Research Methodology in CS

Chapter I

204490 Research Methodology in Computer Science

Engineering vs. Science

Traditional View:

Scientists...

- Create knowledge
- Study the World as it is
- Are trained in scientific method
- Use explicit knowledge
- Are thinkers

Engineers...

- Apply that knowledge
- Seek to change the World
- Are trained in engineering design
- Use tacit knowledge
- Are doers

More Realistic View

Scientists...

- Create knowledge
- Are problem---driven
- Seek to understand and explain
- Design experiments to test theories
- Prefer abstract knowledge but rely on tacit knowledge

Engineers...

- Create knowledge
- Are problem---driven
- Seek to understand and explain
- Design devices to test theories
- Prefer contingent knowledge but rely on tacit knowledge

Both involve a mix of design and discovery

Two Types of Research

- Quantitative vs. Qualitative Research
- Quantitative – use of statistical, formulaic or numerical analysis to generate results
  - Main approach: analysis; causal determination, prediction, generalization of findings
  - Results: "This solution is N% better"
- Qualitative – not quantitative; use of non-numeric techniques
  - Main approach: discovery; illumination, understanding, extrapolation to similar circumstances
  - Results: "This is a new way of solving our problem"

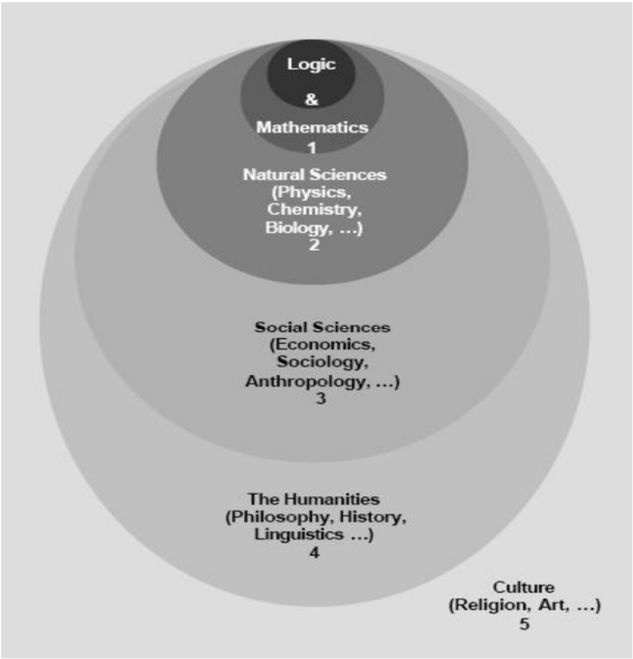
Scope of Research

- Varies by level of work
  - Ph.D. students – contribution expected at world level; e.g.
    - background investigation on all past work
    - make meaningful addition to world knowledge
  - Undergraduate students – contribution can be at local to national to world level; e.g.
    - background investigation at university up to world level
    - make meaningful addition to university up to world level of knowledge

Not CS Research

- Playing with technology
- Book report
- Programming project
- Doing what others have already done
- However, each of these can be done as part of research

Domain Related CS Research

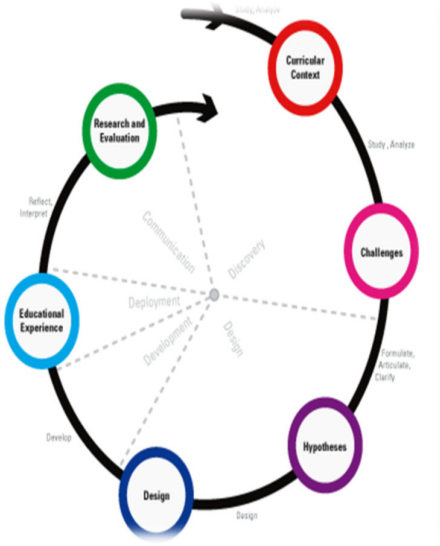


Research Methods in CS

- Experimental Method
  - Experimental shows the experiments that will occur in order extract results from real world implementations.
  - Experiments can test the veracity of theories.
- Simulation Method: For
  - the systems that is under invention or construction.
  - complex phenomena that cannot be implemented in laboratories evolution of the universe, such as astronomy, physics or economics
- Theoretical Method: the classical methodology since they are related to logic and mathematics. Theory is important to build methodologies
  - To develop logic and semantic models and
  - To reason about the programs in order to prove their correctness
  - To the design and algorithm analysis in order to find solutions or better solutions (performance issues, for example).

