CMSC 601: Topics

Adapted from slides by Prof. Marie desJardins

February 2011
Sources


• Richard Hamming, “You and your research.” Transcription of the Bell Communications Research Colloquium Seminar, March 7, 1986.

Outline

• Doing Research
• Words from the Wise
• Research Topics
What Is Research??

• Asking “why” and “how”
• Creating innovative solutions to novel problems
• Also:
  – Understanding previous work
  – Testing hypotheses
  – Analyzing data
  – Publishing results
• Not:
  – Applying existing techniques to a new problem
  – Developing a one-shot solution to a problem
What Is Research?

research
Research as search

Search effort is a function of speed and informedness
What is research?

“The best way to have a good idea is to have lots of ideas.”

-- Linus Pauling
Problems

Problems worthy of attack prove their worth by hitting back.

-- Piet Hein
T.T.T

Put up in a place
where it's easy to see
the cryptic admonishment
    T. T. T.
When you feel how depressingly
slowly you climb,
it's well to remember that
    Things Take Time.

-- Piet Hein
A Good Topic

• ...is unsolved
• ...is important
• ...is interesting to you
• ...is interesting to your advisor
• ...is interesting to the research community
• ...has useful applications
• ...applies to more than one problem
Scope

• Too broad is bad
• Too narrow is bad
• Too constrained is bad
• Too unconstrained is bad
• “Telescoping” is best
Getting Jumpstarted

• Read!
• Write
  – Annotated bibliographies
  – Literature surveys (including open challenges)
• Replicate previous work
  – Re-implement
  – Re-derive
  – Re-experiment
• Start varying parameters, assumptions, environments
Read, Read, Read!

• You have to read a lot of research papers to become an expert
• You have to become an expert before you can produce high-quality results
• You have to produce high-quality results before you can complete your Ph.D. (or M.S.)
• ∴ you have to read a lot of research papers (and other people’s theses/dissertations)
• ∴ you might as well get started now!
“People have an amazing ability to become interested in almost anything once they are working on it.”

-- Peters, p. 181
Write Early!

• Write an annotated bibliography
• Write a proposal outline
• Write a literature survey
• Write an outline of a conference paper
• Write an outline of the dissertation
• Get feedback
  – Show your writing to your advisor, other graduate students, colleagues, ...
  – Post your writing on your blog
Articulating Your Topic

• What is the **question** to be answered?
• What is an **approach** you might try to get started?
• What is the **claim** you’d like to make?
• What is the **evidence** you could gather?
CS Units of Study

Each area chooses different units of study:

– **Algorithms**: Algorithms (duh)
– **AI/Graphics**: Methods, techniques, algorithms
– **Languages**: Language components or features
– **Architecture**: Instruction sets, memory hierarchies, architectures
– **Theory**: Models, theorems, proof techniques
– **Systems**: Systems, components, architectures

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Unit Diversity

• Size:
  – Small units: algorithms, language features, architectural components
  – Medium-size units: instruction sets, proof techniques
  – Large units: languages, architectures, machines

• Potential variety:
  – Low variety: sorting algorithms, cache design
  – High variety: AI algorithms, languages, architectures

• Cost of evaluation:
  – Low cost: algorithms, AI methods
  – Medium cost: theorems, components of architectures
  – High cost: languages, architectures, ideal models

• Smaller units generally exhibit less variety and lower evaluation cost, so they are easier to do research on

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Research Life Cycle

• **Definition.** Exploratory research defines a new problem, constraints, opportunities, and/or approaches.

• **Initial Solutions.** Initial algorithms, designs, theorems, and/or programs are developed.

• **Evaluation of Initial Solutions.** Initial solutions are evaluated and refined in isolation.

• **Comparison of Solutions.** Solutions are compared to one another, to baselines, and to ideal solutions.

• **Space of Possible Solutions.** Theorems are proved about the limits on any solutions. Existing solutions are placed in a common framework to determine whether all possible solutions have been found.

• **Technology Transfer.** Best approaches are transferred to users and to new problems.

