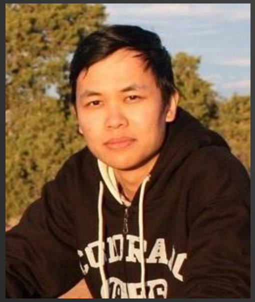
Mining Source Code Repositories with

Boa

Robert Dyer, Hoan Nguyen, Hridesh Rajan, and Tien Nguyen

{rdyer,hoan,hridesh,tien}@iastate.edu

Iowa State University

The research and educational activities described in this talk was supported in part by the US National Science Foundation (NSF) under grants CCF-13-49153, CCF-13-20578, TWC-12-23828, CCF-11-17937, CCF-10-17334, and CCF-10-18600.

What is actually practiced

Keep doing what works

To find better designs

Empirical validation

Spot (anti-)patterns

Why mine software repositories?

Learn from the past → **Inform the future**

Open source repositories

Google code

CodePlex
Open Source Project Community

Apache

github
SOCIAL CODING

Java.net

SOURCEFORGE.NET®

Atlassian
bitbucket

launchpad

Open source repositories

1,000,000+ projects

1,000,000,000+ lines of code

10,000,000+ revisions

3,000,000+ issue reports

Open source repositories

1,000,000+ projects

What is the most used PL?

1,000,000,000+ lines of code

How many methods are named "test"?

10,000,000+ revisions

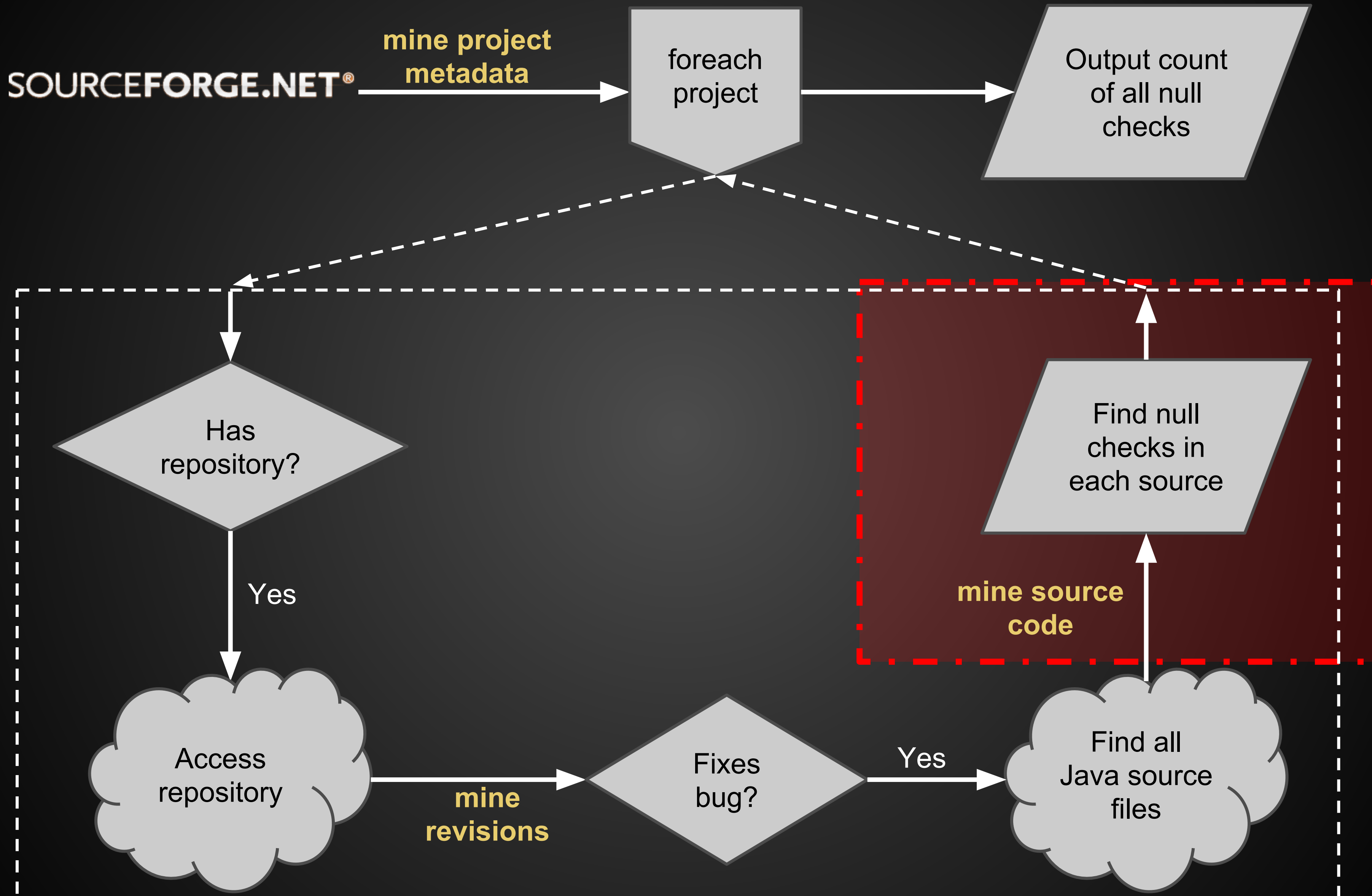
How many words are in log messages?

3,000,000+ issue reports

How many issue reports have duplicates?

Consider a task to answer

"How many bug fixes add checks for null?"


SOURCEFORGE.NET®
mine project metadata
foreach project
Output count of all null checks
Has repository?
Yes
Access repository
mine revisions
Fixes bug?
Yes
Find all Java source files
mine source code
Find null checks in each source

A solution in Java...

```
class AddNullCheck {
    static void main(String[] args) {
        ... /* create and submit a Hadoop job */
    }
    static class AddNullCheckMapper extends Mapper<Text, BytesWritable, Text, LongWritable> {
        static class DefaultVisitor {
            ... /* define default tree traversal */
        }
        void map(Text key, BytesWritable value, Context context) {
            final Project p = ... /* read from input */
            new DefaultVisitor() {
                boolean preVisit(Expression e) {
                    if (e.kind == ExpressionKind.EQ || e.kind == ExpressionKind.NEQ)
                        for (Expression exp : e.expressions)
                            if (exp.kind == ExpressionKind.LITERAL && exp.literal.equals("null")) {
                                context.write(new Text("count"), new LongWritable(1));
                                break;
                            }
                }
            }.visit(p);
        }
    }
    static class AddNullCheckReducer extends Reducer<Text, LongWritable, Text, LongWritable> {
        void reduce(Text key, Iterable<LongWritable> vals, Context context) {
            int sum = 0;
            for (LongWritable value : vals)
                sum += value.get();
            context.write(key, new LongWritable(sum));
        }
    }
```

Too much code!
Do not read!

