Technology Maturation Studies

Mary Shaw
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http://spoke.compose.cs.cmu.edu/ser01/

Building Blocks

• Previously
  > Redwine & Riddle evolution model
  > Redwine & Riddle specific examples
  > Shaw research paradigm model
  > Newman pro forma abstracts
  > Timelines

• Today
  > Reconciliation of Shaw classification and Newman pro formas
  > Conceptual genealogy — CSTB “tire tracks”
  > Overview of elements of technology maturation studies

Pro Forma Abstracts

• Idea: Identify the methodological “signature” of the research and state major points in a predictable way
  > Existing state models are deficient in dealing with dependability of object-oriented designs.
  > An enhanced state model is described, capable of providing more accurate analyses/predictions of dependability in object-oriented designs.
  > The model has been tested by comparing analyses/predictions with empirically measured values of dependability.
• Risk: Filling in slots mechanically and missing major points.
• Suggestion: In addition to Newman’s skeleton, add a sentence describing the essence of the result:

A Common Plan

<table>
<thead>
<tr>
<th>Question</th>
<th>Strategy/Result</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility</td>
<td>Qualitative model</td>
<td>Persuasion</td>
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<tr>
<td>Characterization</td>
<td>Technique</td>
<td>Implementation</td>
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<tr>
<td>Generalization</td>
<td>Empirical model</td>
<td>Analysis</td>
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<tr>
<td>Selection</td>
<td>Analytic model</td>
<td>Experience</td>
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</tbody>
</table>

Can X be done better? Build a Y Measure Y, compare to X
Types of Research Questions

- **Feasibility**
  - Does X exist, and what is it?
  - Is it possible to do X at all?

- **Characterization**
  - What are the characteristics of X?
  - What, exactly, do we mean by X?
  - What are the varieties of X, and how are they related?

- **Method/Means**
  - How can we do X?
  - What is a better way to do X?
  - How can we automate doing X?

- **Generalization**
  - Is X always true of Y?
  - Given X, what will Y be?

- **Discrimination**
  - How do I decide whether X or Y?

Types of Research Results

- **Qualitative & descriptive models**
  - Report interesting observations
  - Generalize from (real-life) examples

- **Techniques**
  - Invent new ways to do some tasks, including implementation techniques
  - Develop ways to select from alternatives

- **System**
  - Embody result in a system, using the system both for insight and as carrier of results

- **Empirical models**
  - Develop empirical predictive models from observed data

- **Analytic models**
  - Develop structural models that permit formal analysis

Good examples of abstracts/summaries

- **Parnas85 Modular Struct Cheng Latronico Poladian** (critique)
- **Booch86 Halloran (critique) Newman**
- **Hoare72 Shelton**
- **Liskov74 note diversity of types Li (new form, merge two ideas)**
- **Guttag85 Cheng**
- **McCabe82 Halloran (RS vs ET depends on context)**
- **DeRemer86 Fairbanks (solution or model?)**
Types of Research Validation

- **Persuasion**: I thought hard about this, and I believe...
- **Implementation**: Here is a prototype of a system that...
- **Evaluation**: Given these criteria, the object rates as...
- **Analysis**
  - Formal model: Rigorous derivation and proof
  - Empirical model: Data on use in controlled situation
- **Experience**
  - Qualitative model: Narrative
  - Decision criteria: Comparison of systems in actual use
  - Empirical model: Data, usually statistical, on practice

Maturity: Kinds of Research Results

Brooks proposed recognizing three kinds of results, with individual criteria for quality:

- **Findings**: well-established scientific truths --
  judged by truthfulness and rigor
- **Observations**: reports on actual phenomena --
  judged by interestingness
- **Rules-of-thumb**: generalizations, signed by an author (but perhaps not fully supported by data) --
  judged by usefulness

with freshness as criterion for all

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Enhanced Model

**EM: Enhanced model**

Existing model-type models are deficient in dealing with properties of solution strategy. An enhanced model-type is described, capable of providing more accurate analyses / predictions of properties in solution strategy designs. The model has been tested by comparing analyses / predictions with empirically measured values of properties.

**Key**: EM provides a new or better way of looking at problems

**Question**

- Characterization: What, exactly do we mean by X?
- Generalization: Is X always true of Y?

**Result**

- Models, preferably analytic or empirical, descriptive or qualitative if precise

**Validation**

- Empirical analysis, possibly empirical experience, implementation

Enhanced Solution

**ES: Enhanced solution**

Studies of existing artifact-type have shown deficiencies on property. An enhanced design for an artifact-type is described, based on solution strategy. In comparison with existing solutions, it offers enhanced levels of property, according to analyses based on model-type. These improvements have been confirmed / demonstrated in tests of a working artifact-type based on the design.

**Key**: ES “solution” is result for client, not means of getting it

**Question**

- [no good matches]

**Result**

- System that embodies the improvements

**Validation**

- Empirical analysis, possibly empirical experience, implementation
The effectiveness of model-type/solution strategy in supporting the design of artifact-type has been demonstrated. An enhanced tool/method is described for the design of artifact-type based on model-type/solution strategy. Examples are provided confirming the effectiveness of its support for model-type/solution strategy in design.

