Static Detection of Brittle Parameter Typing

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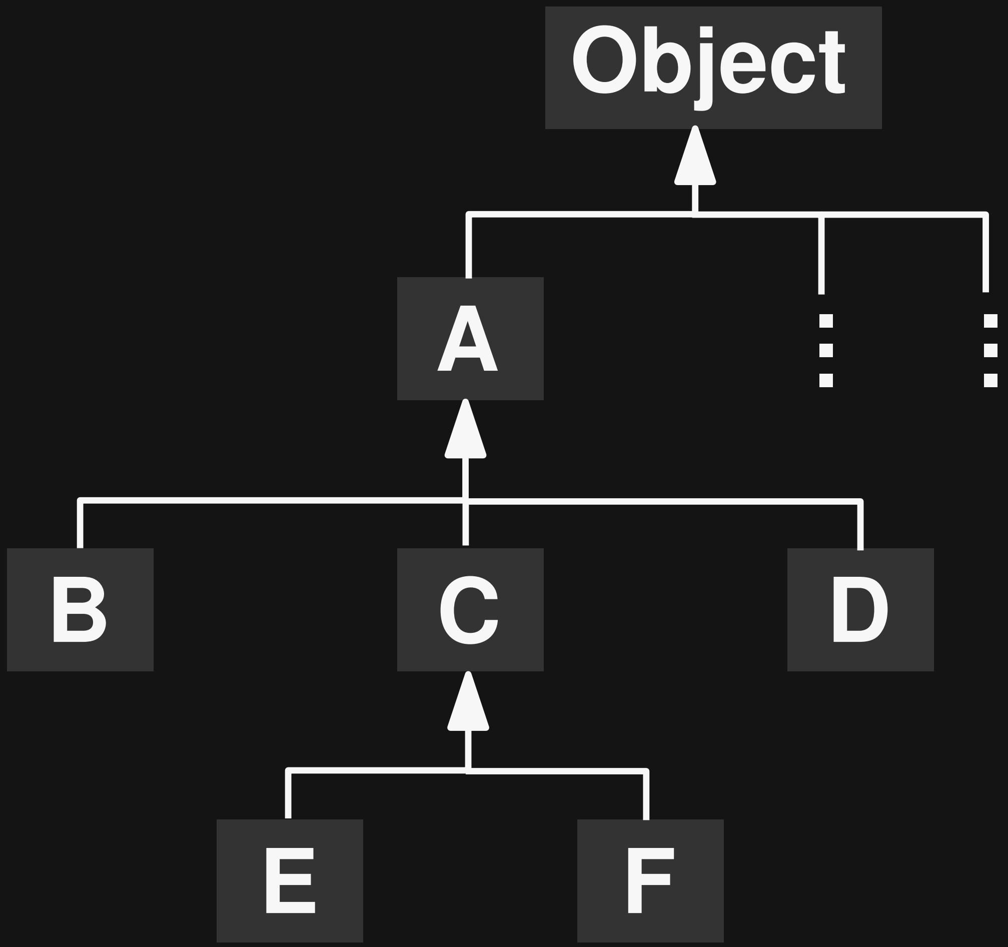
Motivation

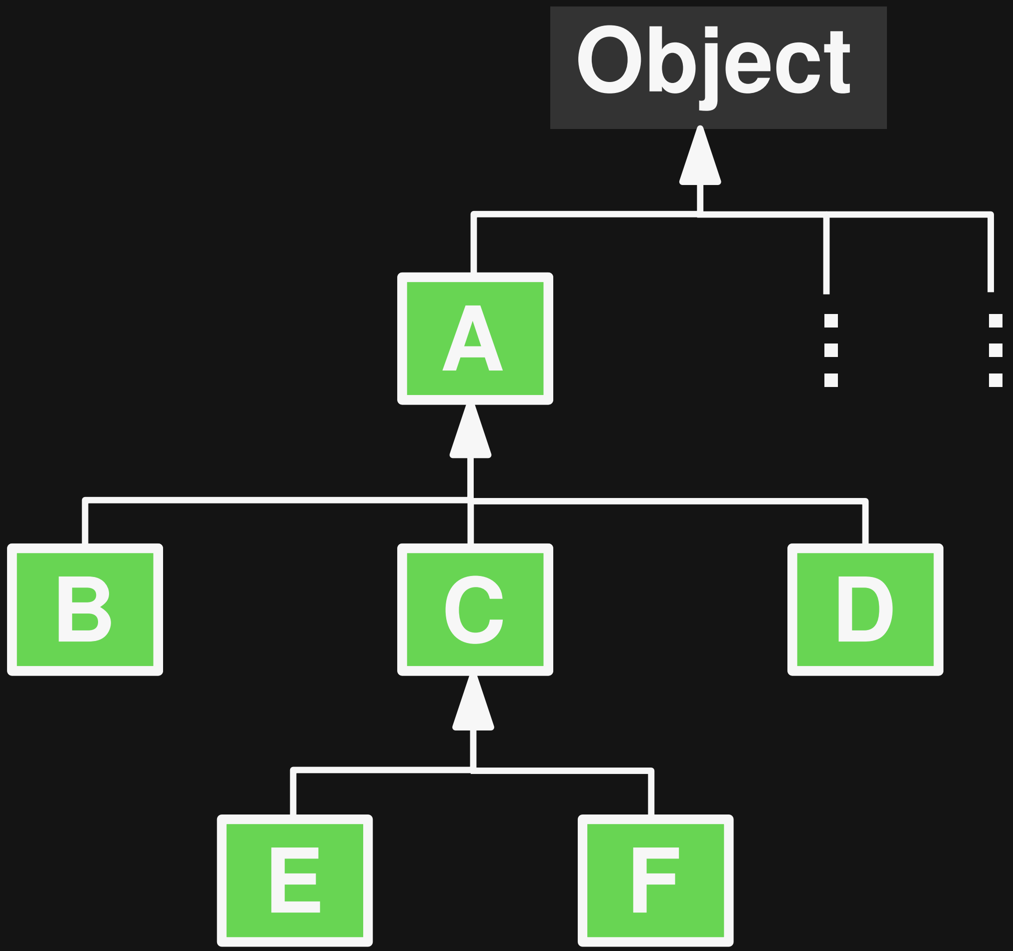
```
void m(A a) { ... }
```



Motivation

```
void m(A a) { ... }
```

Compatible types



Motivation

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void m(A a) { ... }
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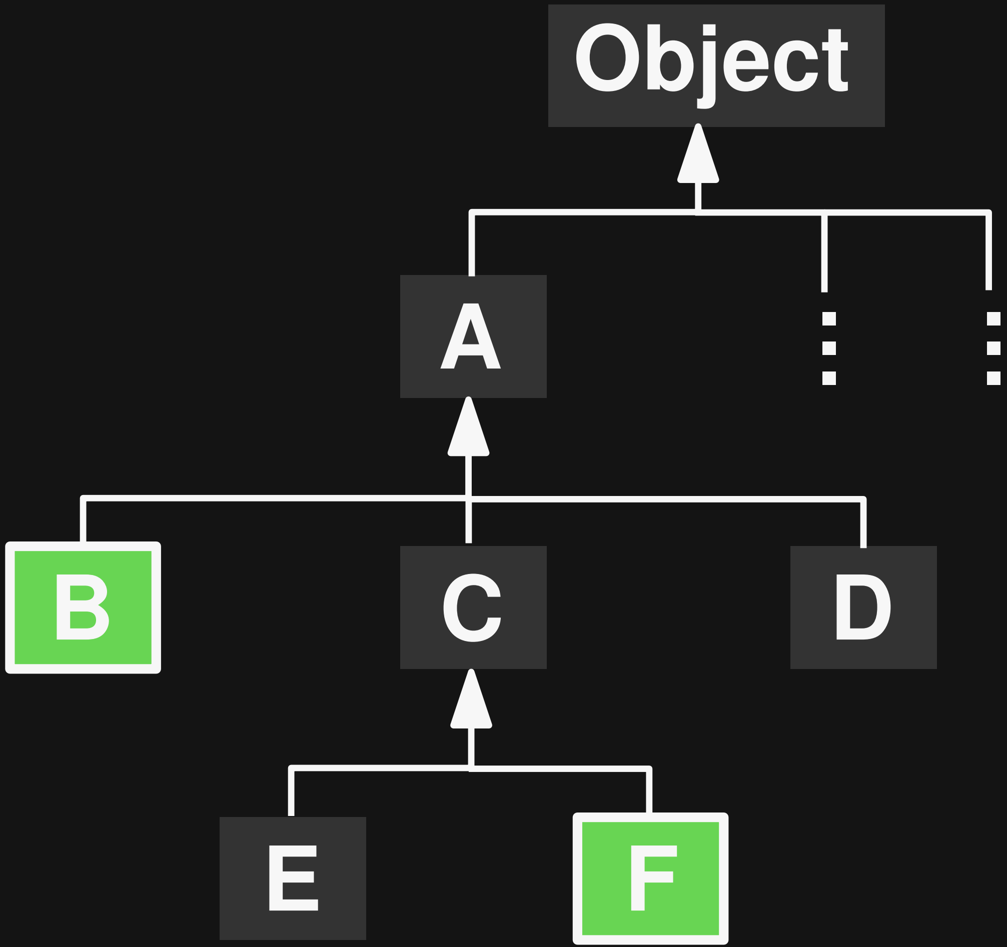
Expected by method



