



Ekstazi

# Practical Regression Test Selection with Dynamic File Dependencies

Milos Gligoric, Lamyaa Eloussi, and Darko Marinov



ISSTA, Baltimore, USA

07/16/2015

CNS-0958199

CCF-1012759

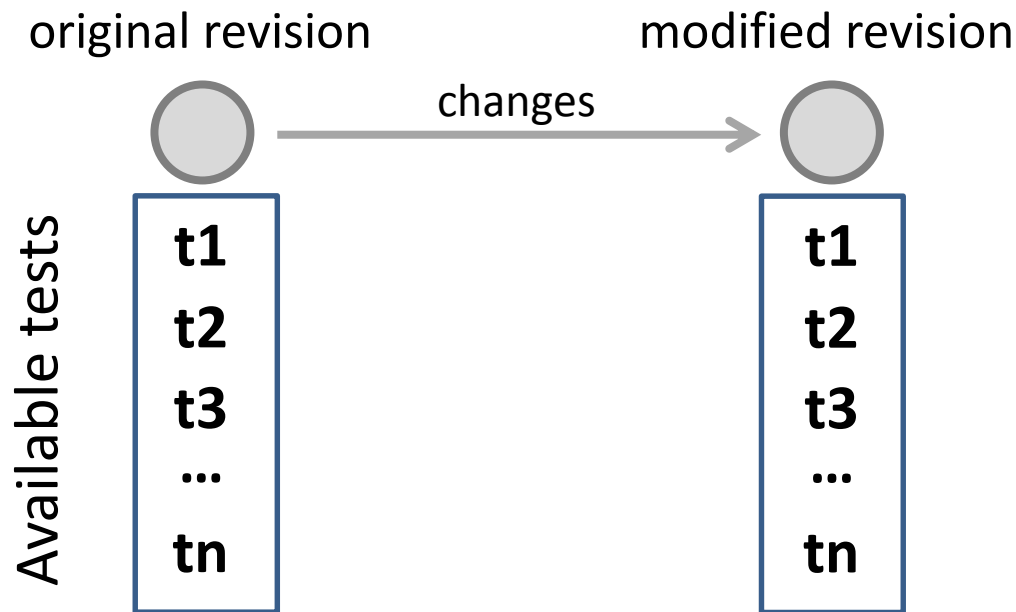
CCF-1421503

CCF-1439957



# Regression Testing

- Executes tests for each new code revision
- Checks if changes broke something
- Widely used in industry



# Regression Testing is Costly (1)

test execution time single revision	number of tests single revision
--	------------------------------------



