Research universities/institutes

- Doing research on anything you like
- Working with graduate students
- Teaching classes
  - Amount of teaching depends on country
- Applying for grants
- Flying around to work with other researchers and to give talks on your research
- Doing service for your department
- Doing service for the community
  - Reviewing papers, organizing conferences

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Academia: Teaching schools

- Teaching lots of classes
- Doing service for your department
- Occasionally advising undergraduates on undergraduate research, or doing a little of your own research

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Industry: Research labs

- Doing research
  - Always need to be useful for company
- Working with other people in the company
  - Could also have students as interns
- Traveling around a little to give talks and work with others
- Doing service for the community
  - Reviewing papers, organizing conferences
- Importance of each of these tasks depends on the company (more R or more D)

From: M. Harchol-Balter, "Applying to Ph.D. Programs in Computer Science"
http://www-2.cs.cmu.edu/~harchol/gradschooltalk.pdf

Should you get a doctorate?

- Evaluate
  - What type of career do you want?
  - Do you have the elements (personality, drive, passion) to succeed?
  - Is this the best use of your time?
- If not, it is OK to leave
  - At any time
- If so, optimize your decisions (life, career, research choices) around making the most of it
  - If you're going to "half ass" it, why bother?

From: N. Feamster, A. Gray, "What is a Ph.D.?"
http://www.gtnoise.net/classes/cs7001/fall_2008/syllabus.html#Schedule

If you decide to get a doctorate

- A successful career
  - Ability to have real impact
  - A lifetime of learning and advancement of knowledge
  - A job you love
  - Freedom: much less structure than other jobs
  - Many people are not so lucky
- High-quality research
  - You will be evaluated on your publication record and contributions to science, not on your dissertation
  - You have an opportunity to fundamentally change the world we live in. Dissertation is a minimal requirement…think BIG!

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How to do good research?

"A successful person isn't necessarily better than her less successful peers at solving problems; her pattern-recognition facilities have just learned what problems are worth solving."

– *Ray Kurzweil*

Factors to consider

- Importance
  - How important is the research topic within the larger research and application community?
- State of knowledge
  - What do we know already? What is the position of the research with respect to "the frontier"?
- Unique competence
  - Are you uniquely qualified to address this research? What is your "secret weapon"?
- Interest
  - How much does this research problem interest you personally? Do you have a passion for this problem?

From: "Research Methods for Empirical Computer Science"
Class by David Jensen at University of Massachusetts, Amherst

Assessing importance

- Audience
  - Who will care about the answer?
- Impact
  - Will different answers change...
    - ...what research gets done next?
    - ...what is done by practitioners?
- Longevity
  - How long will the answer be relevant and important?

From: "Research Methods for Empirical Computer Science"
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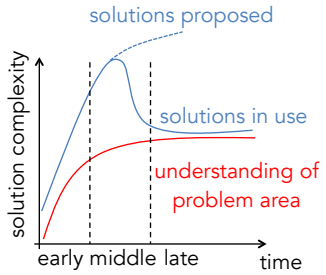
Choosing a research problem

- Pick your problems carefully!
  - what's the fundamental issue you're solving?
  - will the problem be of interest five, ten years from now?
  - focus on fundamentals in a world with an increasingly short attention span
- Avoid crowded areas
  - unless you have a unique talent, viewpoint
  - low-hanging fruit has been picked
  - researchers working on "next big thing" are not in the crowd

From: J. Kurose, "10 pieces of advice I wish my PhD advisor had given me"
http://www-net.cs.umass.edu/kurose/talks/

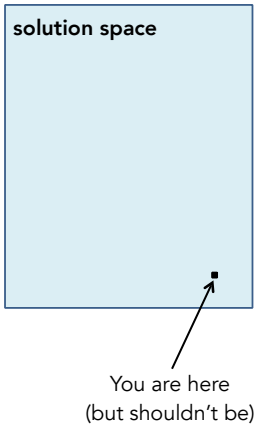
Complexity of solutions



- complexity, sophistication are themselves not of interest (except to purist)
  - means, not an end
  - how is the "story" changed in the end?

From: J. Kurose, "10 pieces of advice I wish my PhD advisor had given me"
http://www-net.cs.umass.edu/kurose/talks/

Avoid point solutions



- Insights that cut across solution space vs. point solution
- what broader conclusions can be drawn from your work?

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http://www-net.cs.umass.edu/kurose/talks/

Be thorough

- Always begin with a literature survey
- Start with the smallest non-trivial instance
- Learn as you go
- Prepare to change
- Crystallize solutions
- Keep an eye open for the unexpected
- Carry a notebook

From: S. Keshav, "Hints on doing research"
http://blizzard.cs.uwaterloo.ca/keshav/wiki/index.php/Hints_on_doing_research

Be part of a community of scholars

- Meet people, listen, collaborate
  - Good students, colleagues, friends
- Approach, talk with people
- Interactions with peer students
  - research discussions
  - paper presentations
  - practice talks

From: J. Kurose, "10 pieces of advice I wish my PhD advisor had given me"
http://www-net.cs.umass.edu/kurose/talks/

Last pieces of advice

- Can you help me extend the list?

References

Recommended reading

- Loehle, C. (1990). A guide to increasing creativity in research - inspiration or perspiration? Bioscience 40:123-9

  http://www.pef.uni-lj.si/ceps/knjiznica/doc/mojca/Loehle%201990.pdf

Reading for the next weeks

- V. Paxson, "End-to-End Routing Behavior in the Internet." *IEEE/ACM Transactions on Networking*, Vol.5, No.5, pp. 601-615, October 1997.

  http://conferences.sigcomm.org/sigcomm/1996/papers/paxson.pdf

If you want to learn more

- Oliver, J. (1991). The Incomplete Guide to the Art of Discovery. Columbia University Press. 0-231-07620-7.

  PDF available at: https://ecommons.cornell.edu/handle/1813/83

- D. Patterson, "How to Have a Bad Career In Research/ Academia"

  Slides available at: http://www.cs.berkeley.edu/~pattrsn/talks/nontech.html