Statistical Deobfuscation for Android Applications

Benjamin Bichsel

Veselin Raychev

Petar Tsankov

Martin Vechev

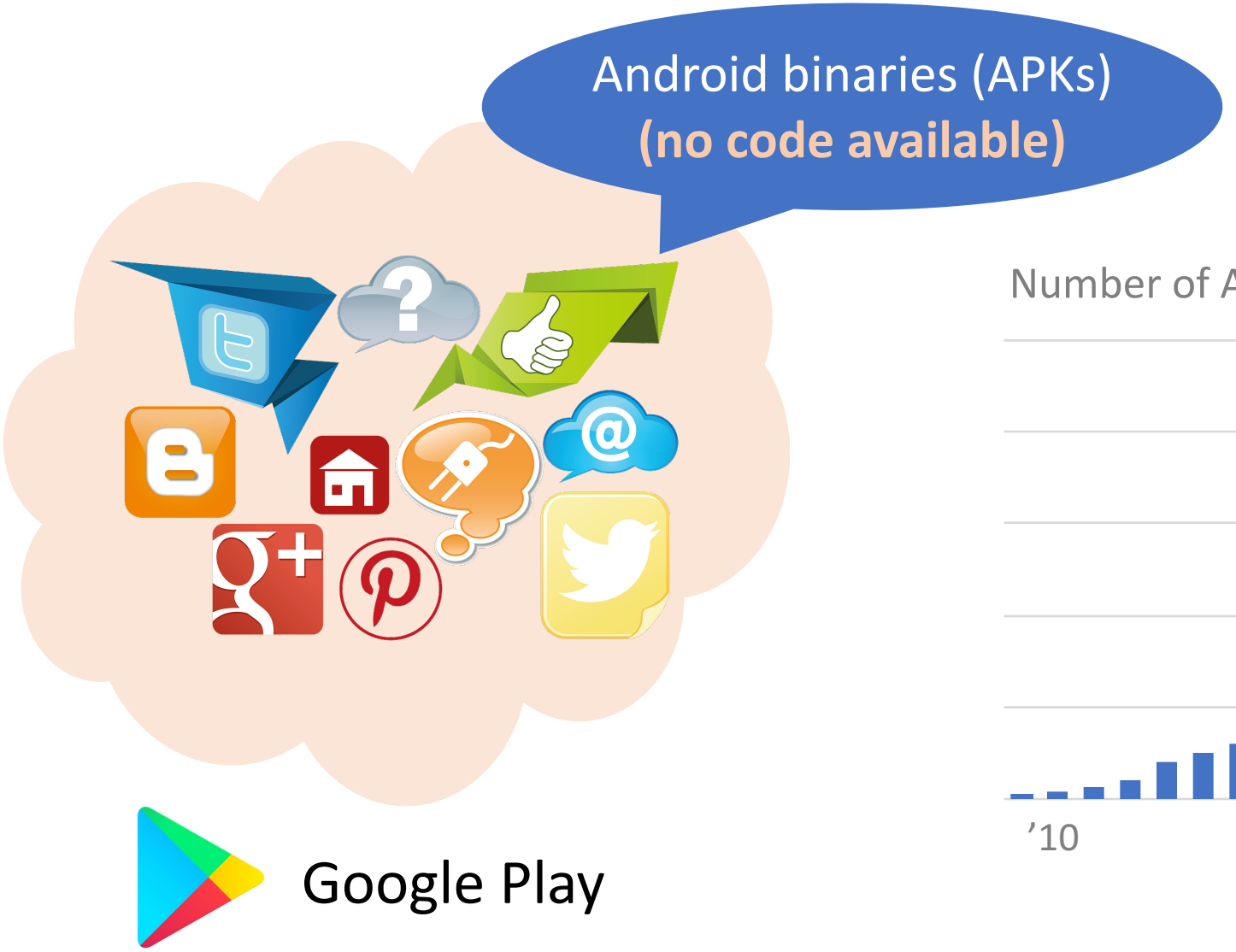
ETH Zürich

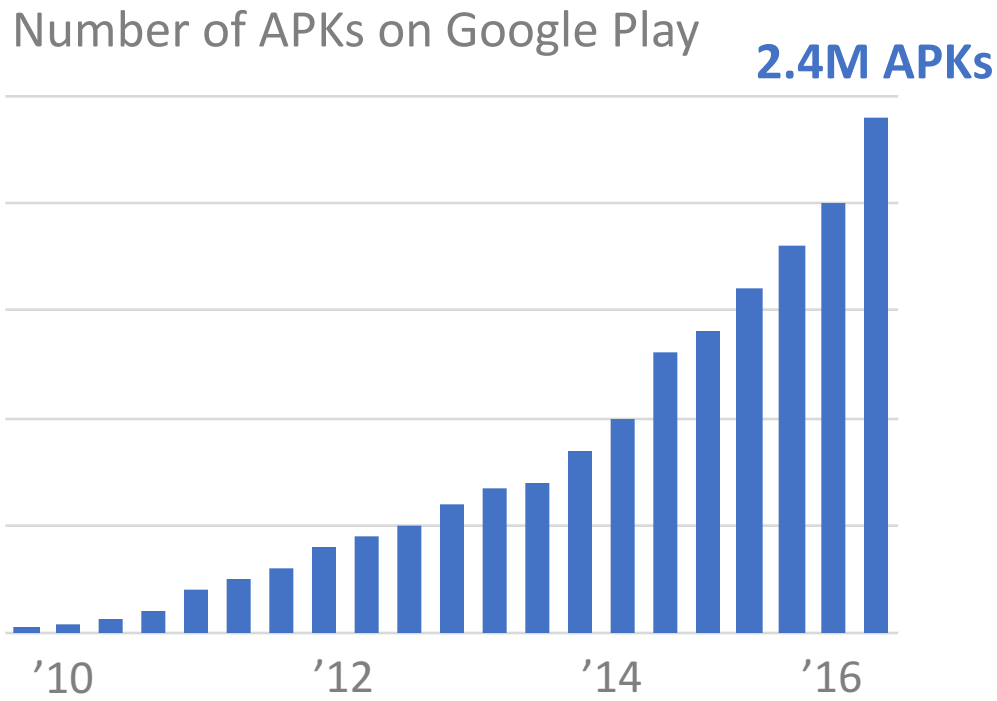
Department of Computer Science

SRL

SOFTWARE RELIABILITY LAB

Why De-obfuscate?





