Performance and Concurrency Bug Detection Tools for Java Programs

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Fighting software bugs is crucial

- Software is everywhere
  - http://en.wikipedia.org/wiki/List_of_software_bugs
- Software bugs are widespread and costly
  - Lead to 40% system down time [Blueprints 2000]
  - Cost 312 Billion lost per year [Cambridge 2013]

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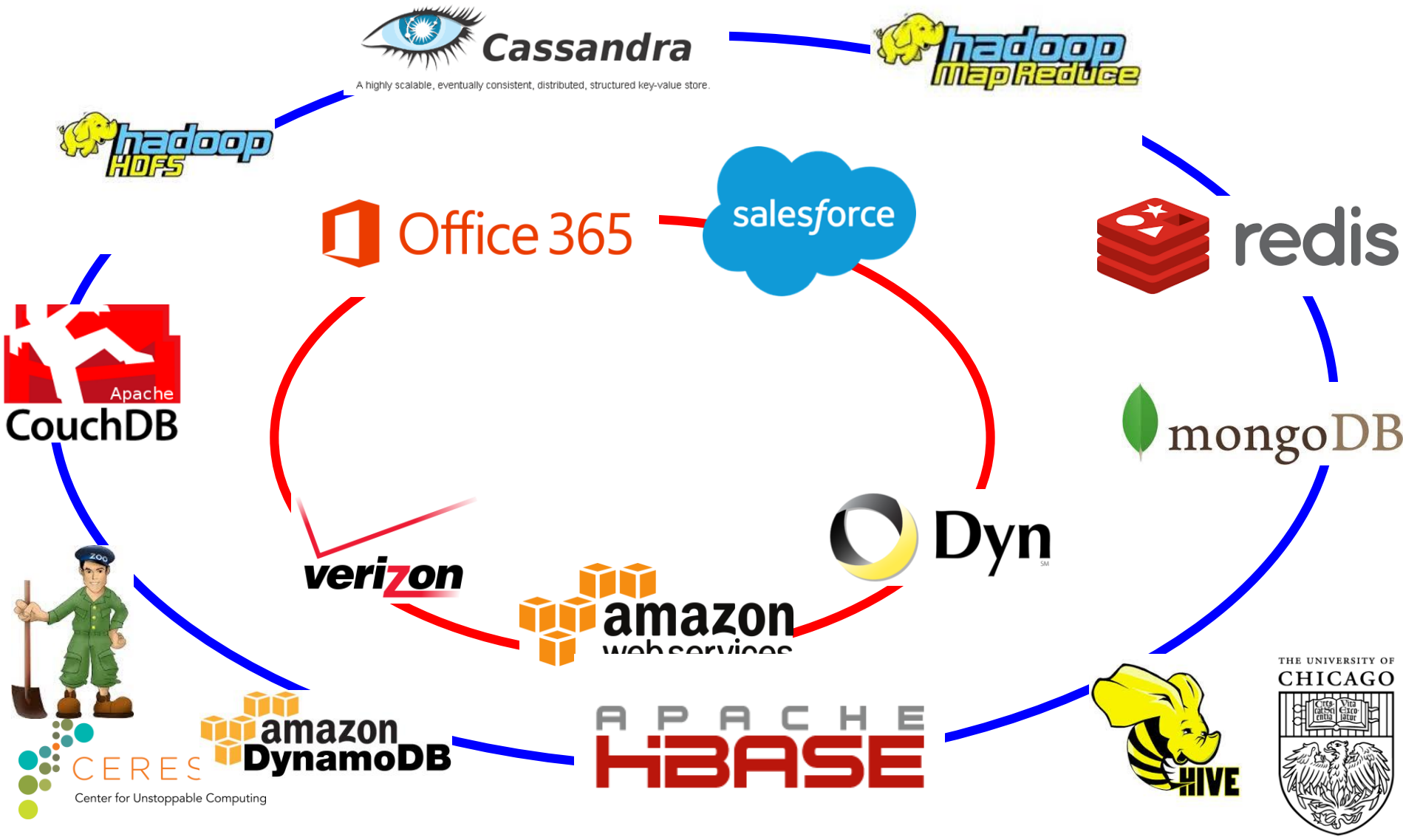
Fighting bugs in cloud systems …



… is crucial

Cassandra

A highly scalable, eventually consistent, distributed, structured key-value store.

