Design Pattern Decay

A Study of Design Pattern Grime and Its Impact on Quality and Technical Debt

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MONTANA STATE UNIVERSITY

Gianforte School of Computing

Technical Debt

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2012 - CAST Research Group Findings

In an analysis of 745 applications comprising 365 MLOC, on average, there is **$3.61 of Technical Debt per LOC**

Technical Debt

Definition

"In software intensive systems, technical debt–is a design or implementation construct that is expedient in the short term, but sets up a technical context that can make a future change more costly or impossible. Technical debt is a contingent liability whose impact is limited to internal system qualities, primarily maintainability and evolvability"[a]

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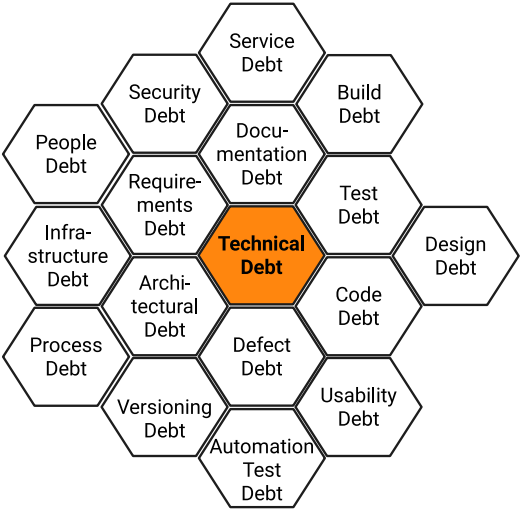
- **Principal** - The effort required to refactor the software and remove the debt.
- **Interest** - The increase in development effort caused by debt affected components which have yet to be refactored.

Technical Debt



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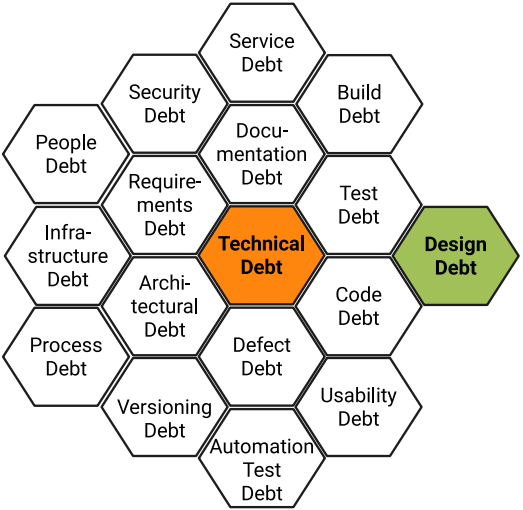

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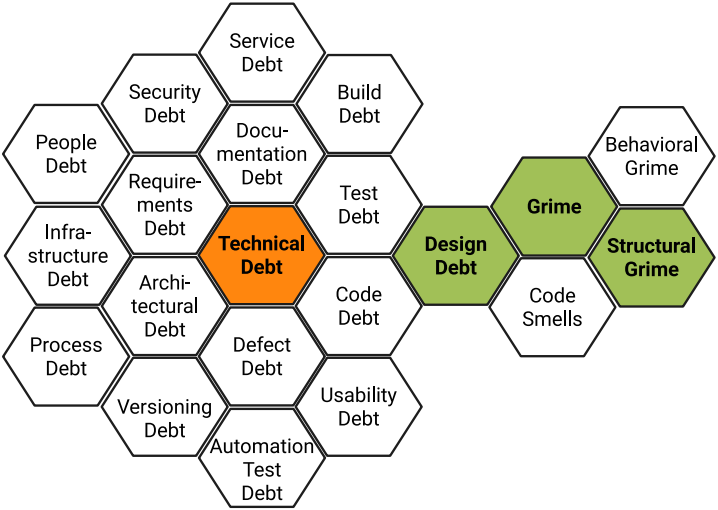

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- **Behavioral Grime** - Reimanis and Izurieta
  - Buildup of errant behavioral elements within a pattern instance (i.e. *Excessive Actions* or *Improper Order of Sequences*)

Problem Statement

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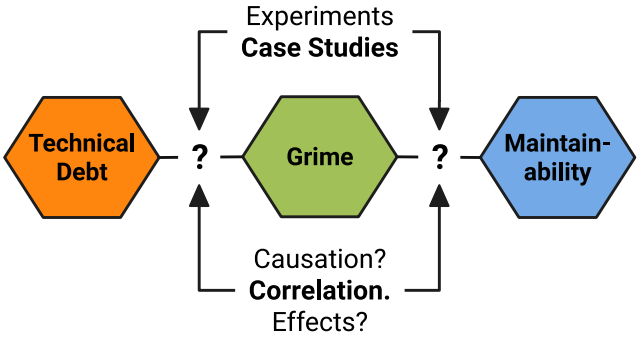

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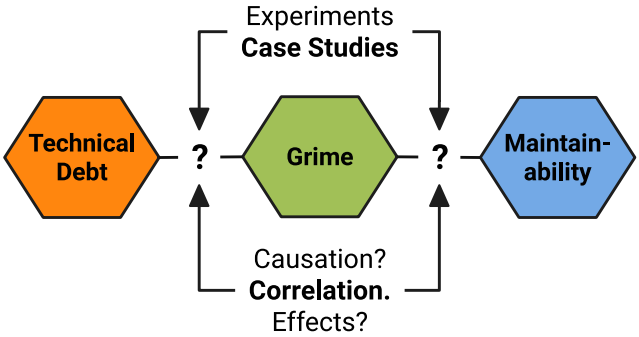

What is the nature of the relationships between structural design pattern grime, software maintainability, and technical debt measurement?

Design Science

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- **Knowledge Questions:** “do not call for a change but ask for knowledge about the world as it is”
  - Result in a proposition
  - Addressed by following an *empirical cycle*

Phase 01 - Extending Grime Taxonomies

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- **RQ1.2:** What are the types of Organizational Grime?

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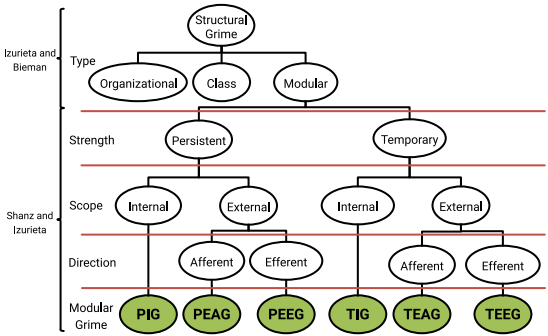

Class Grime

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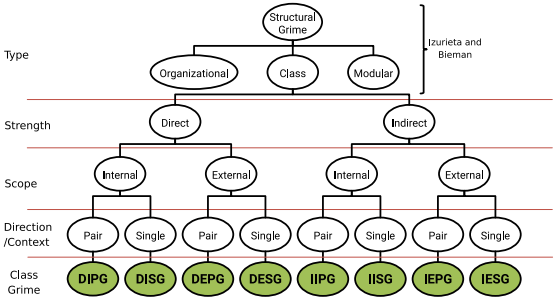

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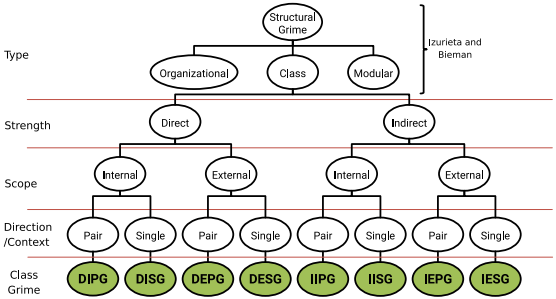

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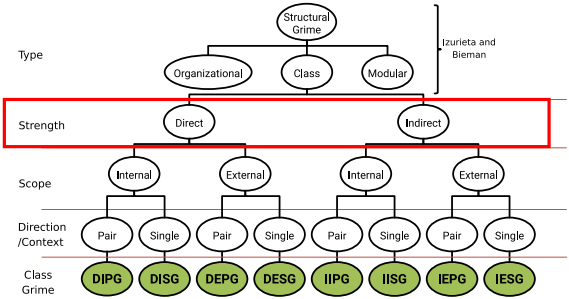

