Predicting Fault-Prone Modules Based on Metrics Transitions

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Outline

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- Preliminaries
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  - Version Control System
- Proposal
  - Predict fault-prone modules
- Case Study
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Background

- It is becoming more and more difficult for developers to devote their energies to all modules of a developing system
  - Larger and more complex
  - Faster time to market
- It is important to identify modules that hinder software development and maintenance, and we should concentrate on such modules
  - Manual identification requires much costs depending on the size of the target software

Automatic identification is essential for efficient software development and maintenance

Preliminaries -Software Metrics-

- Measures for evaluating various attributes of software
- There are many software metrics

- CK metrics suite is one of the most widely used metrics
  - CK metrics suite evaluates complexities of OO systems from
    - Inheritance (DIT, NOC)
    - Coupling between classes (RFC, CBO)
    - Complexity within each class (WMC, LCOM)
  - CK metrics suite is a good indicator to predict fault-prone classes[1]

[1] V. R. Basili, L. C. Briand, and W. L. Melo. A Validation of Object-Oriented Design Metrics as Quality Indicators. IEEE Transactions on Software Engineering, 22(10):751–761, Oct 1996.

Preliminaries -Version Control System-

- Tool for efficiently developing and maintaining software systems with many other developers
- Every developer
  1. gets a copy of the software from the repository (checkout)
  2. modifies the copy
  3. sends the modified copy to the repository (commit)
- The repository contains various data
  - Modified code of every commitment
  - Developer names of every commitment
  - Commitment time of every commitment
  - Log messages of every commitment

Motivation

- Software Metrics evaluate the latest (or the past) software product
  - They represent the states of the software at the version
- How the software evolved is an important attribute of the software

Motivation -example-

- In the latest version, the complexity of a certain module is high
  - The complexity of the module is stable at high through multiple versions?
  - The complexity is getting higher according to development progress?
  - The complexity is up and down through the development?

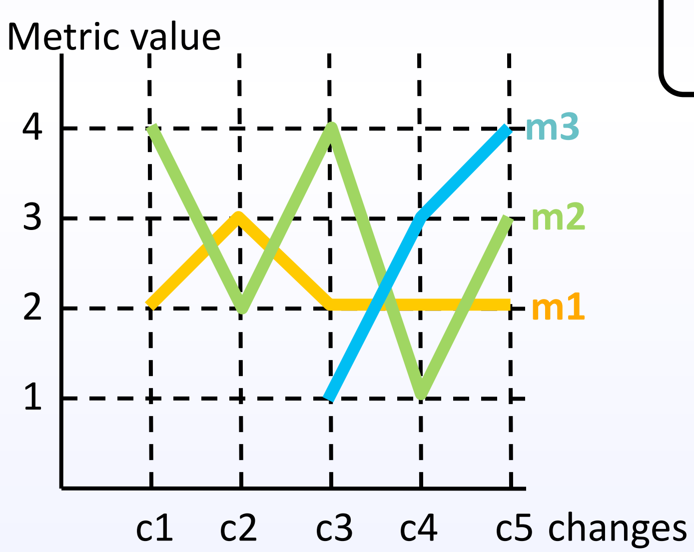
- The stability of metrics is an indicator of maintainability
  - If the complexity is stable, the module may not be problematic
  - If the complexity is unstable, big changes may be added repeatedly

Proposal: Metrics Constancy

- Metrics Constancy (MC) is proposed for identifying problematic modules
  - MC evaluates the changeability of the metrics of each module
- MC is calculated using the following statistical tools
  - Entropy
  - Normalized Entropy
  - Quartile Deviation
  - Quartile Dispersion Coefficient
  - Hamming Distance
  - Euclidean Distance
  - Mahalanobis Distance

