Lecture 3:
Basics of Doing Research

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Research?

Never do research when you know it is a common fact.
Don't even try to write it!

We take it one step at a time!

- pick a topic
- identify the research questions(s)
- check the literature
- identify the appropriate theories/frameworks
- choose the appropriate method(s)

- design of the study
  - target population?
  - sampling technique?
  - data collection techniques?
  - metrics for key variables?
- conduct the study
- analyze the data
- validate with subject matter expert
- write up the results and publish them

Research Questions

A research investigation starts with a moment of insight

- Dissatisfaction with the state of the art
- Questioning assumptions and conventional wisdom
- Exploring intriguing ideas

Usually it's impossible to know if you will be successful at the beginning

Ask These Questions

EXPLORATORY

- Existence:
  - Does x exist?
- Description & Classification:
  - What is x like?
  - what are the its properties?
  - how can it be categorized?
  - how to measure them?
- Descriptive-Comparative:
  - how does x differ from y

BASERATE

- Frequency & Distribution:
  - how often does x occur?
  - what is the median of the data?
- Descriptive-Process:
  - how does x normally work?
  - by what process does x happen?
  - what are the steps as x evolves?

CORRELATION

- Relationship:
  - are x and y related?
  - do occurrences of x correlate with occurrences of y?
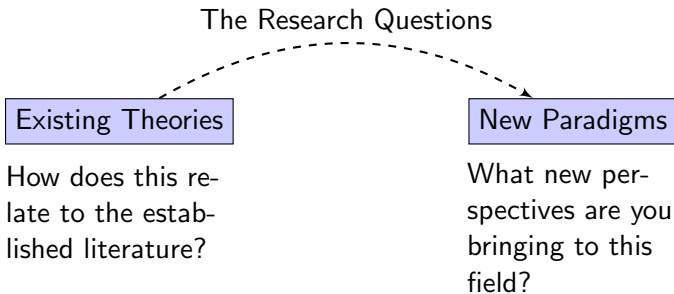
Ask These Questions

CAUSALITY

- Causality:
  - does x cause y?
  - does x prevent y to happen?
  - what causes x?
  - what effect does x have on y?
- Causality-Comparative:
  - does x cause more y than does z?
  - is x better at preventing y that is z?
  - what causes x?
  - what effect does x have on y?

Ask These Questions

DESIGN

- Design:
  - what is an effective way to achieve x?
  - how can we improve x?

Putting the Question in Context

What you are trying to do is to "transform" from *existing theories* into *new paradigms*

The Research Questions

Existing Theories

How does this relate to the established literature?

New Paradigms

What new perspectives are you bringing to this field?

Shaping A Research Topic

Experienced scientist

- Quickly design a series of experiments or theoretical goals
- Investigate the relevant literature
- Set deadlines

Students

- Training is involved
    - planning, reading, programming, testing, analysis, critical thinking, writing, and presentation
- Short term and long term goals
    - Short term: publish a research paper on a specific topic
    - Long term: this topic is part of a wider investigation that forms the basis of the student's thesis

Shaping a Research Topic

Two key questions

- what is the broad problem to be investigated?
- what are specific initial activities to undertake and outcomes to pursue?

What makes the topic interesting?

- use a strong motivating example
- explore questions where work can be done
- example: develop robots to play soccer instead of exploring other planets where the technology may eventually be used

Shaping a Research Topic

The right advisor/supervisor for you

- Equally important as choosing the right topic
- Choose someone that you can work with for several years
- A charismatic or famous advisor isn't necessarily likeable or easy to work with

Don't choose a topic just because it is fashionable

- Choose a topic that you believe will continue to be relevant

Choose a topic at the right technical level for you

- one that makes use of your specific strengths. Some prefer theoretical research while another prefer empirical research

Shaping a Research Topic

Project scope, don't be too ambitious

- Ambitious projects have a high potential for failure
- Research is usually incremental without major breakthroughs
- Start with easy to achieve outcomes and then move on to more challenging goals

Research problems claimed to be solved by commercial software

- Is the company being honest, can you verify their claims? Examples: Security claims, Quantum computers, etc..
- What is the quality of the solution?

Students and Advisors

- Every student-advisor relationship is different
- A research program:
    - provides a student with research training while the student demonstrates the capability to undertake research from conception to write-up
    - Publishable research is a side-benefit
- In the early stages of research, advisor specifies each small step the student should take
- As students mature as researchers, students become more independent and advisors leave more space for them to assert their independence

An advisors expertise is critical in scoping the project.

- Sufficiently alone from other current work while being relevant to a groups wider activities
- Open enough to allow innovation and freedom while having a good likelihood of success
- Close enough to the advisors core expertise to allow the advisor to verify that the work is sufficiently novel and that the appropriate literature has been thoroughly explored.

Finding Research Literature

- After identifying your topic, you need to specify a set of keywords, or search terms related to your topic.
- Doing research requires a thorough knowledge of the work of others.
- Locating prior work can be a tremendous challenge.
- The number of papers published each year in CS is at least tens of thousands.
- However, in an active field, other researchers usually have already explored and digested the older literature a $\Rightarrow$ complete exploration of archives in rarely necessary.