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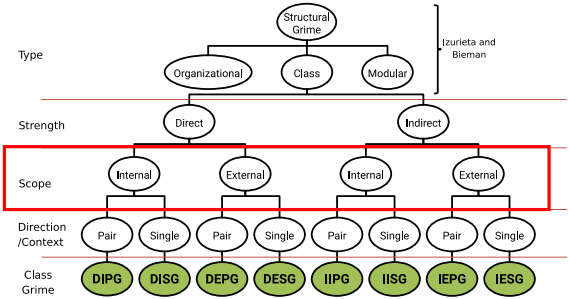

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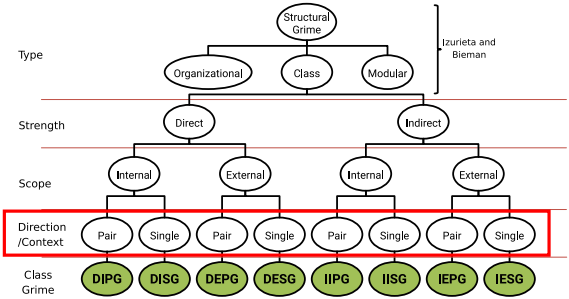

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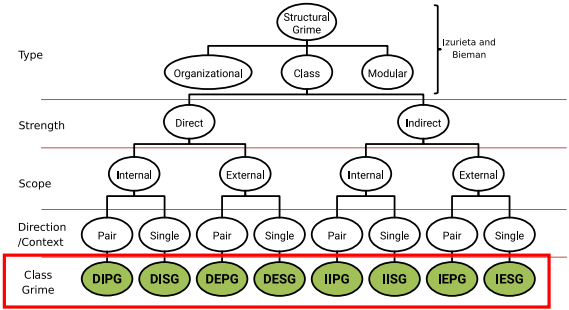

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  - Pair: Tight Class Cohesion (TCC)
  - Single: Ratio of Cohesive Interactions (RCI)

Package Organizational Grime

RQ1.2: What are the types of Organizational Grime?

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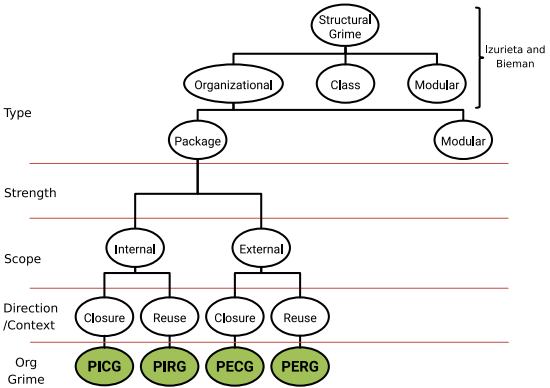

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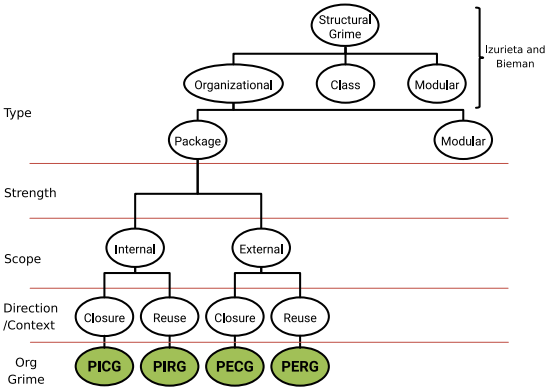

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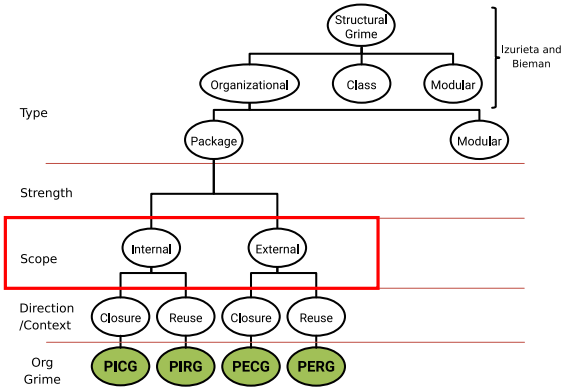

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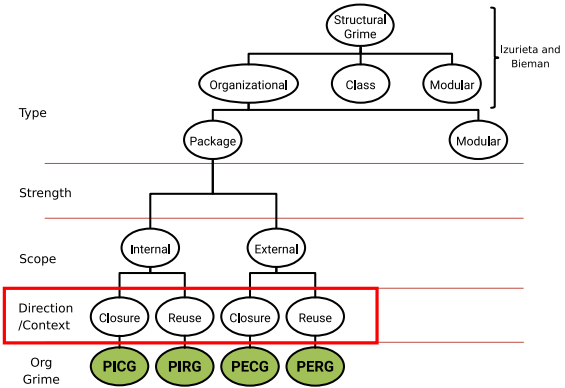

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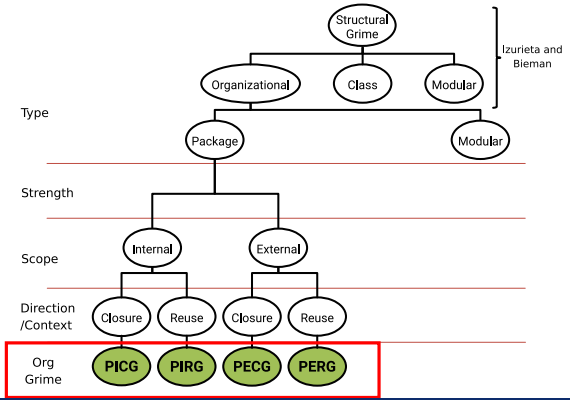

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- **Principles:** CCP and CRP
- **Scope:** Whether a class in a package is a member of the pattern
- **Context:** Considers how well a class fits within the package
  - Closure - as measured by $CohesionQ$
  - Reuse - as measured by $CouplingQ$

Modular Organizational Grime

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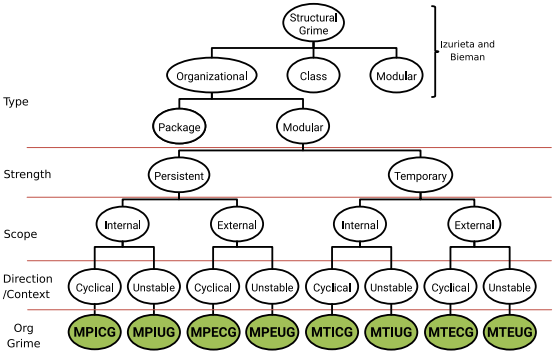

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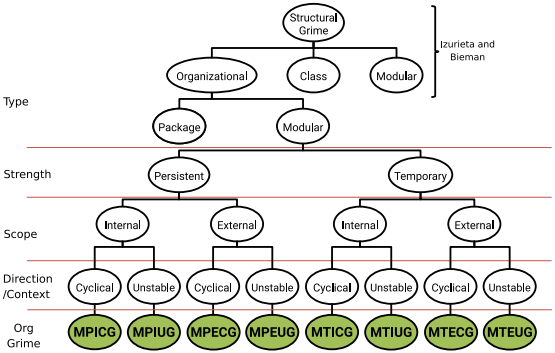

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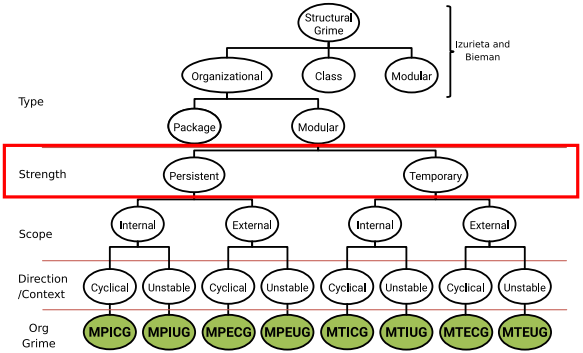