hadoop MapReduce

hadoop HDFS

redis

Apache CouchDB

mongoDB

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amazon DynamoDB

APACHE HBASE

HIVE

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Different aspects of fighting bugs

In-house bug detection

In-field failure recovery

In-field failure diagnosis

In-house bug fixing

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Work from my group (local systems)

	In-house bug detection	In-field failure recovery	In-field failure diagnosis	In-house bug fixing
concurrency bugs	[ASPLOS06];[SOSP07]; [ASPLOS09];[ASPLOS10]; [ASPLOS11]; [OOPSLA13]; [ICSE17a]	[ASPLOS13a] [FSE14]	[OOPSLA10]; [ASPLOS13b]; [ASPLOS14]; [OOPSLA16]	[PLDI11]; [OSDI12]; [FSE16]
performance bugs	[PLDI12]; [ICSE13]	n/a	[OOPSLA14]; [ICSE17b]	[CAV13]; [ICSE15]




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performance bugs	[PLDI12]; [ICSE13]	n/a	[OOPSLA14]; [ICSE17b]	[CAV13]; [ICSE15]

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Work from my group (cloud systems)

	In-house bug detection	In-field failure recovery	In-field failure diagnosis	In-house bug fixing
concurrency bugs	[ASPLOS16]; [ASPLOS17]	On-going	n/a	On-going
performance bugs	[CIKM'17]; On-going	[SOSP'15]; [OSDI'16]	[SOCC'17]	On-going




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Our bug-tools for Java programs

	Empirical bug studies	In-house bug detection	In-field failure diagnosis	In-house bug fixing
distributed concurrency bugs	[ASPLOS16]	[ASPLOS17]		
performance bugs	[PLDI12]	[ICSE13]	[OOPSLA14]; [ICSE17b]	[ICSE15]

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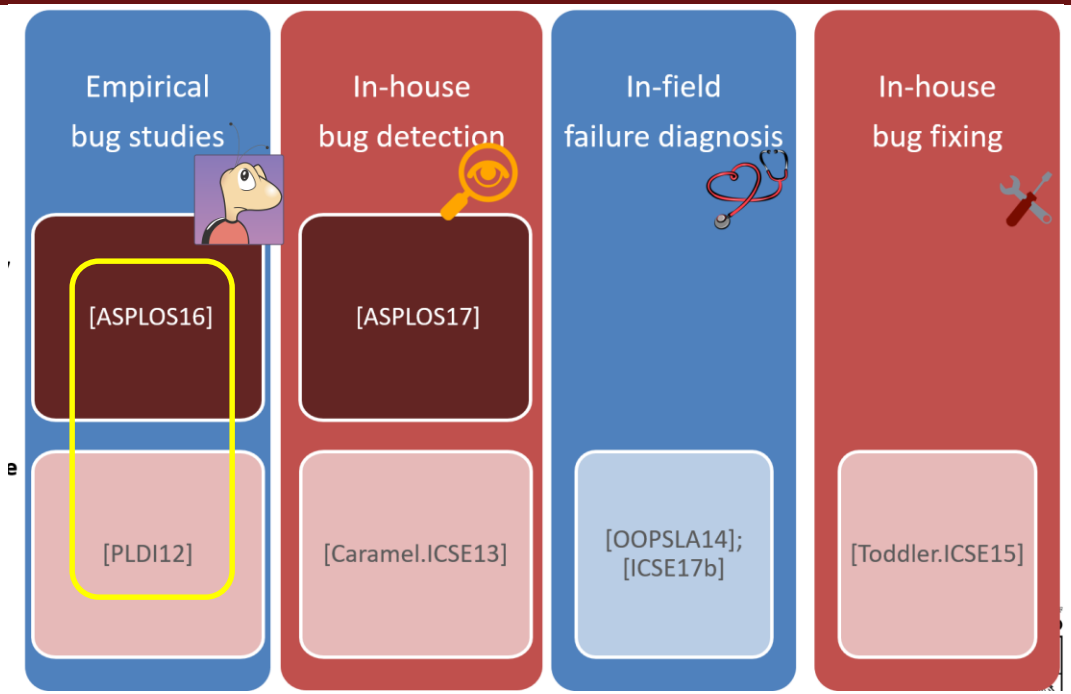
Empirical Bug Studies



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Understanding and detecting real-world performance bugs [**PLDI '12**]

TaxDC: A Comprehensive Taxonomy of Non-Deterministic Concurrency Bugs in Cloud Distributed Systems [**ASPLOS '16**]

Performance bug studies

- Why did we do this study?