Motivation

```
void m(A a) { ... }
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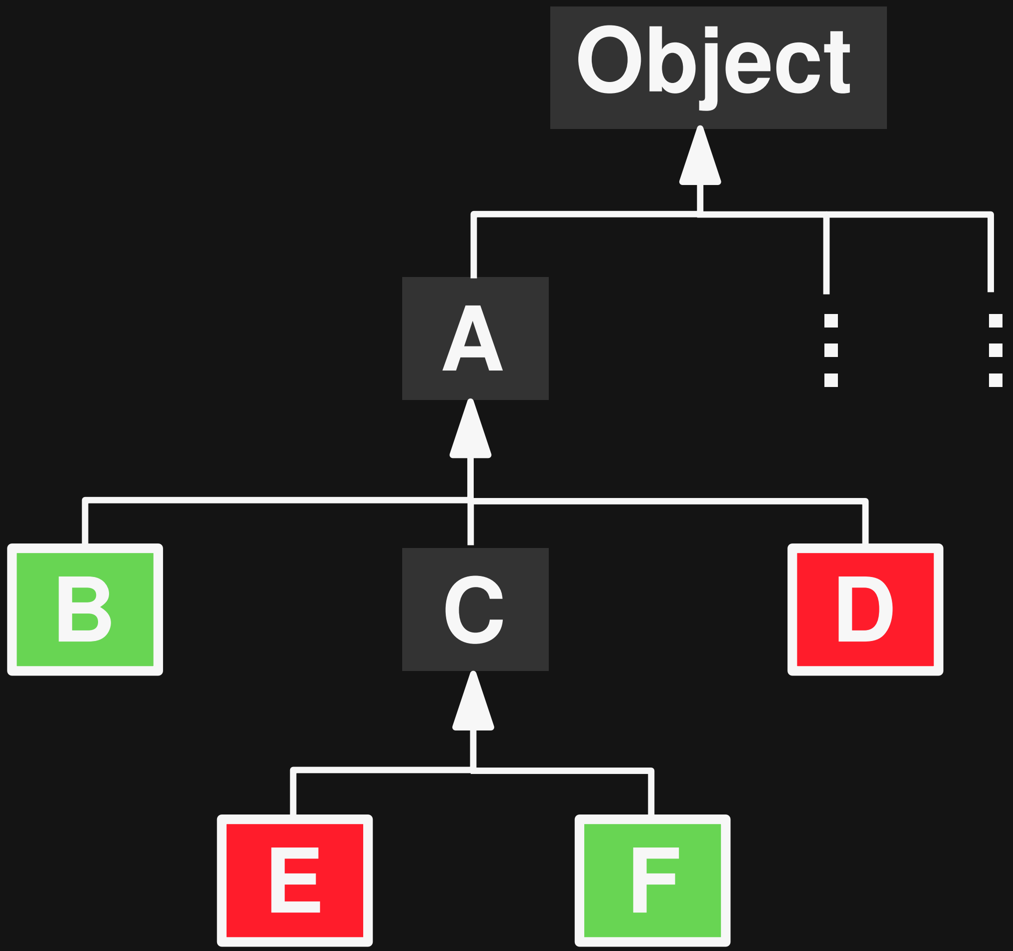
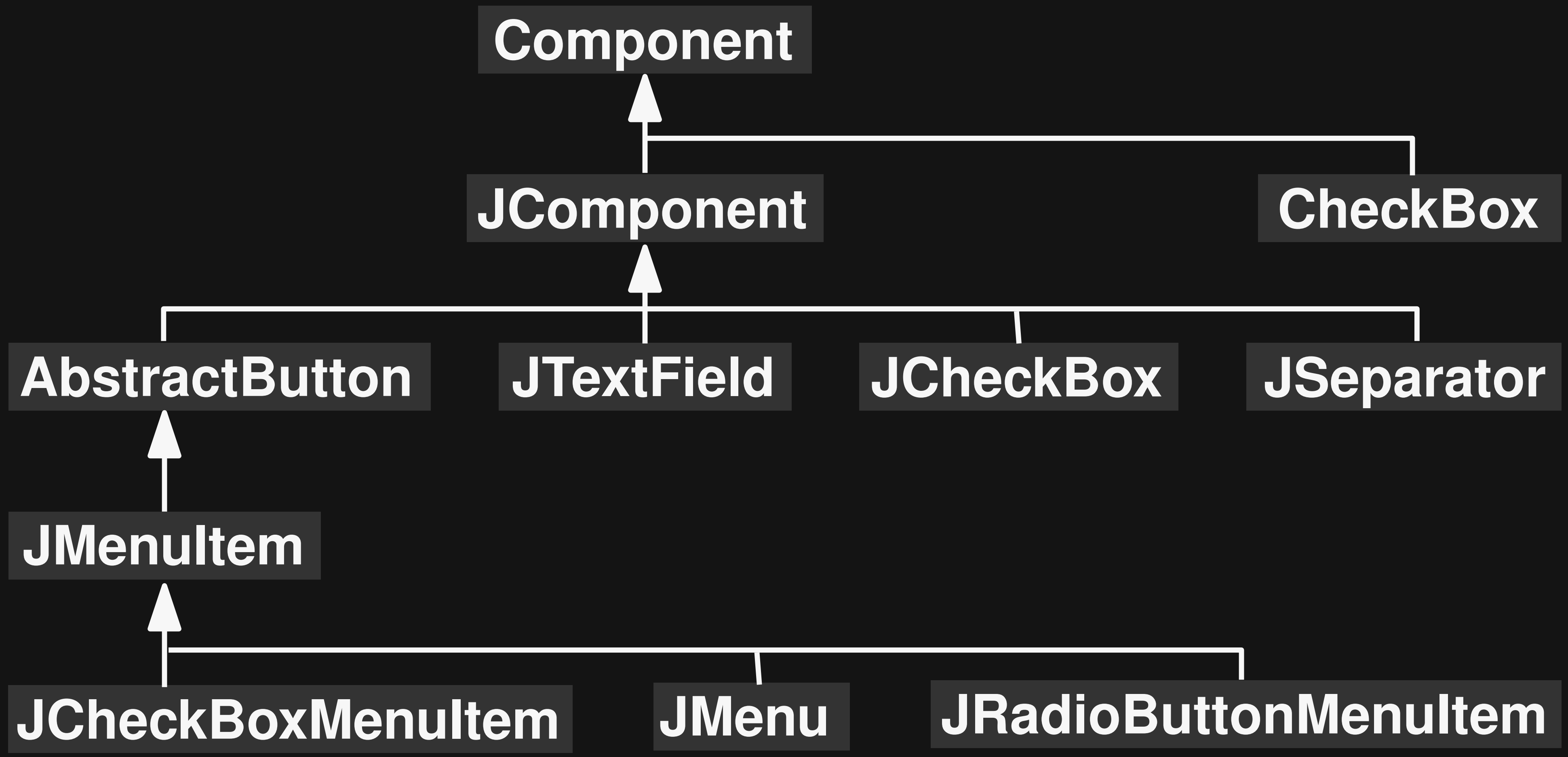


Expected by method

Unexpected by method

Example: Swing API (1)

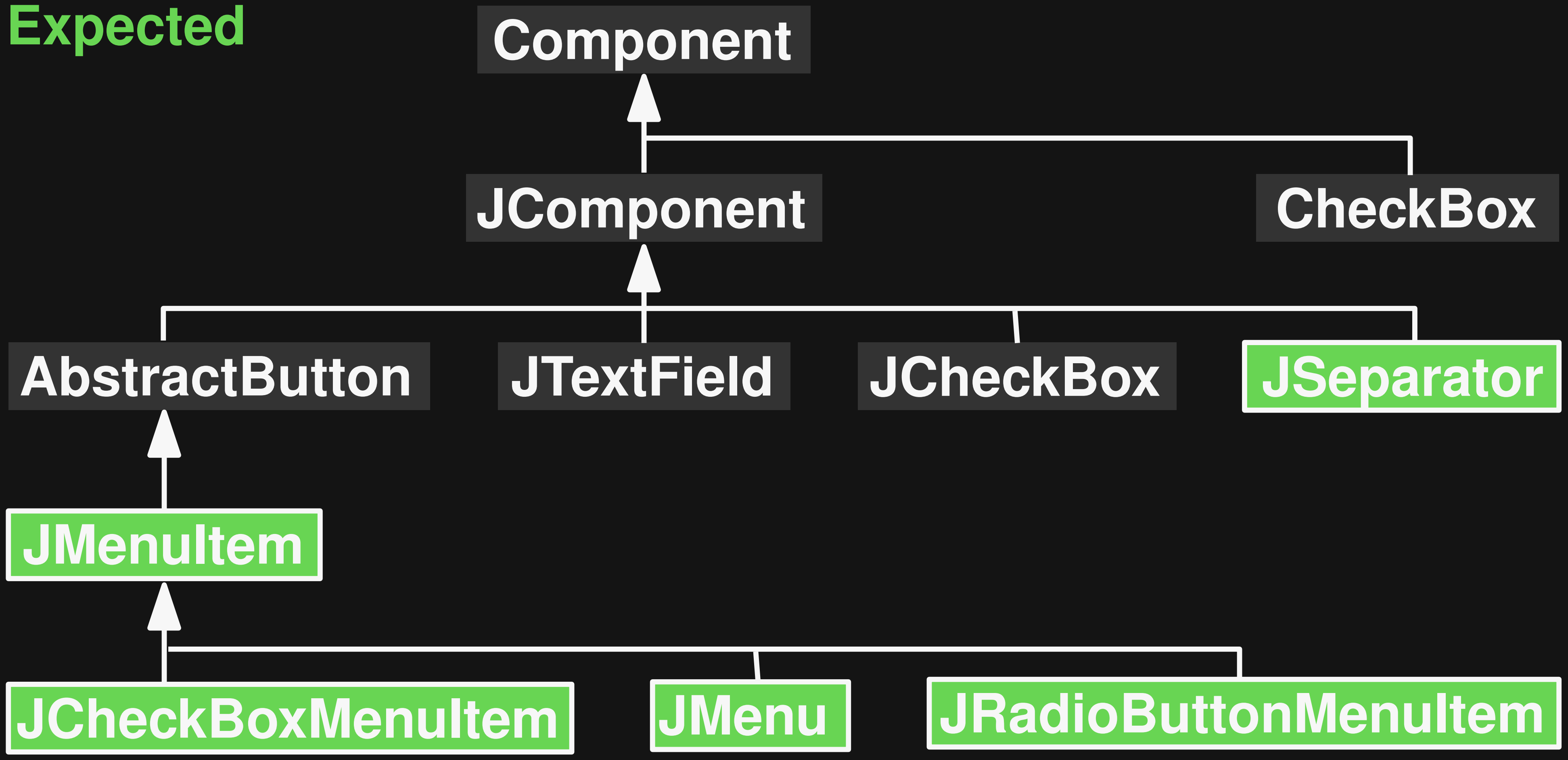
`JMenu.add(Component)`



Example: Swing API (1)

`JMenu.add(Component)`

Expected



Example: Swing API (1)

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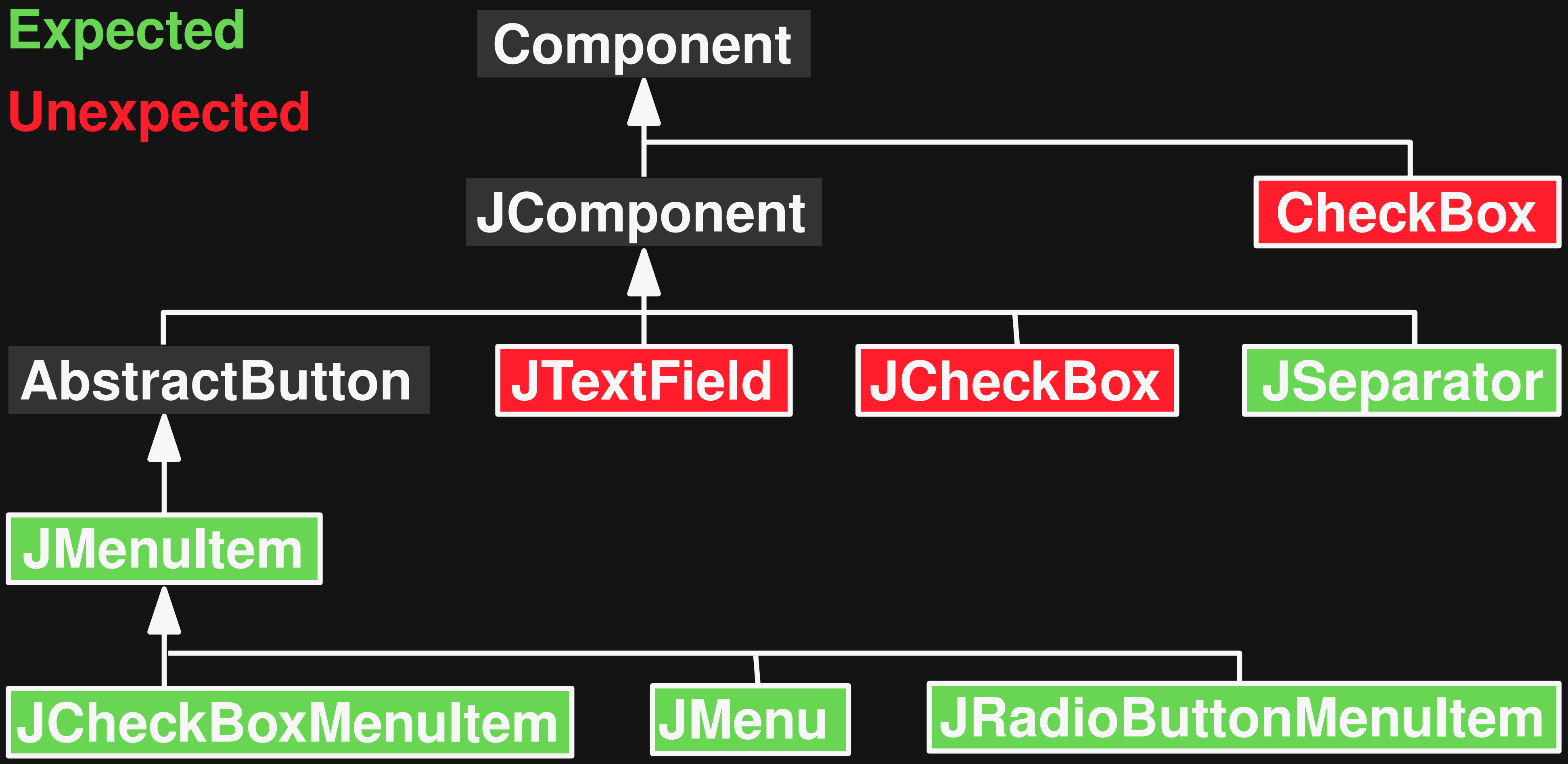
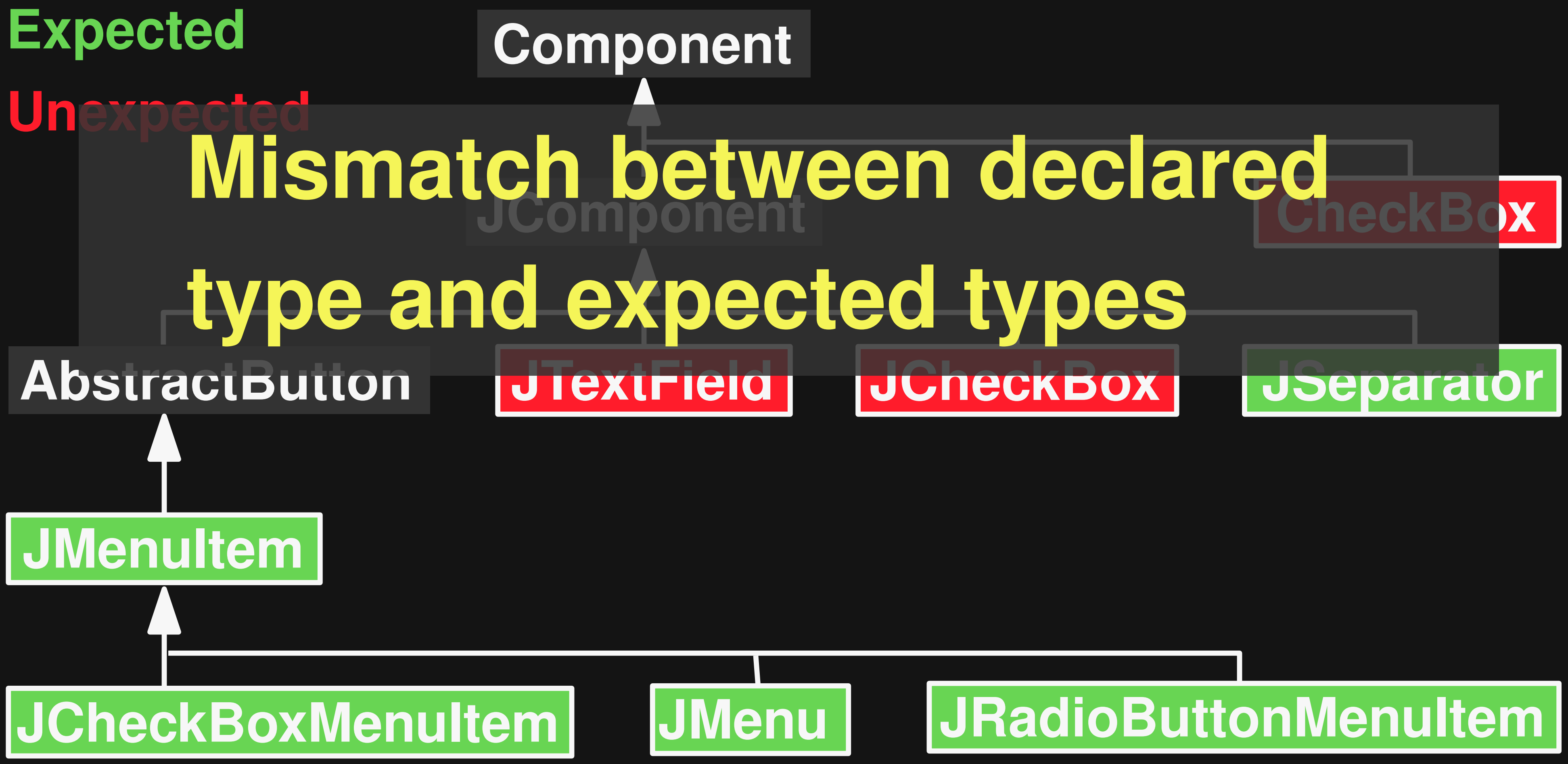


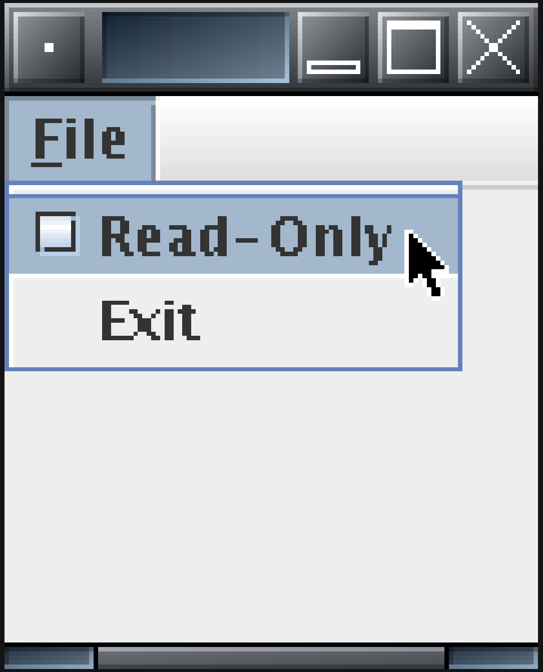
Example: Swing API (1)

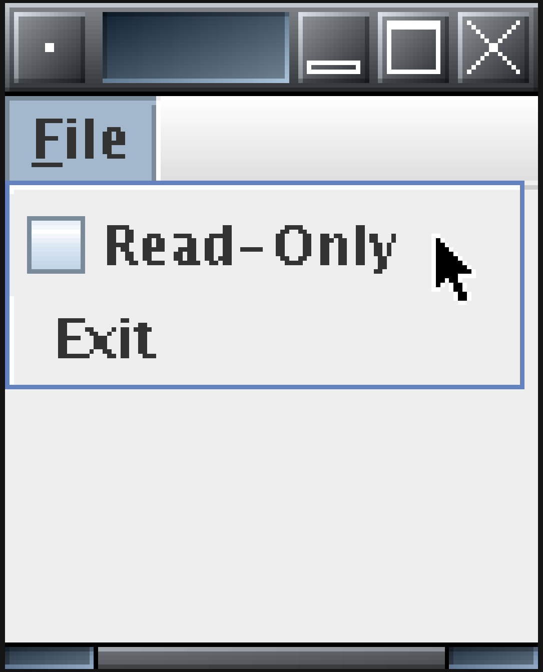
```
JMenu.add(Component)
```



Mismatch between declared type and expected types

Example: Swing API (2)





Expected argument type: JCheckBoxMenuItem

Unexpected argument type: JCheckBox

Confirmed as bug: See nTorrent issue #136

The Problem

Brittle parameter type:

Has subtypes that are not expected by callee

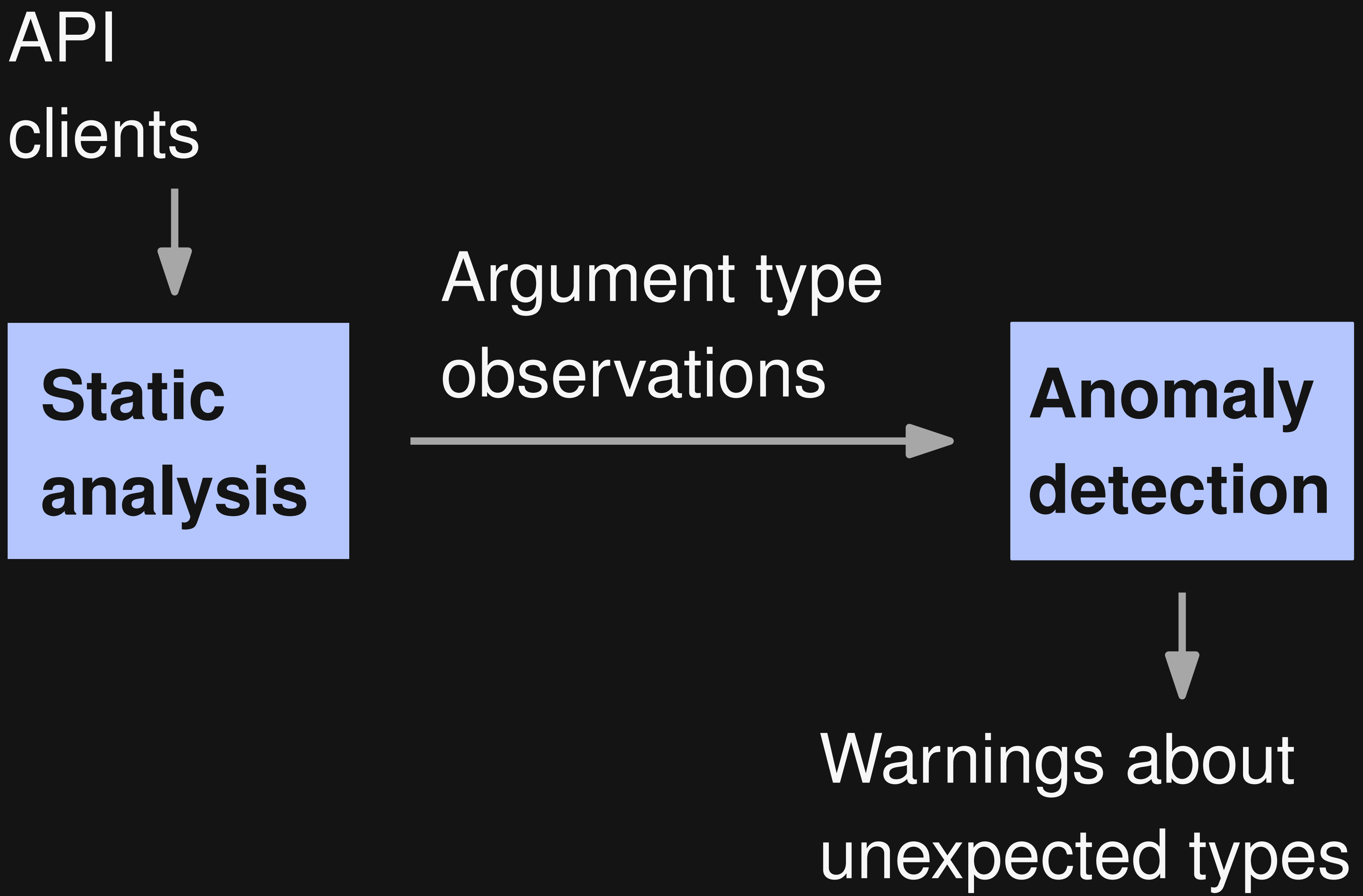
Compatible but unexpected arguments:

Subtle errors hidden from the type system

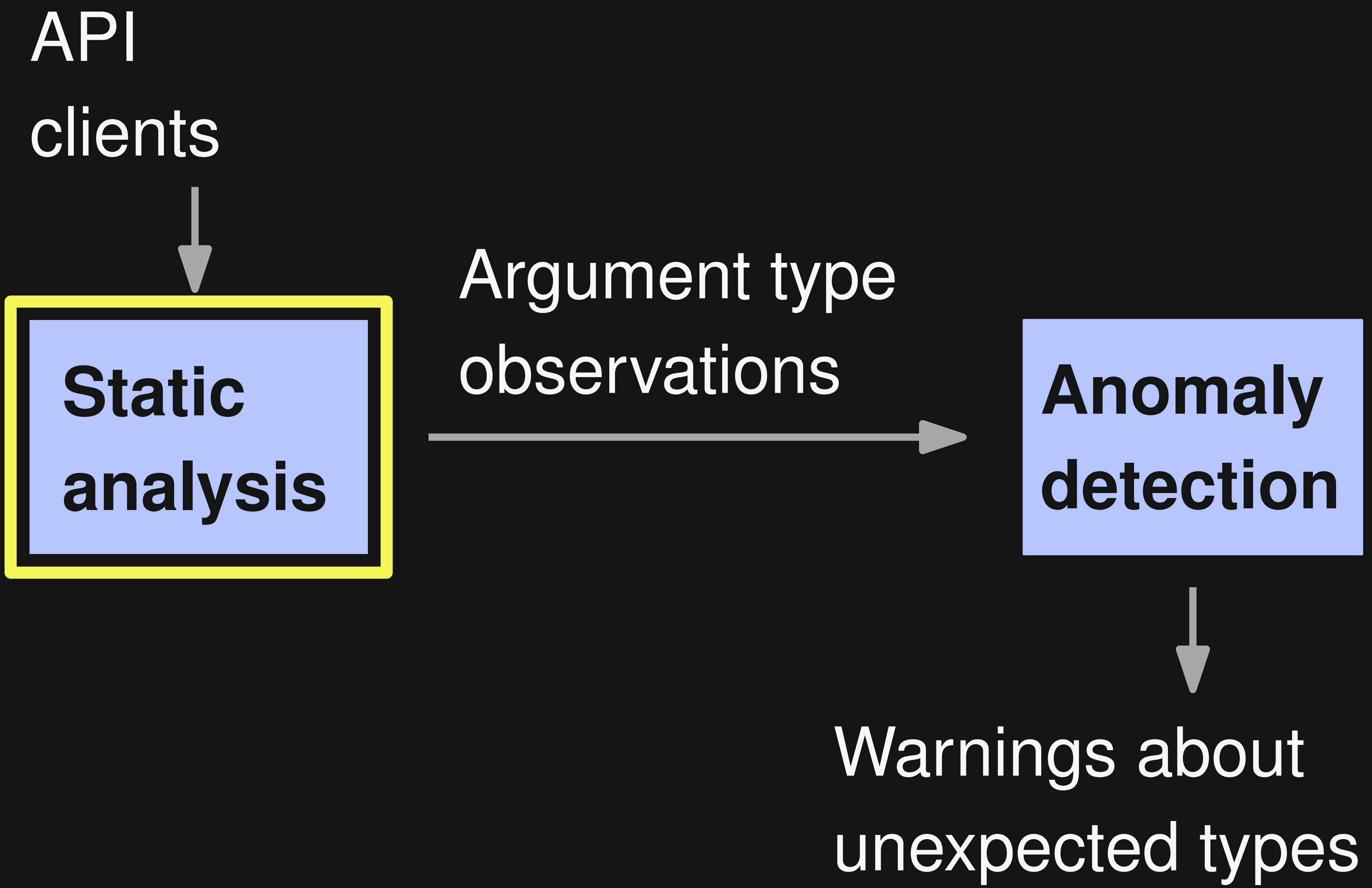
This Talk

Infer from API clients which parameters are brittle and search for unusual argument types

Overview


API clients
Static analysis
Argument type observations
Anomaly detection
Warnings about unexpected types

Overview



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Static Analysis

Goal

- Find types of arguments given to API methods

Two variants

- Simple: Statically declared type
- Points-to analysis: Use points-to set of arguments

Argument Type Observations (1)

Client:

```
Foo foo = new Foo();
JLabel label = new JLabel();
api(foo, label);
```

API:

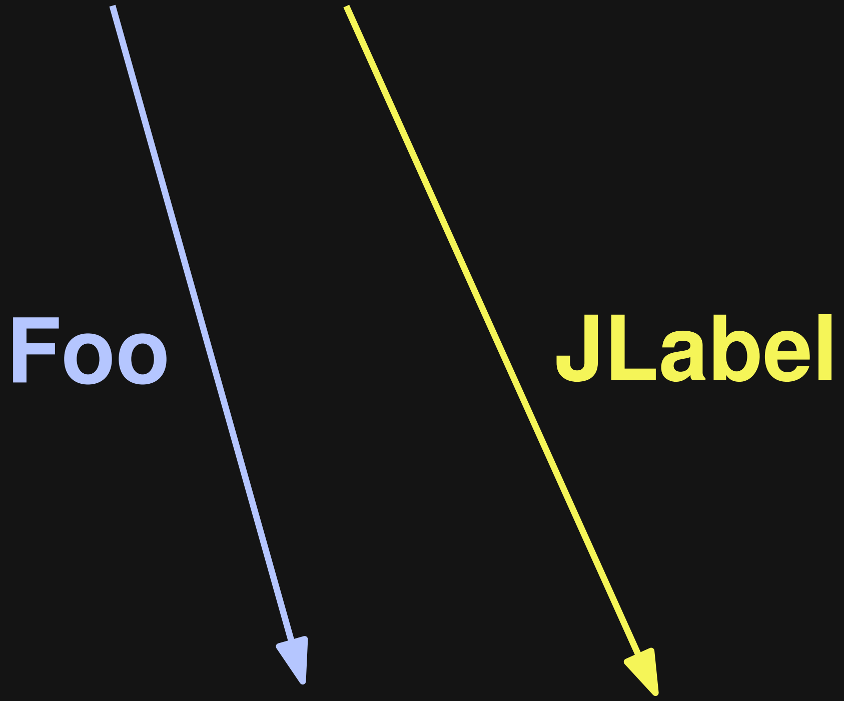
```
void api(Object, Component)
```

Argument Type Observations (1)

Client:

```
Foo foo = new Foo();
JLabel label = new JLabel();
api(foo, label);
```

Simple analysis:

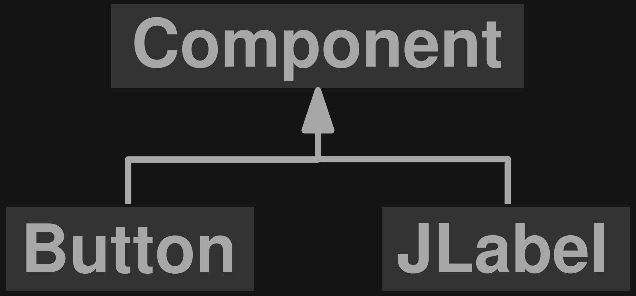


API:

```
void api(Object, Component)
```

Argument Type Observations (2)

Client:



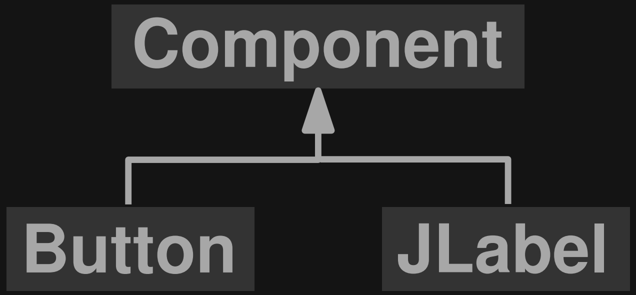
```
Foo foo = new Foo();
Component comp;
if (...) comp = new JLabel();
else comp = new Button();
api(foo, comp);
```

API:

```
void api(Object, Component)
```

Argument Type Observations (2)

Client:



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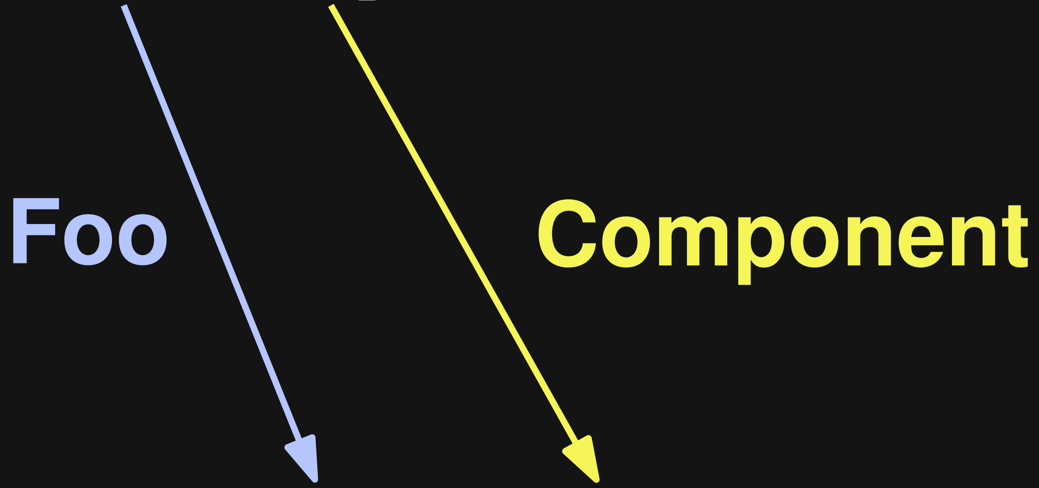

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```
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```

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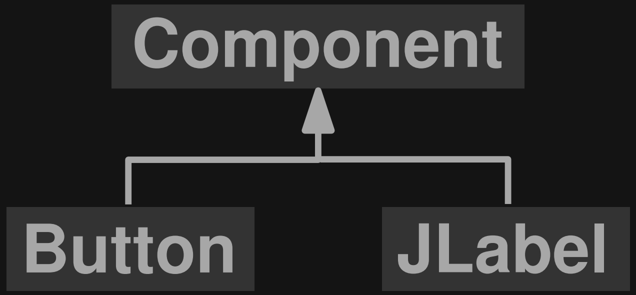
Client:



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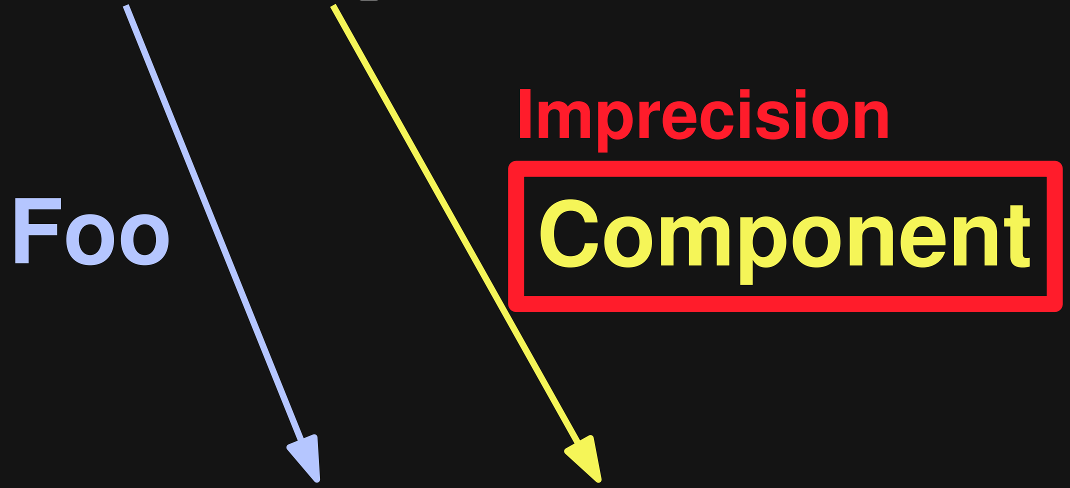

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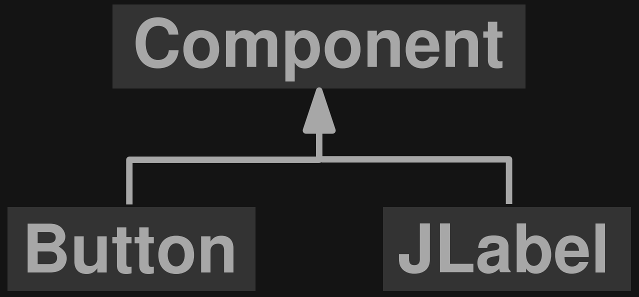
Argument Type Observations (2)

Client:



```
Foo foo = new Foo();
Component comp;
if (...) comp = new JLabel();
else comp = new Button();
api(foo, comp);
```

Points-to analysis:

Foo

JLabel,
Button

API:

```
void api(Object, Component)
```

Argument Type Observations (2)

Client:

```
Foo foo = new Foo();
Component comp;
if (...) comp = new JLabel();
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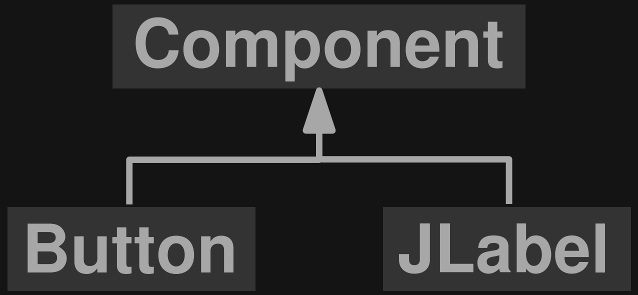