~5min

1667



~10min

641534



~45min

1296



~45min

361



~45min

631



~4h

4975



~17h

8663



Run many times each day

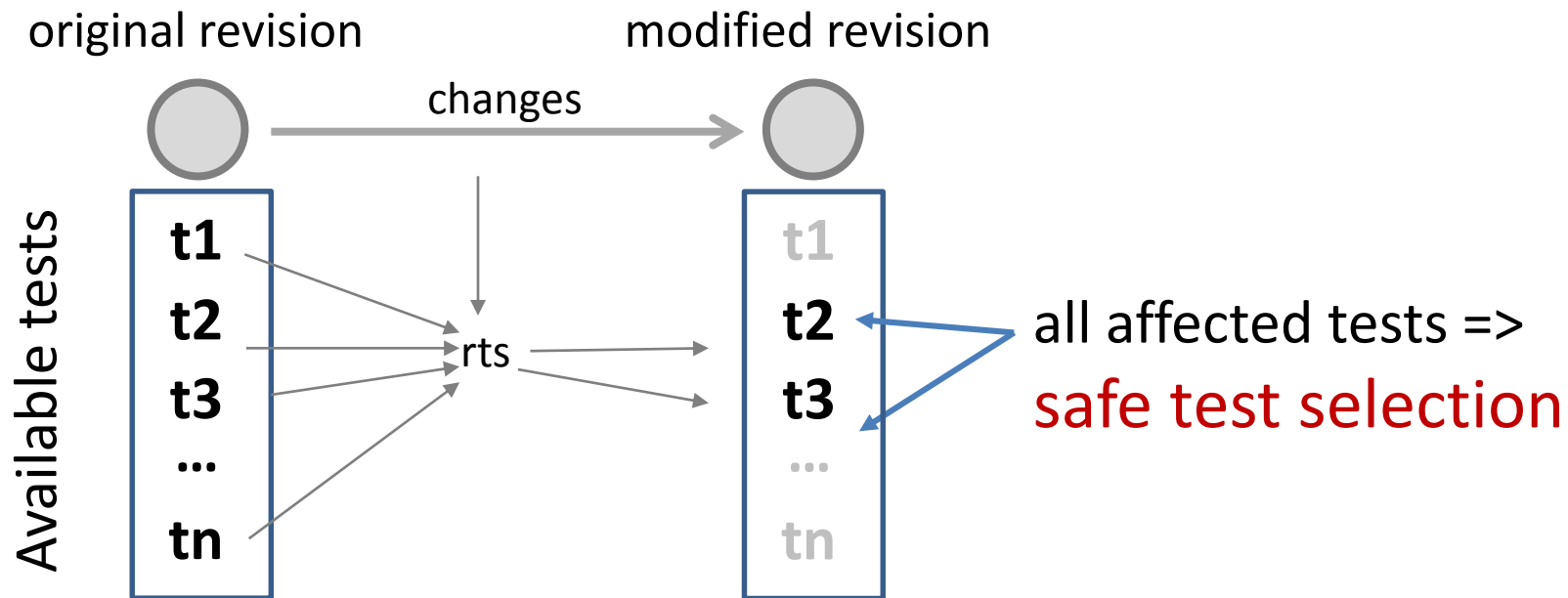
# Regression Testing is Costly (2)



- \* linear increase in the number of revisions per day
- linear increase in the number of tests per revision
- => **quadratic increase in test execution time**
- 75+ million tests run per day
- 20+ revisions per minute**

# Regression Test Selection (RTS)

- Speeds up regression testing
  - Without requiring more computers or energy
- Analyzes changes to a codebase
- Runs only tests whose behavior may be affected



# Outline

- Motivation
- **Ekstazi RTS Technique**
- **Tool for Java**
- **Evaluation**
- **Conclusions**



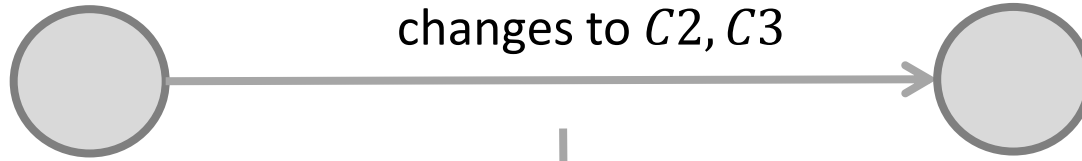
Ekstazi

<http://www.ekstazi.org>

# Ekstazi – Example

original revision

modified revision



changes to C2, C3

	C1	C2	C3	f
t1	★			
t2		★		
t3			★	
t4	★	★		★

Ekstazi(original, modified)

	C1	C2	C3	f
t1	★			
t2		★		
t3			★	
t4	★	★	★	

```
t1() {  
  C1 obj = new C1();  
  assert(obj.m() == 1);  
}
```

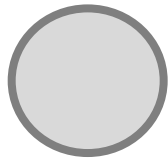
```
class C1 {  
  int m() { return 1; }  
}
```