Full program
over 140 lines of code

Uses ***JSON, SVN, and Eclipse JDT libraries***

Uses ***Hadoop framework***

Explicit/manual
parallelization

The Boa language and data-intensive infrastructure

http://boa.cs.iastate.edu/

Design goals

- Easy to use
- Scalable and efficient
- Reproducible research results

Design goals

➡ Easy to use

- Simple language
- No need to know details of
  - Software repository mining
  - Data parallelization

Design goals

➡ Scalable and efficient

- Study ***millions*** of projects
- Results in minutes, not days

Design goals

Reproducible research results

Replicating MSR:
A study of the potential replicability of papers published in the Mining Software Repositories Proceedings

Gregorio Robles
GSyC/LibreSoft
Universidad Rey Juan Carlos
Madrid, Spain
Email: grex@gsyc.urjc.es

***Abstract*—This paper is the result of reviewing all papers published in the proceedings of the former International Workshop on Mining Software Repositories (MSR) (2004-2006) and now Working Conference on MSR (2007-2009). We have analyzed the papers that contained any experimental analysis of software projects for their potentiality of being replicated. In this regard, three main issues have been addressed: i) the public availability of the data used as case study, ii) the public availability of the processed dataset used by researchers and iii) the public availability of the tools and scripts. A total number of 171 papers have been analyzed from the six workshops/working conferences up to date. Results show that MSR authors use in general publicly available data sources, mainly from free software repositories, but that the amount of publicly available processed datasets is very low. Regarding tools and scripts, for a majority of papers we have not been able to find any tool, even for papers where the authors explicitly state that they have built one. Lessons learned from the experience of reviewing the whole MSR literature and some potential solutions to lower the barriers of replicability are finally presented and discussed.**

***Keywords*-replication, tools, public datasets, mining software repositories**

Replication package: http://gsyc.urjc.es/~grex/msr2010.

I. Introduction

Mining software repositories (MSR) has become a fundamental area of research for the Software Engineering

Among these threats, we may encounter: lack of independent validation of the presented results; changes in practices, tools or methodologies; or generalization of knowledge although a limited amount of case studies have been performed.

A simple taxonomy of replication studies provides us with two main groups: exact replications and conceptual replications. The former ones are those in "which the procedures of an experiment are followed as closely as possible to determine whether the same results can be obtained", while the latter ones are those "one in which the same research question or hypothesis is evaluated by using a different experimental procedure, i.e. many or all of the variables described above are changed." [2]. In this paper, we will target exact replications as the requirements that have to be met to perform an exact replication are more severe, and in general make a conceptual replication feasible.

We are focusing in this paper on potential replication as we have actually not replicated any of the studies presented in the papers under review. Our aim in this sense is more humble: we want to check if the necessary conditions that make a replication possible are met.

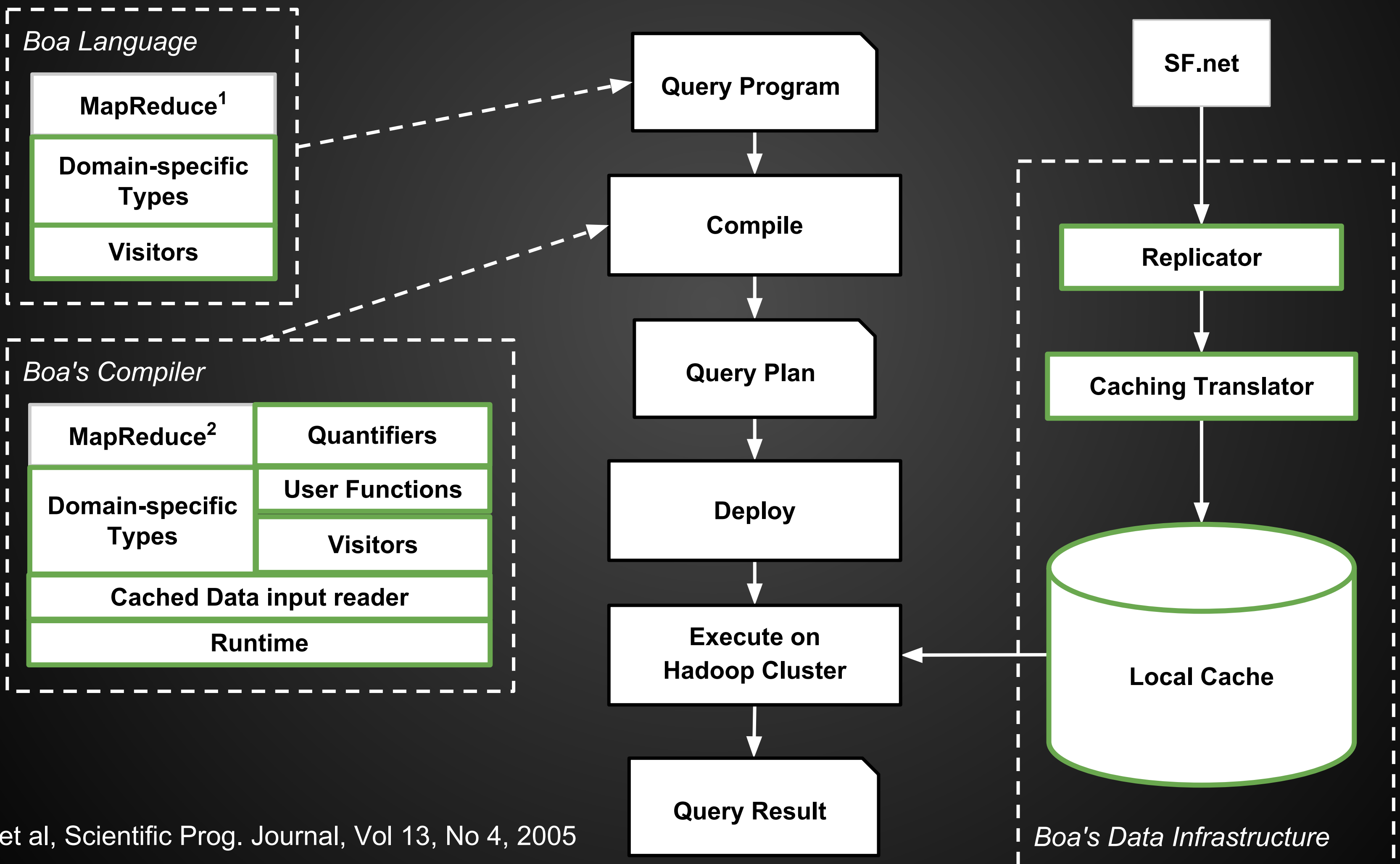
The rest of the paper is structured as follows: in the next section, the method used for this study is presented. Then some general remarks on the MSR conference are given, to give the reader a sense of the type of papers that are

Robles, MSR'10

Studied 171 papers

Only 2 were "replication friendly"

Boa architecture



[1] Pike et al, Scientific Prog. Journal, Vol 13, No 4, 2005

[2] Anthony Urso, http://github.com/anthonyu/Sizzle

Recall: A solution in Java...

```
class AddNullCheck {
    static void main(String[] args) {
        ... /* create and submit a Hadoop job */
    }
    static class AddNullCheckMapper extends Mapper<Text, BytesWritable, Text, LongWritable> {
        static class DefaultVisitor {
            ... /* define default tree traversal */
        }
        void map(Text key, BytesWritable value, Context context) {
            final Project p = ... /* read from input */
            new DefaultVisitor() {
                boolean preVisit(Expression e) {
                    if (e.kind == ExpressionKind.EQ || e.kind == ExpressionKind.NEQ)
                        for (Expression exp : e.expressions)
                            if (exp.kind == ExpressionKind.LITERAL && exp.literal.equals("null")) {
                                context.write(new Text("count"), new LongWritable(1));
                                break;
                            }
                }
            }.visit(p);
        }
    }
    static class AddNullCheckReducer extends Reducer<Text, LongWritable, Text, LongWritable> {
        void reduce(Text key, Iterable<LongWritable> vals, Context context) {
            int sum = 0;
            for (LongWritable value : vals)
                sum += value.get();
            context.write(key, new LongWritable(sum));
        }
    }
```

Too much code!
Do not read!