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The most cited paper in PLDI 2012

Understanding and detecting real-world performance bugs [**PLDI '12**]

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Benchmark Suite

Application	Software	Language	MLOC	Bug DB History	Tags	# Bugs
Apache	Command-line Server + Library	C/Java	0.45	13 y	N/A	25
Chrome	GUI Application	C/C++	14.0	4 y	N/A	10
GCC	Compiler	C/C++	5.7	13 y	Compile-time-hog	10
Mozilla	GUI Application	C++/JS	4.7	14 y	perf	36
MySQL	Server Software	C/C++/C#	1.3	10 y	S5	28

Ant, Tomcat

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What/How did we study?

- Read on-line discussion
- Check patches
- Check source code

All Manual

- Bug root causes
- Bug locations
- Bug triggering conditions
- Bug fix strategies
- Bug symptoms
- Bug-related inputs

Understanding and detecting real-world performance bugs [**PLDI '12**]

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What could have been better?

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- Check patches
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All Manual

- Bug root causes
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Understanding and detecting real-world performance bugs [**PLDI '12**]

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Distributed concurrency bug studies

- Why did we do this study?

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Benchmark Suite

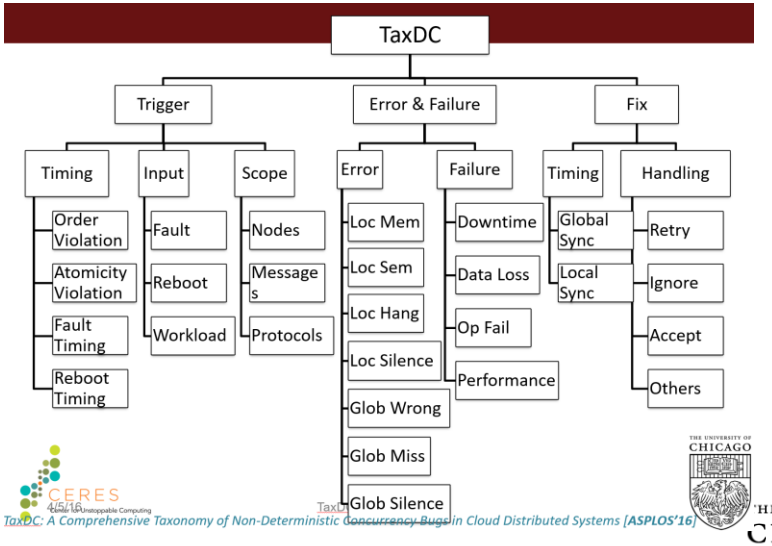
Application	Software Type		MLOC	Bug DB History	# Bugs
Cassandra	Distributed Key-Value Store	Java	0.06	9 y	19
Hadoop	Distributed computing	Java	1.2	12 y	36
HBase	Distributed Key-Value Store	Java	0.2	10 y	30
Zookeeper	Distributed Synch. Service	Java	0.1	10 y	19

What/How did we study?

- Read on-line discussion
- Check patches
- Check source code
- Read software tutorial

