Introduction

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Course Goals

- Create/evaluate empirical studies/data
  - Understand underlying scientific and theoretical bases
  - Understand fundamentals of experimental design
    - Independent and dependent variables
    - Variable manipulation/data gathering
    - Various issues of validity
    - Empirical logic and reasoning
    - Analytic tools for reasoning about the experiment
  - Understand and control confounding variables
    - Random and systematic biases
    - Alternative explanations
  - Understand and apply appropriate data analysis techniques
  - Understand and create the underlying logics of empirical studies in reasoning out conclusions

Experimenter/Evaluator Goals

- Responsible skepticism
  - Look for
    - Failures in experimental designs
    - Failures of observations
    - Gaps in reasoning
    - Alternative explanations
  - Compare new evidence against old
  - Raise counter objections/hypotheses
  - Question grounds for doubt as well
  - Accumulate weight of evidence

Good Research Practices

- Enthusiasm – an enjoyable endeavor
- Open-mindedness – keen, attentive, inquisitive
- Common sense – avoid looking under the lamppost
- Inventiveness – creative
  - Not only in experimental work
  - In resource management as well
- Confidence in ones own judgment
  - Despite detractors when right
  - Know when you are wrong
- Consistency and care about detail
  - No substitute for accuracy - keep complete records, organize and analyses accurately/carefully
- Ability to communicate
  - Writing is a superb, essential research technique
  - Make your discoveries known to others
- Honesty – integrity and scholarship

Review of SWE

- Factors in software engineered products
  - Theory (basis for product)
    - CS Core
    - Domain specific theory
  - Experience (basis for judgment)
    - Feedback
    - Engineering experiments (prototypes)
    - Empirical studies
      - Observations
      - Correlations
      - Causal connections
  - Process (basis for production)
    - Methods and techniques
    - Technology
    - Organizational structures
      - Teams
      - Projects
      - Cultures

Review of SWE

- SW development processes
  - Phases
    - Requirements
    - Architecture
    - Design
    - Construction
    - Deployment and maintenance
  - Integral to all phases
    - Documentation
    - Measurement & Analysis
    - Evolution
    - Teamwork
    - Management of artifacts

Daily Life of SWE: Decisions

- Determine what users want/need
- Make architecture, design and implementation decisions
- Evaluate/compare architecture and design choices
- Evaluate functional characteristics
- Evaluate non-functional properties
- Evaluate/compare technologies
  - For supporting tools
  - For product support
  - For process support
- Determine what went wrong
- Determine good resource allocations
- etc

Some Illustrative Examples

- Most frequently stolen car
- Language/Solution comparisons
- Inspection reading techniques
- Exit Interviews

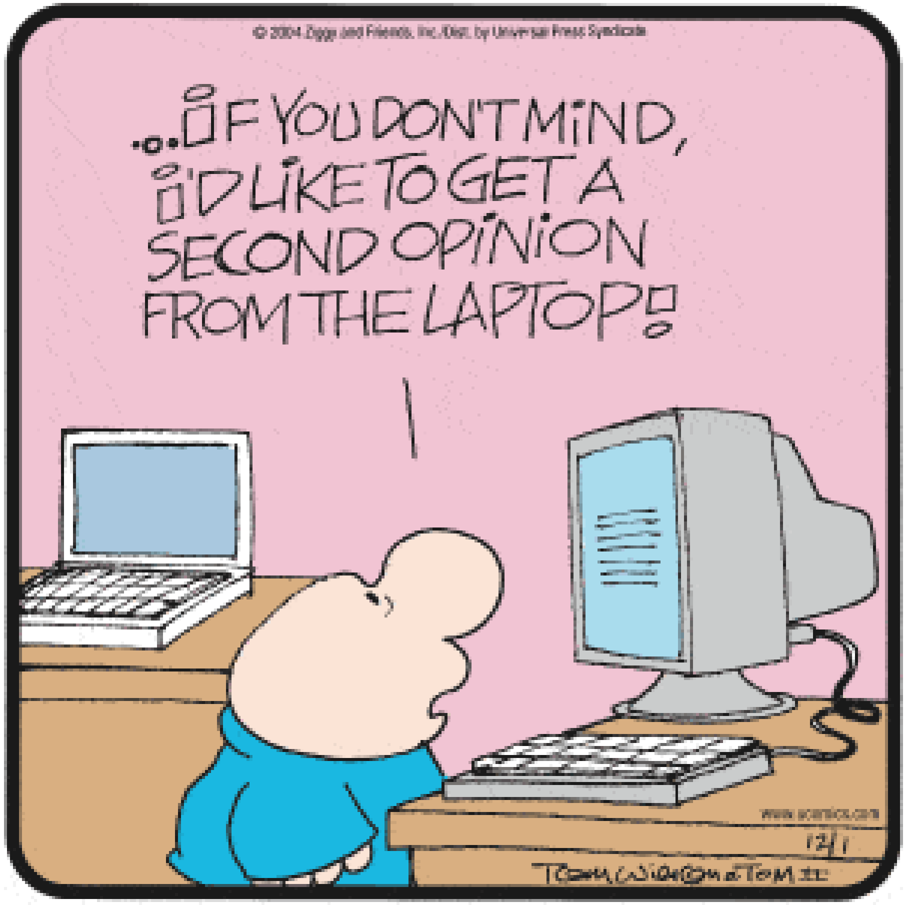
Most Frequently Stolen Car

- Honda Accord
  - Study presented in media
    - Honda most frequently stolen automobile
  - What does this study tell us?
    - Actually very little
  - What can we infer from this?
    - Shouldn't buy a Honda?
    - Buy a Mercedez instead?
  - Very misleading
- More recently
  - Frequency relative to the total number of cars
    - Claims per 1000
  - Different story
    - Lincoln Navigator – 12.2; Cadillac Escalade – 10.3; etc
      - ✓ All Escalades recovered – GPS system
    - Honda and Camry didn't make it anywhere near the top 10
      - ✓ Percentage of thefts claims is low compared to the number on road

Language/Solution Comparison

- From a summer project
- Comparing Java/C
- 2 different computers used
  - Pentium III 600MHz 128M
    - C 1.4 times faster than Java
  - AMD 1GHz 256M
    - Java 1.09 times faster than C
- Conflicting evidence
- How do we account for it?
- What are the differences?
- How do we resolve these differences?
- What can we conclude, if anything?