Layout Obfuscation in Android

```
package com.example.dbhelper

class DBHelper extends SQLiteHelper {
  SQLiteDatabase db;

  public DBHelper(Context ctx) {
    db = getWritableDatabase();
  }

  Cursor execSQL(String str) {
    return db.rawQuery(str);
  }
}
```

Names provide key semantic information

Obfuscate

```
package a.b.c

class a extends SQLiteHelper {
  SQLiteDatabase b;

  public a(Context
    b = getWritableDa
  }

  Cursor c(String str) {
    return b.rawQuery(str);
  }
}
```

Non-descriptive names

Some names remain

Layout Obfuscation in Android

Non-descriptive names

```
package com.example.
class DBHelper exter
  SQLiteDatabase db;
  public DBHelper(Cc
    db = getWritable
  }
  Cursor execSQL(Str
    return db.rawQue
  }
}
```

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ome names remain

{
tr);

Nan
key semantic information

Security Challenges

- Code Inspection
- Third-party Library Detection
- … many others

Layout Obfuscation in Android

```
package com.example.dbhelper

class DBHelper extends SQLiteHelper {
  SQLiteDatabase db;

  public DBHelper(Co
    db = getWritableDa
  }

  Cursor execSQL(String str) {
    return db.rawQuery(str);
  }
}
```

Names provide key semantic information

Can we reverse layout obfuscation ?

Non-descriptive names

```
package a.b.c

class a extends SQLiteHelper {
  se b;

  ext
  tableDa
  }

  Cursor c(String str) {
    return b.rawQuery(str);
  }
}
```

Some names remain

Layout Obfuscation in Android

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package com.example.dbhelper

class DBHelper extends SQLiteHelper {
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  }
}
```

Names provide

DEGUARD

www.apk-deguard.com

Non-descriptive names

```
package a.b.c

class a extends SQLiteHelper {
  se b;

  ext ctx) {
  tableDatabase();
  }

  Cursor c(String str) {
    return b.rawQuery(str);
  }
}
```

Yes, with roughly 80% accuracy!

DEGUARD

www.apk-deguard.com

Released last week, so far: **> 5K users** **> 5GB APKs**

Reddit posts/comments

[–] **evantatarka** WillowTree • **3 points** 2 days ago

Nice! This should help with debugging issues in play services or other libs that are obfuscated just to make my life harder a bit easier.

permalink embed pocket

[–] **oleeeEncantado** 2 points 4 days ago

Works quite well, I've tried on some small games.

permalink embed pocket

[–] **Tycon712** • **3 points** 2 days ago

Can someone tell me what the point of using Proguard is if there are tools out there like this?

permalink embed pocket

[–] **theheartbreakpug** • **6 points** 2 days ago

As far as I know, this is brand new. I asked the creator of ProGuard a week ago how hard it is to unobfuscate code after it's run through proguard. He said it strips all the names out of the code so it's essentially impossible. I'm super impressed by what they've done here.

Tweets

D|-|AR$|-|IN @dharshin · Oct 17

Deobfuscate #proguard 'ed APKs: apk-deguard.com. The paper on the inner workings: srl.inf.ethz.ch/papers/deguard… **#Android** #MobileSecurity

Brian Carpenter @geeknik · 9h

Android Deobfuscation with Machine Learning reverses the effects of ProGuard [PDF] srl.inf.ethz.ch/papers/deguard…

3 4

rvivek @vivek_310 · Oct 17

"**Android Deobfuscation** with Machine Learning reverses the effects of ProGuard" #security #feedly

Android Deobfuscation with Machine... • /r/Reverse...

8 points and 1 comments so far on reddit

How Does DeGuard Work?

DeGuard: System Overview

```
class a extends SQLiteHelper {
  SQLiteDatabase b;
  public a(Context ctx) {
    b = getWritableDB();
  }
}
```

Obfuscated Code

Static analysis

MAP Inference

Transform

```
class DBHelper extends SQLiteHelper{
  SQLiteDatabase db;
  public DBHelper(Context ctx) {
    db = getWritableDB();
  }
}
```

De-obfuscated Code

Prediction Phase

Learning Phase

Probabilistic model

$P(\square|\square)$

Static analysis

Training

Semantic representation

Open-source, unobfuscated applications

Probabilistic Graphical Models

Probabilistic Graphical Models

	name1	name2	weight
f_1	SQLiteHelper	DBUtils	0.3
f_2	SQLiteHelper	DBHelper	0.2

SQLiteHelper — extends — **a**

a — field-in — **b**

getWritableDB — gets — **b**

	name1	name2	weight
f_5	DBUtils	instance	0.5
f_6	DBHelper	db	0.4
f_7	…	…	…

	name1	name2	weight
f_3	getWritableDB	db	0.7
f_4	getWritableDB	instance	0.4

```
class a extends SQLiteHelper {
  SQLiteDatabase b;
  public a(Context ctx) {
    b = getWritableDB();
  }
}
```

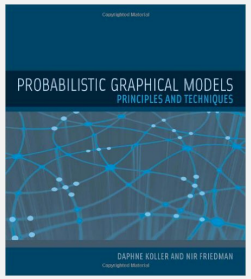
$\vec{K}$ Known variables

$\vec{O}$ Unknown variables

$f_1, f_2, ..$ Feature functions

Graph + features define a **probabilistic graphical model**

$$P(\vec{O} \mid \vec{K}) =$$
$$= P(a, b \mid SQLiteHelper, getWritableDB)$$
$$= \frac{1}{Z}\exp(0.3 \cdot f_1(SQLiteHelper, a) + 0.2 \cdot f_2(SQLiteHelper, a) + \cdots)$$



Probabilistic Graphical Models

	name1	name2	weight
f_1	SQLiteHelper	DBUtils	0.3
f_2	SQLiteHelper	DBHelper	0.2

SQLiteHelper — extends — a

field-in

getWritableDB — gets — b

	name1	name2	wei
f_3	getWritableDB	db	0
f_4	getWritableDB	instance	0.