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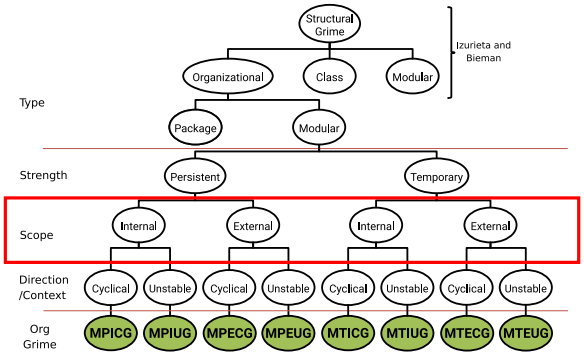

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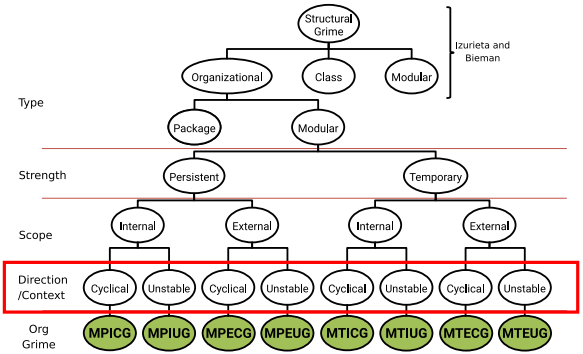

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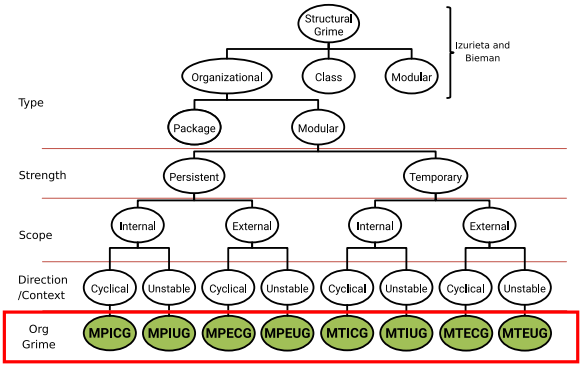

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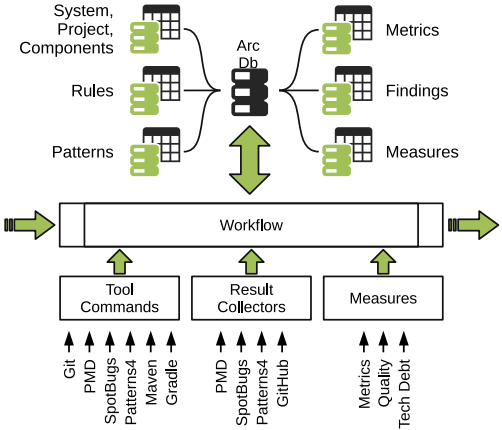
DP1: How can we conduct a full-factorial experiment to evaluate the relationship between grime and quality and grime and technical debt when we are unsure how often design pattern grime occurs?

The Arc Framework

DP1.1 How do we automate the data collection and experimentation process?



Pattern Generation and Grime Injection

DP1.2 How can we generate design pattern instances?

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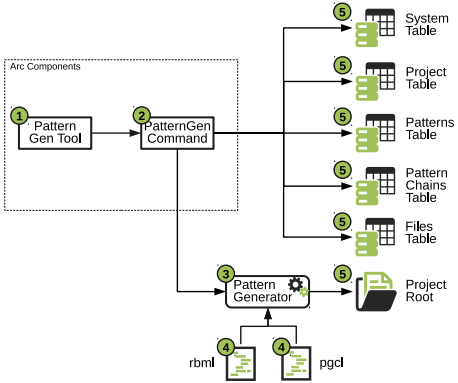

Pattern Generation and Grime Injection

DP1.3 How can we ensure design patterns have the correct type of grime?

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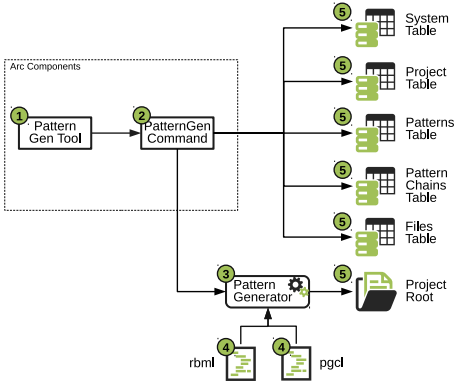
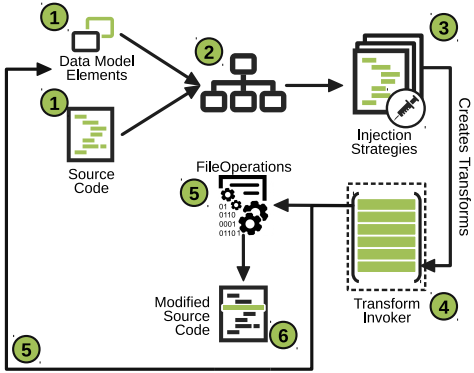


Grime Injection Operation:



Measuring Software Quality

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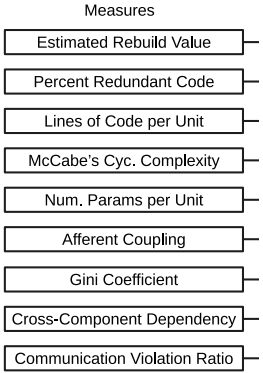

Calibrated using SIG's prescribed method across 106 Open Source Projects from the *Qualitas.Class Corpus*

Measuring Software Quality

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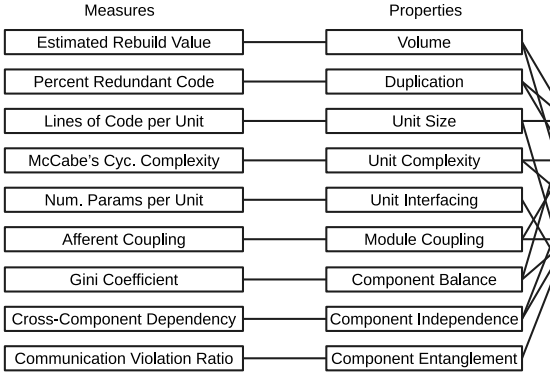

Calibrated using SIG's prescribed method across 106 Open Source Projects from the *Qualitas.Class Corpus*

Measuring Software Quality

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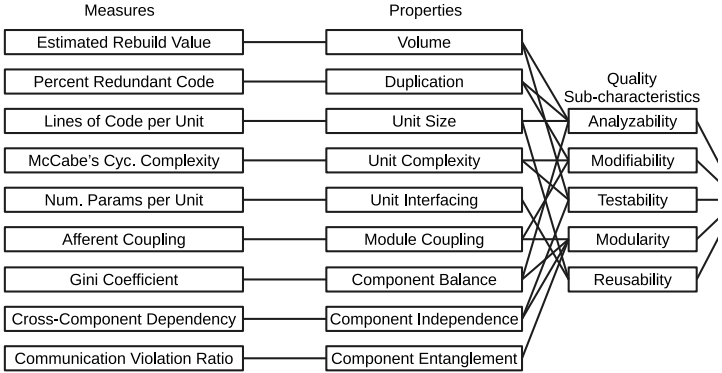

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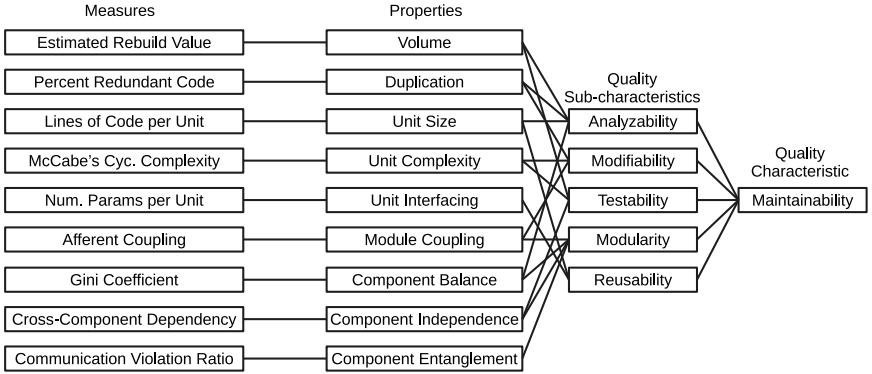
DP1.4 How do we measure the quality of a pattern instance?