Points-to analysis:
(with confidence)

Foo (1.0)

JLabel (0.5), Button (0.5)

API:

```
void api(Object, Component)
```

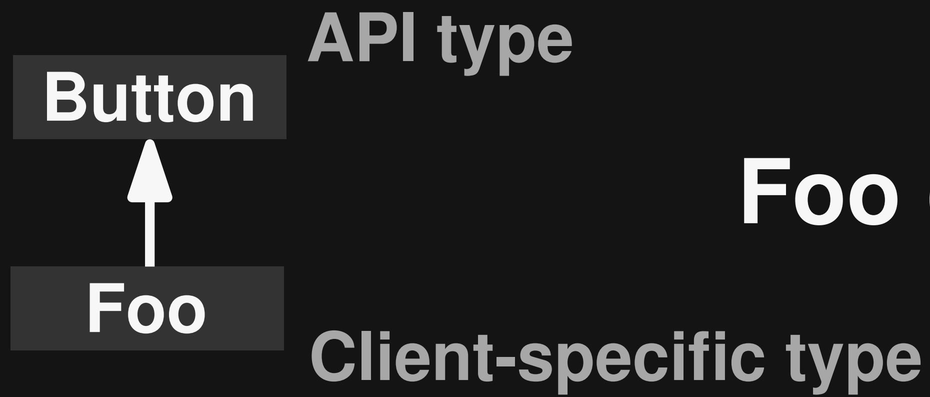
Argument Type Observations (3)

Result:

Parameter	Observations
api(Object, ...)	Foo (1.0)
api(..., Component)	Button (0.5) JLabel (0.5)

Focus on API Types

1. Generalize client types to API types:



Foo (1.0) $\rightarrow$ Button (1.0)

2. Remove all non-API types

Merging Observations

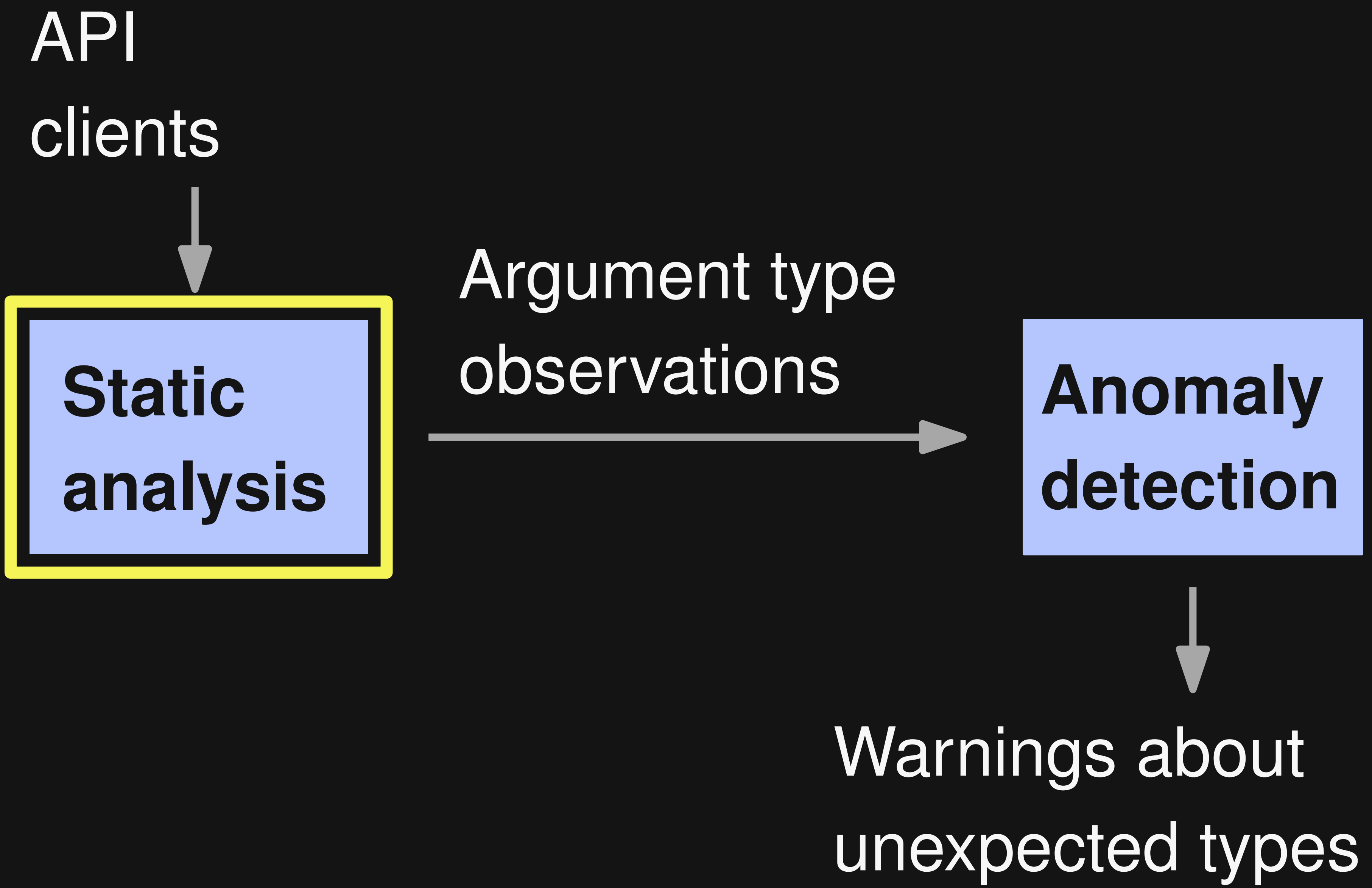
Merge observations from

- Different clients of same API
- Different call sites of same API method

Example:

Parameter	Observations
api(Object, ...)	Button (1.0)
	JList (1.0)
	Button (0.25)
	...
api(..., Component)	...

Overview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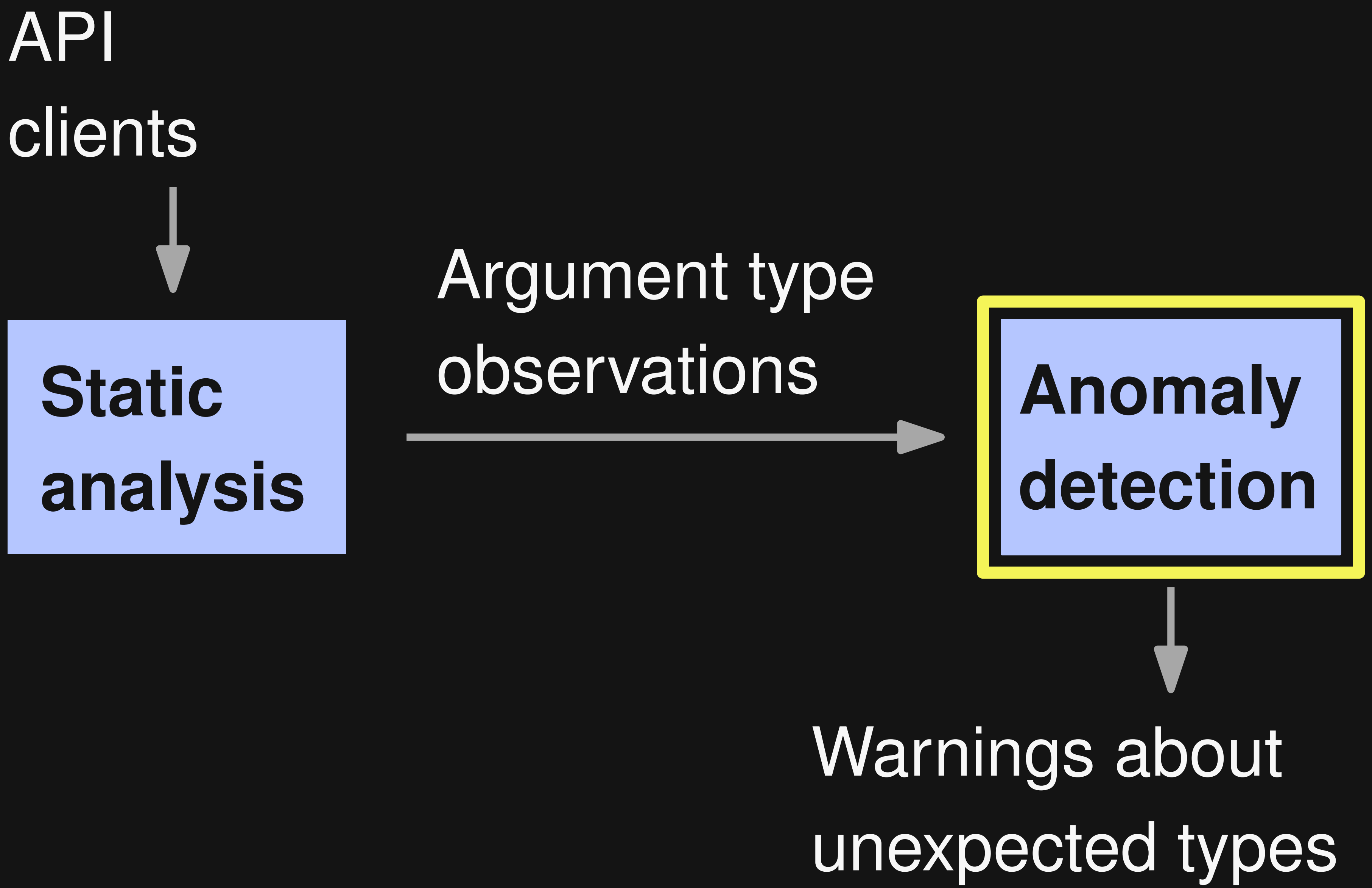
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Anomaly Detection

Goal:

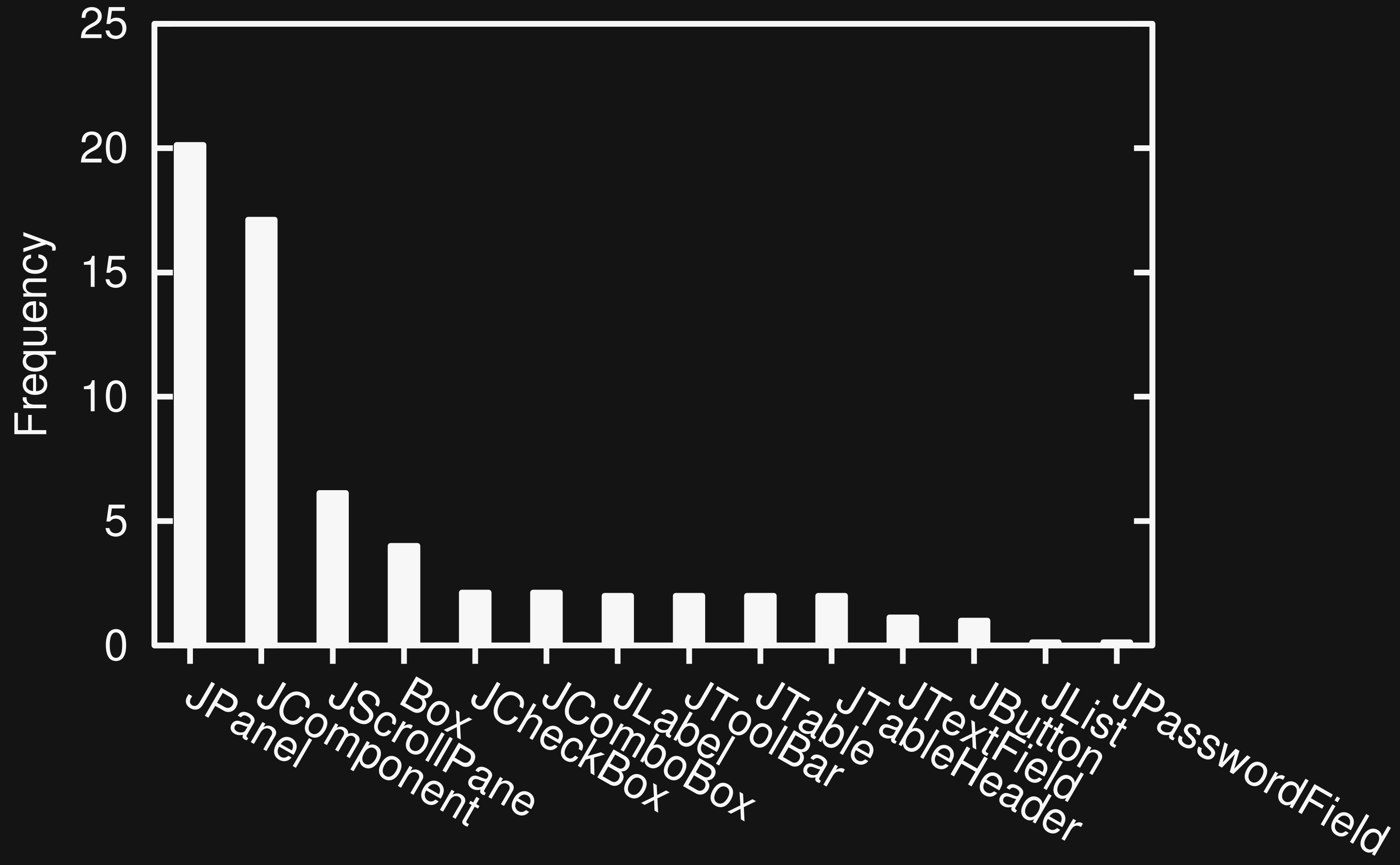
Find unexpected arguments given to likely brittle parameters

