Thoughts on how to do good research

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Developing the Science of Networks

Outline

"It is really important to **do the right research** as well as to **do the research right.**"

George Springer, Stanford University

- Research
  - Choosing your research area
  - Finding the right problem
  - Coming up with a solution
  - Evaluating your idea
  - Dissemination
- You
  - Motivation
  - Time-management
  - Research ethics
  - Work live balance

CHOOSING YOUR RESEARCH AREA

Check Out Research Areas

- Choose something you like, research should be fun (most of the time)!
- Look for areas that have not yet been explored thoroughly
  - Not too broad, not too narrow, not too old
  - With some (practical) relevance
- Talk to researchers in the area and attend as many research talks as you can
  - Find the most well-known research groups
  - Look at what they are publishing and how their focus is changing
- Read survey papers in some areas of interest
  - First go for breadth, then depth
  - Keynote speeches from top researchers are among the best resources out there
- You may have to take PhD courses anyway; pick them wisely!
  - … and use Coursera, Udemy, Udacity, Edx

FINDING THE RIGHT PROBLEM AND SOLUTION

Heilmeier's Catechism

You must know the answers to the following questions before moving on to writing a good paper:

- What problem do you want to solve?
- Who cares about this problem and why?
- What solutions exist and why are they that inadequate?
- What is your proposed solution to this problem?
- What is new about your approach?
- How can you demonstrate that this is a good solution?
- Who will care if you succeed?
- How long will it take?
- What are the risks?

Heilmeier's Catechism: A set of questions credited to George H. Heilmeier that anyone proposing a research project or product development effort should be able to answer.

What problem do you want to solve?

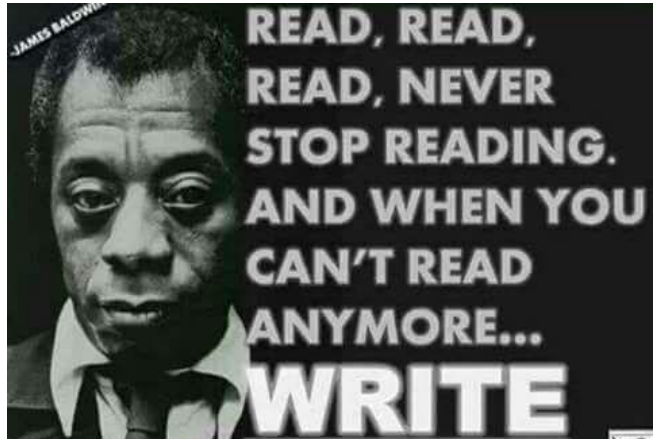
- Follow your passion
  - You're doing this for yourself
- Make sure you **fully** understand the problem
  - You **have to understand the problem** before going on the solution
  - Taking time to think this through at the very beginning will save you loads of time later on
  - Resist the temptation to jump right in with a solution
- Write it down
  - Formulate a clear research question and objective

Who cares about this problem and why?

- Make sure its a problem **you** care about
  - This must be worth your own time!
  - Don't be too picky (at the beginning)
  - … but if you don't care about the problem, the research will be agonizing and you won't come up original ideas
- … and ideally not only you care about
  - Maybe you're brilliant and no one else realized the potential (but then again, maybe not)
  - But you need collaborators, funding, citations, …
  - Having impact is critical

What solutions exist and why are they inadequate?

- Look for a problem for which there is no good (enough) solution yet
- Let your literature search guide you
  - First go for breadth, then depth
- *Critically* review the existing literature
  - It is often not as easy as it seems (assumptions, caveats, …)
  - Questions that arise while reviewing can be excellent seeds for your own research
  - Don't be afraid to contact the authors and ask questions
- The more you understand existing solutions, the better you can find alternative solutions and new questions
  - Avoid duplicate work!
- Yes, you can write a survey paper, but don't overdo it!