**Key:** ET provides a better way to exercise an accepted model

**Question**
Method/Means: How can we do X? What is a better way to X? Automate X!

**Result**
Techniques (invent new ways), System (embody results in system)

**Validation**
Analysis, empirical model

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A radical solution to the problem of problem definition is described, based on solution strategy. In comparison with existing normal solutions it offers advantages, which have been demonstrated in preliminary tests, but it leaves a number of side effects to be addressed including list of side effects. Strategies are suggested for addressing these side effects.

**Key:** RS provides essentially different product for client

**Question**
Feasibility: Does X (solution) exist at all, and what is it? Is X possible?

**Result**
Model or system

**Validation**
Implementation, persuasion

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Studies reported here of application supported by supporting technology generate a number of findings concerning issues, including list-of-findings. They indicate that requirement is/is not met by design-heuristic.

**Key:** XH observes and evaluates a situation in the world

**Question**
Characterization: What are the characteristics or varieties of X?

**Result**
Empirical model, sometimes qualitative

**Validation**
Persuasion, experience

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The technique existing technique has been successfully applied in area-x with benefits benefits for area-x. It is hoped that technique will provide similar benefits in area-y. An experimental evaluation of technique for area-y has been carried out using system from area-y. Benefits benefits for area-y have been shown to hold (optional: if technique is altered by alteration list). Limitations remaining to the application of technique to area-y include limitation list.

**Key:** ON explores new use of technique from different area

**Question**
[no good matches]

**Result**

**Validation**
Experience or Analysis/empirical
Missing Links

• Pro forma abstracts
  > Survey, overview, challenges list
  > Radical model, method, tool
  > Characterization
• Research questions
  > Applicability
  > New solution as distinguished from method/means
• Research results
  > Experiment, includes experience of applying method
  > Toy problem
• Research validation
  > Controlled experiment (empirical analysis doesn’t quite fit)

Possible types of pro forma abstracts

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Product / result</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>Radical</td>
<td>Idea</td>
<td>Solution for client</td>
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<tr>
<td>Enhanced</td>
<td>Model</td>
<td>Development technique</td>
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<td>Method</td>
<td>Notation</td>
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Pro Forma Abstracts and Research Strategies

Locating the pro forma abstracts in research strategy space

Problem Types, Products, Validations

24 classic SE papers, 10 ICSE 2001 software architecture papers
Composable Software Research at Carnegie Mellon

Problem Types, Products, Validations

<table>
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24 classic SE papers, 10 ICSE 2001 software architecture papers

Intellectual Lineages are not Linear

- Products incorporate many ideas
- Ideas may lead to multiple products
- [http://www.nap.edu/catalog/6323.html](http://www.nap.edu/catalog/6323.html) p 20

Points to Cover in Technology Maturity Studies

- Major events distributed along timeline
  - Critical idea or result
  - Research strategy
- Timelines
  - Chronology
  - Maturity
- Annotated bibliography
  - Identify surveys, key papers, other supporting papers
  - Pro forma abstracts as 1st paragraph of annotation
- Idea flows (like tire tracks)
- Cumulative evidence

Complete Research Result

Real World Practical problem

Validation Task 2:
Does the result help to solve the practical problem?

Real World Solution to practical problem

Research Setting Idealized problem

Validation Task 1:
Does the product solve the idealized problem?

Research Setting Solution to idealized problem

Garlan, Shaw, Wing 6 10/17/01
Composable Software Research at Carnegie Mellon

Redwine/Riddle Maturation Model

Basic Research
- Recognize problem
- Invent ideas

Concept Formation
- Refine ideas
- Publish solutions

Development & Extension
- Try it out
- Clarify

Internal Exploration
- Stabilize
- Port, use for real problems

External Exploration
- Broden user group, external

Usable Capability
- Seminal paper or system
- Outsiders use it

Usable Capability
- Production quality
- Commercial support

Key Idea
- Seminal paper or system
- Outsiders use it

Software Technology Maturation Points

Transition Points for Abstract Data Types

- Basic research ==> concept formation
  > 1968: formulation of information hiding
- Concept formation ==> development & extension
  > 1973: abstract data type models
- Development & extension ==> internal exploration
  > 1977: incorporation in programming languages
- Internal exploration ==> external exploration
  > 1980: incorporation in other technologies
- External exploration ==> Popularization
  > late 80’s: object models, C++, Java

Growth in Specification Power

1950
- Signatures
- Prose

1960
- Higher-level languages
- Procedures
- Inmnemonics, macros

1970
- "Software engineering"
- Concrete complexity
- Formal specifications
- Formal syntax

1980
- Generic definitions
- Abstract data types
- Inheritance
- Objects

1990
- Type theory
- Packages
- Formal semantics

2000
- Architectural chunks
- Formal specifications
Assignments

• For each class on technology maturity study
  > Read 2-3 papers before class
  > Write abstract and summary for one
  > After class, send email to presenter and me with constructive suggestions
  > Expect (often) to read another paper for the other part of class
  > If you have time, write an abstract for this one, too
• By Tuesday (tomorrow) evening
  > Send me your top three literature search techniques, locations, tricks, or whatever