```
class a extends SQLiteHelper {
  SQLiteDatabase b;
  public a(Context ctx) {
    b = getWritableDB();
  }
}
```

Next

How are the weights and features learned?

$\vec{K}$ Known variables

$\vec{O}$ Unknown variables

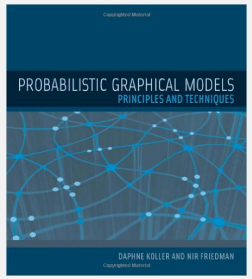
$f_1, f_2, ..$ Feature functions

obabilistic graphical model

$$P(\vec{O} \mid \vec{K}) =$$

$$= P(a, b \mid SQLiteHelper, getWritableDB)$$

$$= \frac{1}{Z} \exp(0.3 \cdot f_1(SQLiteHelper, a) + 0.2 \cdot f_2(SQLiteHelper, a) + \cdots)$$



Learning

Learning

>2,000

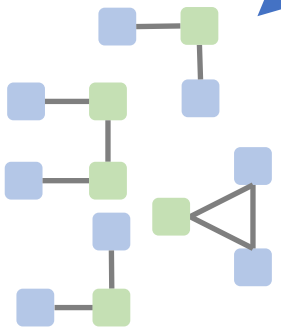
Unobfuscated APKs

Feature templates

28 templates

Static analysis

Actual graphs have >1,000 nodes



Dependency graphs

	name1	name2
f_1	SQLiteHelper	DBUtils
f_2	SQLiteHelper	DBHelper
f_3	getWritableDB	db
f_4	getWritableDB	instance
f_5	DBUtils	instance
f_6	DBHelper	db
f_7	…	…

Features (with candidate names)

>100,000

Train Model

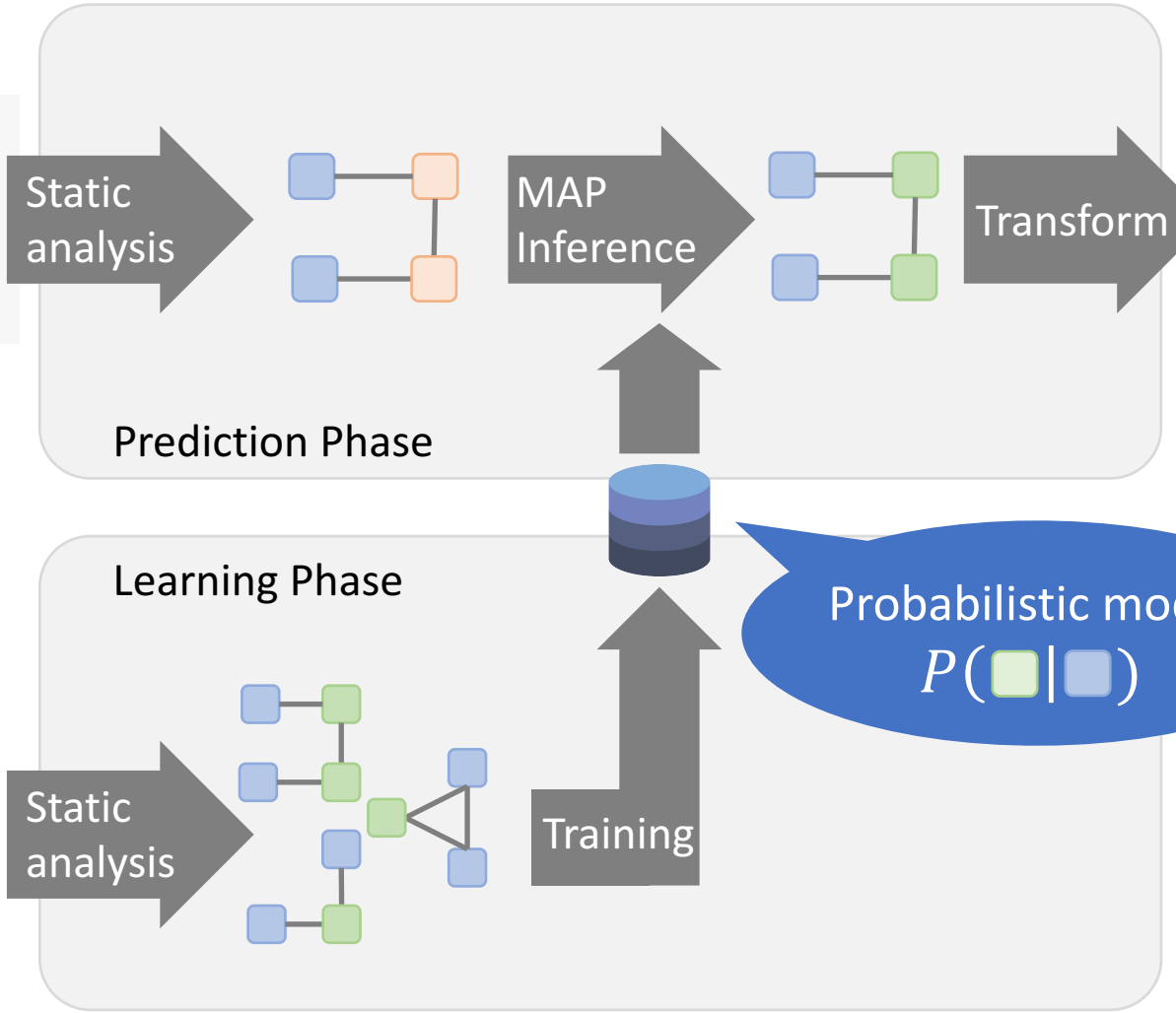
	name1	name2	weight
f_1	SQLiteHelper	DBUtils	0.3
f_2	SQLiteHelper	DBHelper	0.2
f_3	getWritableDB	db	0.7
f_4	getWritableDB	instance	0.4
f_5	DBUtils	instance	0.5
f_6	DBHelper	db	0.4
f_7	…	…	…

Compute weights that maximize $P(\vec{O} = \vec{o_i} | \vec{K} = \vec{k_i})$ for all training samples $(\vec{o_i}, \vec{k_i})$

DeGuard: System Overview

```
class a extends SQLiteHelper {
  SQLiteDatabase b;
  public a(Context ctx) {
    b = getWritableDB();
  }
}
```

Obfuscated Code




```
class DBHelper extends SQLiteHelper{
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  public DBHelper(Context ctx) {
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}
```

De-obfuscated Code

Open-source, unobfuscated applications

DeGuard: System Overview

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class a extends SQLiteHelper {
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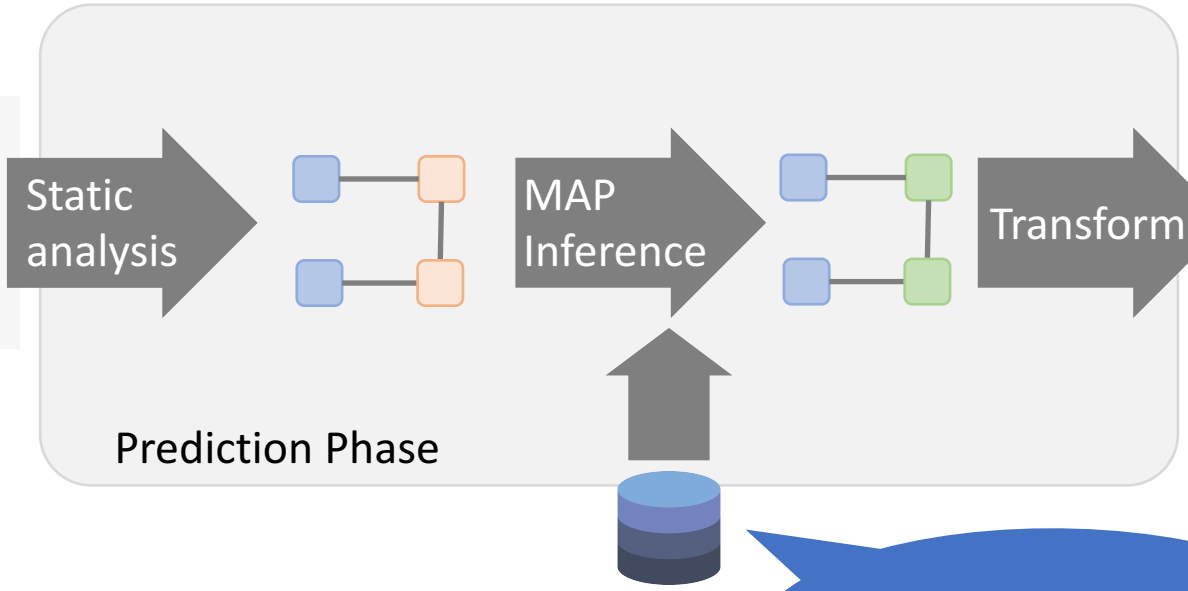
Obfuscated Code

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class DBHelper extends SQLiteHelper{
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De-obfuscated Code

Prediction Phase