Entropy

- An indicator to represent the degree of uncertainty
- Given that MC is uncertainty of metrics, Entropy can be used as a measure of MC



$$H = -\sum p_i \log p_i$$ (p_i is probability)

m1: 5 changes, value 2: 4 times, value 3: 1 time

$$H = -(\tfrac{4}{5}\log\tfrac{4}{5} + \tfrac{1}{5}\log\tfrac{1}{5}) \fallingdotseq 0.72$$

m2: 5 changes, value 1,2,3: 1 time, value4: 2 times

$$H = -(3\times\tfrac{1}{5}\log\tfrac{1}{5} + \tfrac{2}{5}\log\tfrac{2}{5}) \fallingdotseq 1.9$$

m3: 3 changes, value 1,3,4: 1 time

$$H = -(3\times\tfrac{1}{3}\log\tfrac{1}{3}) \fallingdotseq 1.6$$

Calculating MC from Entropy

- MC of module *i* is calculated using the following formula

$$MC(i) = \sum_{MT} H$$

  – *MT* is a set of used metrics

- The more unstable the metrics of module *i* are, the greater *MC(i)* is

Procedure for calculating MC

- STEP1: Retrieves snapshots
  - A snapshot is a set of source files just after at least one source file in the repository was updated by a commitment
- STEP2: Measures metrics from all of the snapshots
  - It is necessary to select appropriate software metrics fitting for the purpose
    - If the unit of modules is class, class metrics should be used
    - If we focus on the coupling/cohesion of the target software, coupling/cohesion metrics should be used
- STEP3: Calculates MC
  - Currently, the 7 MCs are calculated

Case Study: Outline

- Target: open source software written in Java
  - FreeMind, JHotDraw, HelpSetMaker
- Module: class (≒ source file)
- Used Metrics: CK Metrics, LOC

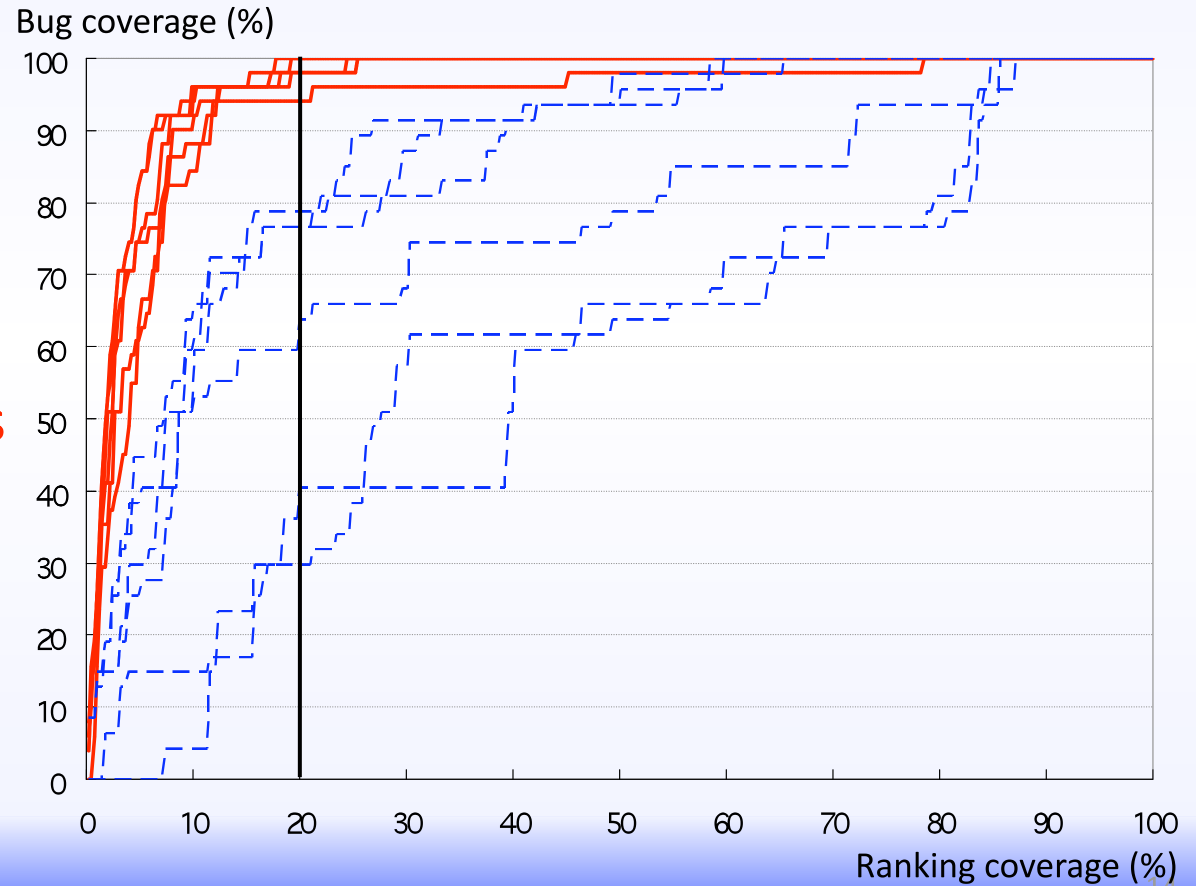
Software	FreeMind	JHotDraw	HelpSetMaker
# of Developers	12	24	2
# of snapshots	104	196	260
First commit time	01/Aug/2000 19:56:09	12/Oct/2000 14:57:10	20/Oct/2003 13:05:47
Last commit time	06/Feb/2004 06:04:25	25/Apr/2005 22:35:57	07/Jan/2006 15:08:41
# first source files	67	144	14
# last source files	80	484	36
First total LOC	3,882	12,781	797
Last total LOC	14,076	60,430	9,167