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Measuring Technical Debt

DP1.5 How do we measure the technical debt of a pattern instance?

Measuring Technical Debt

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Nugroho et al.'s Calculations

- **TD Principal** (*Repair Effort (RE)*):
  $RE = RF * RV * RA$
  - Rebuild Value, $RV = SS * TF$
  - RF - Rework Fraction
  - SS - System Size in KLOC
  - TF - Technology Factor
  - RA - Refactoring Adjustment

Measuring Technical Debt

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  - RF - Rework Fraction
  - SS - System Size in KLOC
  - TF - Technology Factor
  - RA - Refactoring Adjustment

- **TD Interest (TDI)**:
  $TDI = ME_I - ME_C$
  - ME_I = Maintenance Effort at Ideal Quality Level
  - ME_C = Maintenance Effort at Current Quality Level

  $ME = \frac{MF * RV}{QF}$
  - MF = yearly maintenance effort of the system (0.15)
  - RV = Rebuild Value
  - QF = Quality Factor

  $QF = 2^{((QualityLevel-3)/2)}$

Research Questions

- **RQ2(3):** How does each type of grime affect software product maintainability (technical debt estimate)?

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  - **RQ2(3).1:** How does each type of Grime affect design pattern quality for each of the selected maintainability sub-characteristics (technical debt principal and interest)?

Research Questions

- **RQ2(3):** How does each type of grime affect software product maintainability (technical debt estimate)?
  - **RQ2(3).1:** How does each type of Grime affect design pattern quality for each of the selected maintainability sub-characteristics (technical debt principal and interest)?
  - **RQ2(3).2:** What level of injection severity affects a change in design pattern quality for each of the maintainability sub-characteristics (technical debt principal and interest)?

Research Questions

- **RQ2(3):** How does each type of grime affect software product maintainability (technical debt estimate)?
  - **RQ2(3).1:** How does each type of Grime affect design pattern quality for each of the selected maintainability sub-characteristics (technical debt principal and interest)?
  - **RQ2(3).2:** What level of injection severity affects a change in design pattern quality for each of the maintainability sub-characteristics (technical debt principal and interest)?
  - **RQ2(3).3:** What is the difference between the effects of the grime types and their subtypes on maintainability sub-characteristics (technical debt principal and interest)?

Experimental Design

- Design Type: Factorial

Experimental Design

- Design Type: Factorial
- Replication Size: 2496 Units

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  - 16 Design Pattern Types

Pattern Types	
Adapter	Observer
Bridge	Prototype
Chain of Responsibility	Proxy
Command	Singleton
Composite	State
Decorator	Strategy
Flyweight	Template Method
Factory Method	Visitor

Experimental Design

- Design Type: Factorial
- Replication Size: 2496 Units
  - 26 Grime Types for Injection
  - 16 Design Pattern Types
  - 6 Levels of Injection Severity

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Adapter	Observer
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Flyweight	Template Method
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Level	Max % Grime Injected
0	0% (Control)
1	$\leq$ 15%
2	$\leq$ 30%
3	$\leq$ 45%
4	$\leq$ 60%
5	$\leq$ 75%

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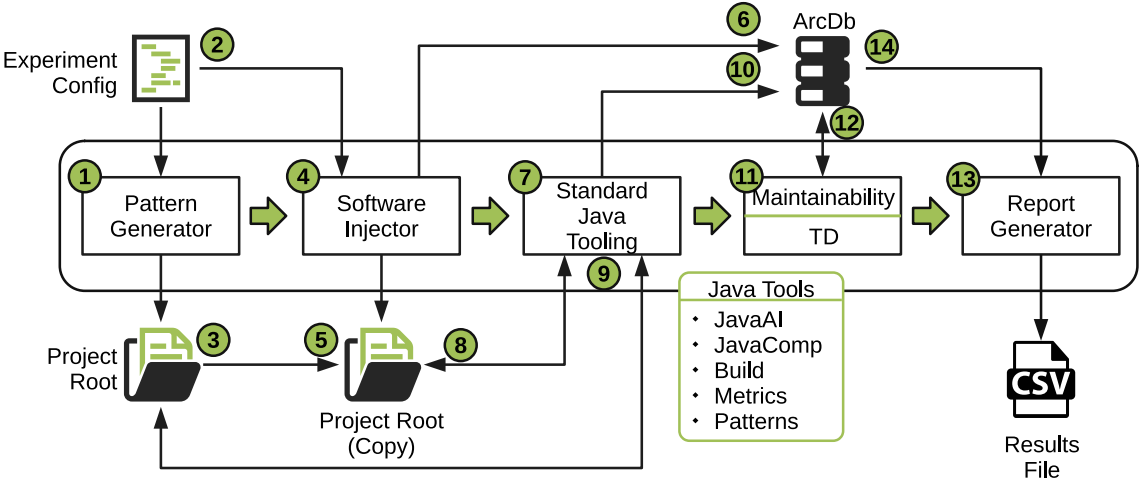
Analysis:

- Each experiment was analyzed using a Permutation F-Test
- Followed by an analysis of interactions between Pattern Type, Injection Type and Injection Severity
- Here we present 3 of the 7 Experiments