Full program
over 140 lines of code

Uses ***JSON, SVN, and Eclipse JDT libraries***

Uses ***Hadoop framework***

Explicit/manual
parallelization

A better solution...

```
p: Project = input;
count: output sum of int;

visit(p, visitor {
    before e: Expression ->
        if (e.kind == ExpressionKind.EQ || e.kind == ExpressionKind.NEQ)
            exists (i: int; isliteral(e.expressions[i], "null"))
                count << 1;
});
```

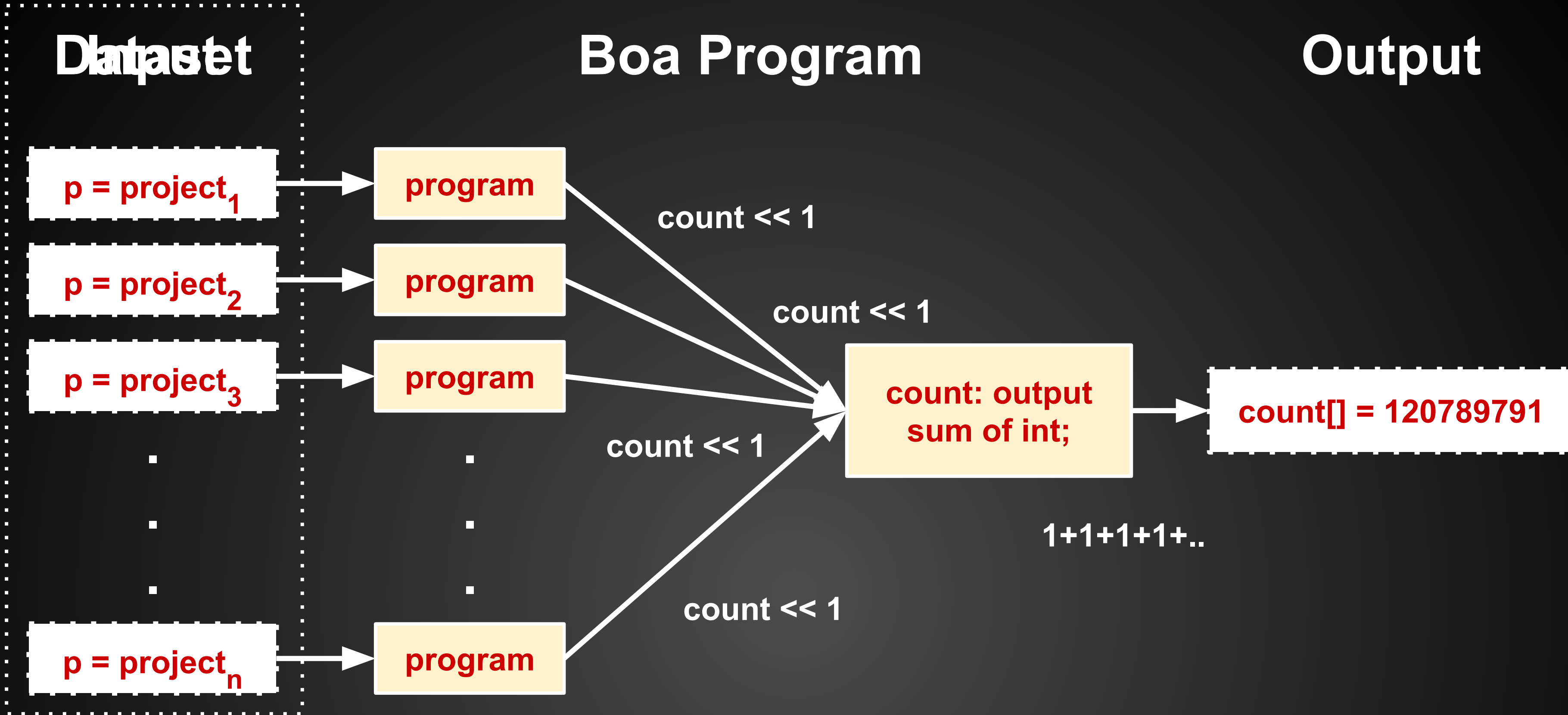
Full program **8 lines of code**!

Automatically parallelized!

No external libraries needed!

Analyzes **28.8 million** source files in about **15 minutes**!

(only 32 ***micro***seconds each!)




```
p: Project = input;
count: output sum of int;

visit(p, visitor {
     before e: Expression ->
          if (e.kind == ExpressionKind.EQ || e.kind == ExpressionKind.NEQ)
               exists (i: int; isliteral(e.expressions[i], "null"))
                    count << 1;
});
```

Design goals

Easy to use

Scalable and efficient

Reproducible research results

Let's see it in action!

http://boa.cs.iastate.edu/boa/

Why are we waiting for results?

Program is analyzing...

699,331 projects

494,158 repositories

15,063,073 revisions

69,863,970 files

18,651,043,238 AST nodes

Let's check the results!

<<demo>>

Domain-specific types

http://boa.cs.iastate.edu/docs/dsl-types.php

```
p: Project = input;
count: output sum of int;

visit(p, visitor {
    before e: Expression ->
        if (e.kind == ExpressionKind.EQ || e.kind == ExpressionKind.NEQ)
            exists (i: int; isliteral(e.expressions[i], "null"))
                count << 1;
});
```

Abstracts details of *how* to mine software repositories

Domain-specific types

http://boa.cs.iastate.edu/docs/dsl-types.php

Project

id	:	`string`
name	:	`string`
description	:	`string`
homepage_url	:	`string`
programming_languages	:	`array of string`
licenses	:	`array of string`
maintainers	:	`array of Person`
....		
code_repositories	:	`array of CodeRepository`

Domain-specific types

http://boa.cs.iastate.edu/docs/dsl-types.php

CodeRepository

url	:	`string`
kind	:	`RepositoryKind`
revisions	:	`array of Revision`

Revision

id	:	`int`
author	:	`Person`
committer	:	`Person`
commit_date	:	`time`
log	:	`string`
files	:	`array of File`

File

name	:	`string`
kind	:	`FileKind`
change	:	`ChangeKind`

Domain-specific functions

http://boa.cs.iastate.edu/docs/dsl-functions.php

```
hasfiletype := function (rev: Revision, ext: string) : bool {
    exists (i: int; match(format(`\.%s$`, ext), rev.files[i].name))
        return true;
    return false;
};
```

Mines a revision to see if it contains any files of the type specified.

Domain-specific functions

http://boa.cs.iastate.edu/docs/dsl-functions.php

```
isfixingrevision := function (log: string) : bool {
    if (match(`\bfix(s|es|ing|ed)?\b`, log))    return true;
    if (match(`\b(error|bug|issue)(s)\b`, log)) return true;
    return false;
};
```

Mines a revision log to see if it fixed a bug.