Case Study: Procedure

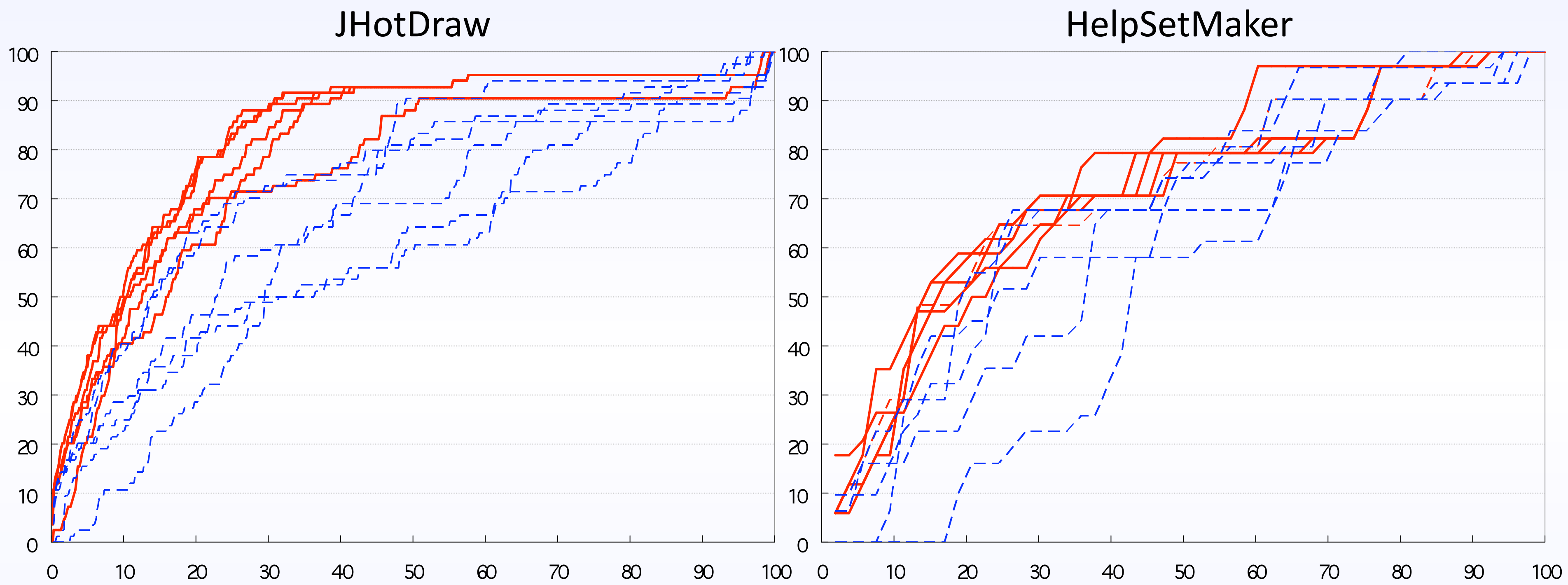
1. Divides snapshots into anterior set (1/3) and posterior set (2/3)
2. Calculates MCs from the anterior set
   – Metrics of the last version in the anterior set were used for comparison
3. Identifies bug fixes from the posterior set
   – Commitments including both ``bug'' and ``fix'' in their log messages were regarded as bug fixes
4. Sorts the target classes in the order of MCs and raw metrics values
   – Also, bug coverage is calculated based on the orders