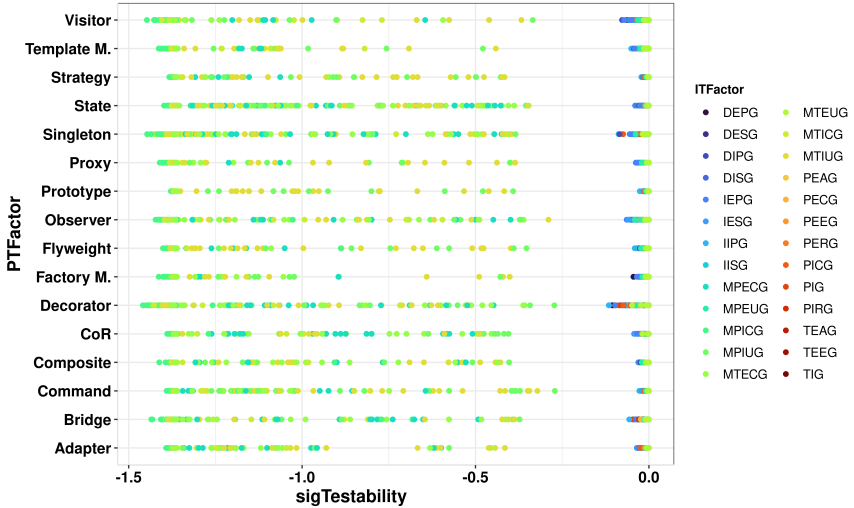
Data Collection



Testability

Experiment

Testability



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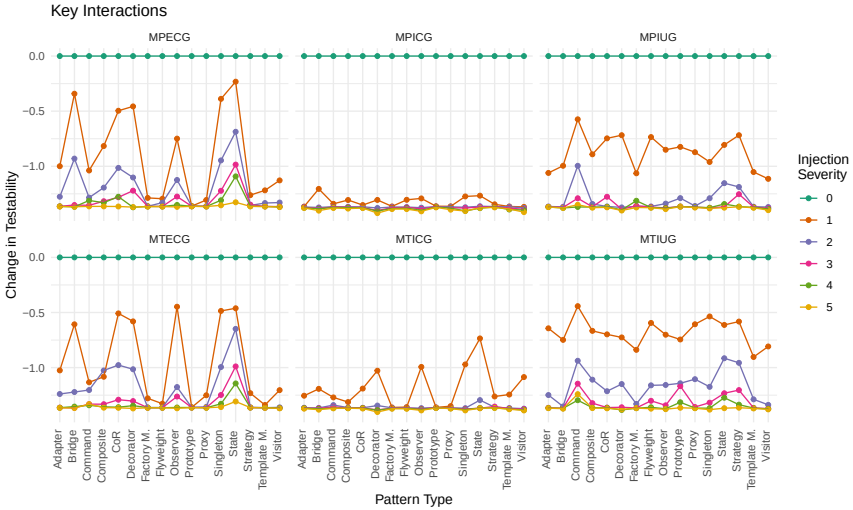
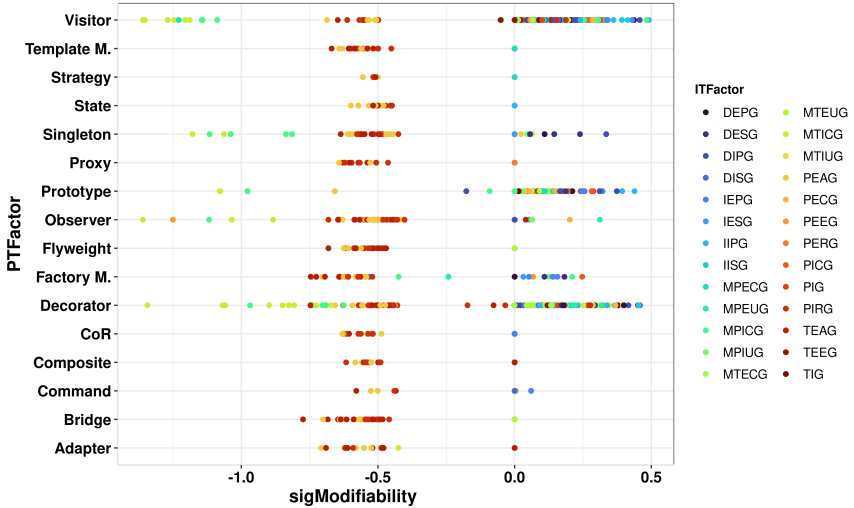


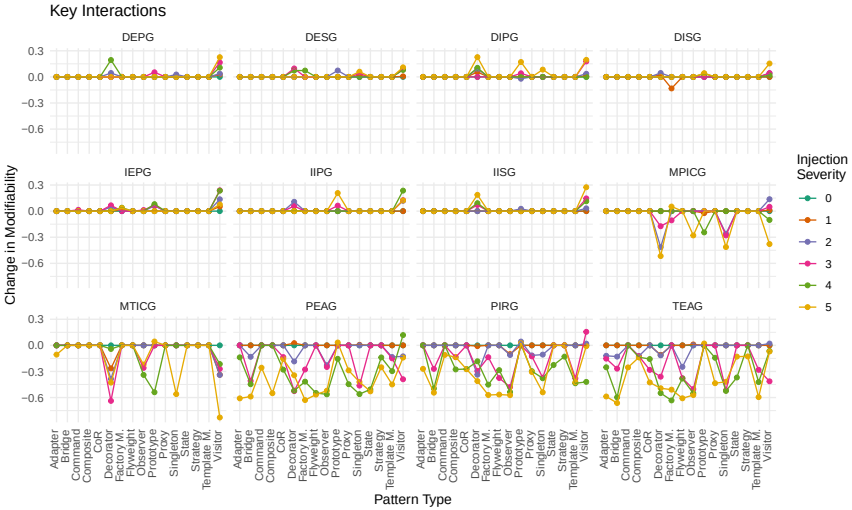
Modifiability

Experiment

Modifiability



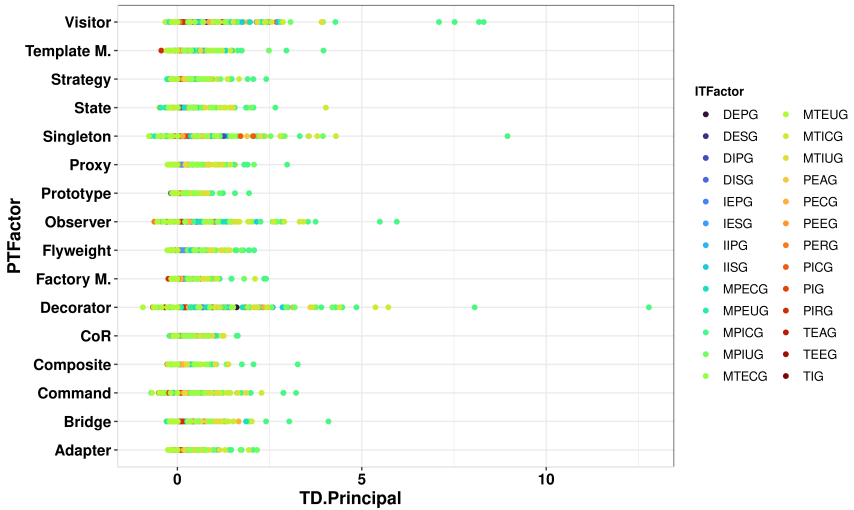
Modifiability



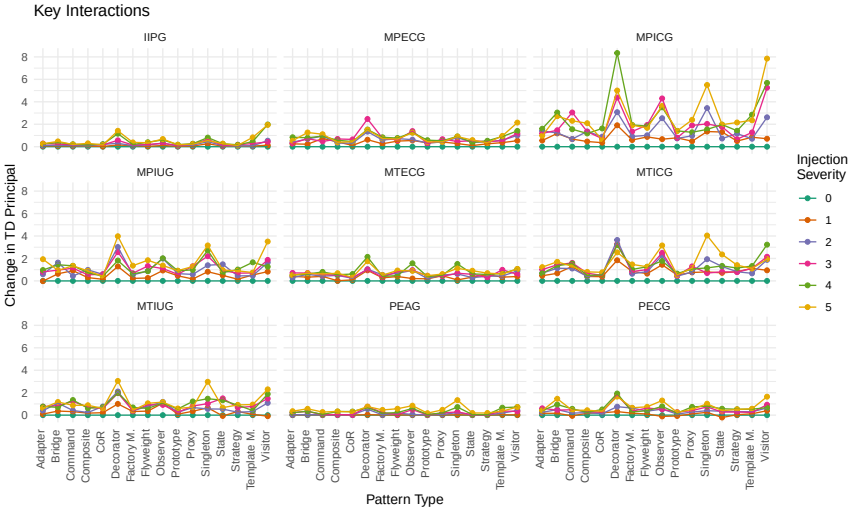
TD Principal

Experiment

TD Principal



TD Principal



Phase 03 - Verification Study

RG4: Analyze design pattern instances for the purpose of comparing injected and observed instances of grime with respect to their ISO/IEC 25010 Maintainability subcharacteristics attributes and Technical Debt Principal and Interest from the perspective of researchers in the context of open source Java™ software projects.

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DP2: How do we verify the results of the experiments with real software?

Design Pattern Detection

DP2.1: How do we incorporate design pattern detection into the Arc Framework?

Design Pattern Detection

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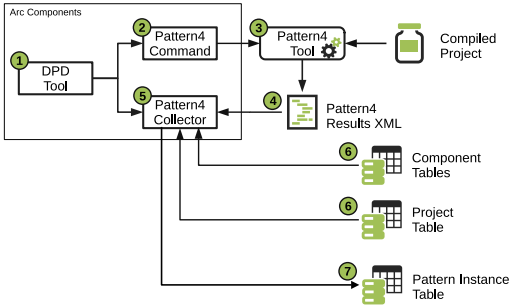
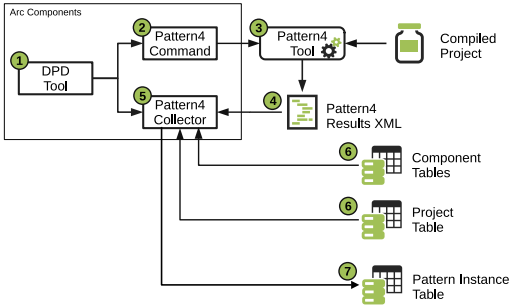


Design Pattern Detection

DP2.2: How do we track instances of design patterns across versions of a software system?