Analysis

Execution of Selected

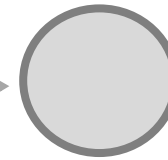
# Fine- vs. Coarse-grained Dependencies: Methods vs. Files

original revision



changes to  $p, r$

modified revision



	C1	C2	C3	
	m	p	q	r
t1	★			
t2		★		
t3			★	
t4	★		★	

→  $rts(\text{original}, \text{modified})$  →

	C1	C2	C3	
	m	p	q	r
t1	★			
t2		★		
t3			★	
t4	★		★	

**RTS with method dependencies select: t2, t3**

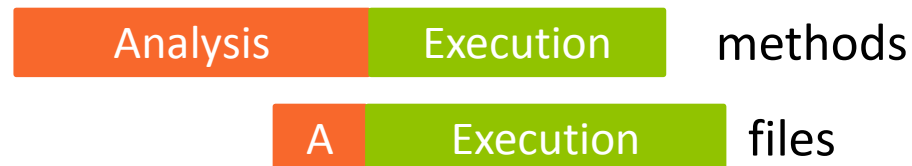
**RTS with file dependencies select: t2, t3, t4**



# Prior RTS Techniques vs. Ekstazi

- 30 years, 300+ papers
- fine-grained dependency
  - methods, basic blocks, statements, ...
- fewer tests
- slow analysis
- unsafe
- coarse-grained dependency
  - dynamically used files (code classes and other files)
- more tests
- fast analysis
- safer

Important: total time = analysis + execution



# Intuition for Surprising Results

- Efficient due to these properties
  - Small fraction of files are modified at each revision
  - Small fraction of tests depend on each file
  - Changes are localized
- Safe for (m)any code/file change
  - Unchanged files cannot affect test execution

# Ekstazi is Safer – Example (1)

revision 0

```
class A {  
  A() {}  
  int m() { return 1; }  
}  
class B extends A {  
  B() {} // calls A()  
}
```

```
test() {  
  B b = new B();  
  assert(b.m() == 1);  
}
```

revision 1

```
class A {  
  A() {}  
  int m() { return 1; }  
}  
class B extends A {  
  B() {}  
  @Override  
  int m() { return 2; }  
}
```

	A()	B()	A.m()
test	★	★	★



	A	B
test	★	★



# Ekstazi is Safer – Example (2)

revision 0

```
class A {  
  A() {}  
  public void m() { ... }  
}
```

revision 1

```
class A {  
  A() {}  
  public void m() { ... }  
  public void n() { ... }  
}
```

```
test() {  
  Method[] methods = A.class.getDeclaredMethods();  
  assert(methods.length == 1);  
}
```

	A()	A.m()
test		



	A
test	★

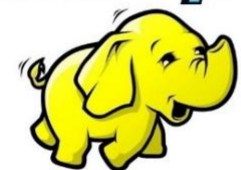


# Ekstazi Tool

- Implemented for JVM languages  
<http://www.ekstazi.org>
- Technical challenges
  - Efficient monitoring of used classes
  - Handling jar files
  - Supporting parallel execution
  - Fast file comparison
  - Smart hashing (i.e., ignoring debug info in classfiles)

# Evaluation – Projects

- 32 projects
- 773,565 tests
- ~5M LOC
- >500 revisions



# Project | #TestClasses

Cucumber	<b>49</b>
JodaTime	<b>124</b>
Retrofit	<b>15</b>
CommonsValidator	<b>61</b>
BVal	<b>21</b>
CommonsXPath	<b>33</b>
GraphHopper	<b>80</b>
River	<b>14</b>
Functor	<b>164</b>
EmpireDB	<b>23</b>
JFreeChart	<b>359</b>
CommonsColl4	<b>145</b>
CommonsLang3	<b>121</b>
CommonsConfig	<b>141</b>
PdfBox	<b>94</b>
GSCollections	<b>1106</b>

CommonsNet	<b>37</b>
ClosureCompiler	<b>233</b>
CommonsDBCP	<b>27</b>
Log4j	<b>38</b>
JGit	<b>229</b>
CommonsIO	<b>84</b>
Ivy	<b>121</b>
Jenkins	<b>86</b>
CommonsMath	<b>461</b>
Ant	<b>234</b>
Continuum	<b>68</b>
Guava	<b>348</b>
Camel	<b>2015</b>
Jetty	<b>504</b>
Hadoop	<b>317</b>
ZooKeeper	<b>127</b>

