Analysis of Pervasive Multiple-Component Defects in a Large Software System

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One-Minute Message

• A certain type of defects:
  – requires more changes to fix
  – relates to sustained defect-prone components
    • Across system phases and releases

• This talk focuses on a case study of a large-scale system where we identified and characterised this type of defects.
Preliminary Motivation

• From the people dealing with the subject system, **we learnt:**
  – Some defects span phases and releases
  – Some defects require relatively more fixes
  – Some components have sustained defects across phases and releases
Literature Background

• Software defects are not uniform, e.g.,
  – 20% of defects – 60-80% of correction efforts [Ebert et al., 2005]

• System components are not uniform, e.g.,
  – 20% of components – 80% of defects [Boehm and Basili, 2001]
Literature Background

• Software defects are not uniform, e.g.,
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• System components are not uniform, e.g.,
  – 20% of components – 80% of defects [Boehm and Basili, 2001]

• Multiple-Component Defects (MCDs)
  – % of defects that require fixes to multiple components:
    • 5% [Endres, 1975],
    • 11% [Basili and Perricone, 1984],
    • 6-15% [Basili and Shull, 2005],
    • 4-24% [Weiss, 1979]
Research Gap

- The **fix-effort** profile of MCDs
- The **relationship** between MCDs and defect-prone components

Benefit: This can help in improving maintenance processes.
The Case Study

• The Subject System
• The Subject Data
• Research Questions
• Hypotheses
• Findings
• Summary of Findings
• Threats to Validity
• Implications for SW Maintenance
The Subject System

• A complex, large-scale, commercial system
  >20 million physical lines of code
  6 of 9 major releases
  >17 years
  Approx. 275 components

• Focus of study: **In-process defects**
The Subject Data

- MCDs: 8%
- Others: 92%

@Li et al., ICSM 2009
The Subject Data

- If fixing a MCD requires changes in components A, B and C, then these components have a fix-relationship.
The Subject Data

- If fixing a MCD requires changes in components A, B and C, then these components have a fix-relationship.

- A MCD is pervasive (PMCD) if it is related to the top 10% of the most frequently occurring fix-relationships. (*insidious, invasive*)
  - 75% of MCDs involve 10% of fix-relationships
The Subject Data

• In the subject system:

  - PMCDs are the most problematic defects.
  - The case study focuses on PMCDs.

@Li et al., ICSM 2009
Research Questions

1. How do PMCDs differ from other defects?
   • W.r.t. the quantity of fixes

2. How do PMCDs relate to sustained defect-prone components?
   • Defect-prone components are top 20% of the most defective components.
   • “sustained” – across phases and releases.

@Li et al., ICSM 2009
Hypotheses

Hypothesis 1 (Defects): PMCDs, in comparison with other defects, consume more effort to fix.

Hypothesis 2 (Components): Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across phases and releases.
Hypothesis 1

H1 (Defects): PMCDs, in comparison with other defects, consume more effort to fix.

Sub-hypotheses: H1a and H1b.

– H1a: The average number of fixes for PMCDs is greater than that for all defects.

– H1b: The average % of PMCDs crossing phases or releases is greater than that for all defects.
Findings -- Hypothesis 1a

H1a: The average **number of fixes** for PMCDs is greater than that for all defects.

- The average number of fixes for a PMCD is **20-30** times that for a general defect.
- Although PMCDs are **6%** of all defects (75% of MCDs), they require **35-50%** of all fixes.
  - **Insidious!**
Findings -- Hypothesis 1b

H1b: The average % of PMCDs crossing phases or releases is greater than that for all defects.

• The average % of PMCDs crossing phases or releases is 4-7 times that for all defects.
Findings -- Hypothesis 1b

H1b: The average % of PMCDs crossing phases or releases is greater than that for all defects.

- The average % of PMCDs crossing phases or releases is $4-7$ times that for all defects.

Thus, Hypothesis 1 is supported:

H1 (Defects): PMCDs, in comparison with other defects, consume more effort to fix.
Hypothesis 2

- **H2 (Components)**: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across phases and releases.
Hypothesis 2

Sub-hypotheses: H2a and H2b.

• H2a: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across one phase or release.
Hypothesis 2

Sub-hypotheses: H2a and H2b.

• H2a: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across **one** phase or release.

• H2b: The **persistence** of defect-prone components containing PMCDs is relatively stronger across **multiple** releases.
H2a: Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across one phase or release.

\[
\frac{\% \text{Defect-prone components containing PMCDs}}{\% \text{Defect-prone components containing no PMCDs}} : \text{Approx. 3 times}
\]
Findings – Hypothesis 2b

H2b: The persistence of defect-prone components containing PMCDs is relatively stronger across multiple releases.

\[
\frac{\% \text{Defect-prone components containing PMCDs}}{\% \text{Defect-prone components containing no PMCDs}} : \text{Approx. 3 times}
\]
Findings – Hypothesis 2

% Defect-prone components containing PMCDs
\[ \frac{\% \text{Defect-prone components containing PMCDs}}{\% \text{Defect-prone components containing no PMCDs}} : \text{Approx. 3 times} \]

Across:
- 1 phase or release
- 2, 3, or 4 releases

Thus, Hypothesis 2 is supported:
- H2 (Components): Defect-prone components containing PMCDs are relatively more likely to remain defect-prone across phases and releases.
Summary of Findings

1. How do PMCDs differ from other defects?
   - PMCDs consume more effort to fix, e.g.,
     - The average number of fixes for PMCDs is 20-30 times that for all defects.

@Li et al., ICSM 2009
Summary of Findings

1. How do PMCDs differ from other defects?
   • PMCDs consume more effort to fix, e.g.,
     – The average number of fixes for PMCDs is 20-30 times that for all defects.

2. How do PMCDs relate to defect-prone components?
   • PMCDs relate to sustained defect-prone components, e.g.,
     – Over 70% of defect-prone components containing PMCDs remain defect-prone across phases and releases (2-4).

@Li et al., ICSM 2009
Threats to Validity

Data noise:

• Only 80% of defect logs **explicitly** specify fix-relationships.
  • Legacy, large system data logs

• It was not possible to exclude the rest **20%** from the dataset.
  • Natural language data, etc.
Implications for SW Maintenance

- Separating **Pervasive MCDs** from **MCDs** can help focus special attention on these *hard-to-fix* defects.

- Identifying the **persistence** of defect-prone components may help in defect correction and prevention.

- The findings may also help in:
  - advancing the quality of software systems
  - reducing maintenance costs
  - improving customer or end-user satisfaction

@Li et al., ICSM 2009
Conclusion & Future Work

• We conducted a case study on a large system.

**PMCDs are defects that:**
- Require more fixes
- Relate to **sustained defect-prone** components

• Future work:
  - Comparing MCDs to PMCDs
  - Investigating techniques to reduce data noise
  - Study replication in other domains
Q & A