User-defined functions

http://boa.cs.iastate.edu/docs/user-functions.php

```
id := function (a1: t1, ..., an: tn) [: ret] {
     ... # body
     [return ...;]
};
```

Return type is optional

- Allows for complex algorithms and code re-use
- Users can provide their own mining algorithms

Quantifiers

http://boa.cs.iastate.edu/docs/quantifiers.php

```
foreach (i: int; condition...)
    body;
```

For *each* value of **i**,

if **condition** holds

then

run **body** (with i bound to the value)

Quantifiers

http://boa.cs.iastate.edu/docs/quantifiers.php

```
exists (i: int; condition...)
    body;
```

For *some* value of **i**,

if **condition** holds

then

run **body** *once* (with i bound to the value)

Quantifiers

http://boa.cs.iastate.edu/docs/quantifiers.php

```
ifall (i: int; condition...)
    body;
```

For *all* values of **i**,

if **condition** holds

then

run **body** *once* (with i not bound)

Output and aggregation

http://boa.cs.iastate.edu/docs/aggregators.php

```
p: Project = input;
count: output sum of int;

visit(p, visitor {
    before e: Expression ->
        if (e.kind == ExpressionKind.EQ || e.kind == ExpressionKind.NEQ)
            exists (i: int; isliteral(e.expressions[i], "null"))
                count << 1;
});
```

- Output defined in terms of predefined data aggregators
  - sum, set, mean, maximum, minimum, etc
- Values sent to output aggregation variables
- Output can be indexed

Declarative Visitors in Boa

http://boa.cs.iastate.edu/

Basic Syntax

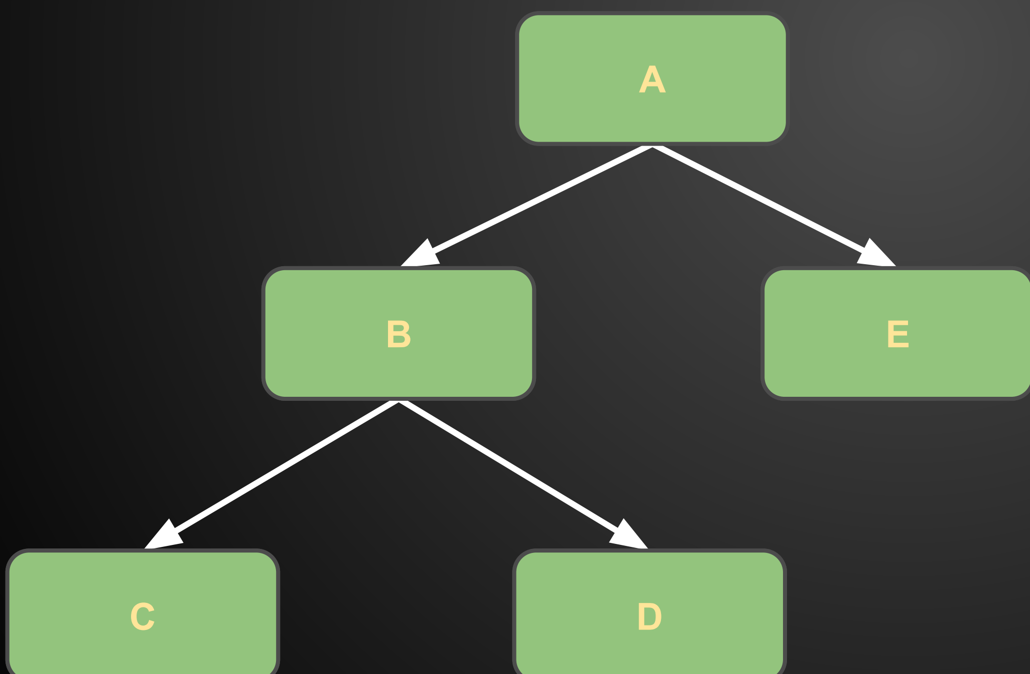
```
id := visitor {
  before id:T -> statement
  after  id:T -> statement
  ...
};
visit(startNode, id);
```

Execute **`statement`** either **`before`** or **`after`** visiting the children of a node of type **`T`**

Depth-First Traversal

Provides a default, depth-first traversal strategy

A -> B -> C -> D -> E




```
before A -> statement
before B -> statement
before C -> statement
after  C -> statement
before D -> statement
after  D -> statement
after  B -> statement
before E -> statement
after  E -> statement
after  A -> statement
```

Type Lists and Wildcards

```
visitor {
   before id:T      -> statement
   after T2,T3,T4 -> statement
   after _          -> statement
}
```

Single type (with identifier)

Attributes of the node available via identifier

Type Lists and Wildcards

```
visitor {
   before id:T     -> statement
   after T2,T3,T4 -> statement
   after _         -> statement
}
```

Type list (no identifier)

Executes **`statement`** when visiting nodes of type **`T2`**, **`T3`**, or **`T4`**

Type Lists and Wildcards

```
visitor {
   before id:T      -> statement
   after T2,T3,T4 -> statement
   after _          -> statement
}
```

Wildcard (no identifier)

Executes **`statement`** for any node not already listed in another similar clause (e.g., T but not T2/T3/T4)

Provides ***default*** behavior

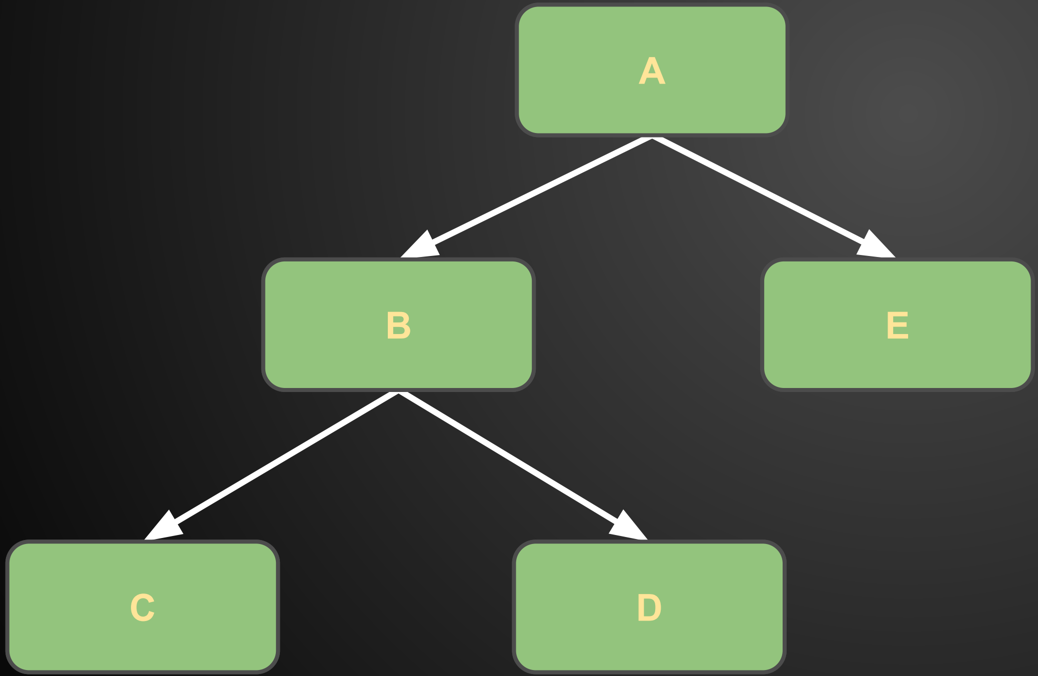
Type Lists and Wildcards

```
visitor {
   before id:T      -> statement
   after T2,T3,T4 -> statement
   after _          -> statement
}
```

