Case Studies as Research Method in Software Engineering

Kevin Bierhoff

Outline

- Motivation by example
- Characterization
- Case study design
- Validation with case studies
- Summary

Futurebus+ validated the idea of model checking by finding bugs
- Formal description of non-trivial part of the IEEE Futurebus+ standard
- Model checker could find bugs
- This is the first time formal methods found bugs in an IEEE standard

TCAS II started as a case study and ended as an official FAA standard
- Specification of the “Traffic Alert and Collision Avoidance System” with Statecharts
- Research project aimed at validating a requirements engineering technique by documenting an ongoing standardization effort of the Federal Avionics Administration
- The project turned into the actual standard
A case study investigates a real-world phenomenon with a specific hypothesis

- Empirical investigation of a complex setting
  - Hard to separate from its real-world context
  - Explanation, description, causal analysis, exploration
- Multiple sources of evidence
  - To cope with \#variables >> \#data points
  - To triangulate valid results
- Based on a theory
  - To structure the problem domain
  - To guide data collection and analysis

Case studies are directed but should not be biased

Outline

- Motivation by example
- Characterization
- Case study design
- Validation with case studies
- Summary

4 common kinds of case studies

- Research questions
  - Typically how? or why?
  - Explanatory study
    - Decide between two rival theories
  - Descriptive study
    - Characterize a phenomenon
  - Causal analysis
    - Causes for a phenomenon
  - Exploratory study
    - Find out more
Case studies intend to confirm proposition about how or why question …

- Research questions
  - Typically how? or why?
  - Explanatory study
  - Descriptive study
  - Causal analysis
  - Exploratory study

- Study propositions
  - Concrete hypothesis about the research question
  - Guide search for evidence
  - Exploratory studies typically without proposition

… but there is little established practice in doing so

- Units of analysis
  - Define the “cases” to study
  - Can be anything

- Logic to link data to propositions
  - The concrete method used
  - No accepted standards

- Interpretation criteria
  - Analytic generalization
  - Can’t use statistics

We look into units and logics in detail now

---

Multiplication increases credibility

- Multiple-case studies
  - Literal replication
  - Logical replication
  - Replication ≠ sampling
  - Theoretical framework to generalize to new cases
  - No subunit pooling

- Multiple units of analysis
  - Distinguish multiple “sub-units” within a case
  - Relay back to case

---

Ideally we want to have lots of good data to corner our hypothesis

- Data analysis approach
  - No established strategies and techniques
  - Develop justification of what to analyze and why
    - Driven by theory
  - Present all evidence
  - Explore alternative interpretations
    - Collect data for refutation
    - This is often forgotten

- Analytic techniques
  - Pattern matching
  - Explanation building
  - Time-series analysis
  - Logic models
  - Cross-case synthesis

- Triangulation
  - Data sources
  - Evaluators
  - Theories
  - Methods
All analytic techniques rely on fitting specific events to theory predictions

- Pattern matching
  - Pattern = Co-occurrence of events
  - Rival explanations predict different patterns
- Explanation building
  - Apply a pre-built explanation
- Time-series analysis
  - Identify events over time
  - Compare to predictions
- Logic models
  - Match chain of events with cause-and-effect theories
- Cross-case synthesis
  - Match cases (mostly quantitatively)

Outline

- Motivation by example
- Characterization
- Case study design
- Validation with case studies
- Summary

Research validations with case studies follow a common design

<table>
<thead>
<tr>
<th>Research question</th>
<th>How does my approach perform compared to common practice? (explanatory: new vs. old)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study proposition</td>
<td>Using my approach helps solving the common problem I am trying to solve</td>
</tr>
<tr>
<td>Units of analysis</td>
<td>Subjects or objects that my approach applies to</td>
</tr>
<tr>
<td>Data linking logic</td>
<td>Find interesting example of common practice</td>
</tr>
<tr>
<td></td>
<td>Apply my approach</td>
</tr>
<tr>
<td></td>
<td>Compare performance in dealing with the problem I try to solve</td>
</tr>
<tr>
<td></td>
<td>Do this by finding specific situations where my approach obviously works (often pattern matching)</td>
</tr>
<tr>
<td>Interpretation criteria</td>
<td>Argue that the studied units were representative and the problems solved by my approach relevant</td>
</tr>
</tbody>
</table>

Construct, internal, external validity? Reliability?

Case studies are very easily invalid

Threats to case studies

- Construct validity
  - Study design driven by subjective hypothesis
- Internal validity
  - Researchers often involved themselves
- External validity
  - Arbitrary case selection
- Reliability
  - Researcher involvement
Outline

- Motivation by example
- Characterization
- Case study design
- Validation with case studies
- Summary

The piggy bag

- Case studies are hard to get right
  - Design carefully if you want to make a real point
- They are largely driven by a hypothesis
  - That easily looks very subjective to readers
- Case studies commonly used in validation
  - Regularly involves researchers doing their thing
  - That looks very, very, very subjective to readers
- Nonetheless probably good practice to increase validity of research methods