All Manual

- Triggering conditions
- Errors & Failures
- Fix strategies



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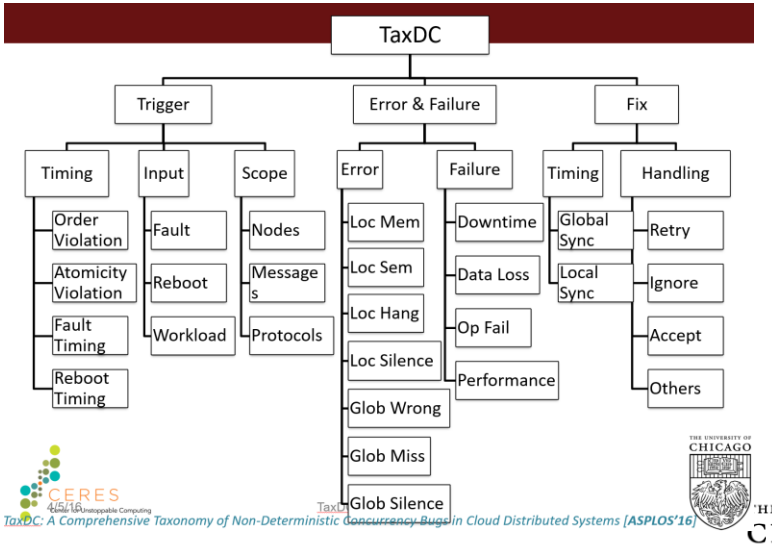
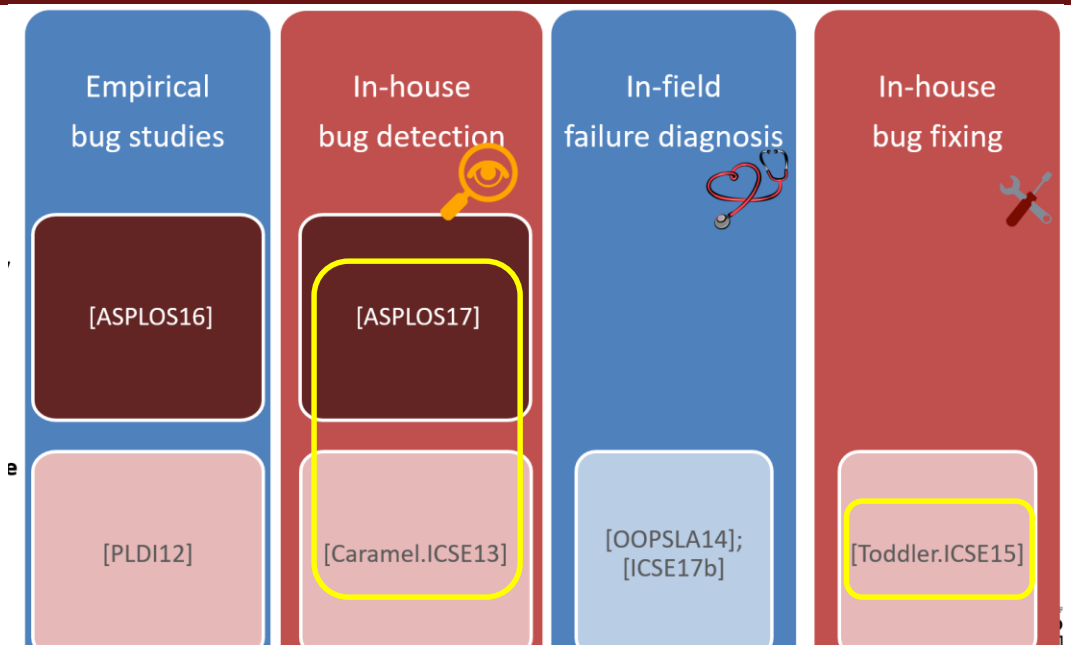


Bug Detection & Fixing



DCatch: Automatically Detecting Distributed Concurrency Bugs in Cloud Systems [**ASPLOS'17**]

Toddler: Detecting Performance Problems via Similar Memory-Access Patterns [**ICSE '13**]

CARAMEL: Detecting and Fixing Performance Problems That Have Non-Intrusive Fixes [**ICSE'15**]

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Dynamic DCbug Detection

- DCbugs
  Bugs caused by improper timing among distributed operations

- Why? Why not applying single-machine detectors?
  - Distributed triggering
  - Different happens-before model
  - Distributed error propagation
  - Much larger scales