Types can be matched by **at most 1 *before* clause** and **at most 1 *after* clause**

Custom Traversals

A -> E -> B -> C -> D




```
before n: A -> {
    visit(n.E);
    visit(n.B);
    stop;
}
```

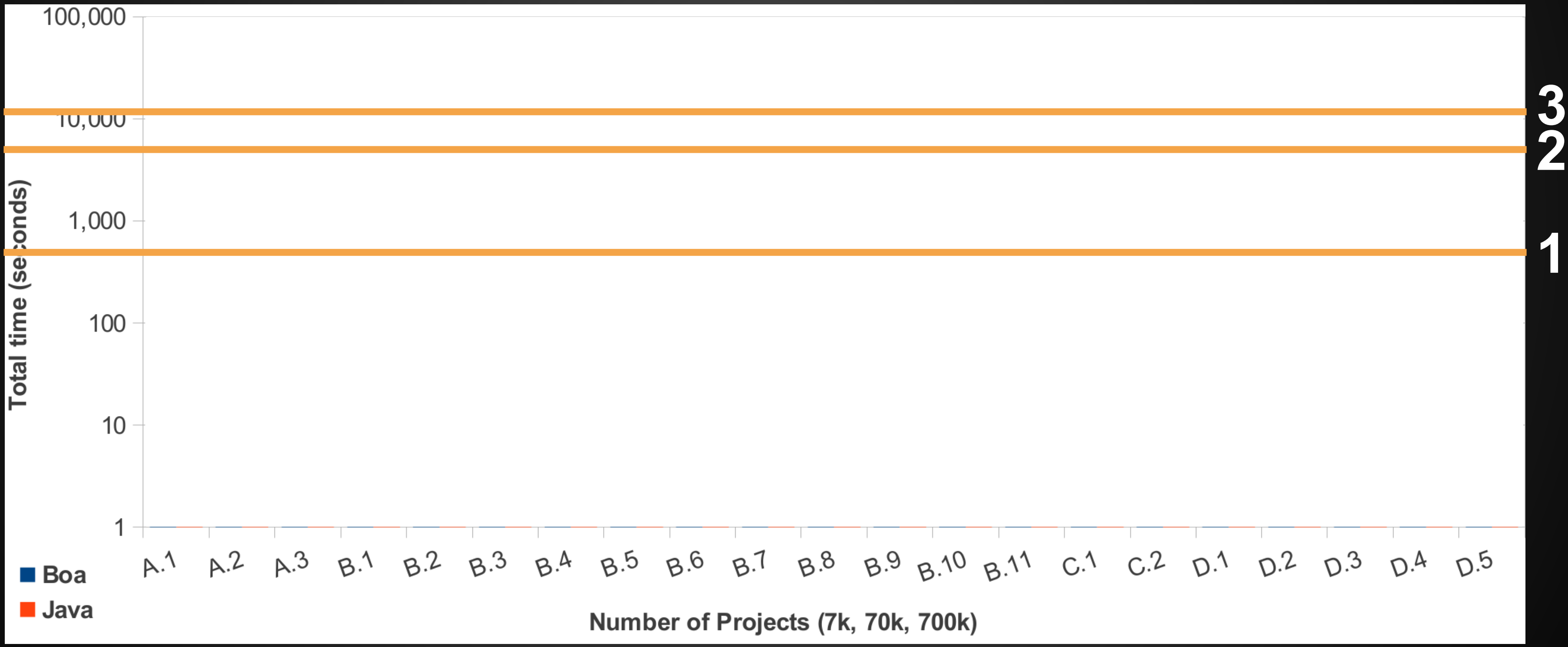
Design goals

Easy to use

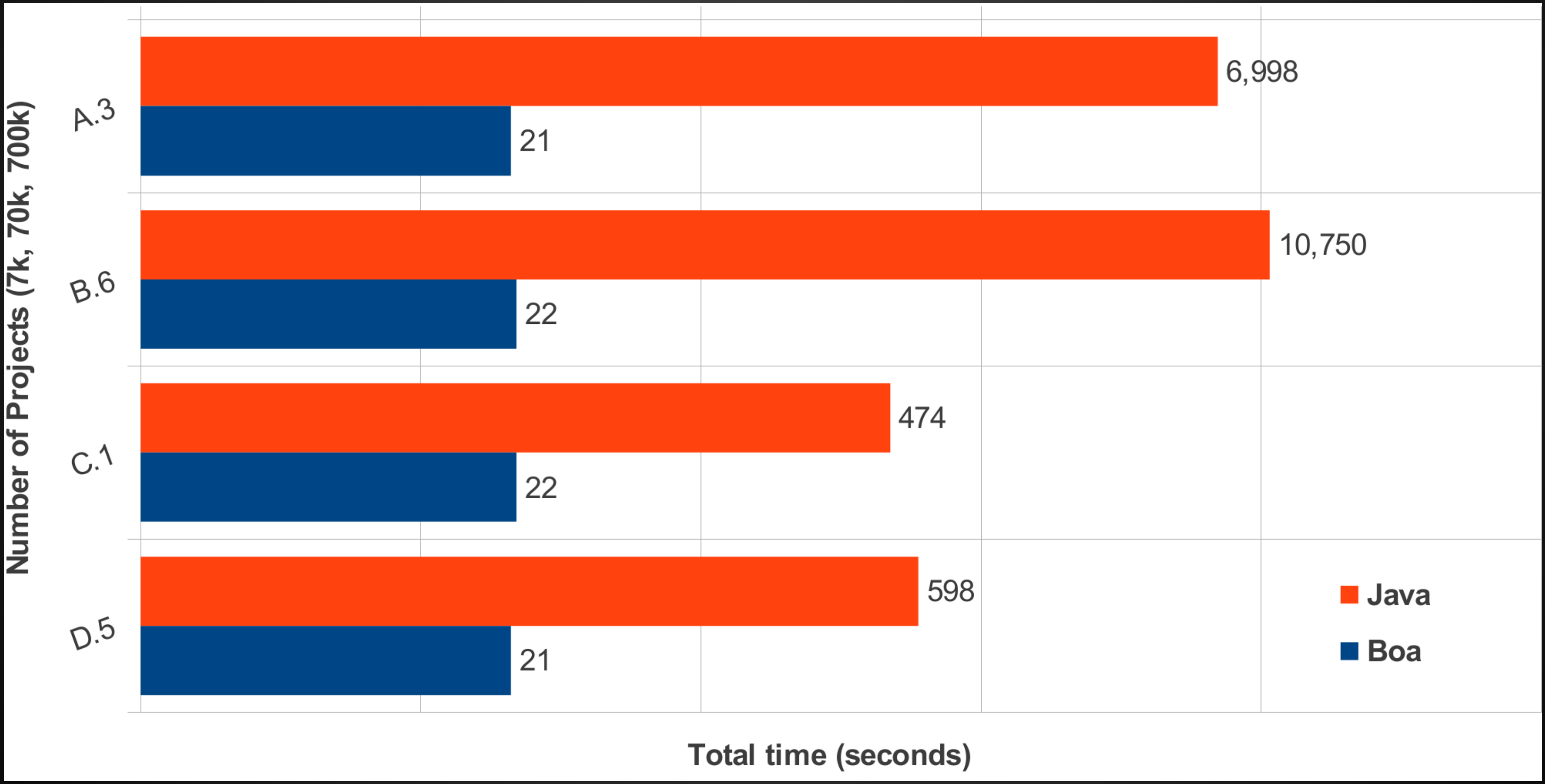
Scalable and efficient

Reproducible research results

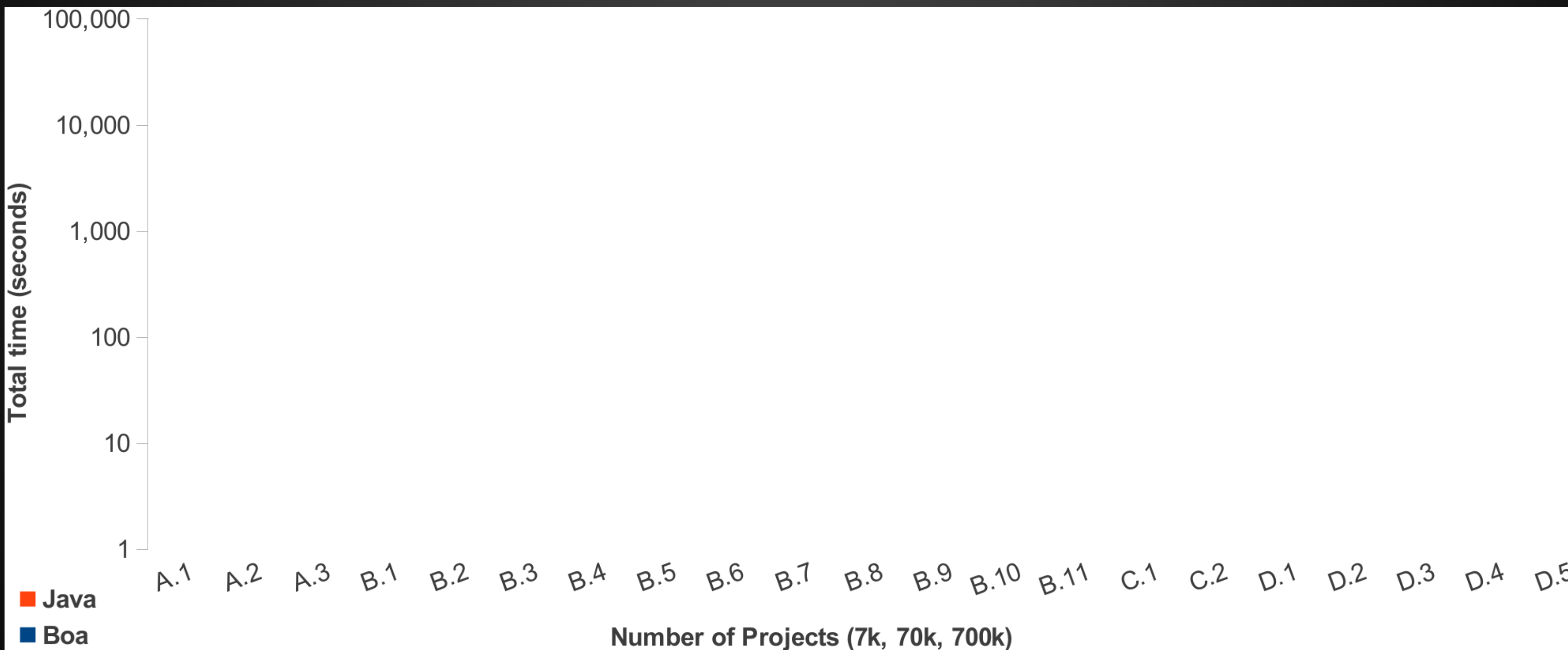
Efficient execution



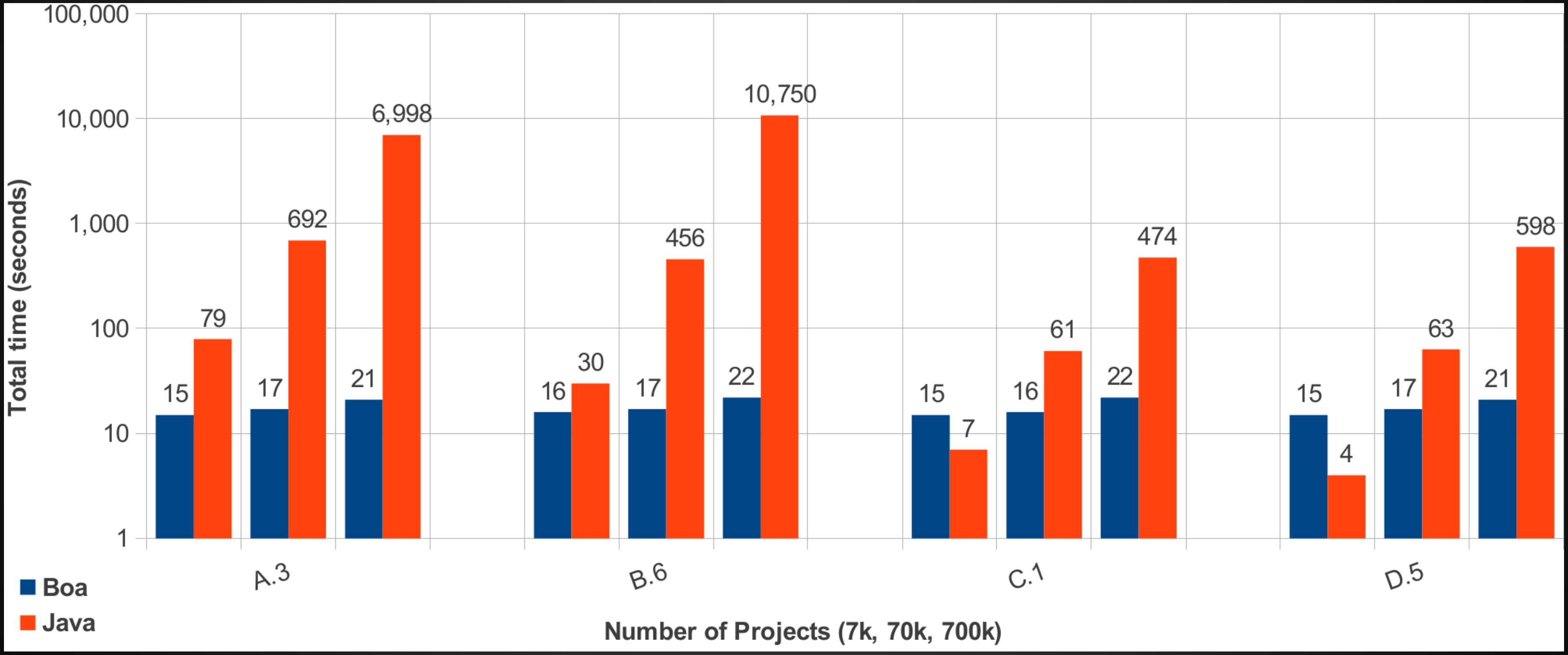
Efficient execution



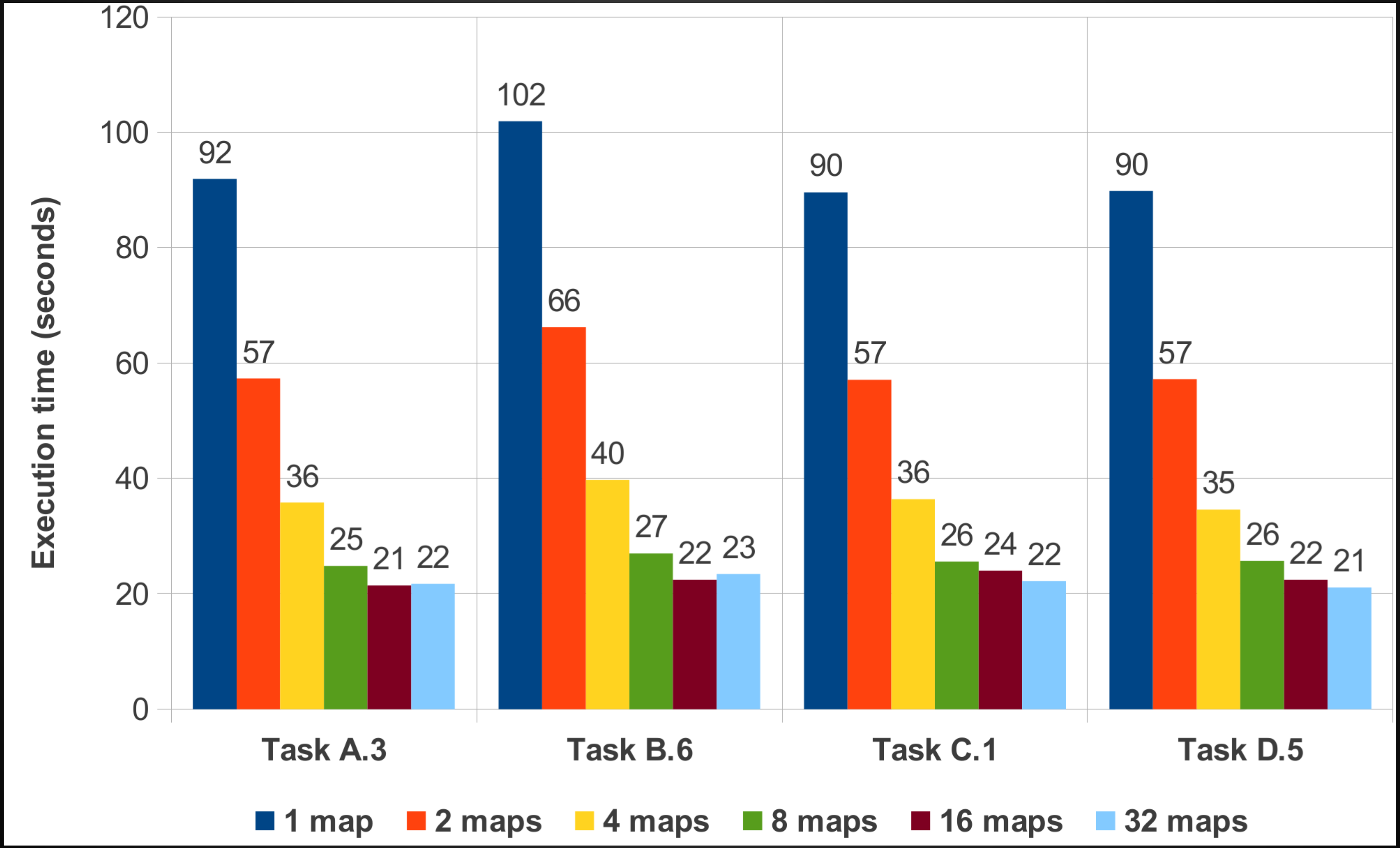
Scalability of input size



Scalability of input size



Scales to more cores



Design goals

Easy to use

Scalable and efficient

Reproducible research results

Reproducing MSR results

Replicating MSR:
A study of the potential replicability of papers published in the Mining Software Repositories Proceedings

Gregorio Robles
GSyC/LibreSoft
Universidad Rey Juan Carlos
Madrid, Spain
Email: grex@gsyc.urjc.es

***Abstract*—This paper is the result of reviewing all papers published in the proceedings of the former International Workshop on Mining Software Repositories (MSR) (2004-2006) and now Working Conference on MSR (2007-2009). We have analyzed the papers that contained any experimental analysis of software projects for their potentiality of being replicated. In this regard, three main issues have been addressed: i) the public availability of the data used as case study, ii) the public availability of the processed dataset used by researchers and iii) the public availability of the tools and scripts. A total number of 171 papers have been analyzed from the six workshops/working conferences up to date. Results show that MSR authors use in general publicly available data sources, mainly from free software repositories, but that the amount of publicly