Characterizing Software Engineering Research Strategies

SSSG
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October MMI

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

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

Redwine/Riddle Maturation Model

Software Technology Maturation Points
Newman: Pro Forma Abstracts

- Asked, “To what extent is HCI an engineering discipline?”
- Characterized engineering research products
- Created 3 pro forma abstracts, templates describing research
- 90% of papers in engineering research fit these templates
- Only 25-30% of HCI papers fit
- Created 2 more pro forma abstracts (arguably engineering)
- Now 95% of HCI papers fit
- Notes
  - Preliminary study, e.g., no check on inter-rater reliability
  - Found this a useful device for reading papers

Newman’s Pro Forma Templates for Engineering

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.

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.

ET: Enhanced tool

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.

Additional Pro Forma Templates for HCI & SE

RS: Radical solution

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 or be addressed including list of side effects. Strategies are suggested for addressing these side effects.

XH: Experience and/or Heuristic

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.

ESNA: Existing Solution Applied to New Area [Latronico]

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.

Inter-Rater Reliability

<table>
<thead>
<tr>
<th>Author</th>
<th>EM</th>
<th>RS</th>
<th>ET</th>
<th>XH</th>
<th>ESNA</th>
<th>MT</th>
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Discussd “solution”
Brooks: 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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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, 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?
- **Evaluation/Discrimination**
  - How can I evaluate the quality of X?
  - How do I decide whether X or Y?
- **Product**
  - What is a (better) design for application X?
  - What is a (better) implementation for X?

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Types of Research Results

- **Qualitative & descri. model**
  - Report interesting observations, generalizations
  - Structure a problem area; ask good questions
- **Empirical model**
  - Develop empirical predictive models from observed data
- **Analytic model**
  - Develop structural models that permit formal analysis
- **Notation**
  - Embody model in notation with a calculus, semantics
- **Technique**
  - Invent new ways to do some tasks, including evaluation, implementation, selection from alternatives
- **Tool**
  - Embody technique (development or eval) in useful tool
- **Specific sol’n**
  - Report solution to application problem that shows SE principles – may be design, not implementation
- **System (incl)**
  - Embody result in a system, using the system

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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**
  - Given the facts, here are consequences ...
    - Formal model: Rigorous derivation and proof
    - Empirical model: Data on use in controlled situation
    - Controlled experiment: Carefully designed statistical experiment
- **Experience**
  - Report on use in practice
    - Qualitative model: Narrative
    - Empirical model, tool: Data, usually statistical, on practice
    - Notation, technique: Comparison of systems in actual use
Composable Software Research at Carnegie Mellon

Complete Research Result

- **Real World**
  - Practical problem

- **Research Setting**
  - Idealized problem

- **Research product**
  - (technique, method, model, system, ...)

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

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

Building Blocks for Research

<table>
<thead>
<tr>
<th>Question</th>
<th>Strategy/Result</th>
<th>Validation</th>
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A Common Plan

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<tr>
<td>Can X be better?</td>
<td>Compare Y to X</td>
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<td>Generalization</td>
<td>Prototype tool Y</td>
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A Common, but Bad, Plan

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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

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### 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

- Product (what is better design or implementation?)

#### Result

- Specific solution that embodies the improvements

#### Validation

- Empirical analysis, possibly empirical experience, implementation

### Enhanced Tool

**ET: Enhanced tool**

The effectiveness of model-type / solution strategy in supporting the design of artifact-type has been demonstrated. An enhanced tool / method 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), Tool (emboby results in system), Notation

#### Validation

- Empirical model, empirical model, (Persuasion???)
Radical Solution

RS: Radical solution
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?
- Product (what is better design or implementation?)

Result
- Specific solution, system

Validation
- Implementation, persuasion

Experience and/or Heuristic

XH: Experience and/or Heuristic
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

Pro Forma Abstracts and Research Strategies

Locating the pro forma abstracts in research strategy space

<table>
<thead>
<tr>
<th>Feature</th>
<th>Feas.</th>
<th>Class</th>
<th>Model</th>
<th>Goal</th>
<th>Spec. Soln</th>
<th>System</th>
<th>Magnitude</th>
<th>Purpose</th>
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<tr>
<td>Product / result</td>
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<tr>
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Extended types of results

<table>
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<th>Magnitude</th>
<th>Purpose</th>
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<td>Product / result</td>
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<tr>
<td>Enhanced</td>
<td>Idea (incl desc model)</td>
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Better SW development
Solution for client
Outstanding Tasks

- Model of research result
  - Refine characterizations of problems, results, validations
    - Simplify if at all possible
  - Express as fragments of pro forma abstracts
  - Establish inter-rater reliability
  - Identify combinations that describe good and bad research strategies

- Relation to maturity model
  - Are different strategies appropriate at different stages of maturity?
  - How do sequences of individual results help establish big results?
    - How does credibility of an idea grow?