Finding Research Literature

- Each research project builds on a body of prior work
- Tips for locating prior work:
  - Visit the web sites of research groups and researchers working in the area
  - Follow up references in research papers
  - Browse the recent issues of journals and conferences in the area
  - Use obvious search terms to explore the web
  - Search the publisher-specific digital libraries Wiley, Springer, ACM, IEEE
  - Take a look at conference web sites
  - Use the citation indexes
  - Go to the library
  - Discuss your work with as many people as possible

Importance of Literature Review

- A researcher has to know a small number of papers very well
- A researcher needs to have read a large number of papers in order to establish their relevance
- Can you believe what you are reading?
    - Some papers are wrong and many are misguided
    - Be questioning and skeptical, but not dismissive

Ask questions such as:

- What is the main result?
- How precise are the claims?
- What is the evidence?
- How was the evidence gathered?
- How were the measurements taken?
- How carefully are the algorithms and experiments described?
- Why is the paper trustworthy?
- Has the right background literature been discussed?
- What would reproduction of the results involve?

Research Planning

- It is important to set deadlines
- Explicitly consider what is needed at the end, then reason backwards
    - Write-up as a thesis, paper, or report
    - Plan the steps necessary to produce the write-up, and use each one as a milestone
      –Previous work
      –Descriptions of experiments
      –Analysis of outcomes
    - What must be done to convince the skeptical reader that that the results are correct?
    - Estimate dates for completing milestones while keeping in mind that things usually take longer than expected
    - Be flexible and overlap stages as much as possible

Plan your experiments properly, so that data gathered is useful.

Hypothesis

- A Hypothesis should be clear and precise, not ambiguous
  –State the limits on any conclusions
- A Hypothesis must be capable of falsification
  –Must be provably right or wrong
- A Hypothesis must be testable
  –Limit the scope to a domain that can be easily explored
- A Hypothesis typically evolves in tandem with refinements in the experiments
  –However, hypotheses should not be made to fit already made observations

Defending Hypotheses

- Construct a convincing argument relating your hypothesis to gathered evidence
- Defend your work against any objections you can think of in the style of an argument
  –Rebut likely objections
  –Concede points
  –Admit when you are uncertain
- Always consider the possibility that your hypothesis is wrong
  –Try to find ways to disprove it in order to make your hypothesis stronger

Evidence

Forms of evidence

- Proof
  - A formal argument that the hypothesis is correct
  - A proof may contain errors
- Model
  - A mathematical description of the hypothesis used to demonstrate that the model corresponds with the hypothesis
- Simulation
  - Implementation of a simplified form of the hypothesis
- Experiment
  - A full test of the hypothesis, based on an implementation using real data

- Different forms of evidence can be used to confirm one another
- Chose what forms of evidence to use based on what would be the most convincing

Good & Bad Science

- lots of research somewhere between bad and good.
- some examples of bad science:
  1. theoretical work that isn't testable
  2. pseudoscience, usually fraud
     –results and ideas don't develop overtime
     –systems are never quite ready for demonstration
     –protagonists argue rather than seek evidence
     –results are inconsistent with accepted facts
  3. works with inconsistent evidence & methods
  4. inventing a problem, a solution, and a measure of the solution
   without external justification.

A Research Checklist

- ☑ Are the ideas clear and consistent?
- ☑ Is the problem worthy of investigation?
- ☑ Does the project have appropriate scope?
- ☑ What are the specific research questions?
- ☑ Is there a hypothesis
- ☑ What would disprove the hypothesis? Does it have any improbable consequences?
- ☑ Are the premises sensible?
- ☑ How are the outcomes to be evaluated? Why are the chosen methods of evaluation appropriate or reasonable?

A Research Checklist

- ☑ Are the roles of the participants clear? What are your responsibilities? What activities will the others undertake?
- ☑ What are the likely weaknesses of your solution?
- ☑ Is there a written research plan?
- ☑ What forms of evidence are to be used?
- ☑ Have milestones, timelines, and deadlines been identified?
- ☑ Do the deadlines leave enough time for your advisor to provide feedback on your drafts, or for your colleagues to contribute to the material?
- ☑ Has the literature been explored in appropriate depth? Once the work is largely done—and your perspective has changed—does it need to be explored again?
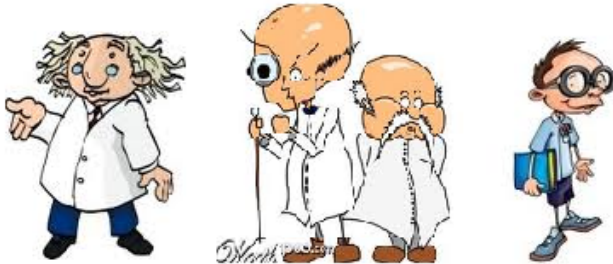
Any of your lecturer look like one of these?

Declaration & Acknowledgment

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