Maximising the Information Gained From an Experimental Analysis of Code Inspection and Static Analysis for Concurrent Java Components

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Background and Related Work

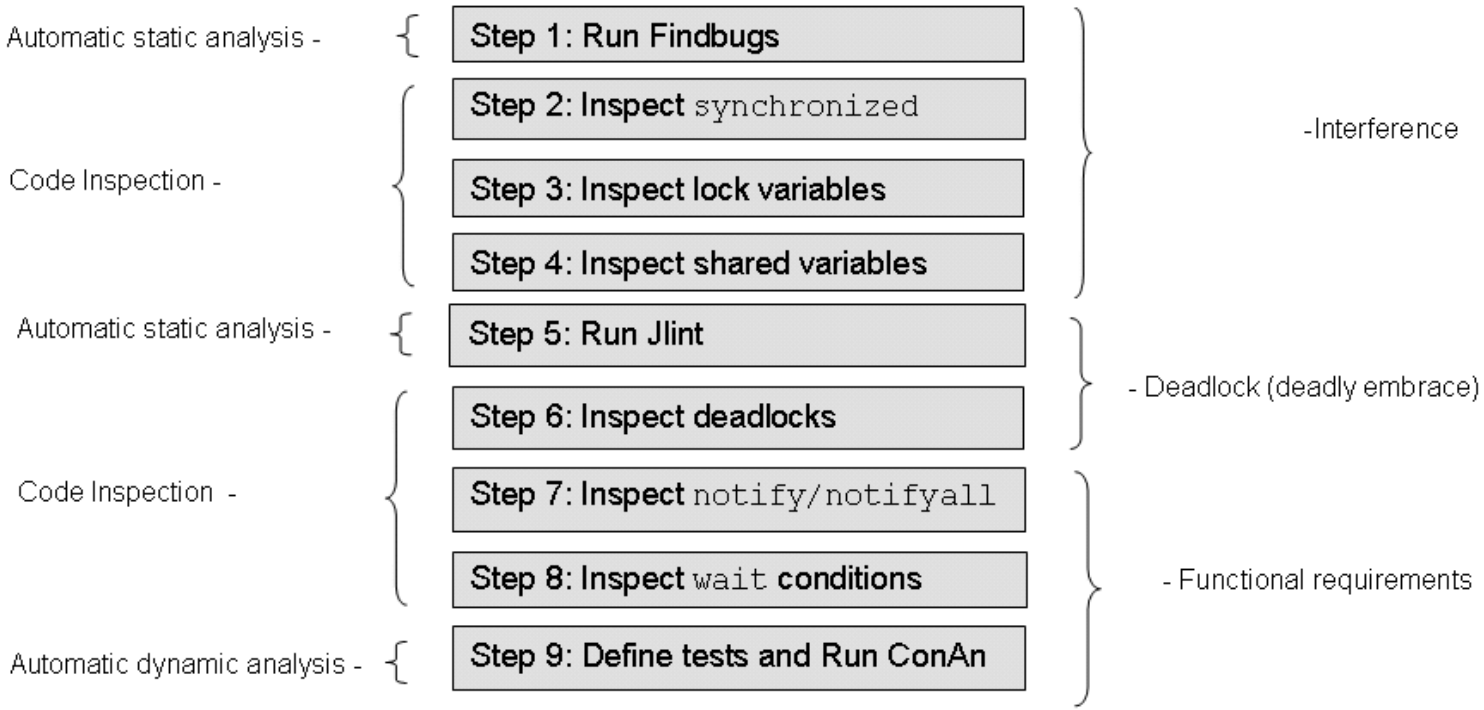
Verification and Validation

- Verification
  - does a computer program conform to its specification?
- Validation
  - does a computer program meet the requirements of the client?
- Verification and Validation (V&V):
  - dynamic
  - static
- Focus on V&V of components

Concurrent Components

- Concurrent components
  - two or more processes cooperate in performing a task
- Specific concurrent component defects
- Concurrent components are non-deterministic
- V&V technology is diverse

TestCon (Java)