# Project | #TestClasses | Time [sec]

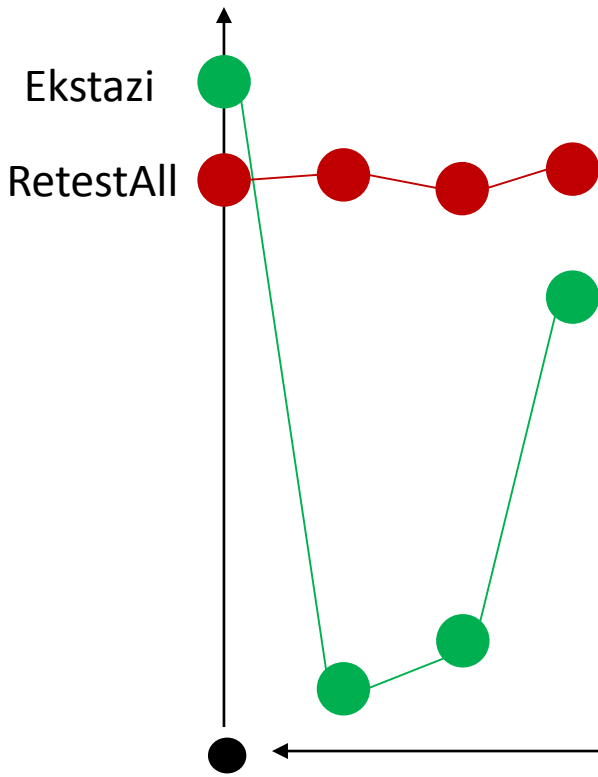
Cucumber	49	<b>8</b>
JodaTime	124	<b>10</b>
Retrofit	15	<b>10</b>
CommonsValidator	61	<b>11</b>
BVal	21	<b>13</b>
CommonsJXPath	33	<b>15</b>
GraphHopper	80	<b>15</b>
River	14	<b>17</b>
Functor	164	<b>21</b>
EmpireDB	23	<b>27</b>
JFreeChart	359	<b>30</b>
CommonsColl4	145	<b>32</b>
CommonsLang3	121	<b>36</b>
CommonsConfig	141	<b>39</b>
PdfBox	94	<b>40</b>
GSCollections	1106	<b>51</b>

CommonsNet	37	<b>68</b>
ClosureCompiler	233	<b>71</b>
CommonsDBCP	27	<b>76</b>
Log4j	38	<b>79</b>
JGit	229	<b>83</b>
CommonsIO	84	<b>98</b>
Ivy	121	<b>170</b>
Jenkins	86	<b>171</b>
CommonsMath	461	<b>249</b>
Ant	234	<b>380</b>
Continuum	68	<b>453</b>
Guava	348	<b>469</b>
Camel	2015	<b>1296</b>
Jetty	504	<b>1363</b>
Hadoop	317	<b>1415</b>
ZooKeeper	127	<b>2565</b>