For each parameter:

1. Build type histogram
2. Search anomalies

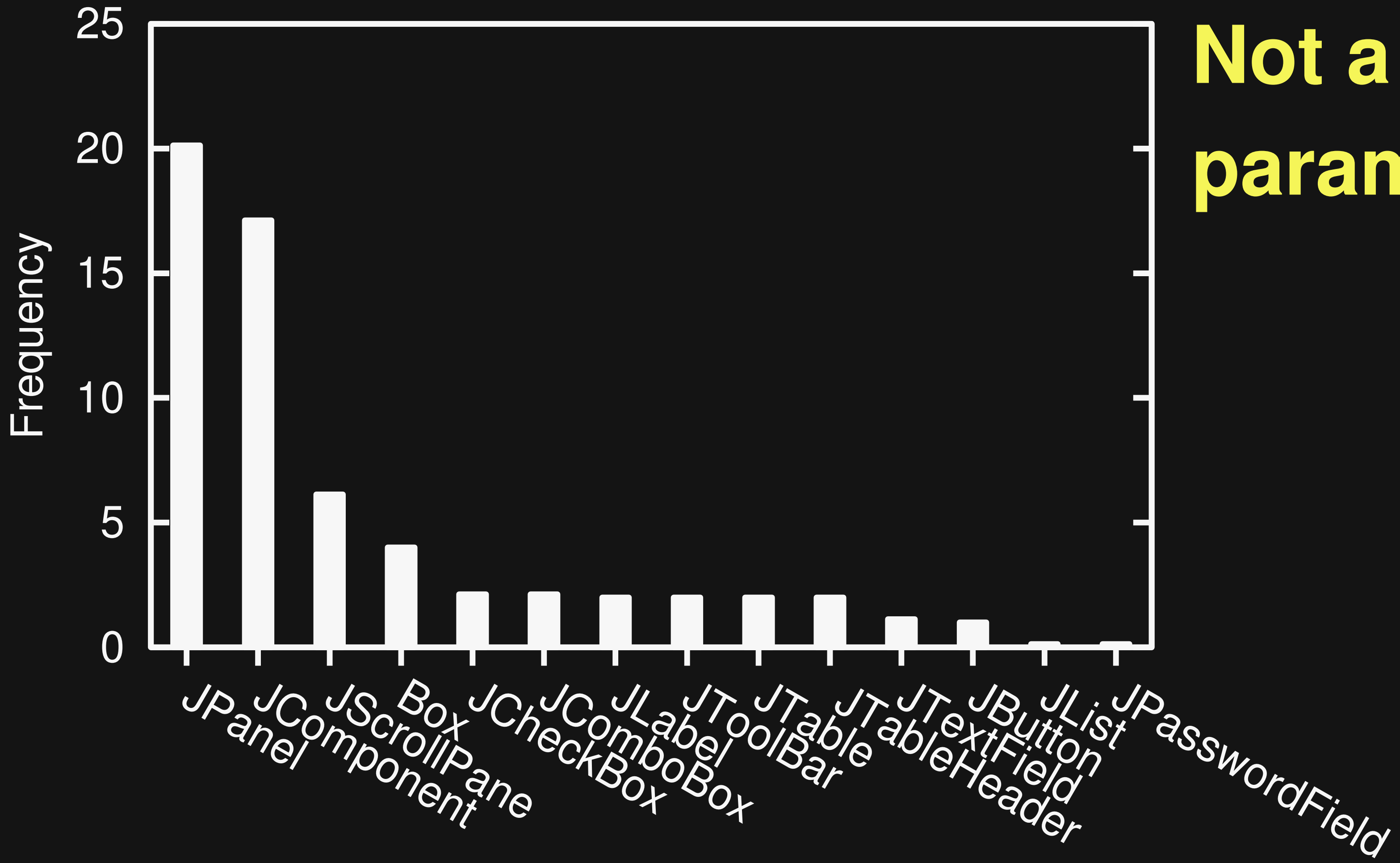
Type Histograms

`JComponent.add(Component, Object)`



Type Histograms

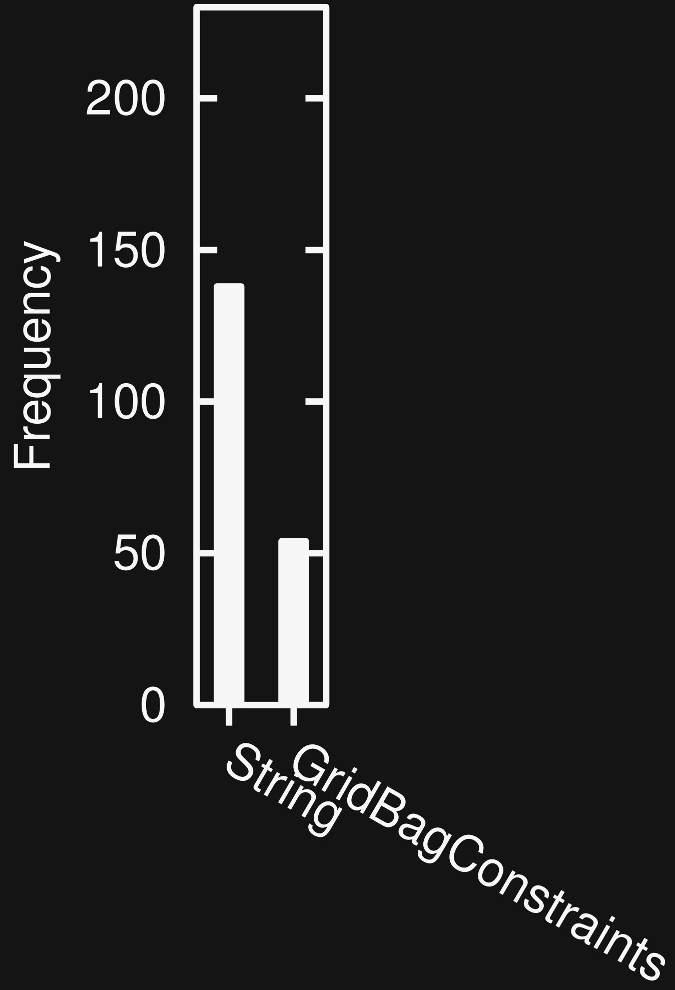
```
JComponent.add(Component, Object)
```



Not a brittle parameter

Type Histograms (2)

`Container.add(Component, Object)`



Type Histograms (2)

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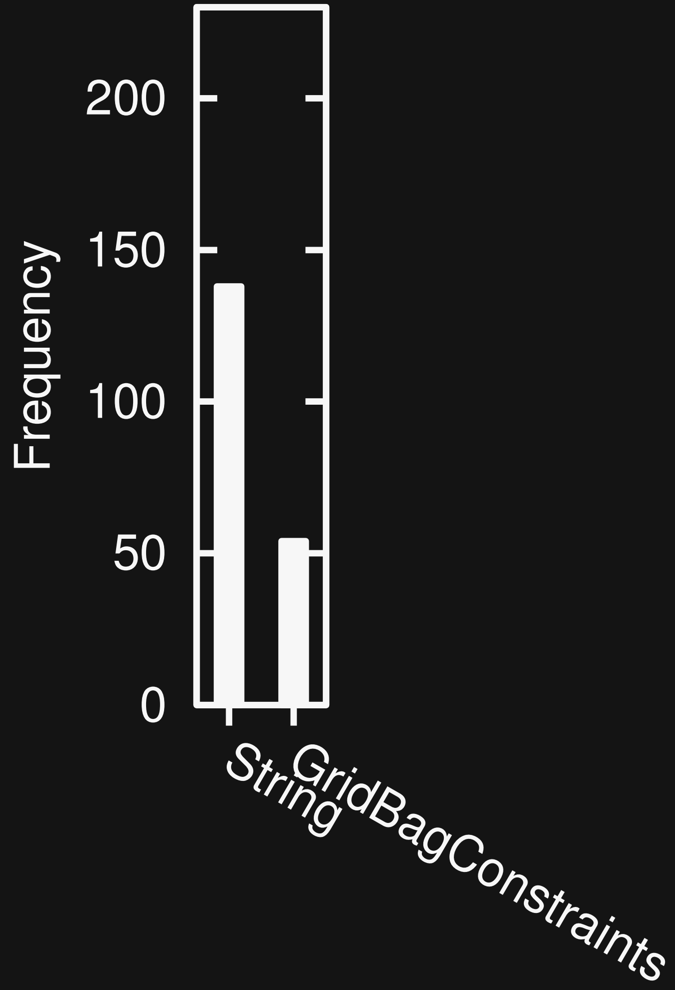
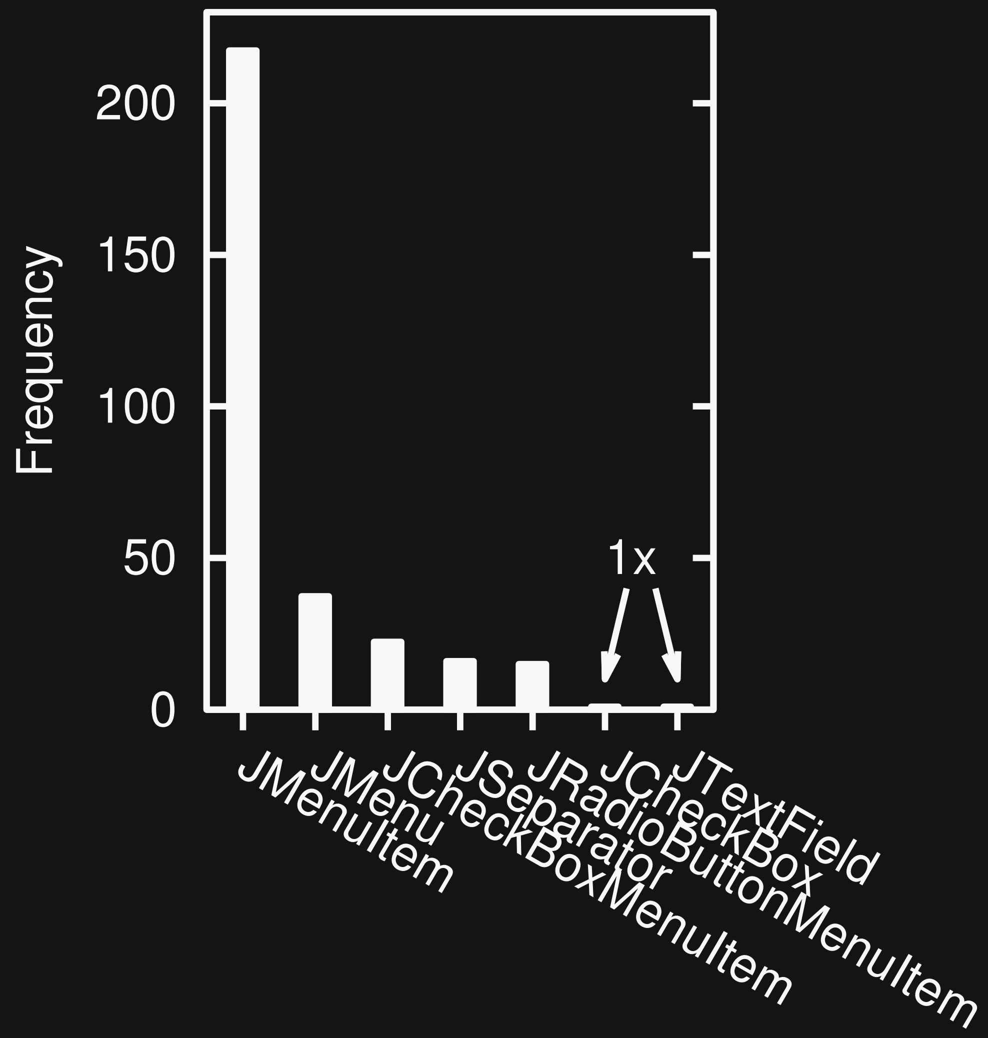