Case Study: Results (FreeMind)

- MCs could identify fault-prone classes more precisely than raw metrics
  - RED: MCs
  - BLUE: raw metrics
- At top 20% files
  - MCs: 94-100% bugs
  - Raw: 30-80% bugs



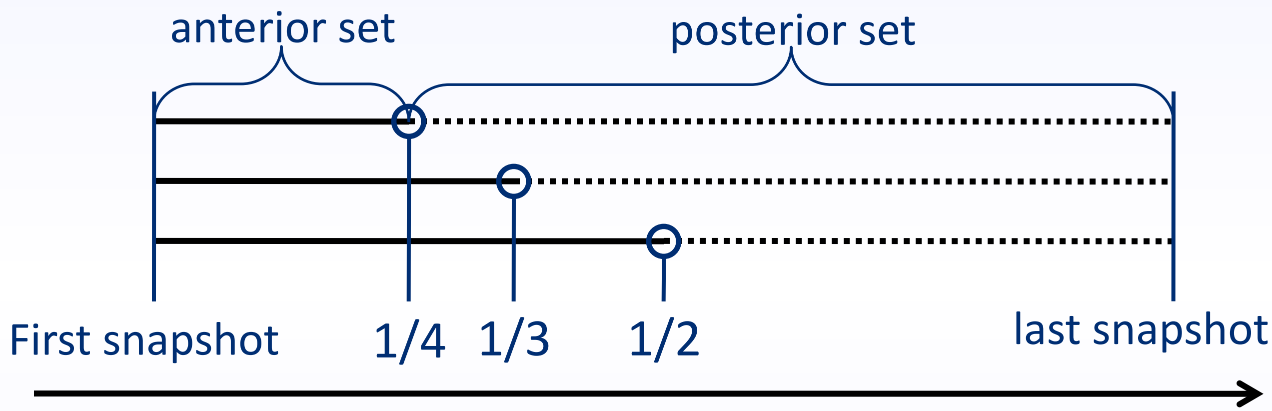
Case Study: Results (Other software)



- For all of the 3 software, MCs could identify fault-prone classes more precisely than raw metrics

Case study: different breakpoints

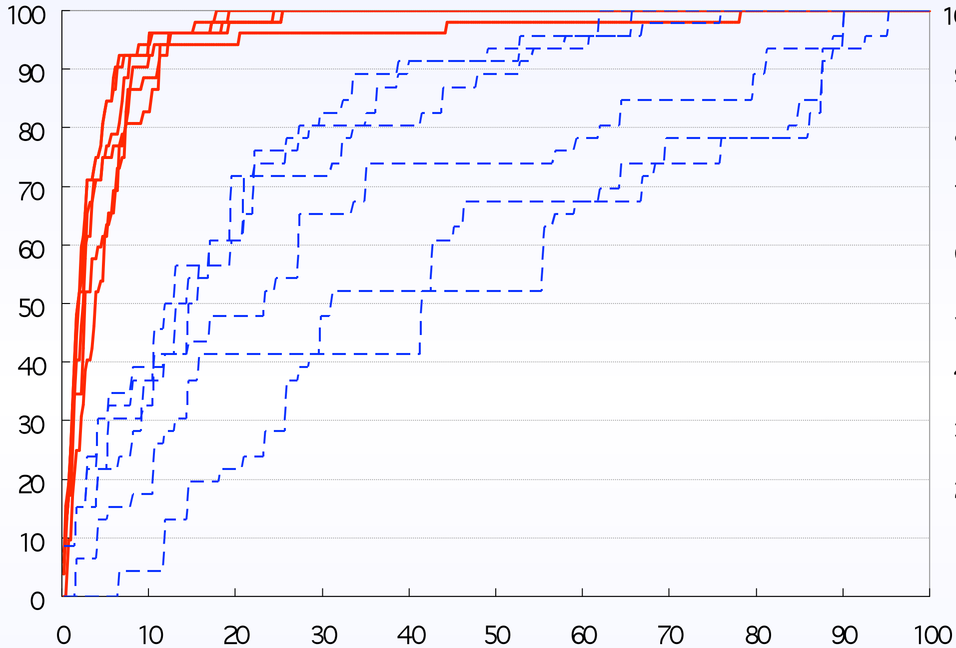
- In this case study, we used 3 breakpoints
  - 1/4, 1/3, 1/2