# Evaluation – Setup

measure execution time



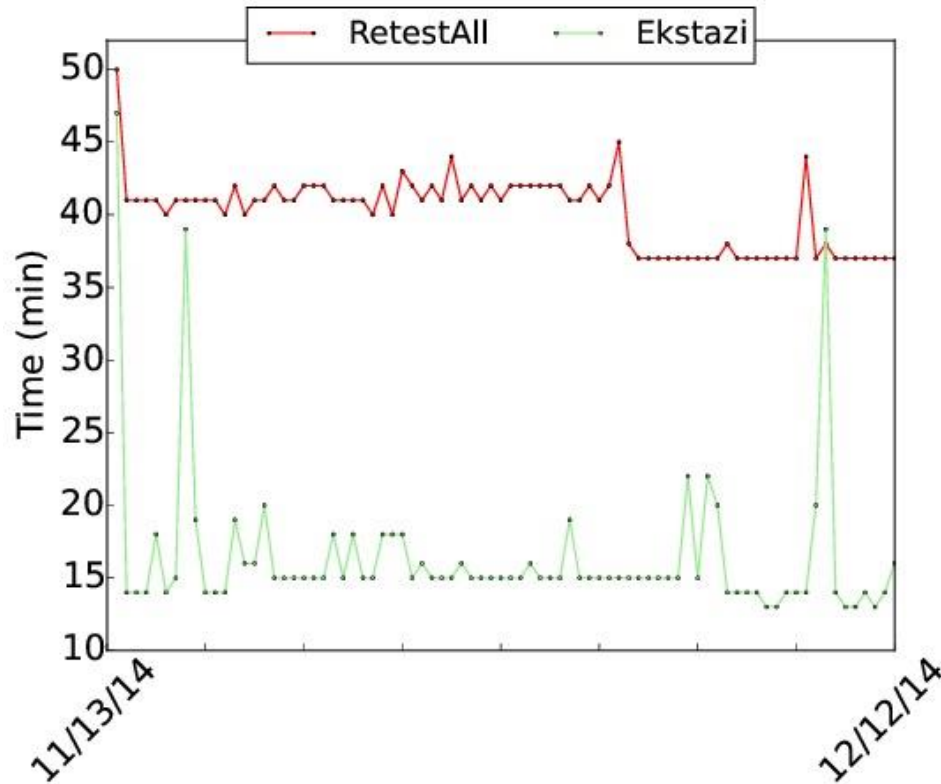
**GitHub**



git clone PROJECT

git checkout 20 revisions earlier

# Evaluation – Apache CXF



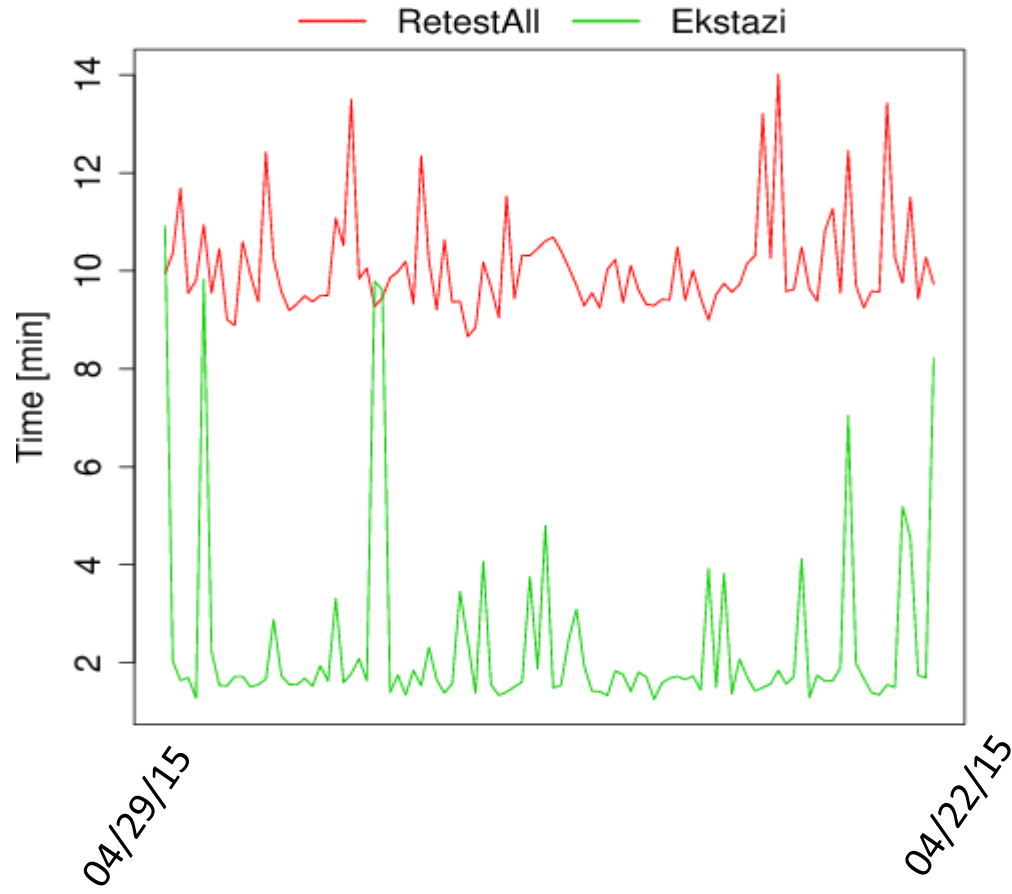
Reduces number of tests: **~15x**

Reduces test execution time: **~8x**

Reduces build+test time: **~3x**

Executed on our group's server

# Evaluation – Guava



Executed on Amazon EC2

# Project | Tests %

Cucumber	12
JodaTime	21
Retrofit	16
CommonsValidator	6
BVal	13
CommonsXPath	20
GraphHopper	16
River	6
Functor	13
EmpireDB	18
JFreeChart	5
CommonsColl4	9
CommonsLang3	11
CommonsConfig	20
PdfBox	12
GSCollections	29

CommonsNet	10
ClosureCompiler	17
CommonsDBCP	21
Log4j	6
JGit	22
CommonsIO	12
Ivy	38
Jenkins	7
CommonsMath	6
Ant	13
Continuum	10
Guava	13
Camel	5
Jetty	26
Hadoop	7
ZooKeeper	20

# Project | Tests % | Time %

Cucumber	12	99
JodaTime	21	107
Retrofit	16	104
CommonsValidator	6	88
BVal	13	138
CommonsXPath	20	94
GraphHopper	16	85
River	6	35
Functor	13	112
EmpireDB	18	112
JFreeChart	5	80
CommonsColl4	9	66
CommonsLang3	11	60
CommonsConfig	20	72
PdfBox	12	80
GSCollections	29	107

CommonsNet	10	21
CommonsMaven	17	62
CommonsDBCP	21	46
JGit	22	65
CommonsIO	12	30
Ivy	38	53
Jenkins	7	74
CommonsMath	6	77
Ant	13	24
Continuum	10	32
Guava	13	45
Camel	5	9
Jetty	26	57
Hadoop	7	38