Brittle parameter

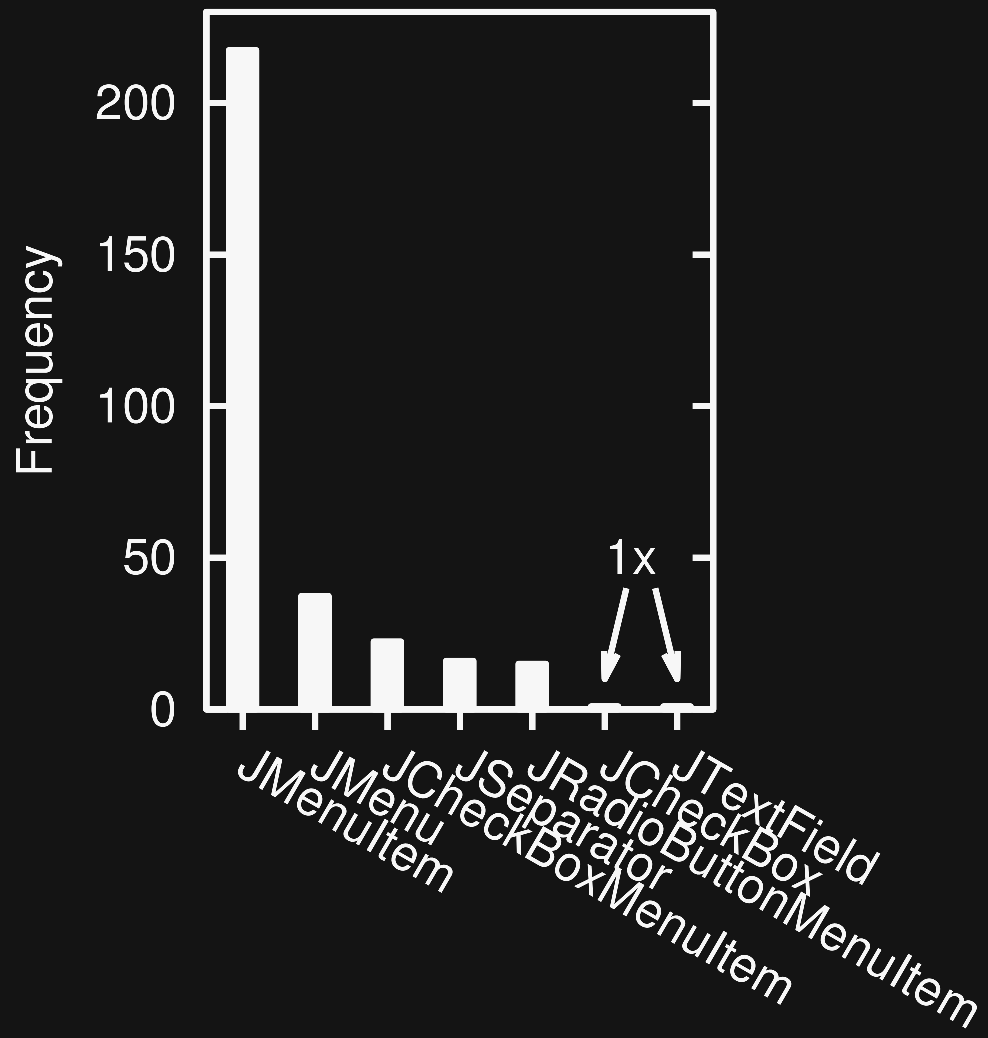
Type Histograms (3)

`JMenu.add(Component)`



Type Histograms (3)

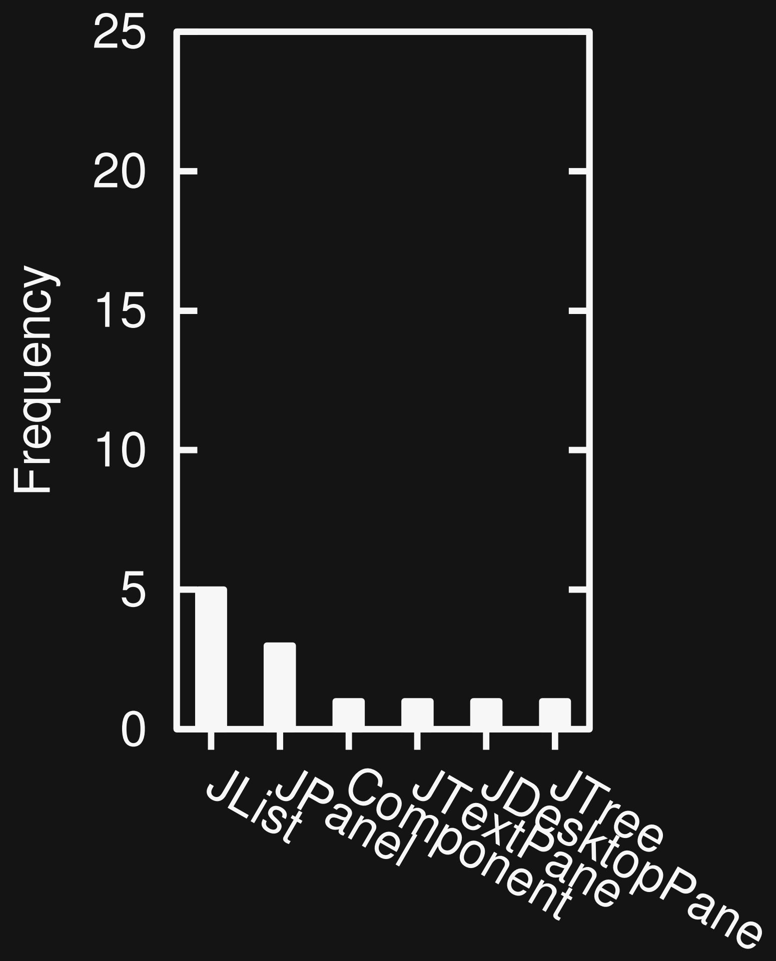
`JMenu.add(Component)`



Brittle parameter, two unexpected arguments

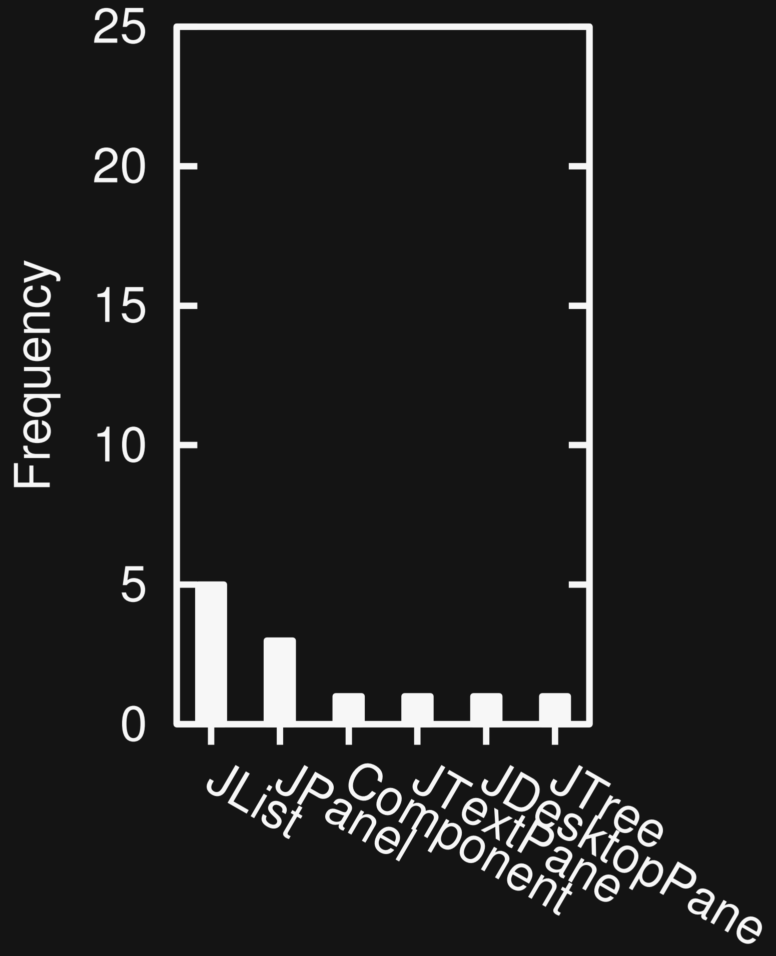
Type Histograms (4)

`JScrollPane.<init>(Component, int, int)`



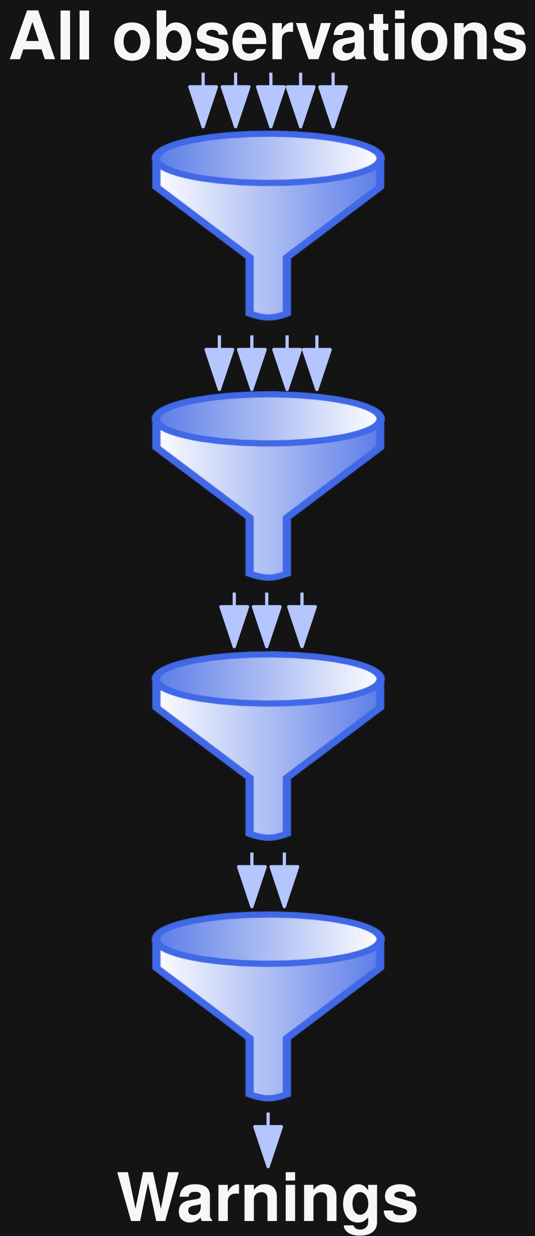
Type Histograms (4)