```
class a extends SQLiteHelper {
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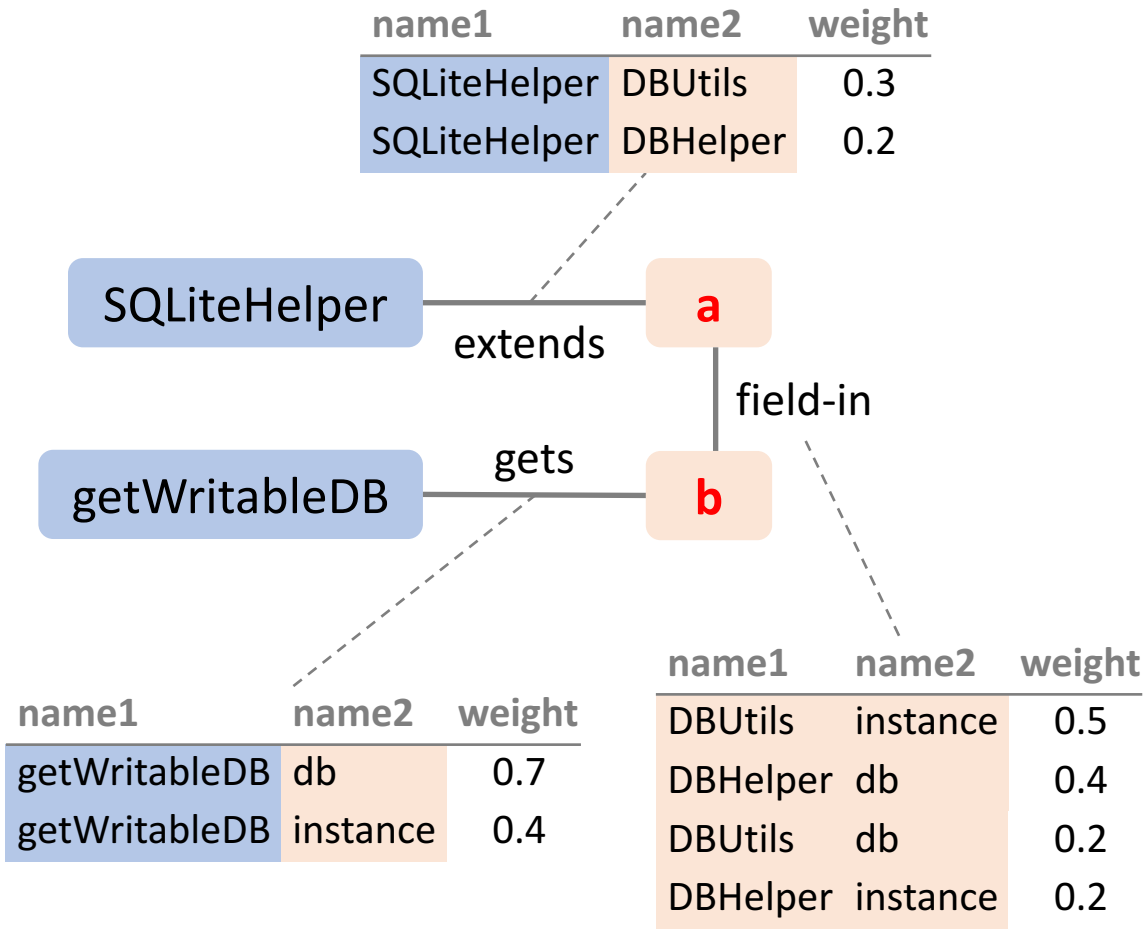
  }
}
```

Obfuscated Code

Static analysis



Prediction Phase

```
class a extends SQLite
  SQLiteDatabase b;
  public a(Context ctx
    b = getWritableDB(
  }
}
```

Obfus

MAP Inference

$$\vec{o} = \underset{\vec{o}' \in \Omega}{argmax}\, P\left(\vec{O} = \vec{o}' \,\middle|\, \vec{K} = \vec{k}\right)$$

Candidate assignment $\vec{o}$		$P(\vec{o}\,\|\vec{k})$*
a = DBUtils	b = instance	1.2
a = DBHelper	b = db	1.3
a = DBUtils	b = db	0.8
a = DBHelper	b = instance	1.2

*Non-normalized

name1	name2	weight
Helper	DBUtils	0.3
Helper	DBHelper	0.2

xtends

gets

a

field-in

b

eight

0.7

0.4

name1	name2	weight
DBUtils	instance	0.5
DBHelper	db	0.4
DBUtils	db	0.2
DBHelper	instance	0.2

Prediction Phase

```
class a extends SQLite
  SQLiteDatabase b;
  public a(Context ctx
    b = getWritableDB(
  }
}
```

Obfus

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name1	name2	weight
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Prediction Phase

```
class a extends SQLiteHelper {
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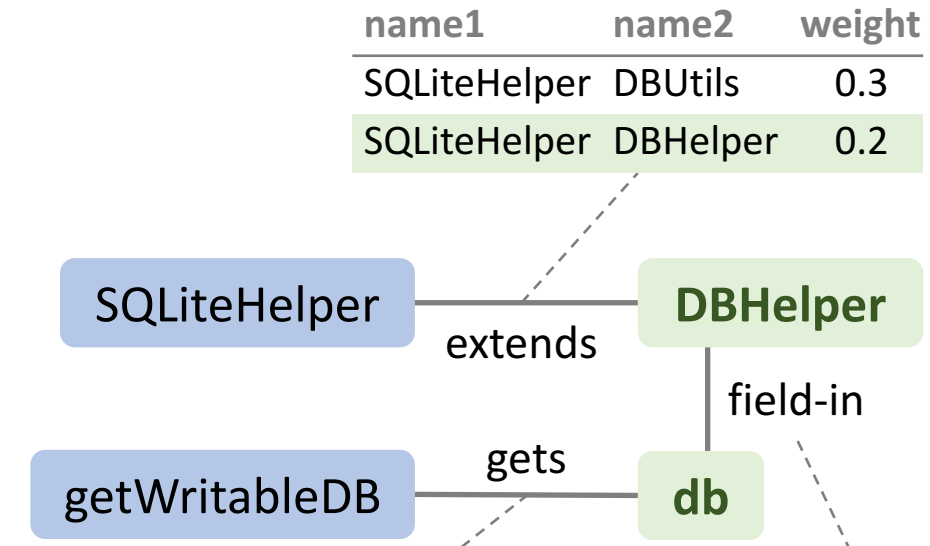
Obfuscated Code

