Course Overview

1. **Choosing Research Projects**

   Research Life Cycle

2. **Methods and Supporting Skills**

   Practice with methods not covered in other classes.

3. **Professional Career Issues**

   Proposals and Presentations

Units of Study

Each area of computer science chooses different units of study.

- In algorithms: algorithms
- In AI: methods, techniques, algorithms
- In Languages: languages, language components or features
- In Architecture: instruction sets, memory hierarchies, architectures
- In Theory: models, theorems, proof techniques
- In Systems: systems, components of systems, system architectures

Units Have Hierarchical Structure

- architecture
  - instruction sets
    - instructions for procedure call/return
    - instructions for branching
  - memory hierarchies
    - support for virtual memory
    - study of caches
    - study of cache coherency
  - floating point units
    - floating point representation
    - arithmetic algorithms
    - implementation strategies
    - pipeline design

Research Life Cycle

- **Definition.** Exploratory research defines a new problem, new constraints, new opportunity, or a new approach.
- **Initial Solutions.** Initial algorithms, designs, theorems, programs are developed.
- **Evaluation of Initial Solutions.** Initial solutions are evaluated and refined in isolation.
- **Comparison of Solutions.** Solutions are compared to one another and also 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.

Not all of these phases are seen in all areas. For units with high cost of evaluation, only relatively weak methods can be applied to evaluate initial solutions and compare solutions.

For units with high variety, it is difficult to understand the space of all possible solutions.

Research Results

- a definition of a problem or task
- a unit for solving a problem, performing a task
- identification of factors influencing the cost, effectiveness, or applicability of a unit (perhaps with some idea of the relative importance of the 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, useability, 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

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, customers
- performing psychological experiments, surveys, observations

Research Methods (2)

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

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 (lifecycle phase)
- Apply appropriate methods to produce research results.
- Write up research results

Research is not complete until it is written up!

Supporting Skills

Different research methods require different supporting skills.

- programming (and hardware design)
- organization
- mathematics
- psychological techniques: protocol analysis, experimental manipulations, survey methods
- statistics
- writing proposals
- writing papers
- critiquing papers
- designing experiments
- giving talks

You study some of these methods in other courses. This course will attempt to cover the remaining ones.

Paper Critique Outline

- **What is the research goal?**

  What question(s) is the author trying to answer?

- **What methods are being applied?**

  What methods is the author applying to answer the question.

- **What are the research results?**

  A paper can contain many different kinds of results.

- **What claims are made in the paper?**

  For theoretical papers, what results are proved?

- **How are these claims supported?**

- **What reasonable claims and results are missing from the paper?**

- **What would be reasonable next steps for the research?**

Evaluation Criteria

Experimental research requires measurable evaluation criteria.

- **CPU Time**
- **Cycles per instruction**
- **Percentage of correct classifications**
- **Number of serious interface flaws identified**

Ideally, these criteria will be

- **Easy to measure**
- **Reliable** (i.e., replicatable)
- **Valid** (i.e., the measure the right thing)
- **Applicable Early in the Design Process**
- **Convincing**

Evaluation Criteria Must Implement Goals

It is very important to consider the relationship between measurable criteria and the underlying goals of the project.

Can a unit score well on the criteria and yet still fail to achieve the underlying goals?