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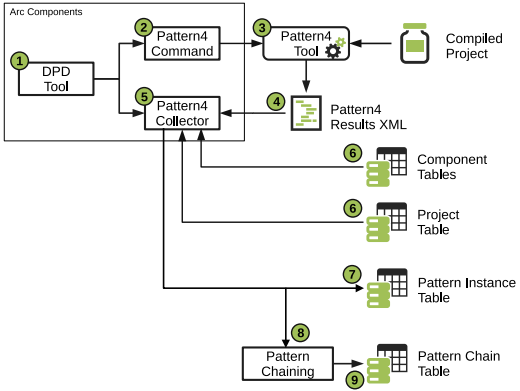

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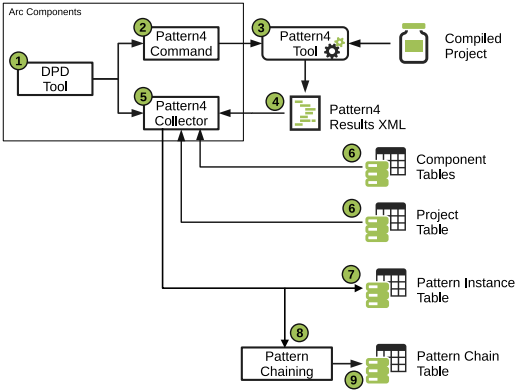

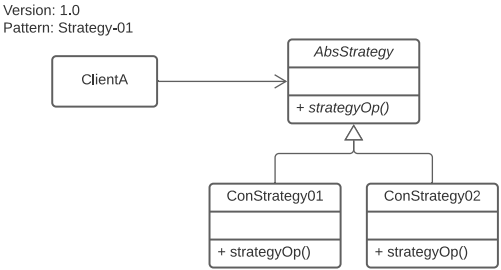

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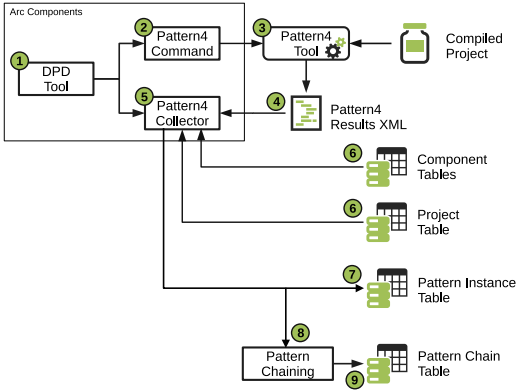

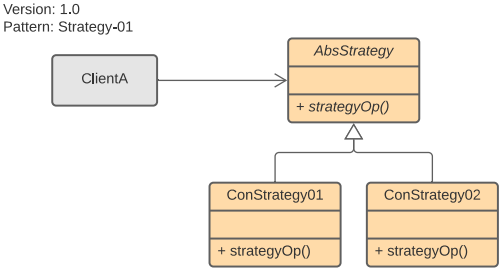

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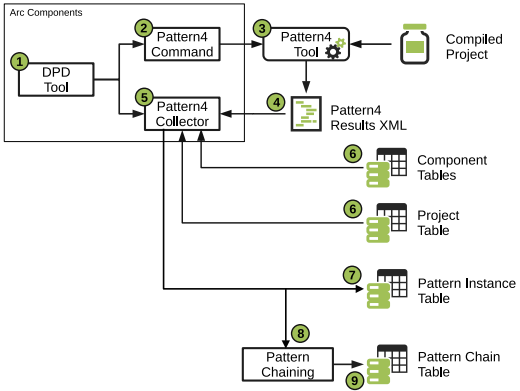
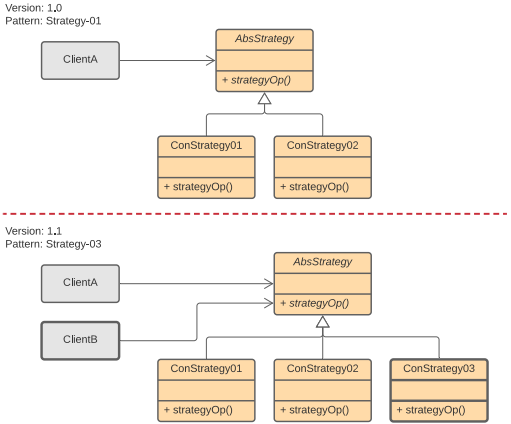
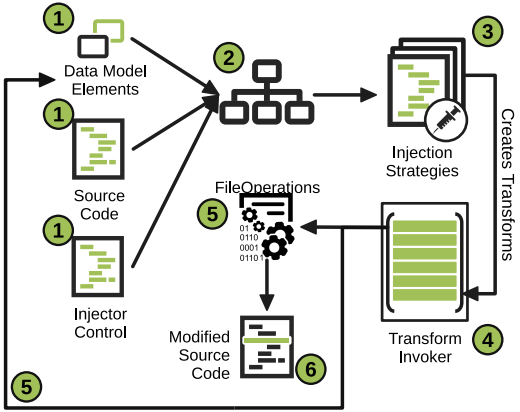




Controlled Injection

DP2.3: How do we modify the Software Injector to allow for controlled injection to mimic the change in grime that occurred between versions?

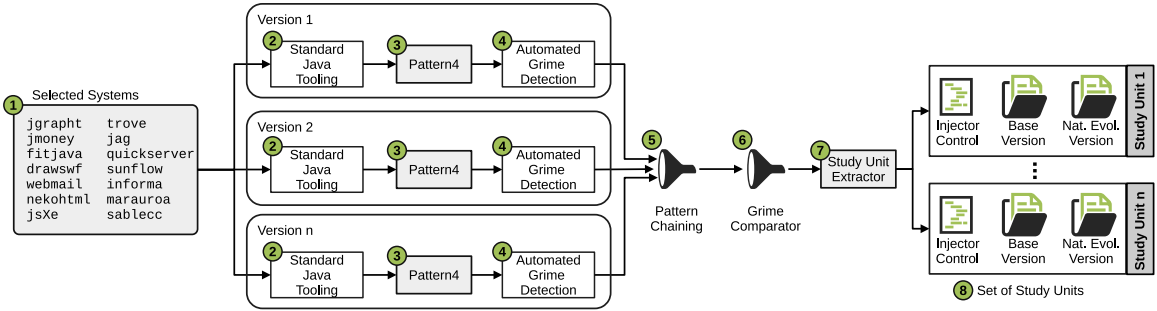


Research Questions

RQ4: Do observed and injected grime have a similar effect on the Maintainability sub-characteristics and Technical Debt Principal and Interest?

Data Collection (1)

Phase 1: Study Unit Extraction



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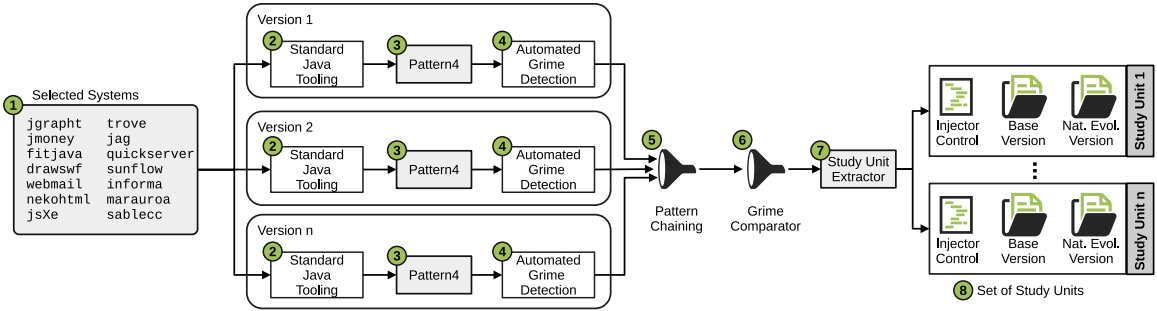
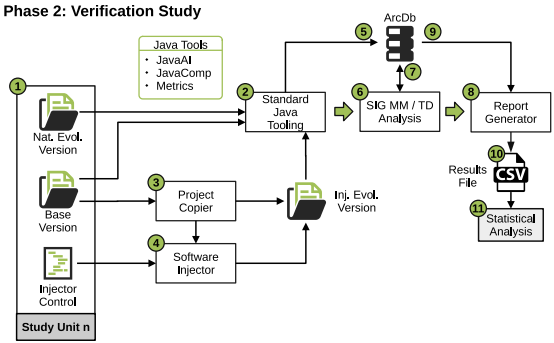
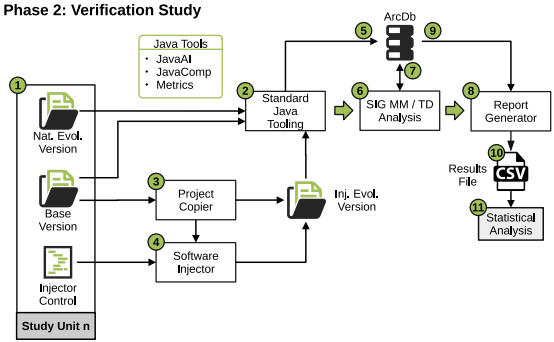