Static analysis



name1	name2	weight
SQLiteHelper	DBUtils	0.3
SQLiteHelper	DBHelper	0.2

name1	name2	weight
DBUtils	instance	0.5
DBHelper	db	0.4
DBUtils	db	0.2
DBHelper	instance	0.2

Transform

name1	name2	weight
getWritableDB	db	0.7
getWritableDB	instance	0.4

```
class DBHelper extends SQLiteHelper {
  SQLiteDatabase db;
  public DBHelper(Context ctx) {
    db = getWritableDB();
  }
}
```

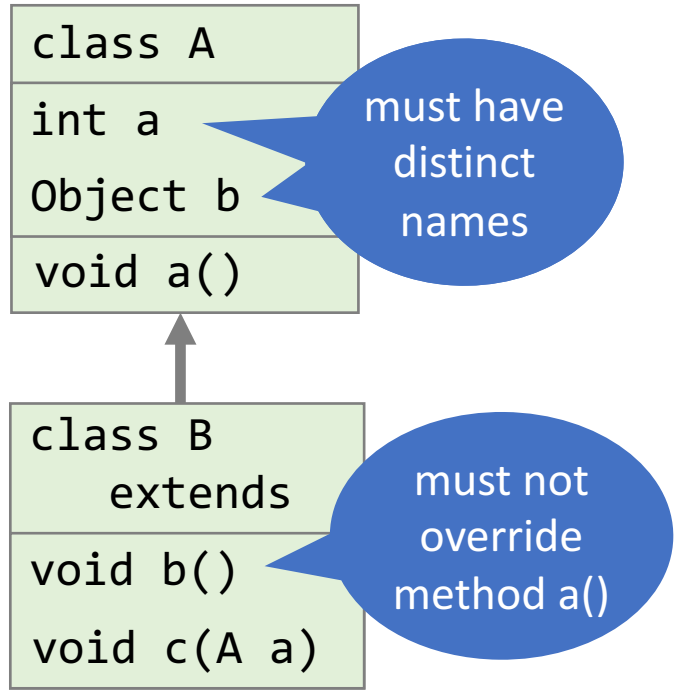
Deobfuscated Code

Preserving Semantics

Freely renaming fields/variables/methods
may **change** the program **semantics**

Syntactic constraints
e.g. *fields within a class must have distinct names*

Semantic constraints
e.g. *method overloads must be preserved*



DeGuard: System Overview

```
class a extends SQLiteHelper {
  SQLiteDatabase b;
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  }
}
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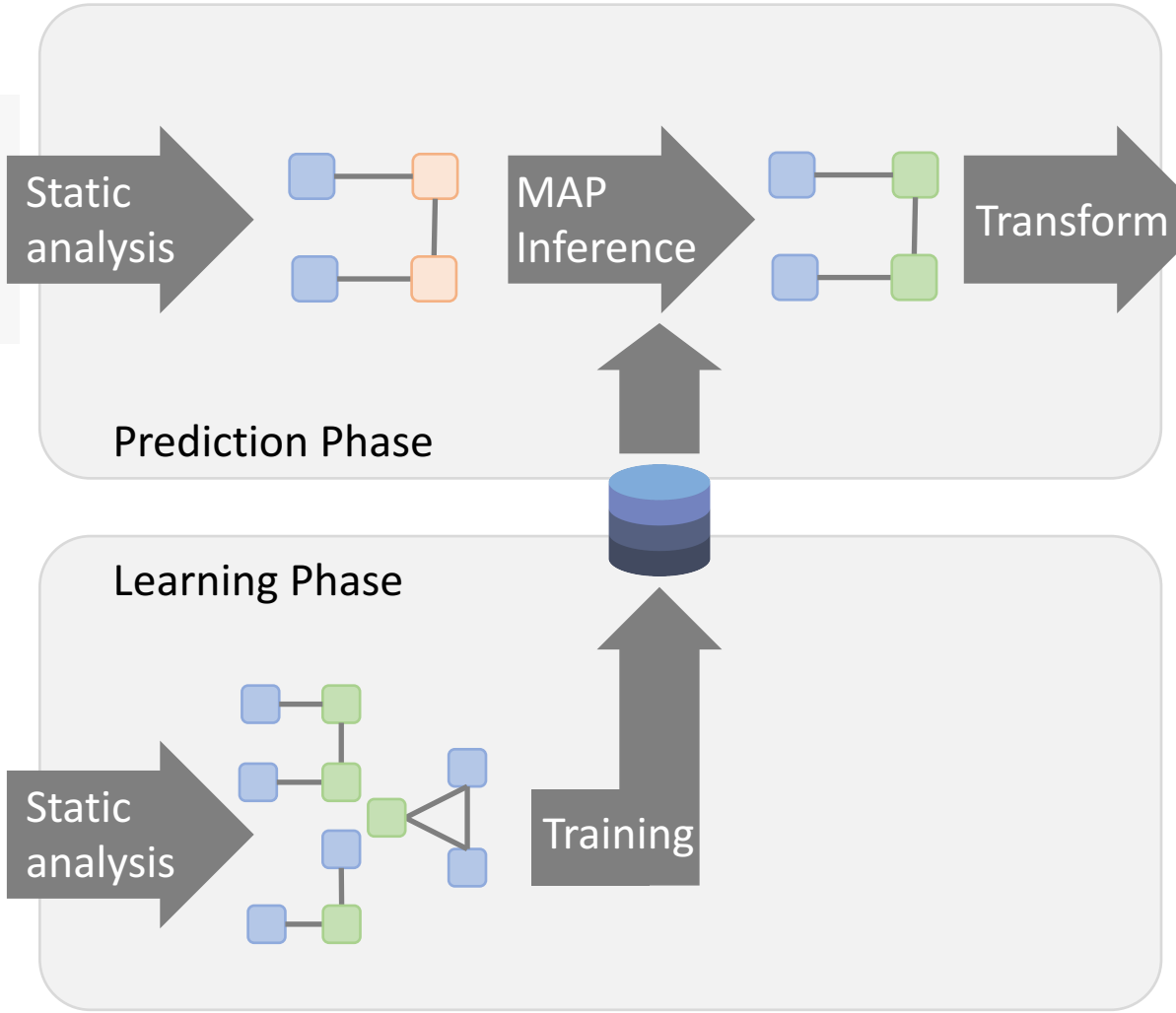
Obfuscated Code

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  public DBHelper(Context ctx) {
    db = getWritableDB();
  }
}
```