Preview of Confounding Variables



Inspection Reading Techniques

- Experiment: evaluate reading techniques for object oriented code inspections
- Inconclusive results
- Possibilities:
  - There are no differences
  - Poor experimental design
  - Insufficient data
  - Poor analyses and reasoning

Surveys

- Exit Polls
  - Used to predict outcome
- 2004 election
  - Significant disagreement with final vote
  - Early calls retracted
- Pollster's response
  - Results with in margin of error
  - Data selectively reported
- Possible biases
  - Questions asked
    - slanted, non-uniform (ie general vs specific), etc
  - Time of polls
    - 7am - men on the way to work
    - 10am – soccer mom's after kids are in school
  - Place of polls
    - East Austin versus Westlake
  - Nature of volunteers

Current State of SE Empirical Work

- Implementation oriented
  - Fenton: poor statistical designs, don't scale
  - Basili: differences in projects make comparisons difficult
  - Johnson: practitioners resist measurement
- Need to be more requirements oriented
  - Think hard about what experiments really are
  - How they can be most effectively used
- Core problem: conceptualizing and organizing a body of work as a scientific basis

Software Development

- Little hard evidence to inform decisions
  - Correlations suggestive but not sufficient in all cases
  - Many times don't know exception cases
- Do not know fundamental mechanisms
  - Software tools
  - Methods and techniques
  - Processes
- Empirical studies are the key
  - Show mechanisms
  - Eliminate alternative explanations
  - Empirical validation is standard in some fields
  - Quality of empirical studies in SE is rising
  - Funding agencies recognizing value of empirical studies
  - Increasing number of tutorials, panels, SOTAs, papers, etc
  - Key consciousness raising papers (Tichy etal, Zelkowitz)
  - Several key organizations: SEL, ISERN

Systematic Problems

- Research ideas are not empirically validated
  - Should retroactively validate
  - Should proactively directed
- Search for perfect study
  - Instead of focus on credibility
- Study the obvious
  - OK, but we need deeper insights
- Lots of data
  - Not enough – should answer important questions
- Lack useful hypotheses
- Lack conclusions from data

Empirical Software Engineering Studies

- Individual programmer studies have credibility due to well understood techniques from psychology and statistics.
- Large software development studies with the addition of large population social factors are not well established or credible.
- General goal:
  - ★ Establish a spectrum of empirical techniques that are robust to large variances from social factors present.

Challenges

- Create better empirical studies
  - Establish principles that are
    - Causal: correlated, temporally ordered, testable theory
    - Actionable: causal agent effectively controllable
    - General: widely applicable
  - Answer important questions
  - Family of focused studies – illuminate related aspects
  - Cost effective and reproducible
- Credible interpretations
  - Degree of confidence we have in conclusions
    - Eliminate alternative explanations
    - Provide a compelling logic in the discussion
  - Validity is critical: construct, internal, external
  - Hypothesis is critical: ask important questions
  - Resolutions appropriate to the intent of the study
  - Make the data public

Some Concrete Steps

- Designing studies
  - Ask significant questions
    - Knight-Leveson, N-version programming
  - Families of studies
    - Schneiderman et al, on the value of flowcharts
  - Build partnerships
    - Takes time; multi-person effort; interdisciplinary, industry
  - Long running in vivo/situ experiments
    - Subparts; subject rights; know when to stop
- Collecting data
  - Retrospective artifact analysis
    - Eg, version management systems
  - Simulation and modeling
    - Eg, integration studies of Solheim and Rowland
- Involving others
  - Meta-analysis – eg Porter and Johnson
  - Educational laboratories
    - Teach empirical studies basics
    - Populate lab with appropriate data/designs/equipment

Goals for SWE Empirical Studies

- Some help
  - ★ Look to other empirical disciplines
  - ★ Adapt what is useful here
- Goals
  - ★ Perform better empirical studies
  - ★ Focus on causal mechanisms
  - ★ Generate theories
  - ★ Iterate and improve
- Good empirical studies enable us to
  - ★ Encode knowledge more rapidly
  - ★ Prune low payoff ideas rapidly
  - ★ Recognize and value high payoff ideas
  - ★ Exploit important practical ideas

What is Critical

- Fundamentals
  - ★ Credible interpretations
  - ★ Repeatability
  - ★ Understanding validity limits
  - ★ Identifying underlying mechanism
  - ★ Practical significance
- Non-fundamentals
  - ★ Whether qualitative or quantitative
    - Both have their place and usefulness
  - ★ Identical results
    - Want congruent results
  - ★ Correlation studies
    - Important precursor, but not the goal
  - ★ Opportunistic studies

Structure of an Empirical Study

- Research context
  - Problem definition
  - Research review
- Hypothesis
  - Abstract – about the world
  - Concrete – about the design
- Experimental design
  - Variables – independent and dependent
  - Plan to systematically manipulate variables
  - Control operational context
- Threats to validity: construct, internal, external
- Data analysis and presentation
  - Quantitative: hypothesis testing, power analysis
  - Qualitative
- Results and conclusions
  - Limits, influences
  - Explain how answered question and its practical significance
  - Sufficient information for repeatability