Total units found: 8

Data Collection (2)



Data Collection (2)



- Next we map the change in each characteristic, Δc to a nominal scale for comparison:

$$map(\Delta c) = \begin{cases} L & \text{if } \Delta c < 0 \\ E & \text{if } \Delta c = 0 \\ G & \text{if } \Delta c > 0 \end{cases}$$

Where Δc is the difference between:

- Natural Evolution and Base Version
- Injected Evolution and Base Version

Results

	Study Units															
	1 - State		2 - State		3 - Sngltn		4 - Adapt		5 - TM		6 - TM		7 - State		8 - Sngltn	
	Nat	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*
Ana	E	G	L	L	G	L	E	E	L	G	L	L	L	L	G	L
Test	E	L	L	L	L	L	E	L	G	L	G	L	G	L	G	L
Modul	E	G	L	L	E	L	E	L	G	L	L	L	L	L	E	L
Modif	E	E	E	E	E	E	E	G	G	G	G	G	E	E	G	G
Reuse	E	G	G	G	G	L	E	L	G	L	G	L	L	L	L	L
TDP	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L
TDI	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L

Results

What is the agreement between natural and injection evolution?

	Study Units															
	1 - State		2 - State		3 - Sngltn		4 - Adapt		5 - TM		6 - TM		7 - State		8 - Sngltn	
	Nat	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*
Ana	E	G	L	L	G	L	E	E	L	G	L	L	L	L	G	L
Test	E	L	L	L	L	L	E	L	G	L	G	L	G	L	G	L
Modul	E	G	L	L	E	L	E	L	G	L	L	L	L	L	E	L
Modif	E	E	E	E	E	E	E	G	G	G	G	G	E	E	G	G
Reuse	E	G	G	G	G	L	E	L	G	L	G	L	L	L	L	L
TDP	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L
TDI	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L

Results

What is the agreement between natural and injection evolution?

	Study Units															
	1 - State		2 - State		3 - Snglton		4 - Adapt		5 - TM		6 - TM		7 - State		8 - Snglton	
	Nat	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*	*Nat*	*Inj*
Ana	E	G	L	L	G	L	E	E	L	G	L	L	L	L	G	L
Test	E	L	L	L	L	L	E	L	G	L	G	L	G	L	G	L
Modul	E	G	L	L	E	L	E	L	G	L	L	L	L	L	E	L
Modif	E	E	E	E	E	E	E	G	G	G	G	G	E	E	G	G
Reuse	E	G	G	G	G	L	E	L	G	L	G	L	L	L	L	L
TDP	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L
TDI	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L

	Attribute						
	Ana	Test	Modul	Modif	Reuse	TDP	TDI
κ	0.16	0.0	0.048	0.75	0.091	-0.077	-0.077
Agreement	Slight	None	Slight	Substantial	Slight	None	None

Results

How does natural and injected evolution compare to experimental results?

	Study Units															
	1 - State		2 - State		3 - Snglton		4 - Adapt		5 - TM		6 - TM		7 - State		8 - Snglton	
	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj
Ana	E	G	L	L	G	L	E	E	L	G	L	L	L	L	G	L
Test	E	L	L	L	L	L	E	L	G	L	G	L	G	L	G	L
Modul	E	G	L	L	E	L	E	L	G	L	L	L	L	L	E	L
Modif	E	E	E	E	E	E	E	G	G	G	G	G	E	E	G	G
Reuse	E	G	G	G	G	L	E	L	G	L	G	L	L	L	L	L
TDP	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L
TDI	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L

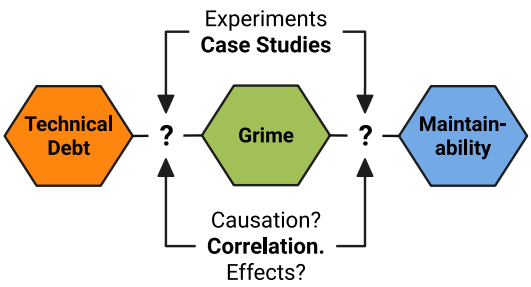
Results

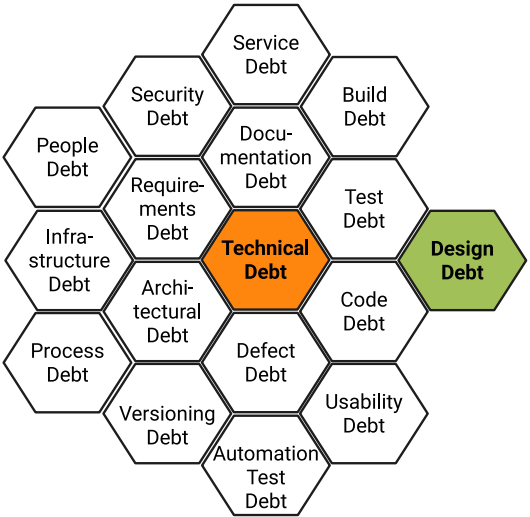
How does natural and injected evolution compare to experimental results?

	Study Units															
	1 - State		2 - State		3 - Sngltn		4 - Adapt		5 - TM		6 - TM		7 - State		8 - Sngltn	
	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj	Nat	Inj
Ana	E	G	L	L	G	L	E	E	L	G	L	L	L	L	G	L
Test	E	L	L	L	L	L	E	L	G	L	G	L	G	L	G	L
Modul	E	G	L	L	E	L	E	L	G	L	L	L	L	L	E	L
Modif	E	E	E	E	E	E	E	G	G	G	G	G	E	E	G	G
Reuse	E	G	G	G	G	L	E	L	G	L	G	L	L	L	L	L
TDP	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L
TDI	E	G	G	G	G	L	E	L	G	L	G	L	G	L	G	L

- 39.583% of the natural evolution results reflect the experimental results
- 52.083% of the injected evolution results reflect the experimental results

Impacts


Experiments
Case Studies
Technical Debt
?
Grime
?
Maintain-ability
Causation?
Correlation.
Effects?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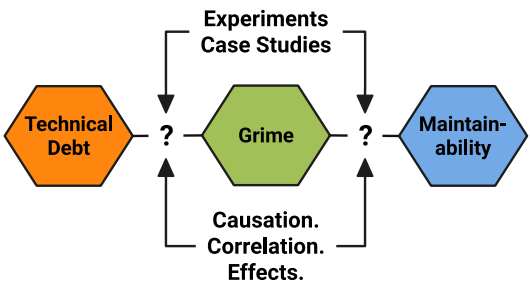
Impacts