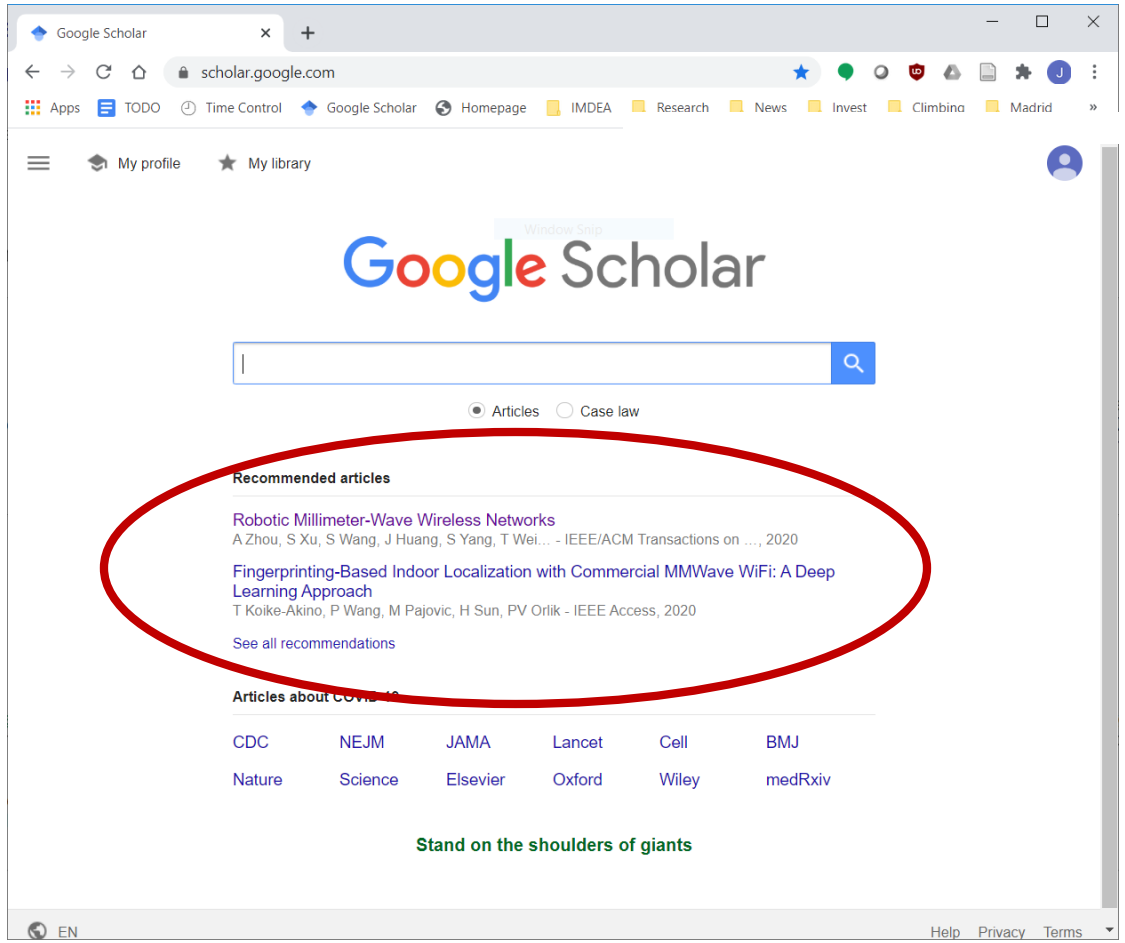


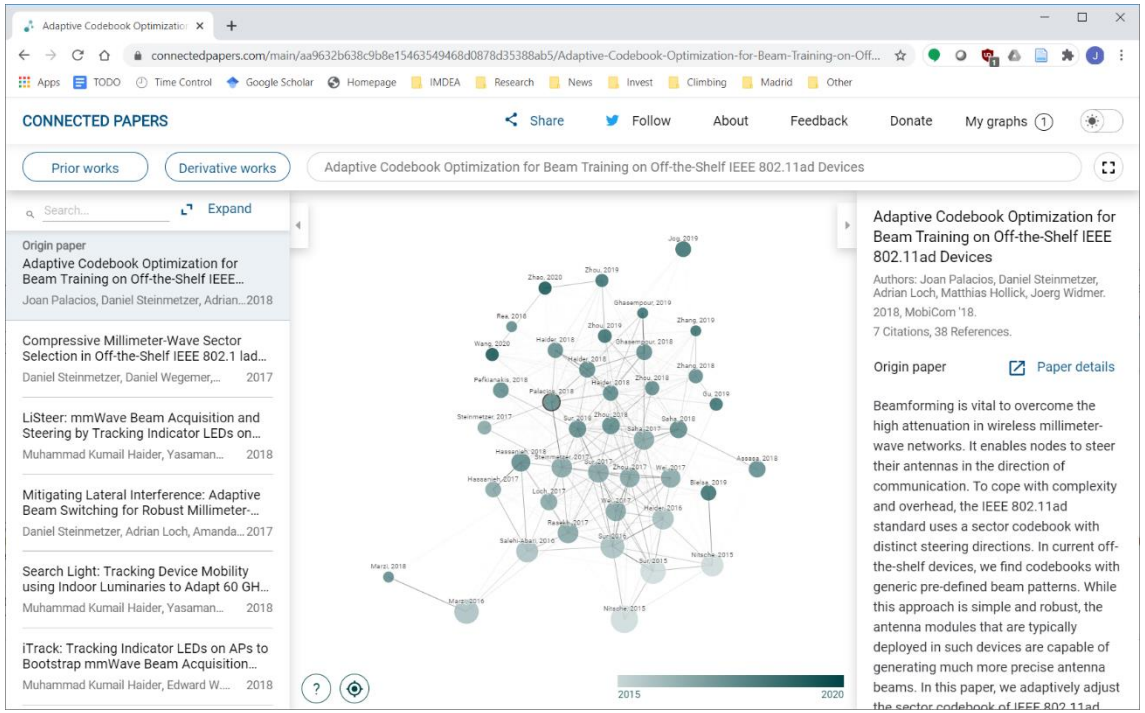
James Baldwin

What solutions exist and why are they inadequate?

- Good background knowledge is essential to develop new ideas
- Know and understand the relevant building blocks from those papers
  - Typical optimization approaches, algorithms
  - Protocol design components
  - Signal processing mechanisms
  - Theoretical background (information theory, …)
- Develop a core tool-set you know in detail and can apply well
- Read technology news to understand the industry, what solutions make it to the market, what are the constraints
- Continue reading *while* doing the research

Google Scholar is Your Friend





https://www.connectedpapers.com/

What is your solution? What is new about it?

- It's fine to start your PhD doing incremental improvements to the state of the art
  - You learn to write papers and sometimes this might lead to a bigger idea
  - BUT: there are already far too many incremental papers
- The goal of your PhD is to learn how to do original research
  - Scientific progress itself is incremental, but it must not lack innovation
  - Make sure you look for more novel ideas and bigger problems as soon as possible
  - Set the bar high: you never write an excellent paper by accident

How can you demonstrate that this is a good solution?