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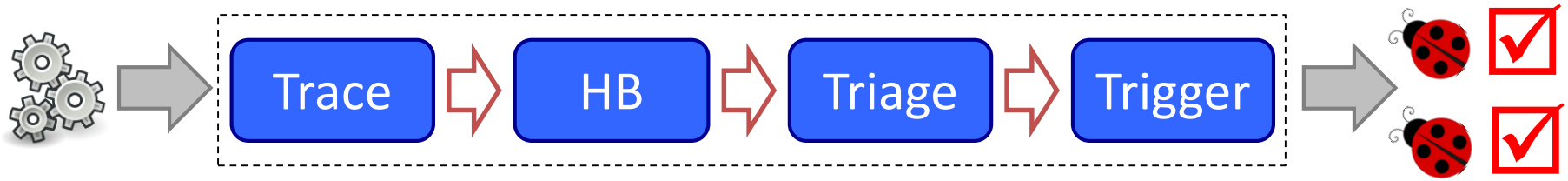
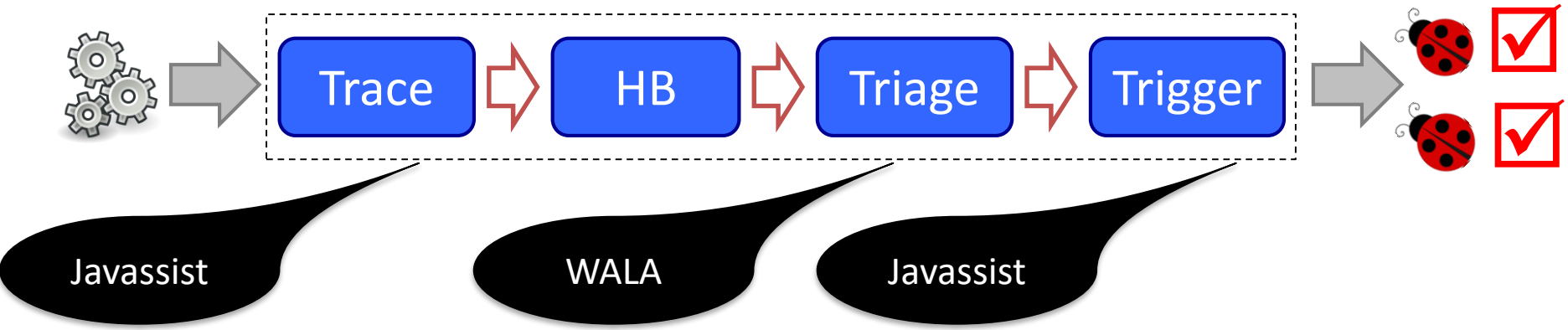
DCatch Tool



DCatch Tool Implementation



Benchmark Suite

Application	Software Type	Workload	# Bugs
Cassandra	Distributed Key-Value Store	startup	1
Hadoop	Distributed Computing	wordcount	2
HBase	Distributed Key-Value Store	enable, split, alter	2
Zookeeper	Distributed Synch. Service	startup	2

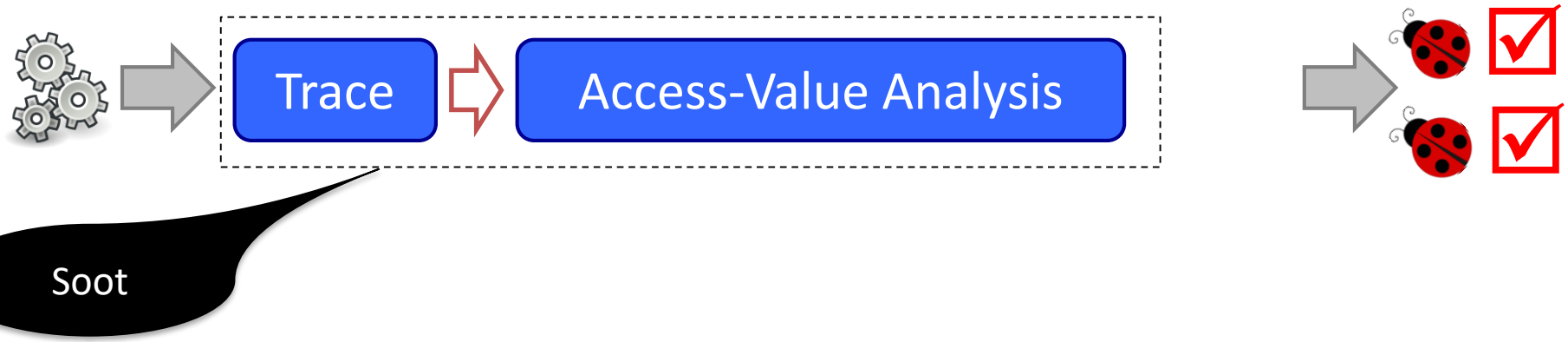
Dynamic PerfBug Detection

- Loop inefficiency bugs
  - Inefficient data structure
  - Redundant computation

- Why?