available processed datasets is very low. Regarding tools and scripts, for a majority of papers we have not been able to find any tool, even for papers where the authors explicitly state that they have built one. Lessons learned from the experience of reviewing the whole MSR literature and some potential solutions to lower the barriers of replicability are finally presented and discussed.**

***Keywords*-replication, tools, public datasets, mining software repositories**

Replication package: http://gsyc.urjc.es/~grex/msr2010.

I. Introduction

Mining software repositories (MSR) has become a fundamental area of research for the Software Engineering community, and of vital importance in the case of empirical studies. Software repositories contain a large amount of valuable information that includes source control systems storing all the history of the source code, defect tracking systems that host defects, enhancements and other issues, and other communication means such as mailing lists or forums. As a result of the possibilities that mining software repositories offer, an annual workshop first, then working conference on this topic has been organized with an extraordinary success in participation and research output.

Being mainly focused on empirical research, we wanted to evaluate how much of the research presented at the MSR can be potentially replicated. Replication is a fundamental task in empirical sciences and one of the main threats to validity that empirical software engineering may suffer [1]. Among these threats, we may encounter: lack of independent validation of the presented results; changes in practices, tools or methodologies; or generalization of knowledge although a limited amount of case studies have been performed.

A simple taxonomy of replication studies provides us with two main groups: exact replications and conceptual replications. The former ones are those in "which the procedures of an experiment are followed as closely as possible to determine whether the same results can be obtained", while the latter ones are those "one in which the same research question or hypothesis is evaluated by using a different experimental procedure, i.e. many or all of the variables described above are changed." [2]. In this paper, we will target exact replications as the requirements that have to be met to perform an exact replication are more severe, and in general make a conceptual replication feasible.

We are focusing in this paper on potential replication as we have actually not replicated any of the studies presented in the papers under review. Our aim in this sense is more humble: we want to check if the necessary conditions that make a replication possible are met.

The rest of the paper is structured as follows: in the next section, the method used for this study is presented. Then some general remarks on the MSR conference are given, to give the reader a sense of the type of papers that are published in the MSR proceedings. Results will be presented in section IV: first, the replication-friendliness of the papers will be shown and then each of the individual characteristics that we have defined will be studied independently. MSR has a special track called the "Mining Challenge", a section is devoted to analyze it with the aim of finding if results differ from those for the rest of papers. Then, other non-quantitative facts from the review are enumerated. Section VII discusses the findings of the paper and hints at possible solutions. Then, conclusions are drawn. In a final section, the replicability of this paper is considered.