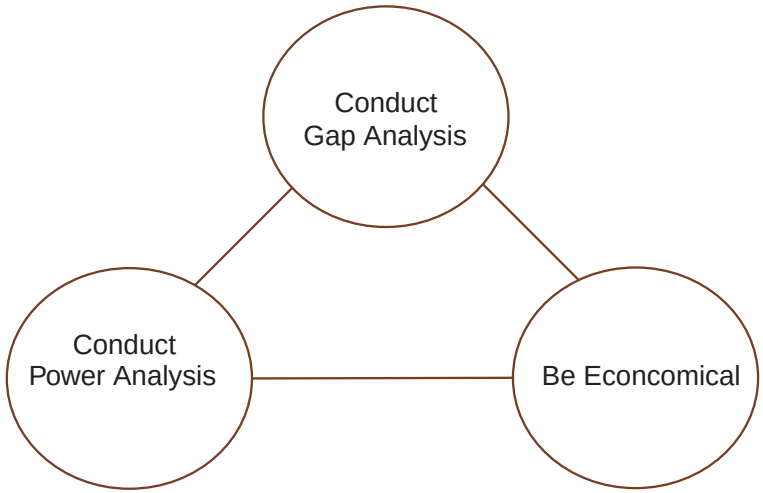
Related Studies

- Comparison (Basili & Selby, Kamsties & Lott) and combination (Selby and Wood et al.)
- Automated static analysis tools evaluated as predictors of field failures
- Empirical Research of V&V in Concurrency:
  - TestCon method & Java PathFinder
  - Other:
    - Constrained Specification Based Testing
    - Atomizer
    - deadlock detection methods for Ada programs

Maximising Strategy

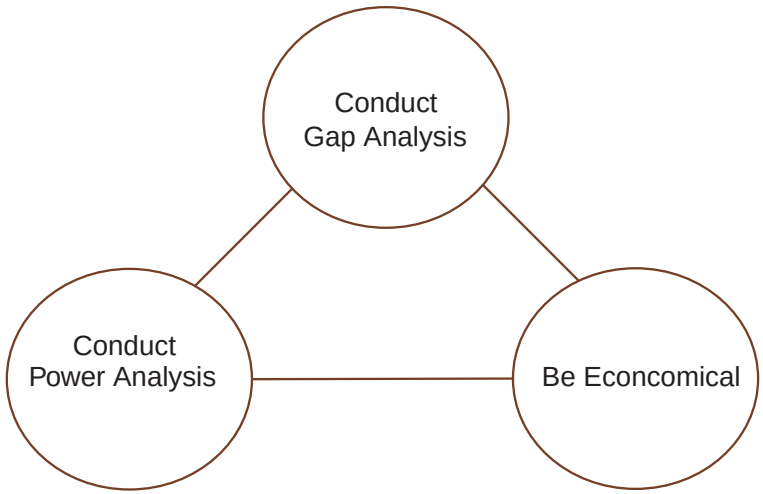
Gap Analysis

- Individual studies cannot produce generalisable results
  - Systematic literature review
  - Replication (close or differentiated)
  - Families of experiments (Basili et al.)



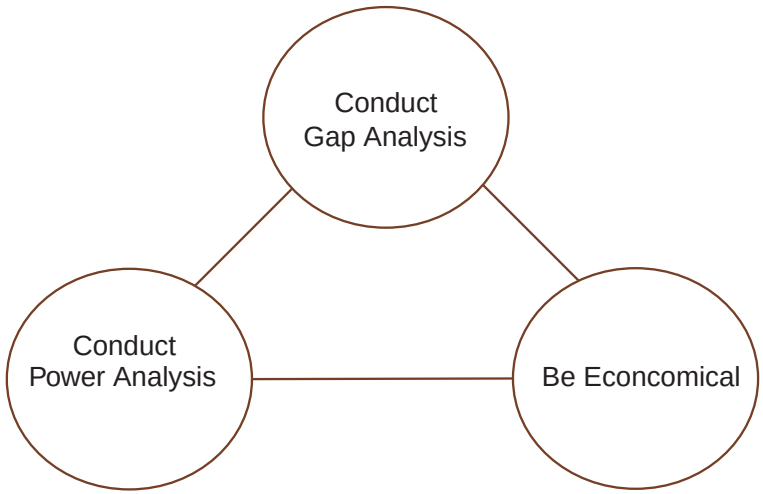
Power Analysis

- Balance Type II vs Type I errors
  - choose an appropriate α for your study (α> 0.05)
  - exploratory study requires higher power (correctly rejecting H_0)
- Use Cohen's sample size tables to determine number of participants
  - Information required: design, α, power and effect size



Being Economical

- Choose most economical experimental design (1-Way vs 2-Way ANOVA)
- Reuse experimental constructs
  - data collection forms
  - metrics (example: motivation)
  - benchmarks



The Experiment - Preparation

Goals, Hypothesis & Metrics

- Evaluating TestCon and combination of code inspection with automated static analysis
- Hypotheses

I. Cost-effectiveness improvement in terms of:

A. effectiveness (percentage of defects detected)
B. effectiveness (percentage of false positives detected)
C. efficiency (defects detected per hour)

II. Motivation and self-perceived mastery of the V&V technology vs effectiveness

Design & Power Analysis

- Design: 2-Way ANOVA
- Main effects: TestCon and Automated Static Analysis Tools
- Power analysis:
  - Cohens effect-size = 0.80
  - ANOVA with F-test (α=0.10 and Power =0.80)
  - minimum sample size is 4 per group