- The Scientific Method: set of general principles for any research

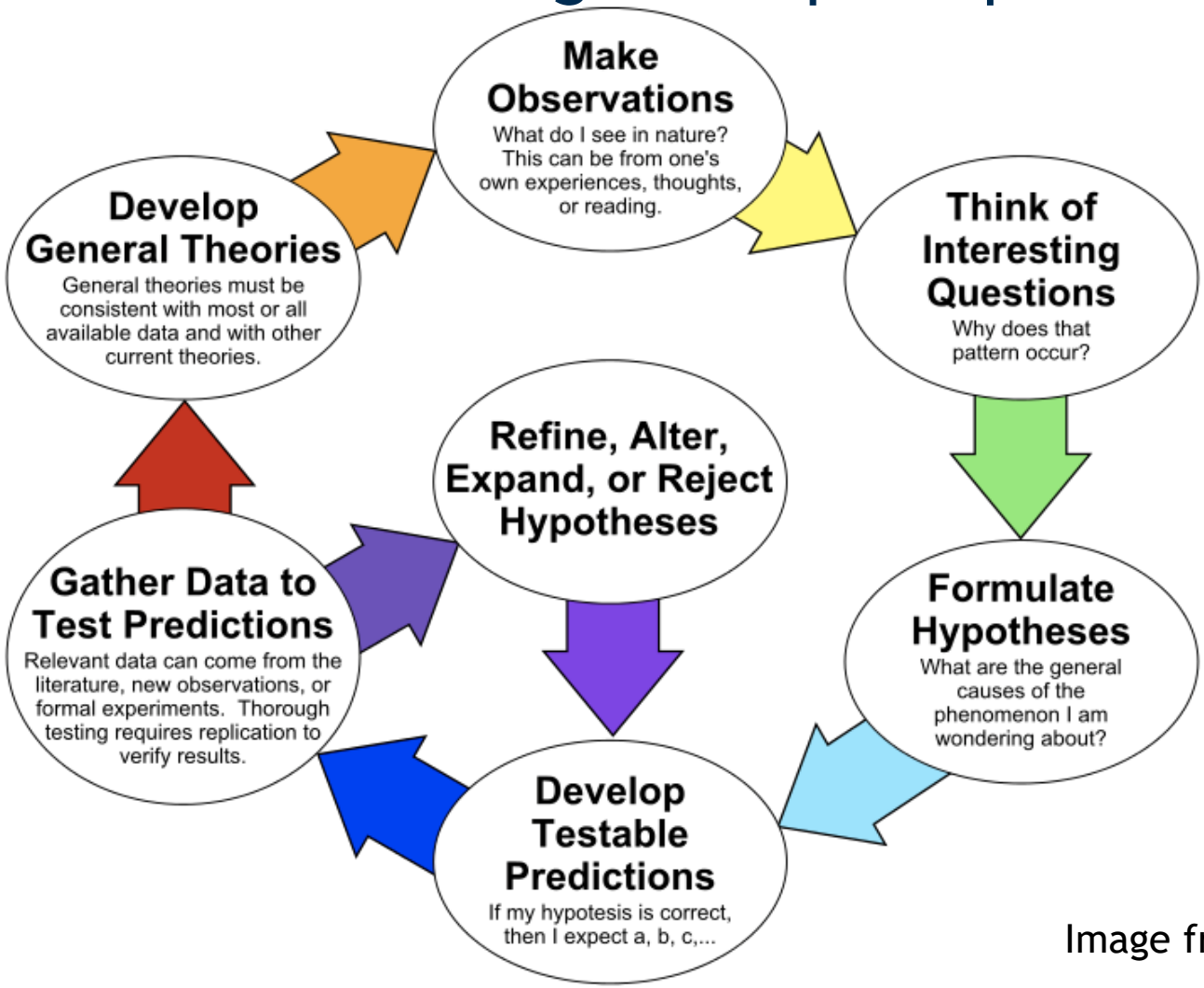


Image from Wikimedia Commons

Critical Thinking

- Constantly question your solution and results
  - Attack your solution from all possible angles to find the holes (or others will)
  - Questioning things is what research is all about
  - More often than not, it's been done before. If not, there may be good reasons why people take a different approach.
- Beware of confirmation bias
  - CS research is often (too) hands on; we can learn a lot from other disciplines
  - Think about what the results mean
  - Is this what you expect? Why?
- It's hard to be creative and critical at the same time → switch between the two
  - Good research needs both!