ZooKeeper	20	43

**Average All = 68%**

**Average Long Running = 46%**

# Ekstazi Without and With Smart Checksum

Project	WO/ Smart Checksum		W/ Smart Checksum	
	Tests%	Time%	Tests%	Time%
CommonsValidator	7	93	6	88
JFreeChart	6	87	5	84
CommonsNet	11	28	9	26
CommonsDBCP	40	60	23	43
CommonsIO	21	42	14	30
Ivy	47	63	38	53
Jenkins	14	72	7	74
CommonsMath	6	85	6	75
Camel	5	9	5	9
<b>Avg.</b>	<b>17</b>	<b>60</b>	<b>13</b>	<b>54</b>

# FaultTracer vs. Ekstazi

Project	FaultTracer		Ekstazi	
	Tests%	Time%	Tests%	Time%
JodaTime	3	663	21	107
CommonsValidator	1	255	6	88
CommonsXPath	14	294	20	94
CommonsLang3	1	183	8	63
CommonsConfig	8	223	19	76
CommonsNet	2	57	9	26
<b>Avg.</b>	<b>5</b>	<b>279</b>	<b>14</b>	<b>76</b>

# Ekstazi Users



**Apache CXF**



Zed - actuator services platform

JBoss Fuse examples

JBoss Operations Network

Proprietary banking software

Example from Apache Camel: commit ff94895c

Date: Thu Nov 13 09:17:06 2014 -0600

**Including Ekstazi ([www.ekstazi.org](http://www.ekstazi.org)) profile to optimize execution of the tests**



# Feedback on Ekstazi



Henryk Konsek @hekonsek · Dec 30

Yay, new version of Ekstazi Maven Plugin is out. Highly recommended! [ekstazi.org/maven.html](http://ekstazi.org/maven.html)



“Your tool is quite impressive; congratulations!”  
an Apache Commons Math developer