Research Process (Methodology)

- Initial Idea
- Background Investigation
- Refinement of Idea
- Core Work
  - Investigation and Development
  - Documentation
  - Prototype (if appropriate)
- Evaluation
- Identification of Future Work
- Presentation



Initial Idea

- Stems from critical thinking
- Be on the lookout for and open to seeing problems
  - Gaps in framework
  - Repetitive behavior that's slightly different (and can be generalized)
  - Manual solutions (that can be automated)
  - Inelegant solutions
- Ask questions
  - "Is something missing here?"
  - "Can this be done in a better way?"
  - "Is there a need for a new approach?"
- Should be an area you're interested in, as:
  - You'll be spending a lot of time with it
  - It won't always be easy/fun to continue…

Background Investigation

- Given an idea, need to determine:
  - Has this work been done previously?
  - What similar work has been done leading up to this point?
  - How is any previous work distinguished from what I'm planning to do?
  - What group of people will be positively impacted by the research?
- Tools
  - Literature Review using library resources (e.g. online databases such as ACM and IEEE, popular magazines)
  - WWW search

Refinement of Idea

- Based on background investigation, need to refine idea
- Issues:
  - Precision – focus on precisely identifying:
    - Problem
    - Possible solutions (plural!)
  - Scope – need to "build fences"
    - What's an essential part of this work? (fence in)
    - What's tangential, additional, or for any other reason best left for later/someone else? (fence out)

Core Work-
Investigation and Development

- Provide yourself with infrastructure
  - equipment / software
  - additional knowledge ("get up to speed")
- Do the work
  - Experimentation (scientific process)
  - Develop opinions
  - Look for better ways of solving problem
    - Can you generalize?
    - Can you develop a framework?
  - Discuss, brainstorm
  - Reevaluate as you proceed
    - Look for improvements, changes to your original ideas

Core Work- Investigation and Development (2)

- Process
  - Work regularly
    - Easier to keep going if have a commitment to a regular work time
    - Helps you keep your past work in mind
  - Allocate large block of time for research
    - Takes time to get going/back to speed
    - Make sure can do something significant each work session

Core Work- Documentation

- Need to document as you go
  - Don't want to lose any information
- 1) Maintain a journal for day-to-day thoughts
  - Can be paper, electronic, …
  - Keep it with you at all times
    - Never know when good ideas will hit
- 2) Keep an updated task list
  - Focus on accomplishing something each work session
- 3) Write up your work
  - Periodically, write a few pages on a subset of your work
    - Summarize work, accomplishments, problems
  - At end, write up a summary document
    - Can be based on steps discussed here

Core Work- Prototype

- Need to demonstrate the merit of your ideas
- If work is non-theoretical, do this through a developed system
  - No need to build the entire system
  - Just need to demonstrate the value of the core ideas

Evaluation

- Perhaps the most difficult part….
  - Best if can show others are already using your work
- Quantitative
  - Test your prototype
  - What improvements exist over currently available alternative?
  - How much of an improvement do you see?
- Qualitative
  - What can you do now that couldn't be done before?
  - What are the benefits of your solution?

Identification of Future Work

- Helps you organize any future efforts
- Helps others build on your work

- Sources:
  - What you excluded in your idea refinement
  - New problems that have surfaced during your work

Presentation

- It's not a contribution to the field if no one knows about it or can use it
- Presentation/Dissemination
  - Conferences, Journals, Web
    - e.g. National Undergraduate Research conference
  - Papers, Talks, Poster Sessions
    - e.g. UWEC and UW System Research Days

Researching Skills

In this "Age of information"

- How to find the '**right**' information — Searching Skills
- How to evaluate it — Reviewing Skills
- How to develop/improve it — Engineering/Scientific Skills
- How to report it clearly and accurately — Writing Skills
- How to make money out of it — Searching Skills

One Fundamental Aspect of Research is "Asking Questions"

- **As many as one can…**
- **Framing Questions**
- **Identifying Sensible/Meaningful/Useful/ Relevant/ Important Questions**
- **Investigate those questions**
- **Report those questions**

Asking Sensible Questions

W5H2 Analysis

- (What) to find the information
- (Which) to evaluate it
- (Where) to report it clearly and accurately
- (Why) How to improve it
- (When) How to make money out of it
- (How)…
- (How Much)…