Empirical Studies of Software Design: Implications for SEEs

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Empirical Research on the Software Process

Individual level
- LIFT experiment
  8 experienced programmers designing the control structure for a set of elevators during an intense 2 hr. session

Team level
- Object server exp.
  Videotaped team meetings from a 7 mo. effort to design and build a tool to support object oriented programming

Project level
- Field study
  Detailed interviews with key members of 18 large development projects to model their decision-making and communication process

Particpant
- Experimentor

Project team
- Customer team
- Observers

Field study team
- Shareholder project member

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Results of the Field Study

- Observations about commonality/difference of projects
- Identification of five areas of organizational breakdown (within that sixteen specific problems)
- Implications for process modeling
- Mapping of problems onto lower-level phenomena

"You need to understand, this project isn't the way we develop software at our company."
## Characteristics of Projects Studied

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<td>✔</td>
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<td>C³, Life Support</td>
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Summary of Results from MCC Field Study*

- Analysis of three significant problems
- Layered behavioral model of software processes
- Conclusions and implications

* Paper appearing in this months CACM
Analysis of Three Significant Problems in Software Design for Large Systems

- Application Knowledge Acquisition
- Fluctuating and Conflicting Requirements
- Communications Breakdowns

Effect on productivity and quality through behavioral processes
Layered Behavioral Model of Software Processes

- Business Milieu
- Company
- Project
- Team
- Individual

Cognition and Motivation
Group Dynamics
Organizational Behavior
Implications of Field Study Results

- For Software Technology
  - Environment support needed for:
    = Knowledge integration
    = Change facilitation
    = Broad communication and coordination
  - Beginnings of an empirical model to measure improvement for a tool/practice

- For Project Management
  - Expertise is the primary determinant, new ways of effectively organizing should be pursued
  - Key role players identified and described:
    superconceptualizer, diagnostician, gatekeeper, boundary spanner
  - Coordination by shared model of process, product

- For Software Process Models
  - Difference between prescriptive and actual processes
  - Current process models do not reflect:
    learning, technical communication, requirements negotiation, and customer interaction
  - Framework for an "ideal" process model emerging

- For Further Empirical Research on Professional Software Engineering
  - Much more to do
  - Focus on "variation" and its effect on the difference in productivity and quality outcomes among people, situations, and their interaction
The Software Project as an Ecological System

**Changing World**
- External Technology

**Project**
- Internal Processes of Interest
  - Assimilation of knowledge
  - Communication and coordination
  - Managing change
  - Issue resolution and decision making
  - Technical design
  - Organizational bureaucracy

**Application Knowledge**

**Specific Needs of Customers**

**Contracting Mechanisms**

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Five Crucial Problem Areas in Large Software Projects*

External Context
- Change & Uncertainty

Project
- Communication
- Technology Transfer
- Design Evolution and Analysis
- Communication and Coordination
- Application Knowledge

* see STP-390-86p

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Overall Conclusion

The Greatest Leverage Is in Supporting the Intersection of:

The Technical Task

- Assessing customer needs
- Assimilating application knowledge
- Negotiating requirements, technology, and resources
- Identifying and exploring design assumptions/alternatives
- Decomposing and recomposing functionality
- Defining and controlling component interfaces

The Management Task

- Strategically managing system features and attributes
- Assessing and controlling risks
- Ensuring developers work from the same models
Results of the "LIFT" Study

- Observations on relative effort distribution
- Observations about individual differences
- Identification of six process breakdowns
- A cognitive model of design problem solving
Information Model of Design Exploration

Problem Models
- essential aspects

Exploration Process
- commitments
- assumptions
- scenarios of use
- test cases
- simulations
- trade-off analysis

Solution Models
- focal points
- issues
- constraints
- evaluation criteria
- discarded alternatives

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Individual Differences in Software Design Strategies

- Domain-Specific Strategies
  - Exemplar driven
  - Method (process) driven
  - Computational paradigm driven
  - Trial and error driven

General computation strategies
Results of the Team Design Study*

- Identification of conflict behavior as key to achieving shared models
- Observations on the limitations of "documents"
- Observation of ombudsman to facilitate communication between customer and design teams
- Observations on the effect of midnight prototype creation
- Videotape identified as history capture mechanism

* being completed at U.T. - D. Walz, 1988
Future SSEs Should Contain Facilities For

1) Focus on Productivity and Quality
   - Statistical QC
   - Reduce waste and redundancy
   - Institutionalized reuse process yields component parts (via standards)

2) Process Engineering
   - Introduction of good practices, tools, etc.
   - Process definition, tailoring, monitoring, analysis, and improvement
   - Embodiment in education programs

3) Process Efficiency through Teamwork and Communication
   - Revocation of Brook’s Law
   - High performance teamwork
   - "Groupware"

4) Flexible Organization Evolution
   - Coordinated technology, policy and organizational structure
     around process management concerns
   - Commitment to improve (facilitation of change)
   - Capture of corporate domain knowledge (via issue-oriented domain analysis)
   - Negotiation-based requirements technology

5) Liveware Support
   - Variety of "experts" (stakeholders)
   - Significant variation in abilities
PUBLICATIONS

Field Study Papers


Team Study Papers


Individual Study Papers


In a study of 38 U.S. and Japanese Companies a wide variety of software management strategies were observed (Cusumano, 1987). It was concluded that Japanese firms are significantly ahead in applying a disciplined and flexible factory approach, as evidenced by:

<table>
<thead>
<tr>
<th>Country</th>
<th>Bugs per 1000 SLOC</th>
<th>Projects late</th>
<th>Reuse</th>
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<tr>
<td>Japan</td>
<td>.26</td>
<td>5%</td>
<td>34%</td>
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<tr>
<td>U.S.</td>
<td>8.3</td>
<td>43%</td>
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