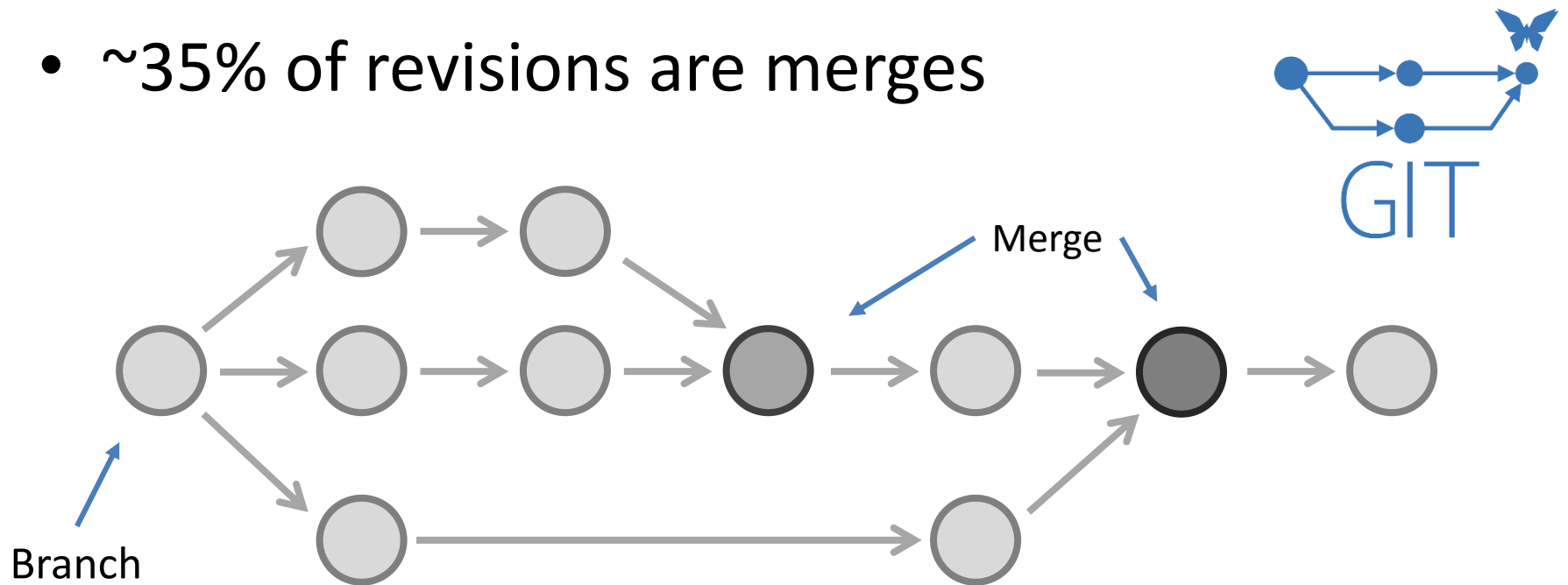


Hangout with Google managers and developers

Several requests from various (Apache) developers,  
e.g., forcefailing

# Ekstazi for Distributed Software Histories

- Distributed version control systems (e.g., Git)
- Complex DAGs due to branches, merges, etc.
- ~35% of revisions are merges



# Conclusions



Ekstazi

- Novel regression test selection technique
  - tracks dynamic file dependencies
  - guarantees safety in many common cases
  - speedups up regression testing for many projects
- Adopted by several popular open-source projects

<http://www.ekstazi.org>

THE UNIVERSITY OF  
**TEXAS**  
— AT AUSTIN —



**ILLINOIS**  
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Milos Gligoric <[milos.gligoric@gmail.com](mailto:milos.gligoric@gmail.com)>

Lamyaa Eloussi <[eloussi2@Illinois.edu](mailto:eloussi2@Illinois.edu)>

Darko Marinov <[marinov@Illinois.edu](mailto:marinov@Illinois.edu)>



# Ekstazi – Maven Integration

```
<plugin>  
<groupId>org.ekstazi</groupId>  
<artifactId>ekstazi-maven-plugin</artifactId>  
<version>4.6.0</version>  
<executions>  
  <execution>  
    <id>ekstazi</id> <goals> <goal>select</goal> </goals>  
  </execution>  
</executions>  
</plugin>
```