De-obfuscated Code

Open-source, unobfuscated applications

DeGuard Implementation

DeGuard Implementation

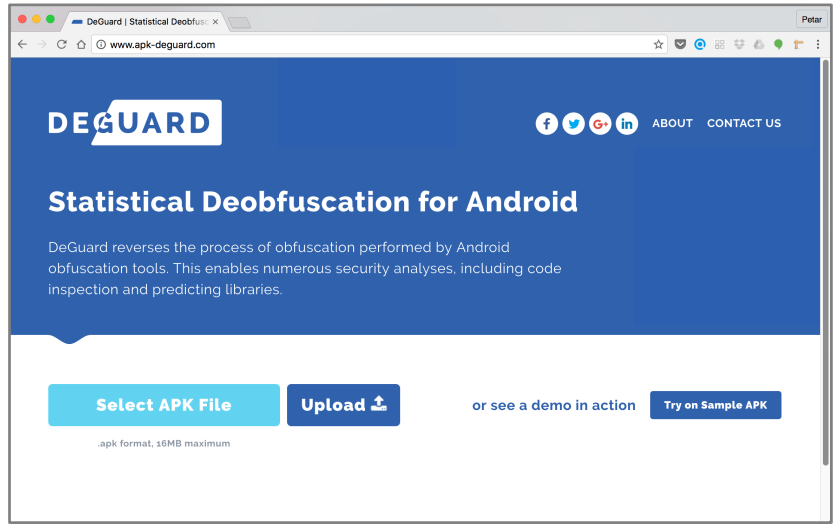
Static Analysis

- Static analysis framework for Java and Android

Learning and MAP Inference

- Scalable open-source framework for structured prediction
- Open-source: http://nice2predict.org