	TestCon - No	TestCon - Yes
Tools - No	(T1) Ad-hoc code inspection and code walkthrough	(T2) TestCon code inspection
Tools - Yes	(T3) Automated static analysis tools	(T4) TestCon and automated static analysis tools

Subjects & Objects

- Components and defects:
  - 4 concurrent components (Java)
  - 8 seeded and 2 prior defects
  - 6 of the 10 defects reported by the automated static analysis tools
  - 4 of the 10 defects only detectable by inspection of the code
- 16 COMP3402 students (90 min session):
  - training (15 minutes)
  - defect detection (60 minutes)
  - debriefing

Data Collection

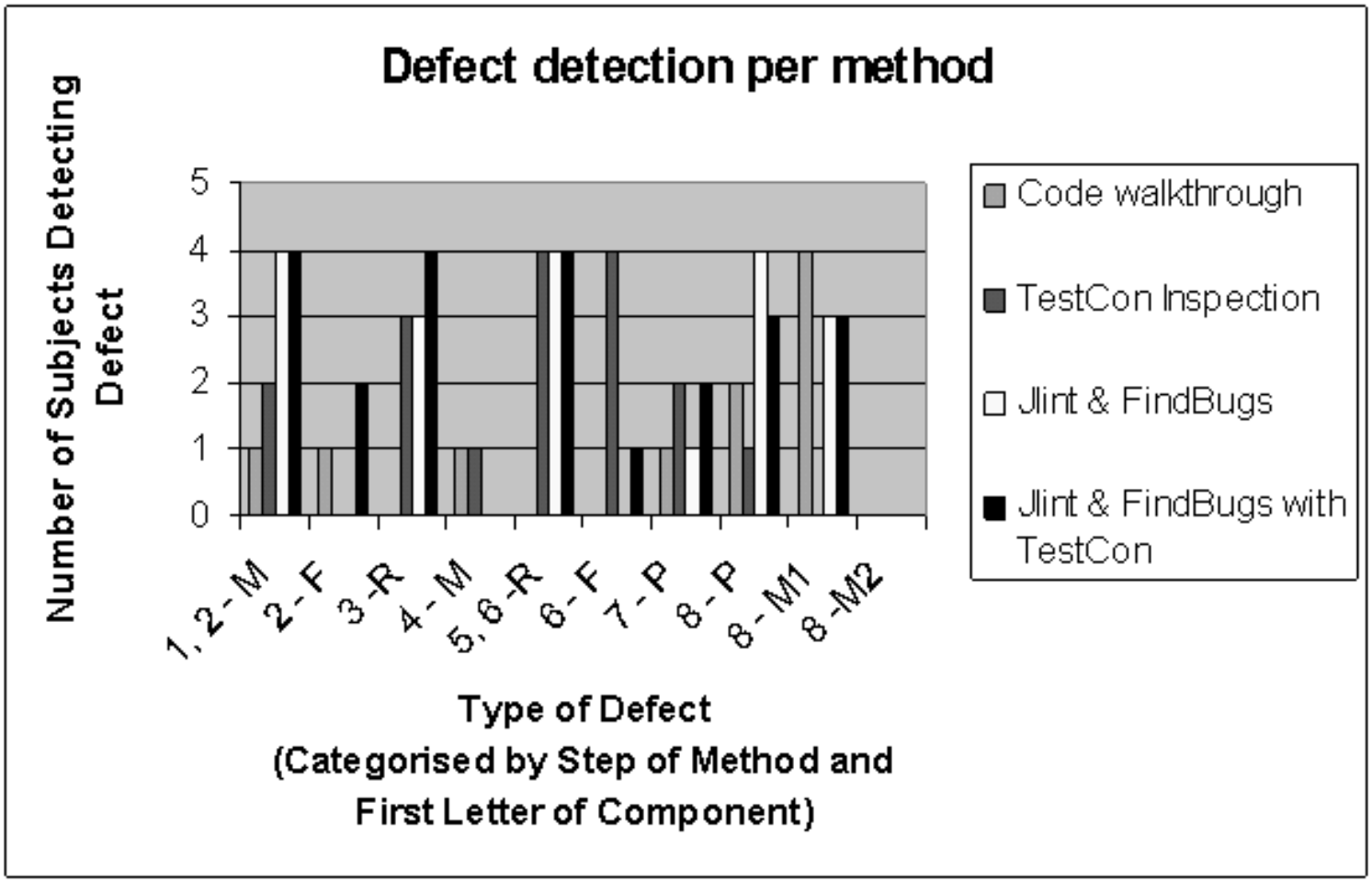
- Templates from Kamsties & Lott experimental package:
  - ☐ Information sheet prior to application of V&V technology
  - ☐ Defect detection report:
    - defects
    - time of detection
    - duration of TestCon step (if applicable)
  - ☐ Experimenter records time to apply V&V
  - ☐ After V&V appilcation participants report on:
    - perceived mastery
    - process conformance
    - motivation