Dissemination

- The best results are worthless if others don't see them
  - Prioritize quality over quantity
  - Avoid salami paper writing
- Learn how to communicate scientific results
  - How to write a good research paper is addressed below
- Open science: collaborative, reproducible and reusable research
  - Common in other areas, and critical for CS/EE to advance more rapidly
  - Open-access publishing, open-source software, open data, open hardware
  - Common testbeds

Paper Writing

- Abstract: concisely state the problem, your approach and solution, and the main contributions results of the paper
- Introduction: (Stanford InfoLab's patented five-point structure)
  1. *What is the problem?*
  2. *Why is it interesting and important?*
  3. *Why is it hard?*
  4. *Why hasn't it been solved before?*
  5. *What are the key components of my approach and results?*
- Don’t overclaim, don’t over-criticize others

From: Tips for Writing Technical Papers
Jennifer Widom, January 2006

Paper Writing

- The paper should tell a *coherent story*
  1. What is the problem?
  2. Why is it interesting and important?
  3. Why is it hard?
  4. Why hasn't it been solved before?
  5. What are the key components of my approach and results?
- Tell the story the results should evoke in the mind of the reader, *not* the story of how you arrived at your results
- Use a "top-down" description: readers should be able to see where the story is going
  - Note: readers may/will skip the math and details
  - Justify your design choices
  - Rule of thumb: clear new important technical contribution by page 3
- Clearly delineate material that is not original but is needed for the paper