- Training data: 2K open-source, unobfuscated Android applications

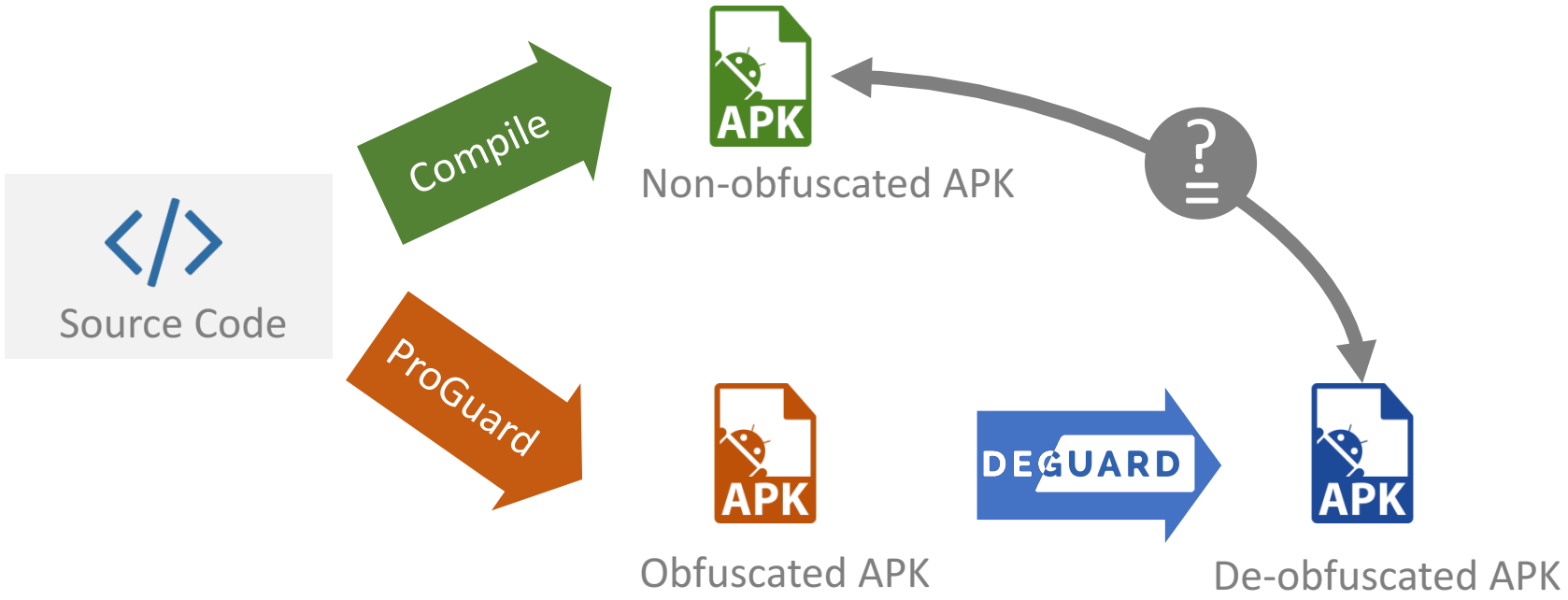


www.apk-deguard.com

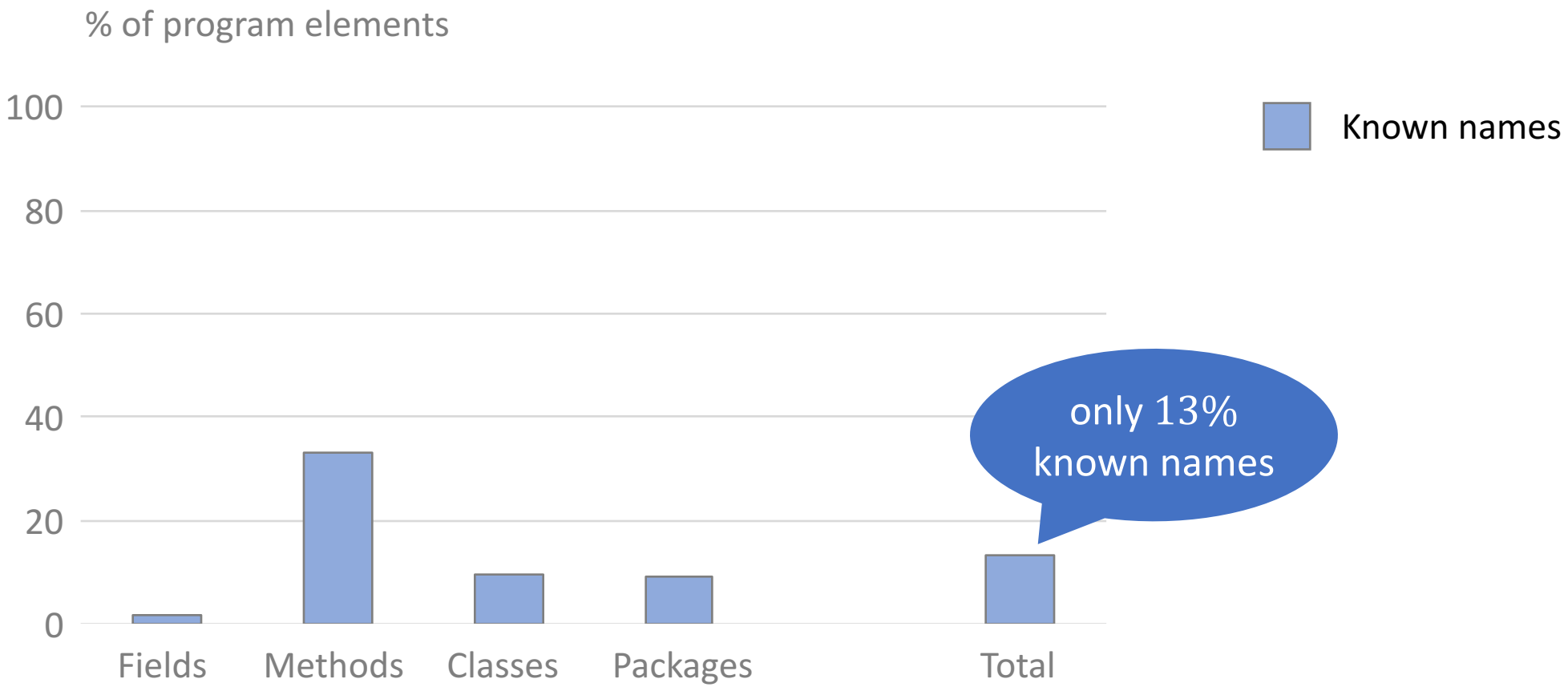
Evaluation

1. Can DeGuard reverse ProGuard?
2. Can DeGuard detect third-party libraries?
3. Is DeGuard useful for malware inspection?