Toddler Tool

Toddler Tool



Benchmark Suite

Application	Software Type		KLOC	Known Bugs	New Bugs
Ant	Build tool	Java	110	1	8
Apache Col.	Collections library	Java	51	1	20
Groovy	Dynamic language	Java	137	1	0
Ggl Core Lib	Collections library	Java	156	2	10
JFreeChart	Chart framework	Java	64	1	8
JMeter	Load testing tool	Java	86	1	1
Lucene	Text search engine	Java	321	2	0
PDFBox	PDF framework	Java	78	1	0
Solr	Search server	Java	373	1	0

How to get inputs?

Static PerfBug Detection & Fixing

- Missing-break bugs

How Is Computation Wasted?

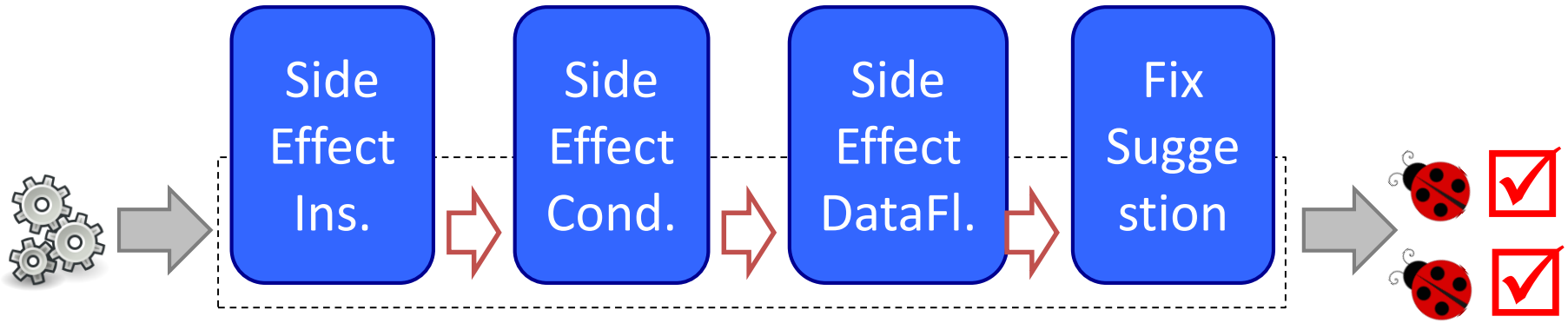
Where Is Computation Wasted?

	Every Iteration	Late Iterations	Early Iterations
No-Result	**Type 1**	**Type 2**	Type Y
Useless-Result	Type X	**Type 3**	**Type 4**

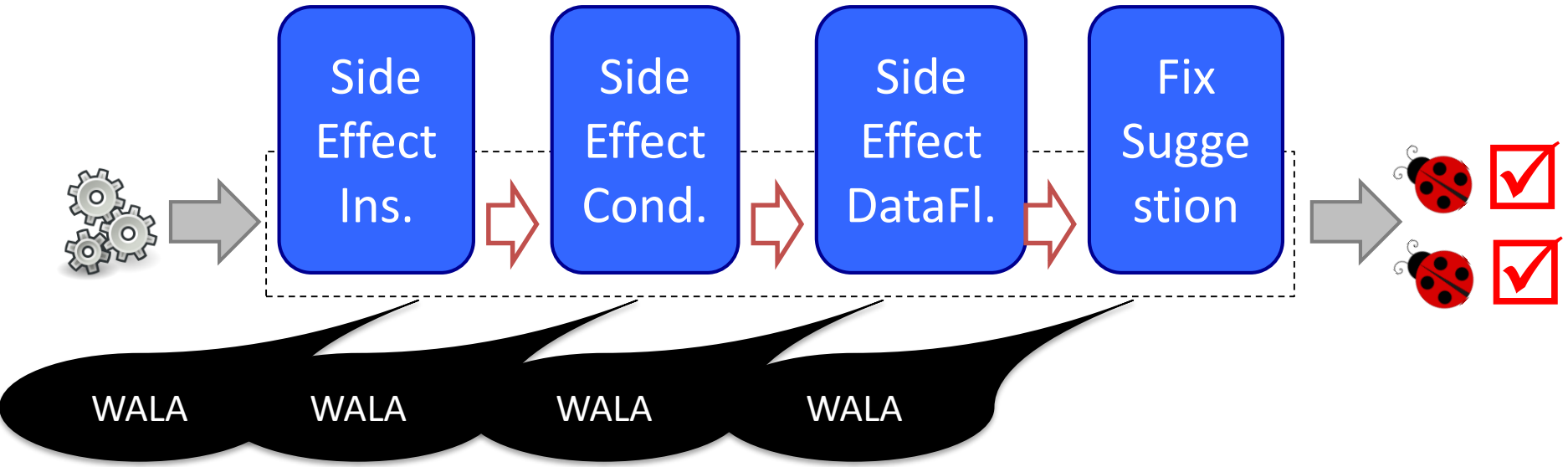
- Why?