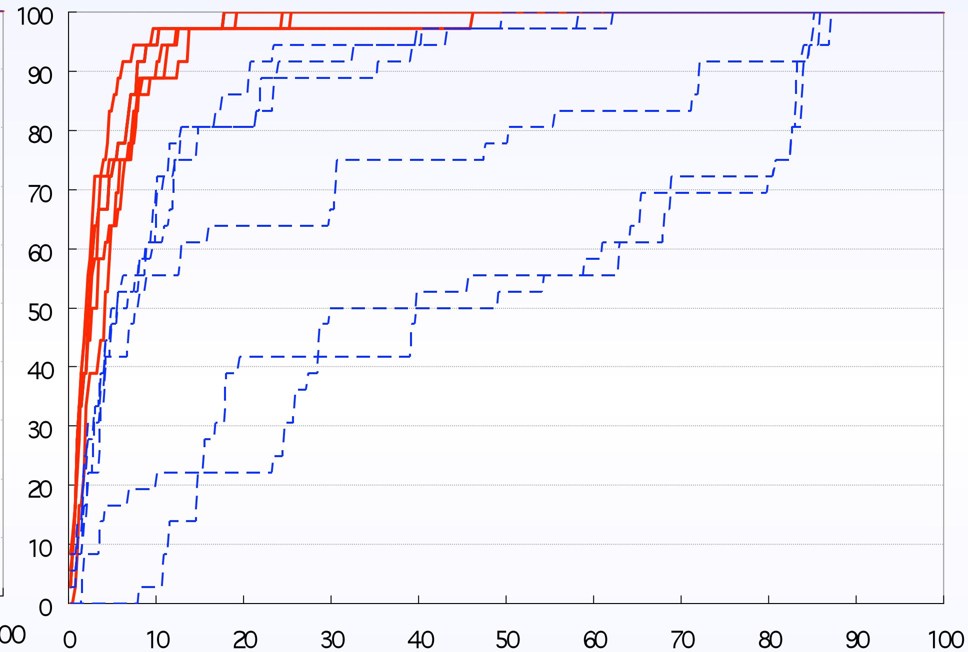
- The previous graphs are the results in case that anterior set is 1/3

Case study: Results (different breakpoints)

FreeMind: anterior ¼, posterior ¾



FreeMind: anterior ½, posterior ½



- MC’s identifications are good on all of the breakpoints

Case study: Results (different breakpoints)

Top 20% files bug coverage, FreeMind

	1/4	1/3	1/2
MCs	94-100%	94-100%	97-100%
Raw metrics	22-72%	30-80%	22-86%

- MC's bug coverage is very high for all of the breakpoints
- Raw metrics are not suited for predicting far future

Discussion

- MCs are good indicators for identifying fault-prone modules as well as CK metrics
  - FreeMind
    - MCs: 95-100% bugs
    - Raw: 30-80% bugs
  - JHotDraw
    - MCs: 44-59% bugs
    - Raw: 10-48% bugs
  - HelpSetMaker
    - MCs: 60-75% bugs
    - Raw: 28-63% bugs

- Calculating MCs required much more time than measuring raw metrics from a single version
  - FreeMind
    - MCs: 28 minutes
    - Raw: 1 minute
  - JHotDraw
    - MCs: 40 minutes
    - Raw: 1 minutes
  - HelpSetMaker
    - MCs: 18 minutes
    - Raw: 1 minutes

Conclusion

- Metrics Constancy (MC), which is an indicator for predicting problematic modules, was proposed
- MCs were compared with raw CK metrics
  - The case study showed that MCs could identify fault-prone modules more precisely than raw CK metrics
- In the future, we are going to
  - conduct more case studies on software written in other programming languages (e.g., C++, C#)
  - compare MCs with other identification methods