The Experiment - Execution and Analysis

Execution

- Sample:
  - average of 3 years experience with Java
  - average of 4 courses with Java
  - no prior use of automated static analysis tools
- Preparation:
  - random assignment to one of four treatment groups
  - training (15 minutes)
  - overview of component interfaces (familiarisation prior to defect detection)

Analysis & Interpretation



I.A. Defect detection effectiveness

- Automated Static Analysis tools improve effectiveness of defect detection in terms of percentage of defects detected ($p<0.10$)

	TOOLUSED-N	TOOLUSED-Y	ROWS
TESTCON-N	.250 (.1732)	.450 (.1000)	.350 (.1690)
TESTCON-Y	.425 (.1500)	.550 (.2646)	.488 (.2100)
COLUMNS	.338 (.1768)	.500 (.1927)	.419 (.1974)

I.B. Defect detection effectiveness

- Both automated static analysis tools and TestCon improve the effectiveness of defect detection in terms of false positives detected ($p<0.10$)

	TOOLUSED-N	TOOLUSED-Y	ROWS
TESTCON-N	.7056 (.12620)	.3215 (.14232)	.5090 (.24423)
TESTCON-Y	.4214 (.22820)	.2468 (.13605)	.3341 (.19906)
COLUMNS	.5635 (.22849)	.2797 (.24423)	.4216 (.23342)

I.C. Defect detection efficiency

- Both automated static analysis tools and TestCon do not significantly improve the efficiency of defect detection

	TOOLUSED-N	TOOLUSED-Y	ROWS
TESTCON-N	3.6223 (2.93185)	7.1497 (2.65839)	5.3860 (3.20432)
TESTCON-Y	5.3034 (1.89792)	6.0953 (2.27549)	5.6994 (1.98545)
COLUMNS	4.4628 (2.45666)	6.6225 (2.35912)	5.5427 (2.58019)

Time of TestCon Steps

- Descriptive statistics of the mean time (std. dev.) in minutes of steps in the TestCon treatments
- Steps 6-8 take less time with tools.

Steps/Treatments	Step 2	Step 6	Step 7	Step 8
Treatment 2	3.19 (2.12)	3.37 (2.50)	4.83 (5.35)	4 (4.36)
Treatment 4	3.35 (1.68)	2.17 (0.99)	2.69 (1.46)	2.06 (1.01)

II. Correlation Testing

- Using Spearman rank-correlation test for ordinal values
- No correlation between motivation (r=0.344) and effectiveness
- No correlation for self-perceived mastery of V&V technology (r=0.059 Jlint and r=0.111 FB) and effectiveness

Threats to Validity and Conclusions

Threats to Validity

- Internal:
  - convenience sample (motivation did not influence performance) (-)
  - examination-like environment (-)
  - consistent training (+)
- External:
  - not random sample of software engineers (-)
  - small components (-)
  - limit of 60 minutes (-/+)
  - defects ensure that TestCon was evaluated (+)

Threats to Validity

- Conclusion:
  - percentage of defects and false positives and time repeatable and have high validity (+)
  - motivation and perceived mastery of the V&V technology do not have high validity (recorded after application like K&L) (-/+)
- Construct:
  - effectiveness and efficiency are common measures in evaluation of V&V technology (+)
  - motivation and perceived mastery have been used in prior studies (+)

Conclusions

- Automated static analysis tools
  - Improve defect detection effectiveness (percentage of defects detected)
  - Speed up TestCon
  - participants may become overly dependent on tools
- TestCon and Automated Static Analysis tools
  - Improve defect detection effectiveness by reducing the amount of false positives detected
  - Inform practitioner
  - Efficiency not improved, possibly due to size of components

Discussion of Maximising Strategy and Conclusion

Maximising Strategy - Advantages

- Study is not performed in isolation
  - context of past and future related studies
- Guide research and encourage replication
  - overcome threats to validity of past studies
- Information and analysis gained despite small size of study
  - dependence on tools can occur despite process conformance
  - effectiveness is improved with respect to false positives
- Effect size for percentage of defects detected that were false positives was accurate

Maximising Strategy - Drawbacks

- Lower statistical significance
- Effect size for percentage of defects detected was actually smaller than expected (more subjects required for future studies with the same significance)
- Limited generalisation
- Possible effects on results (efficiency)

Conclusion

- Empirical studies are costly therefore maximising information gained is important
- Maximise information gained through:
  - gap analysis
  - power analysis
  - being economical (reducing preparation and execution costs)
- Study supports combination of V&V technologies for concurrent components with empirical evidence
- Overcome limitations of single study to encourage empiricism in new contexts

Questions & Answers