From: Tips for Writing Technical Papers
Jennifer Widom, January 2006

YOU

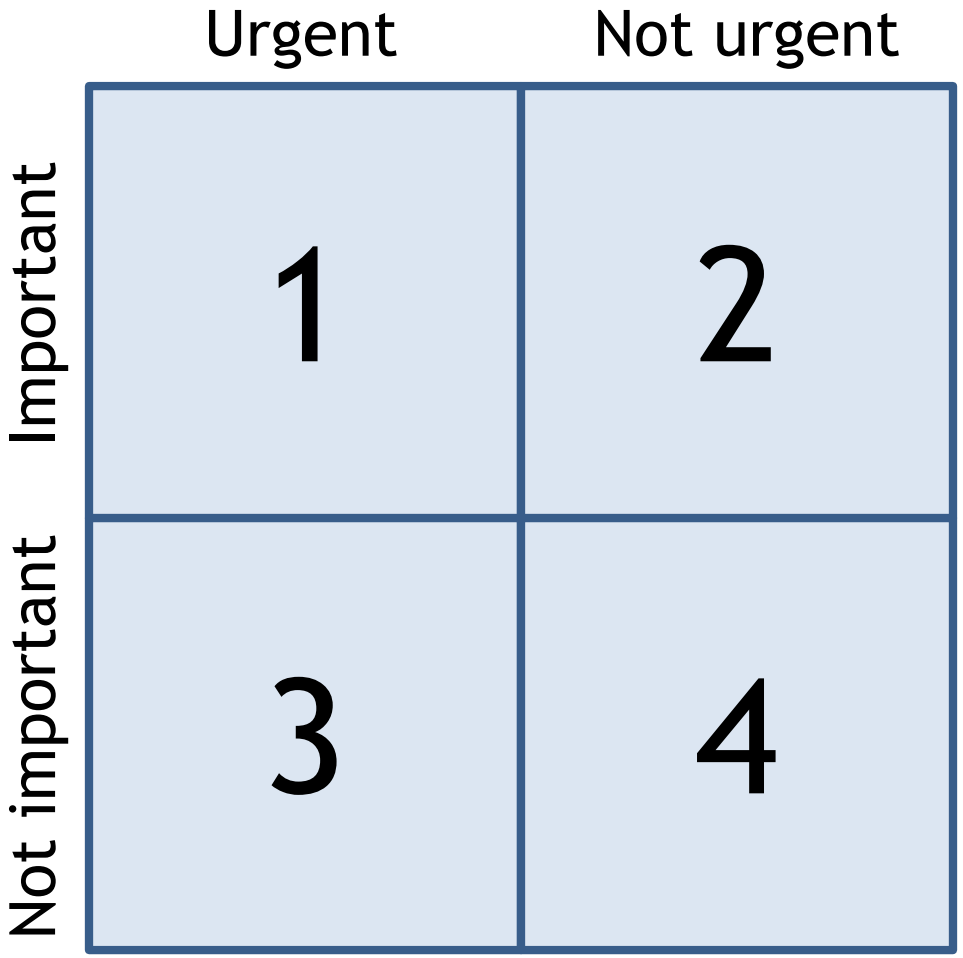
Motivation

- There’s no easy way: doing research/a PhD is hard and at times you will get frustrated along the way
- Take away the pressure
  - Remind yourself that you’re doing this because it's fun and you're curious!
- Breaking down a concept into its core elements, understanding these elements and then use them for your own ideas
  - This a challenge, but drives the ideas that fundamentally progress science
  - While you are formulating questions, you are already moving towards the answers

Time management

- There is plenty of material out there; use it
- Work in intervals (say 30-90 minutes, followed a break)
  - You cannot sustain mental productivity for 8 hours a day
- But make time for deep work
  - Dedicate continuous interruption-free time to unraveling one small subquestion of your research question
- There is no such thing as multitasking
  - Remove time-wasters; keep Whatsapp, Facebook, mail/news notifications, games, etc. separate from your work time
- Learn to say “No”, learn to delegate

Stephen Covey's Time Management Matrix



S. Covey, "The Seven Habits of Highly Effective People"

Write It Down!

- Keep a research journal, try to write in it every day
  - Keep track of what you have done, why you have done it, and what is/is not working
  - Easy to forget the details of what you worked on two weeks ago, let along half a year ago (you'd be surprised how fast you forget things)
  - Revisiting thoughts prevents you from reinventing the wheel
- Write down your research problem and ideas
  - Great exercise to organize your thoughts
  - Great practice for paper writing
  - … and it helps when you're stuck
- Weekly/monthly progress monitoring
  - Most important results and insights from last week/month
  - What deviations were there and why
  - Goals for next week/month

Research Ethics

- Always maintain scientific integrity:
  Trust is the basis of scientific relationships!
  - Nothing hurts your research more than losing the trust of others
- This not only refers to plain fraud (falsifying results or omitting what doesn't suit you), but just as much trying not to kid yourself (confirmation bias)
  - Careful, this starts small; fight it every step along the way!
- Be very careful with (self-)plagiarism: never copy, use proper citation
- Fortunately our area is also changing: stronger focus on repeatability, verification, open access to data, …

Work life balance

- Eat, sleep, and exercise above all else
  - Exercise is a great way to keep your brain fresh and stress-free
  - Huge difference in mental clarity and focus
  - Helps avoid tunnel vision

Summary

- Plan your work
- Know what you're doing and why
- Read, write!
- Find out what works for you
  - One size does not fit all
- Have fun!


Thank you

Resources

- Eva Lantsoght, “The A-Z of the PhD Trajectory: A Practical Guide for a Successful Journey”
- Ken Blanchard and Spencer Johnson, “The one minute manager”
- Stephen Covey, “The Seven Habits of Highly Effective People”
- How to do good research
  - https://www.site.uottawa.ca/~bochmann/Projects/how-to-do-good-research/index.html
  - https://terrytao.wordpress.com/career-advice/
  - https://www.cs.cmu.edu/~mleone/how-to.html
  - https://dspace.mit.edu/handle/1721.1/41487
  - http://www.cs.cmu.edu/~mblum/research/pdf/grad.html
  - http://www.cs.utexas.edu/~EWD/transcriptions/EWD06xx/EWD637.html
  - http://www.paulgraham.com/hamming.html

Resources

- How to choose a research topic?
  - https://isrl.byu.edu/wp-content/uploads/2015/05/How-to-Choose-a-Research-Topic.pdf
  - https://www.chronicle.com/article/Choosing-a-Research-Topic/45641
- How to Write Research Papers
  - https://users.cs.northwestern.edu/~kch670/useful/writepapers
  - https://www.cs.tufts.edu/~nr/pubs/two.pdf
  - And countless more