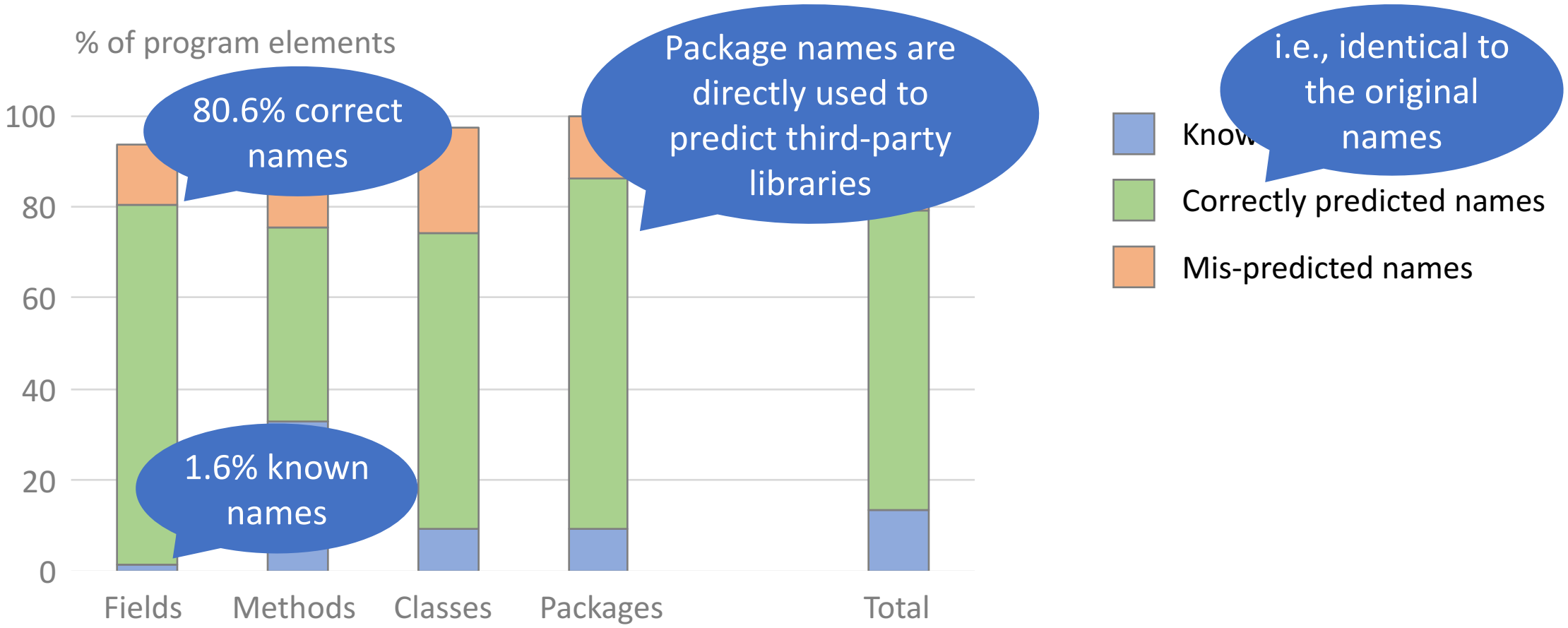
ProGuard Experiment



After Obfuscation

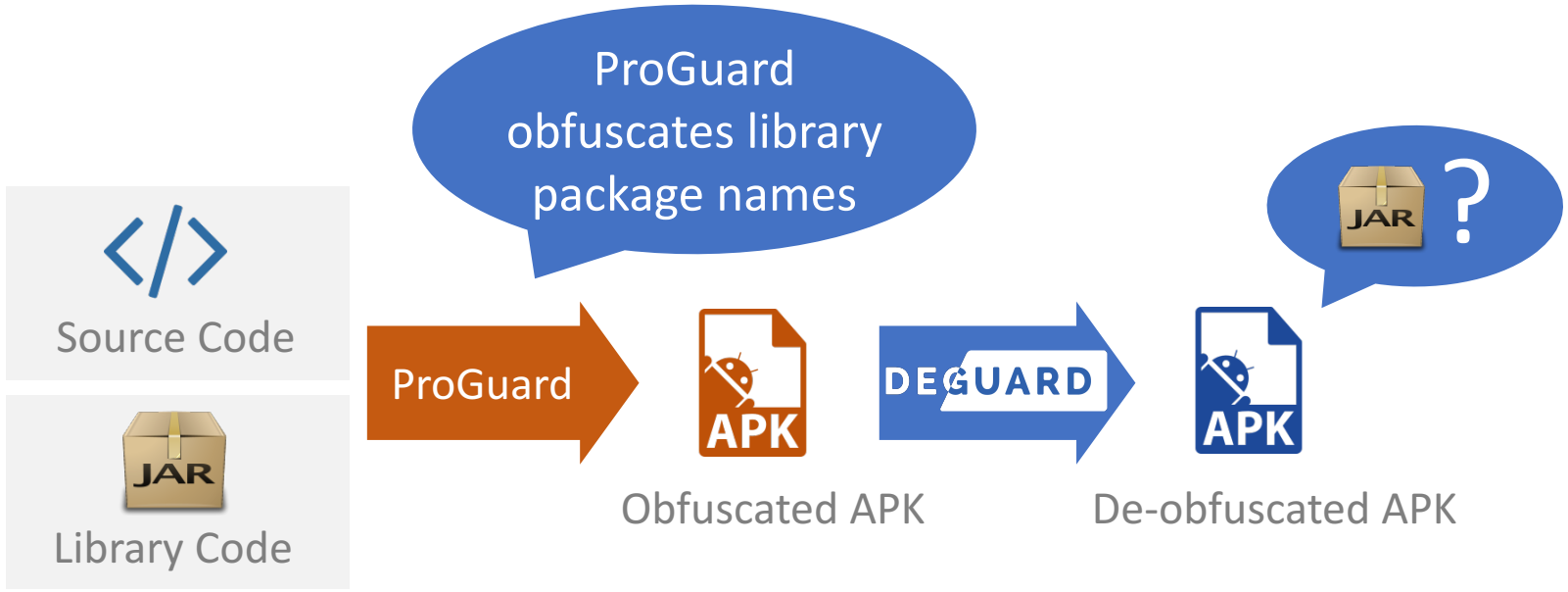


Can DeGuard reverse ProGuard?



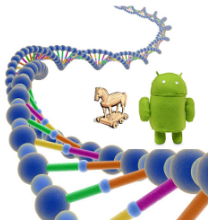
80% of the names are identical to the original ones

Can DeGuard Detect Third-Party Libraries?



Precision: 93.1% Recall: 91%

Is DeGuard Useful for Malware Inspection?



De-obfuscating samples from the Android Malware Genome Project

```
class d {
  String a = System.getProperty(..)
  char[] b;
  byte [] c;
  byte[] a(String) {}
}
```

Malware Sample

DEGUARD

```
class Base64 {
  String NL = S                perty(..)
  char[] ENC;
  byte [] DEC;
  byte[] decode(String) {}
}
```

Base64 Decoder

De-obfuscated Malware Sample

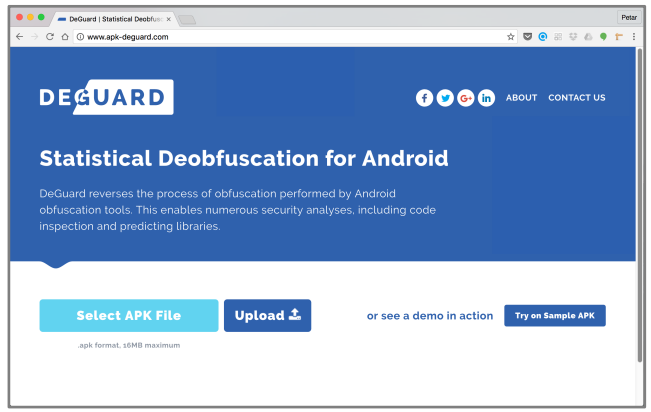
- ☑ Reveals string decoders
- ☑ Reveals classes that handle sensitive data (e.g. Location)
- ⊘ Hard to handle heavily-obfuscated code (e.g. reflection)

Summary

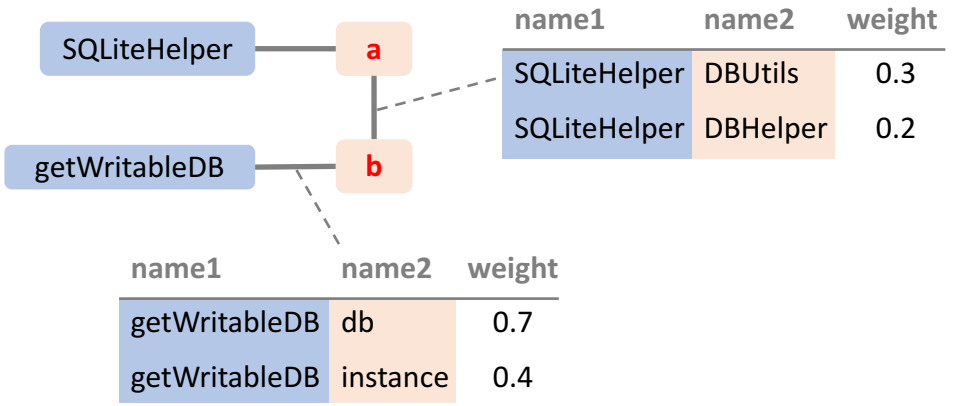
```
package com.example.dbhelper

class DBHelper extends
SQLiteHelper {
  SQLiteDatabase

  public DBHel
    db = getWri
  }

  Cursor execSQL(String str) {
    return db.rawQuery(str);
```

```
package a.b.c

class a extends
SQLiteHelper {
                e b;

                ext ctx) {
                ableDB();
  }

  Cursor c(String str) {
    return b.rawQuery(str);
```

DEGUARD



Try online: www.apk-deguard.com



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name1	name2	weight
getWritableDB	db	0.7
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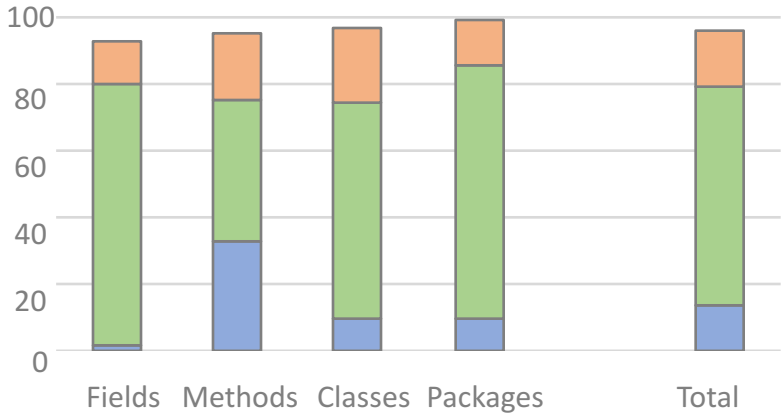
Probabilistic Models



High Prediction Accuracy

More info: http://www.srl.inf.ethz.ch/spas