Automated Software Fault Measurement

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The work described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology. This work is sponsored by the National Aeronautics and Space Administration’s Office of Safety and Mission Assurance under the NASA Software Program led by the NASA Software IV&V Facility. This activity is managed locally at JPL through the Assurance Technology Program Office (ATPO).
Agenda

- Motivation
- Current State of Affairs
- Approach
  - Examples
- Identifying and Counting Faults
  - Examples
- Current Work
One goal of current work is to improve understanding of the type of faults that are inserted into a software system during its lifetime by identifying relationships between types of structural change and the number and types of faults inserted.

Developing software fault models depends on definition of what constitutes a fault.

Desired characteristics of measurements, measurement process:
- Repeatable, accurate count of faults
- Measure at same level at which structural measurements are taken
  - Measure at module level (e.g., function, method)
- Easily automated
Motivation (cont’d)

Measurement of Structural Evolution

Darwin Portal

Graph of Code Churn and Code Delta for the project fdms_mdsv5_cvs.

Click here for help
Motivation (cont’d)
Structural Evolution at the Module Level

(Non-zero) Modules for build 2001-08-09 of project mdsv5_cvs, sorted by Churn since baseline.

- test2a()
- ParseListEstimatorTraits::Thread: predictState() Parameter: getTypeFromStringNoNS(const std::string &)
- Parameter: getTypeFromString(const std::string &)
- Interval::TestIntervalValue() mdomain(const char* const char* arg[])
- TestDiscrete::TestDiscrete() examples()
- TestViewFinder::runTests()
- SimpleNormalPositionEstimatorTraits::Thread: processMeasurement() PositionEstimateFunction* Test(Dispatcher, const std::string & key, const CGIArgs & arg)
- AirDragModel::ParameterEstimatorTraits::Thread: predictState() Server::getNextRequest() FileReaderHandler::start(Dispatcher, const string & key, const CGIArgs & arg)
- GreaseFilterTest(Dispatcher, const std::string & key, const CGIArgs & arg)
- OTService::svq(void)
- AttributeSetter::setB(const std::string & name & value String)
- LengthTest(Dispatcher, const std::string & key, const CGIArgs & arg)
- CarExampleMain(int argc, char* argv[], CppUnit::TestSuite & arg)
Motivation (cont’d)
Measurement Framework

- Extract Repaired Source Files
  - Problem Reports
  - Identify Source Files
  - Repaired File IDs
  - Repaired Source Files
  - Compare Repairs to Faulty Files
  - Fault Regions

- Extract Faulty Source Files
  - Fault Identification and Counting
  - Faulty Source Files
  - Find Initial Fault Occurrence
  - Initial Fault Placement
  - Add fault placement to repository

- Extract changed source files
  - OM Library
  - Most recently changed source files
  - Raw structural measurements
  - Add structural measurements to repository

- Compute fault index
  - Measurement Baseline
  - Fault Indices
  - Place fault indices into repository
  - module name, revision number, structural measurements

- Compute Proportional Fault Burden
  - module names, revision numbers, fault indices

- Develop fault content regression model
  - Compute absolute fault burden
  - Absolute Fault Burden

- Compute fault index
  - module name, revision number, fault index

- Compute fault burden
  - module names, revision numbers, fault indices
Current State of Affairs

- No existing definition of fault in measurable terms
  - IEEE Standards
  - ODC
  - Previous work (Annual Oregon Workshop on Software Metrics, May 11-13, 1997)
  - Frankl, Hamlet, Littlewood, Stringini (IEEE TSE, vol. 24, no. 8, August 1998)
Approach

- Examine changes made in response to reported failures
- Base recognition/enumeration of software faults on the grammar of the software system’s language
  - Faults found in executable, non-executable statements
- Fault measurement granularity in terms of tokens that have changed
Examples

Example 1

- Original statement: \( a = b + c \times d; \)
- Intended statement: \( a = b + c \div d; \)
- One token changed – "\( \times \)" \( \Rightarrow \) "\( \div \)"
  ✤ Coding error
- Count number of faults as 1
Examples (cont’d)

Example 2
- Original statement: \( a = b + c \times d; \)
- Intended statement: \( a = b + (c \times x) + \sin(z); \)
- Substantial difference between first and second statements
  ✤ Reflects design rather than coding problem
- Fault measurement method should reflect the degree of change
Identifying and Counting Faults

- Consider each line of text in each version of the program as a bag of tokens
  - If a change spans multiple lines of code, all lines for the change are included in the same bag
- Number of faults based on bag differences between
  - Version of program exhibiting failures
  - Version of program modified in response to failures
- Use version control system to distinguish between
  - Changes due to repair and
  - Changes due to functionality enhancements and other non-repair changes
Fault Identification Examples

Example 1

- Original statement: \( a = b + c \);
  \( B_1 = \{<a>, <\rightarrow>, <b>, <+>, <c>\} \)
- Modified statement: \( a = b - c \);
  \( B_2 = \{<a>, <\rightarrow>, <b>, <\rightarrow>, <c>\} \)
- \( B_1 - B_2 = \{<+>, <\rightarrow> \} \)
- \( |B_1| = |B_2|, |B_1 - B_2| = 2 \)
- One token has changed \( \Rightarrow 1 \) fault
Fault Identification Examples (cont’d)

Example 2

- Original statement: a = b - c;
  - $B_2 = \{<a>, \langle=\rangle, <b>, \langle->, <c>\}$
- Modified statement: a = c - b;
  - $B_3 = \{<a>, \langle=\rangle, <c>, \langle->, <b>\}$
- $B_2 - B_3 = \{\}$
- $|B_2| = |B_3|$, $|B_2 - B_3| = 0$
- 1 fault representing incorrect sequencing
Fault Identification Examples (cont’d)

Example 3

- Original statement: \( a = b - c; \)
  \( B_3 = \{<a>, <\rightarrow>, <c>, <\rightarrow>, <b>\} \)
- Modified statement: \( a = 1 + c - b; \)
  \( B_4 = \{<a>, <\rightarrow>, <1>, <\rightarrow>, <c>, <\rightarrow>, <b>\} \)
- \( B_3 - B_4 = \{<1>, <\rightarrow>\} \)
- \( |B_3| = 6, |B_4| = 8, |B_4| - |B_3| = 2 \)
- 2 new tokens representing 2 faults
Current Work

- Current Work
  - Application to JPL software development effort
    - Research
    - Production
  - Develop better models relating
    - Structural measurements of software evolution during development
    - Number and types of faults inserted