# Method and Class Granularities

Project	Method			Class		
	Entities%	Time (AEC)	Time (AE)	Entities%	Time (AEC)	Time (AE)
Bval	16	138	94	13	138	97
ClosureCompiler	20	96	53	17	62	50
CommonsColl4	7	81	60	9	66	55
CommonsConfig	19	76	57	20	72	58
CommonsDBCP	23	43	37	21	46	39
CommonsIO	14	30	24	12	30	24
CommonsLang3	8	63	51	11	60	53
CommonsMath	6	75	17	6	77	16
CommonsNet	9	26	22	10	21	21
Cucumber	13	105	78	12	99	76
EmpireDB	13	117	100	18	112	99
<b>Avg.</b>	<b>13</b>	<b>87</b>	<b>61</b>	<b>14</b>	<b>77</b>	<b>59</b>

# Name Meaning

[www.vocabulary.com](http://www.vocabulary.com)

If you've ever been so happy that the rest of the world seemed to disappear, you've felt *ecstasy* — a feeling or state of intensely beautiful bliss.

# Ekstazi – Results

Project	Tests%	Time%
Camel	5	9
CommonsDBCP	40	60
CommonsIO	21	42
CommonsMath	6	85
CommonsNet	11	28
CommonsValidator	7	93
Ivy	47	63
Jenkins	14	72
JFreeChart	6	87
<b>Avg. (all)</b>	<b>17</b>	<b>60</b>



# Ekstazi Without and With Smart Checksum

Project	WO/ Smart Checksum		W/ Smart Checksum	
	Tests%	Time%	Tests%	Time%
Camel	5	9	5	9
CommonsDBCP	40	60	23	43
CommonsIO	21	42	14	30
CommonsMath	6	85	6	75
CommonsNet	11	28	9	26
CommonsValidator	7	93	6	88
Ivy	47	63	38	53
Jenkins	14	72	7	74
JFreeChart	6	87	5	84
<b>Avg. (all)</b>	<b>17</b>	<b>60</b>	<b>13</b>	<b>54</b>

# FaultTracer vs. Ekstazi

Project	FaultTracer		Ekstazi	
	Tests%	Time%	Tests%	Time%
CommonsConfig	8	223	19	76
CommonsXPath	14	294	20	94
CommonsLang3	1	183	8	63
CommonsNet	2	57	9	26
CommonsValidator	1	255	6	88
JodaTime	3	663	21	107
<b>Avg.</b>	<b>5</b>	<b>279</b>	<b>14</b>	<b>76</b>

# Project | #TestClasses

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GraphHopper	<b>15</b>
River	<b>17</b>
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CommonsIO	<b>98</b>
Ivy	<b>170</b>
Jenkins	<b>171</b>
CommonsMath	<b>249</b>
Ant	<b>380</b>
Continuum	<b>453</b>
Guava	<b>469</b>
Camel	<b>1296</b>
Jetty	<b>1363</b>
Hadoop	<b>1415</b>
ZooKeeper	<b>2565</b>

# Project | Time [sec] | #TestClasses | Tests%

Cucumber	8	49	<b>12</b>
JodaTime	10	124	<b>21</b>
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CommonsValidator	11	61	<b>6</b>
BVal	13	21	<b>13</b>
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GSCollections	51	1106	<b>29</b>

CommonsNet	68	37	<b>10</b>
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CommonsDBCP	76	27	<b>21</b>
Log4j	79	38	<b>6</b>
JGit	83	229	<b>22</b>
CommonsIO	98	84	<b>12</b>
Ivy	170	121	<b>38</b>
Jenkins	171	86	<b>7</b>
CommonsMath	249	461	<b>6</b>
Ant	380	234	<b>13</b>
Continuum	453	68	<b>10</b>
Guava	469	348	<b>13</b>
Camel	1296	2015	<b>5</b>
Jetty	1363	504	<b>26</b>
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CommonsDBCP	76	27	21	<b>46</b>
Log4j	79	38	6	<b>62</b>
JGit	83	229	22	<b>65</b>
CommonsIO	98	84	12	<b>30</b>
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