Experiments
Case Studies
Technical Debt
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Grime
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Maintain-ability
Causation.
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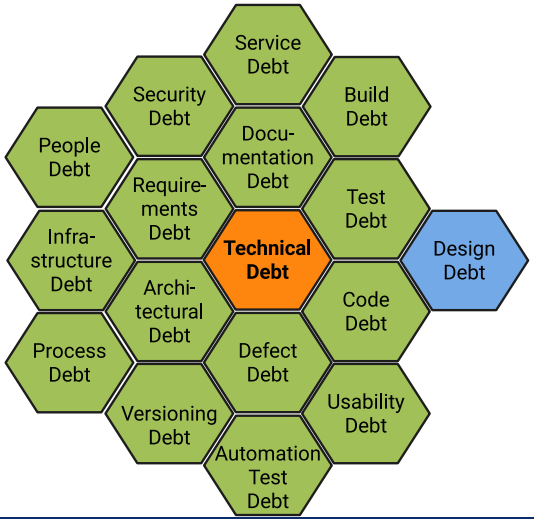
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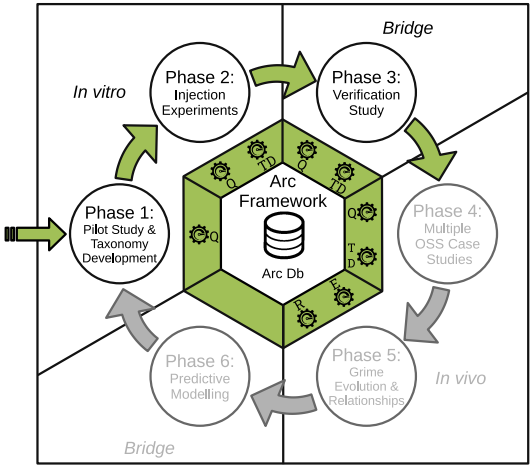

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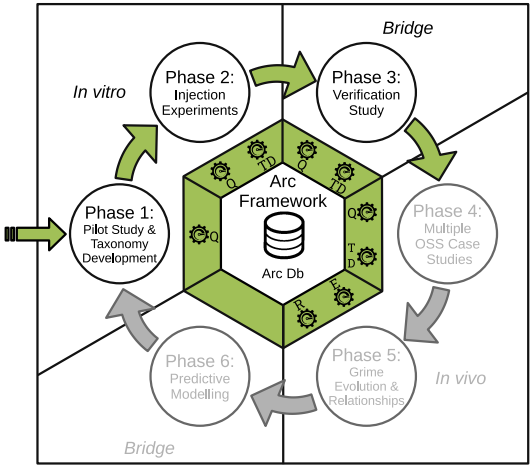

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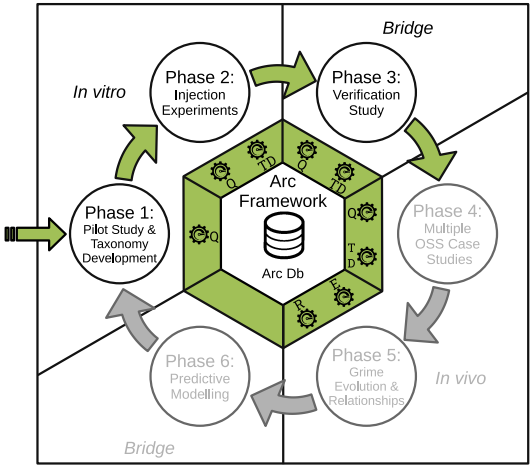

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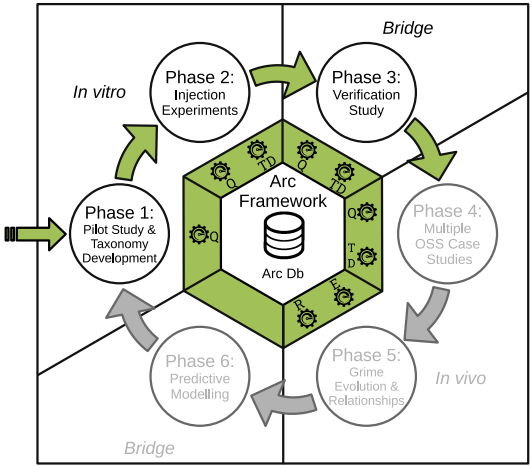

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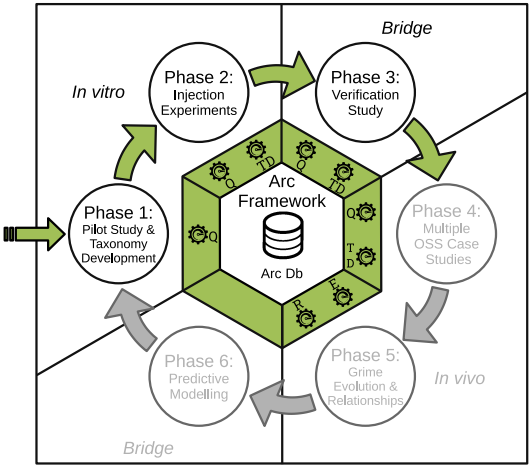

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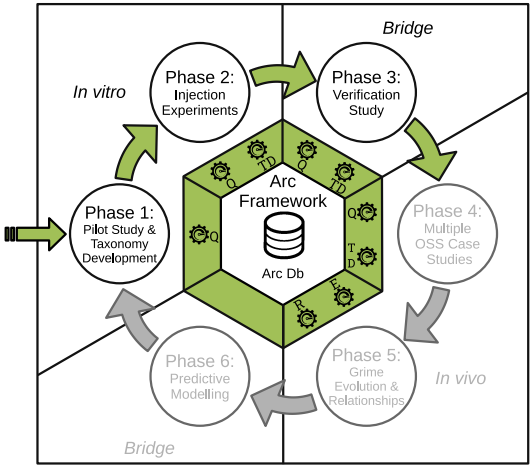

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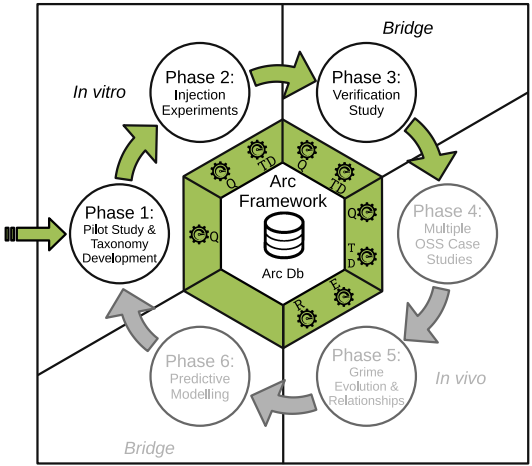

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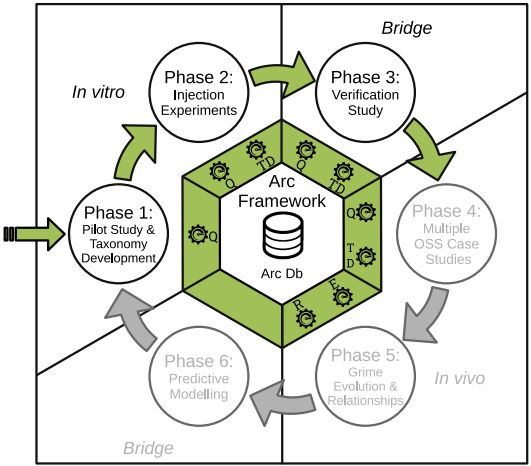

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External Validity

- Experiments:
  - Injection used generated rather than real systems
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  - Only analyzed the Java language
- Validation Study:
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  - Small sample size
  - Limited coverage of grime types
  - Limited coverage of pattern types

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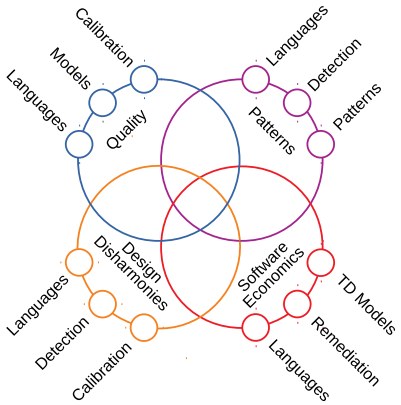

Thank You!

Are there any questions?