II. Method

The method that has been used to perform this study is a complete literature review of the papers published in

978-1-4244-6803-4/10/$26.00 © 2010 IEEE

Robles, MSR'10

2/154 experimental papers "replication friendly."

48 due to lack of published data

Prior research results are difficult
(or impossible) to reproduce.

Boa makes this easier!

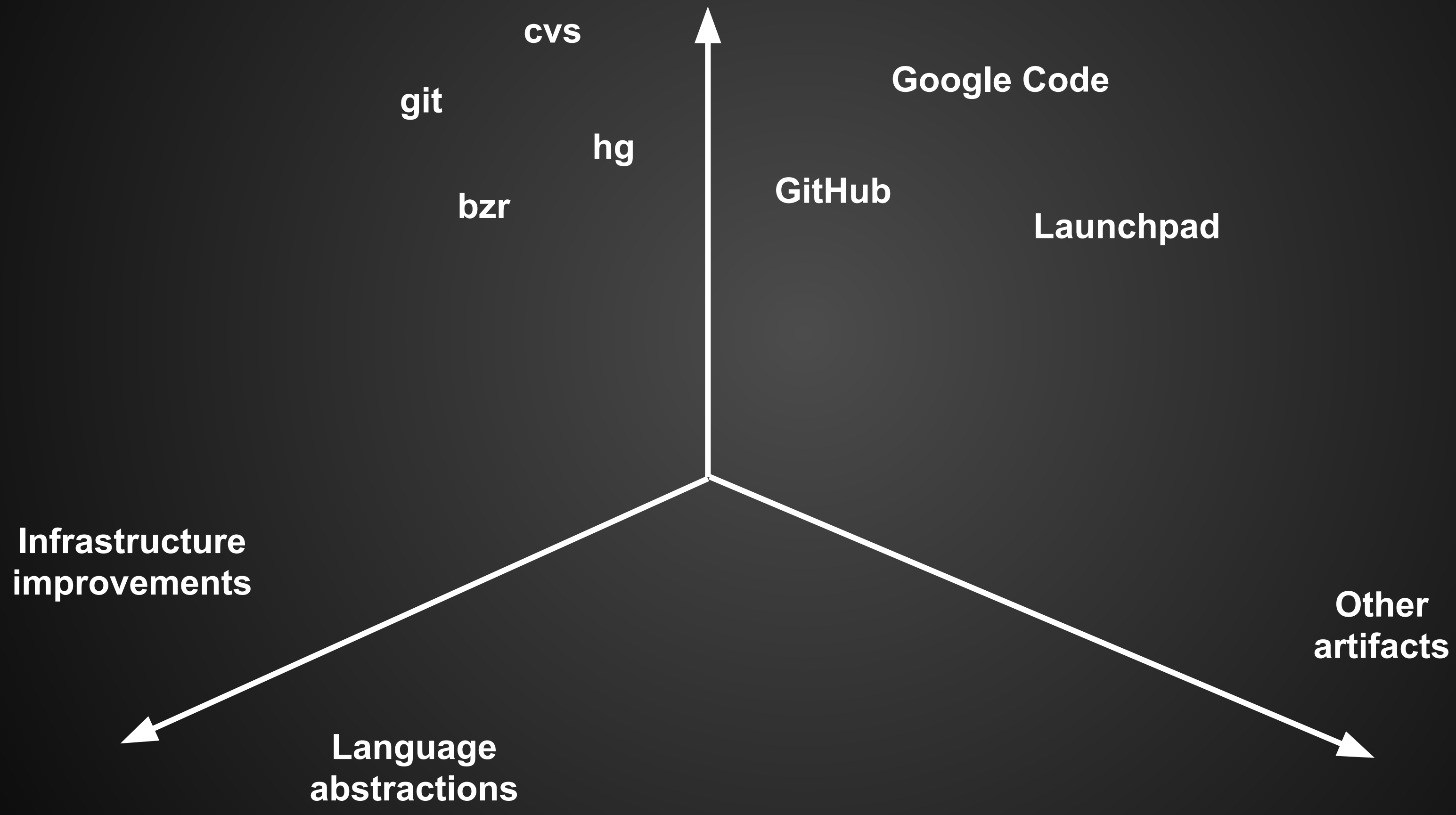
Controlled Experiment

- Published artifacts (Boa website):
  - Boa source code
  - Dataset used (timestamp of data)
  - Results

		Intro	Task 1		Task 2		Task 3	
Expert	**Education**	**Time**	**Task**	**Time**	**Task**	**Time**	**Task**	**Time**
Yes	Post-doc	6	B.1	1	B.6	4	B.9	3
Yes	PhD	5	A.1	3	B.6	2	B.7	6
No	PhD	4	B.6	1	B.10	4	B.9	4
No	PhD	4	A.2	2	B.6	2	D.5	4
No	MS	4	A.1	4	B.6	1	D.3	2
No	MS	3	B.6	2	C.1	2	D.4	10
No	MS	6	A.1	2	B.7	3	B.10	3
No	BS	2	A.2	2	D.1	2	D.3	2

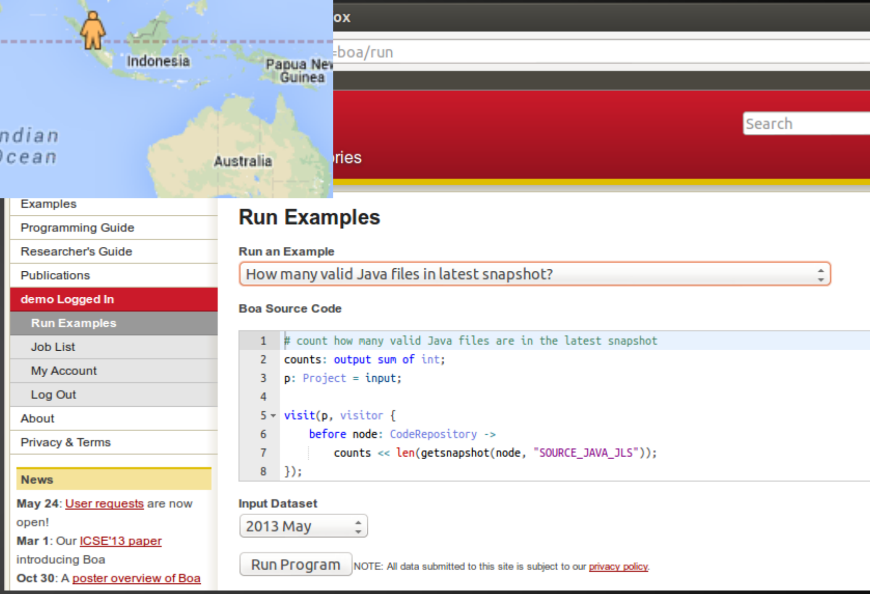
Fig. 16. Study results. All times given in minutes.

Ongoing work



Boa

http://boa.cs.iastate.edu/



Domain-specific language and infrastructure for software repository mining that is:

- Easy to use
- Efficient and scalable
- Amenable to reproducing prior results