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The Research Process

• Research is not linear
• Balance your time among
  – reading
  – writing
  – thinking
  – doing
• and between
  – narrow focus
  – broad focus
Research Results

• a **definition** of a problem or task
• a **unit** for solving a problem or performing a task
• identification of **factors** influencing the cost, effectiveness, or applicability of a unit (perhaps with some idea of the relative importance of factors)
• development of an **ideal model**
• a **finished unit** that can be distributed to users
• measurement of some **properties** of a unit: run time, chip area, representation requirements, reliability, usability, etc.
• identification of **problems and shortcomings** in a unit
• a **demonstration** that one unit is better than another
• a definition and demonstration of a **tradeoff**
• **analysis of a tradeoff** showing how different points on the curve can be obtained and selected
• a **generative (explanatory) theory** for some set of units

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Research Methods

• writing programs
• writing systems
• developing architectures
• developing content architectures (ontologies, knowledge bases, class libraries, graphics toolboxes, etc.)
• measuring properties of units
• finding and proving theorems
• analyzing and consolidating previous research
• interviewing experts and customers
• performing psychological experiments, surveys, observations

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Research Methods (cont.)

• building hardware
• reading literature
• importing techniques and results from other fields
• measuring and predicting constraints on future units (e.g., VLSI technology, government regulation, user expectation and requirements)
• writing papers, monographs, and textbooks

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Research Project Phases

An individual research project (such as a Ph.D. dissertation) follows a lifecycle related to the research life cycle:

– Choose research question/problem/tradeoff
– Determine current state of knowledge
– Apply appropriate methods to produce research results
– Write up research results

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Supporting Skills for Research

- Programming and hardware design
- **Organization**
- Mathematics
- Algorithm analysis and proof methods
- Psychological techniques: Protocol analysis, experimental manipulations, survey methods
- **Statistics**
- Writing proposals
- Writing papers
- Critiquing papers
- Designing experiments
- Giving talks

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Words from the Wise
Peters’ Criteria for Research Topics

- Financial support
- Interest to you
- Extendibility after completion
- Controversy
- Time to complete
- “Hotness”
- Advisor’s enthusiasm
- Closeness to advisor’s research
- Depth of existing research
- Duplication or uniqueness
- Narrow focus
- Tractability

Peters p. 189
A Comment on Peters

“Once you have identified some topics you are interested in, you can research them rapidly by spending a few hours on the telephone calling up experts in the field and pumping them for information.”

– What is this telephone you speak of?
– Proceed with caution!!
– Don’t do this without your advisor’s blessing
– E-mail is better than telephone
– Be specific
– Remember that you are asking for free consulting advice from an expert who is paid to give it to others
Hamming’s Advice

• Work on important problems
• Commit yourself emotionally to your work
• Work hard
• Tolerate uncertainty
• Generalize
• Don’t make excuses
• Sell yourself and your work
• Don’t fight the system
• Be collegial
• Look for the positive
• Know your strengths and weaknesses

See Richard Hamming’s popular comments on research: [here](#) and [here](#)
“If you are to do important work then you must work on the *right problem* at the *right time* and in the *right way*. Without any one of the three, you may do good work but you will almost certainly miss real greatness.”
Quotes from Hamming

“The first person to produce definitive results generally gets all the credit. ... Thus working on the problem at the right time is essential.
Quotes from Hamming

“An important aspect of any problem is that you have a good attack, a good starting place, some reasonable idea of how to begin.”
ANNOUNCEMENTS

CRN Online
January 2011, Vol. 23/No. 1

CRA Elections Committee Announces 2011 Slate
Petition Nominations Due Feb 7, 2011
Undergrad Researcher Awardees 2011
Meet the Awardees
CRA Distinguished Service Award
Nominations Due Jan 28, 2011
CRA A. Nico Habermann Award
Nominations Due Jan 28, 2011

COMPUTING RESEARCH NEWS
A Publication of the Computing Research Association

PCAST Finds IT R&D Critical to U.S. Competitiveness, Calls for Renewed Federal Investment

QUICK LINKS
PostDocs in Computer Science  Job Announcements  Taulbee Survey
Outstanding Undergrad Researchers  Best Practices Reports  CRA-Deans
Snowbird  CRA Leadership Summit  Forsythe List  CiFellows
NetSE Research Agenda  CRA E-mail Announcements
Research Advice from CRA-W

• Start with problems, not with solutions
  – I have a hammer! Where’s the nearest nail?
  – Ideally, focus on a general problem or class of applications

• Question assumptions
  – ...of your work and previous work

• Break your research into manageable pieces

• Know how you will evaluate your method
  – Understand the standard methodologies for your field
  – Identify evaluation metrics
  – Develop baseline methods and benchmark problems

• Have long-term and short-term goals

• Sell yourself and your work
Good Research Practices from CRA-W

• Be a good colleague
  – Help your advisor, other students, other faculty, colleagues
  – Collaborate!

• Use other activities to benefit your research

• Announce your accomplishments

• Seek out supportive environments