CARAMEL: Detecting and Fixing Performance Problems That Have Non-Intrusive Fixes [**ICSE'15**]

Caramel Tool



Caramel Tool Implementation



Benchmark Suite (1)

Application	Software Type		KLOC	New Bugs
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~~***Apache Col.***~~	~~Collections library~~	~~Java~~	~~51~~	~~20~~
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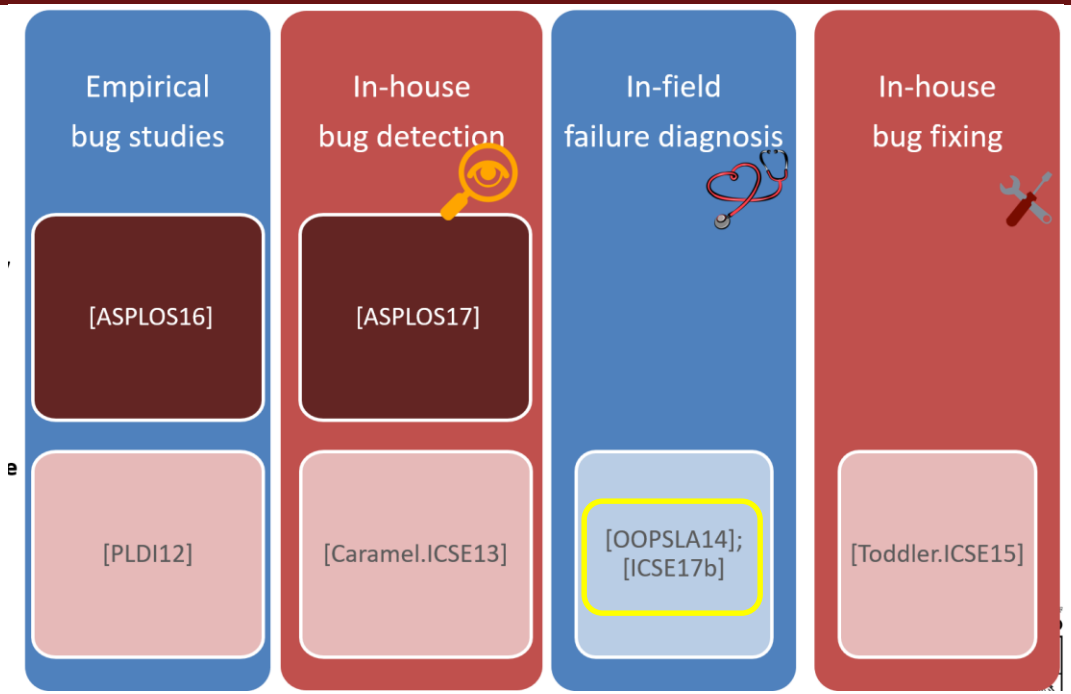
~~***JFreeChart***~~	~~Chart framework~~	~~Java~~	~~64~~	~~8~~
JMeter	Load testing tool	Java	86	4
Lucene	Text search engine	Java	321	14
PDFBox	PDF framework	Java	78	10
Solr	Search server	Java	373	2

Benchmark Suite (2)

Application	Software Type		KLOC	New Bugs
Log4J	Logging framework	Java	52	6
Sling	Web app. framework	Java	202	6
Struts	Web app. framework	Java	175	4
Tika	Content extraction	Java	50	1
Tomcat	Web server	Java	295	4

No input requirements

Failure Diagnosis



Performance Diagnosis for Inefficient Loops [**ICSE'17**]

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Conclusion

- 2 bug studies, 3 bug detection tools
- 18 Java benchmark software (4 distributed)
- Workloads
  - Functionality & Performance
- Analysis mechanisms
  - Human
  - WALA, Soot, Javassist
- Others
  - Bug-tracking systems

Thanks!

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