`JScrollPane.<init>(Component, int, int)`



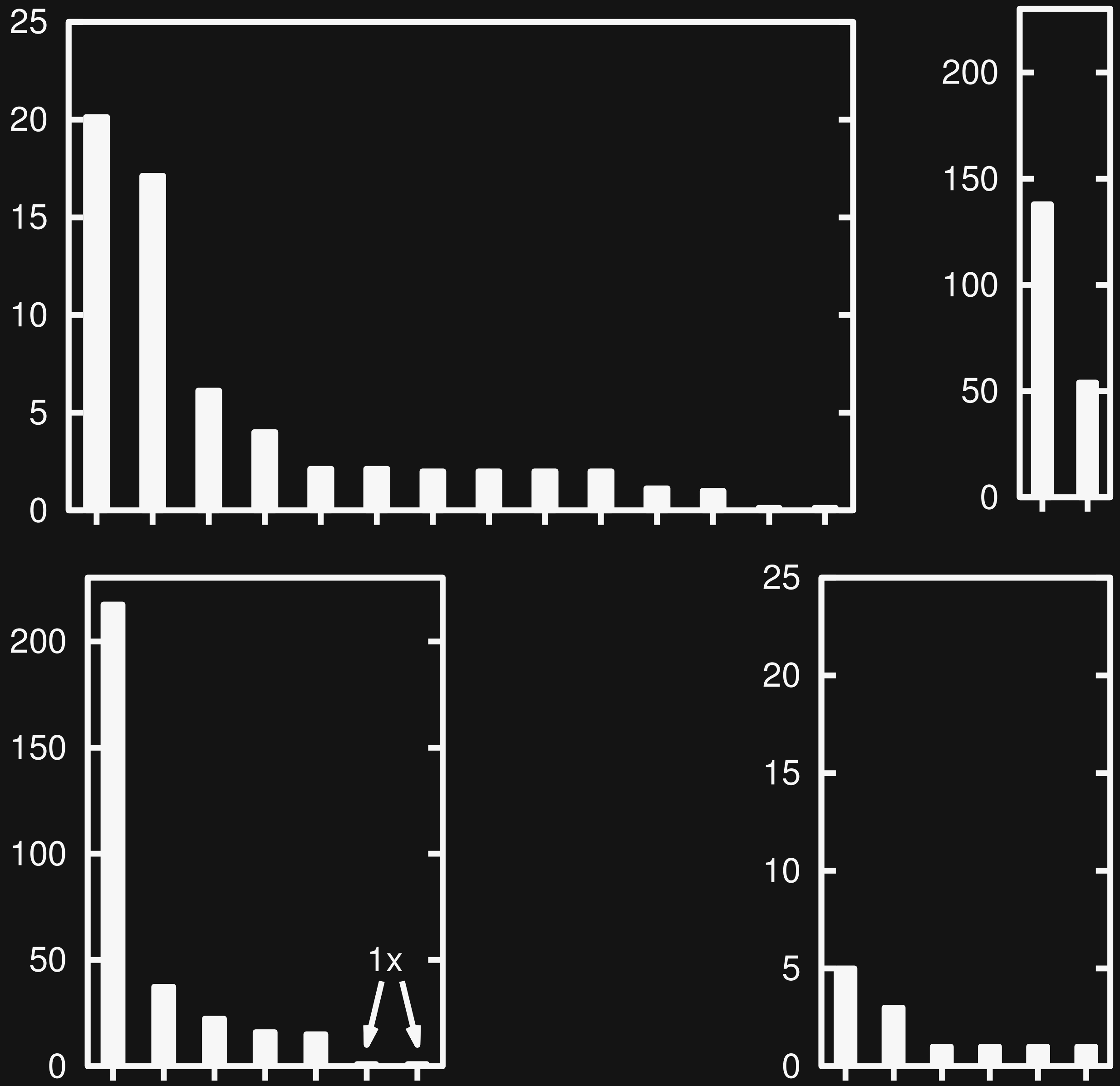
Little information

Finding Anomalies

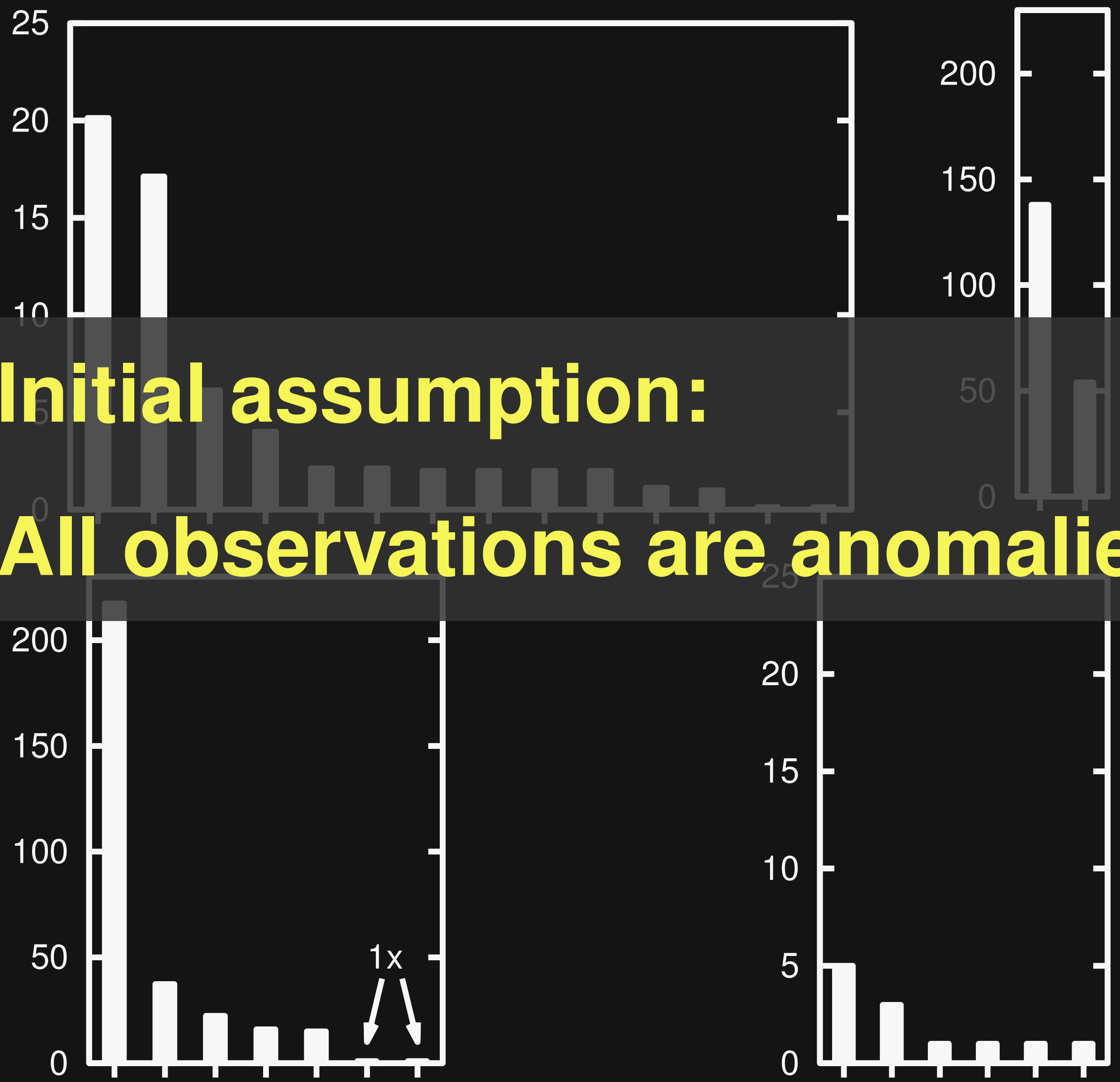


- Initial assumption: Each observation = potential anomaly
- Filters to remove false warnings
- If all filters passed: Warning about unexpected argument

Filtering



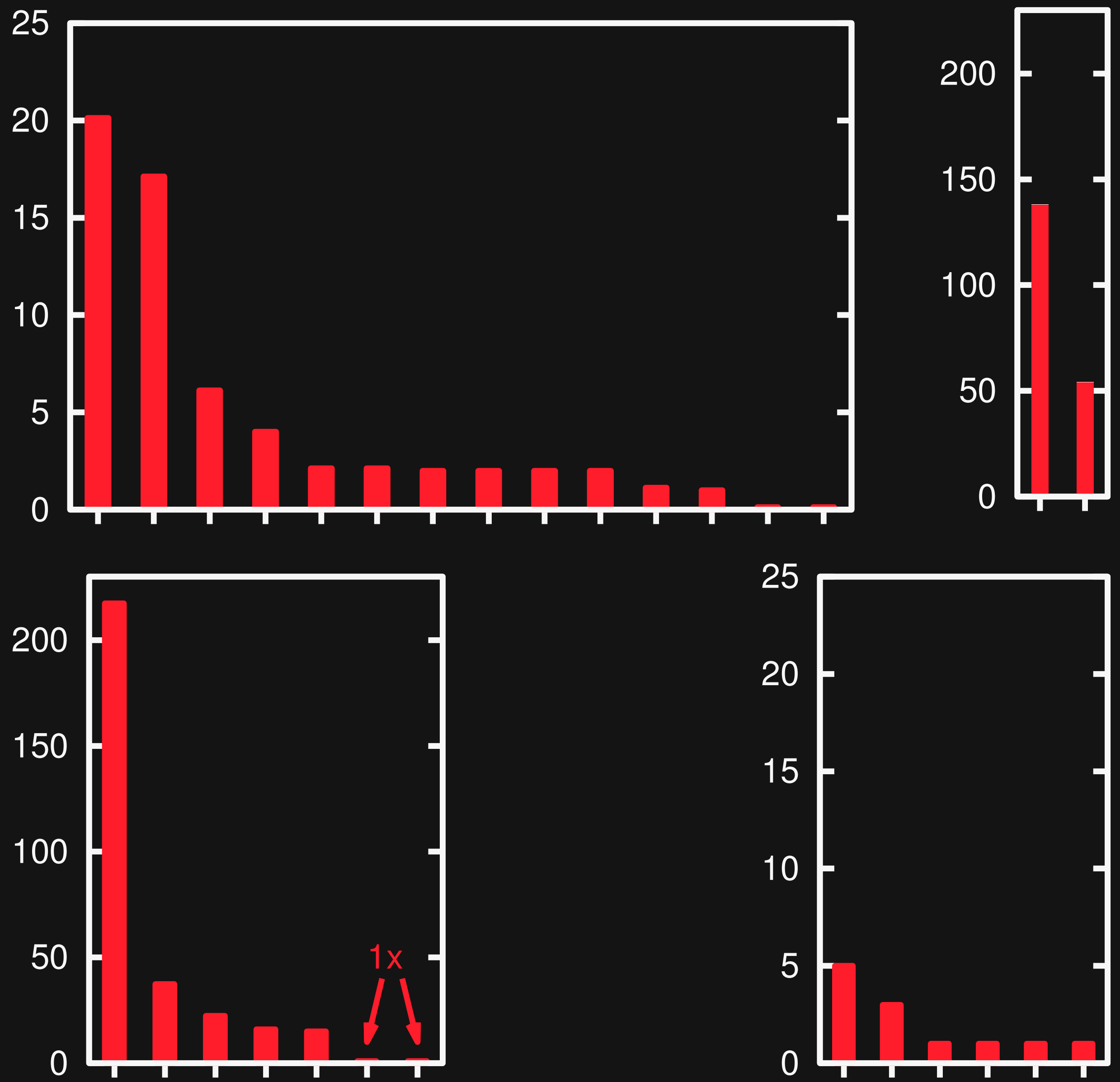
Filtering



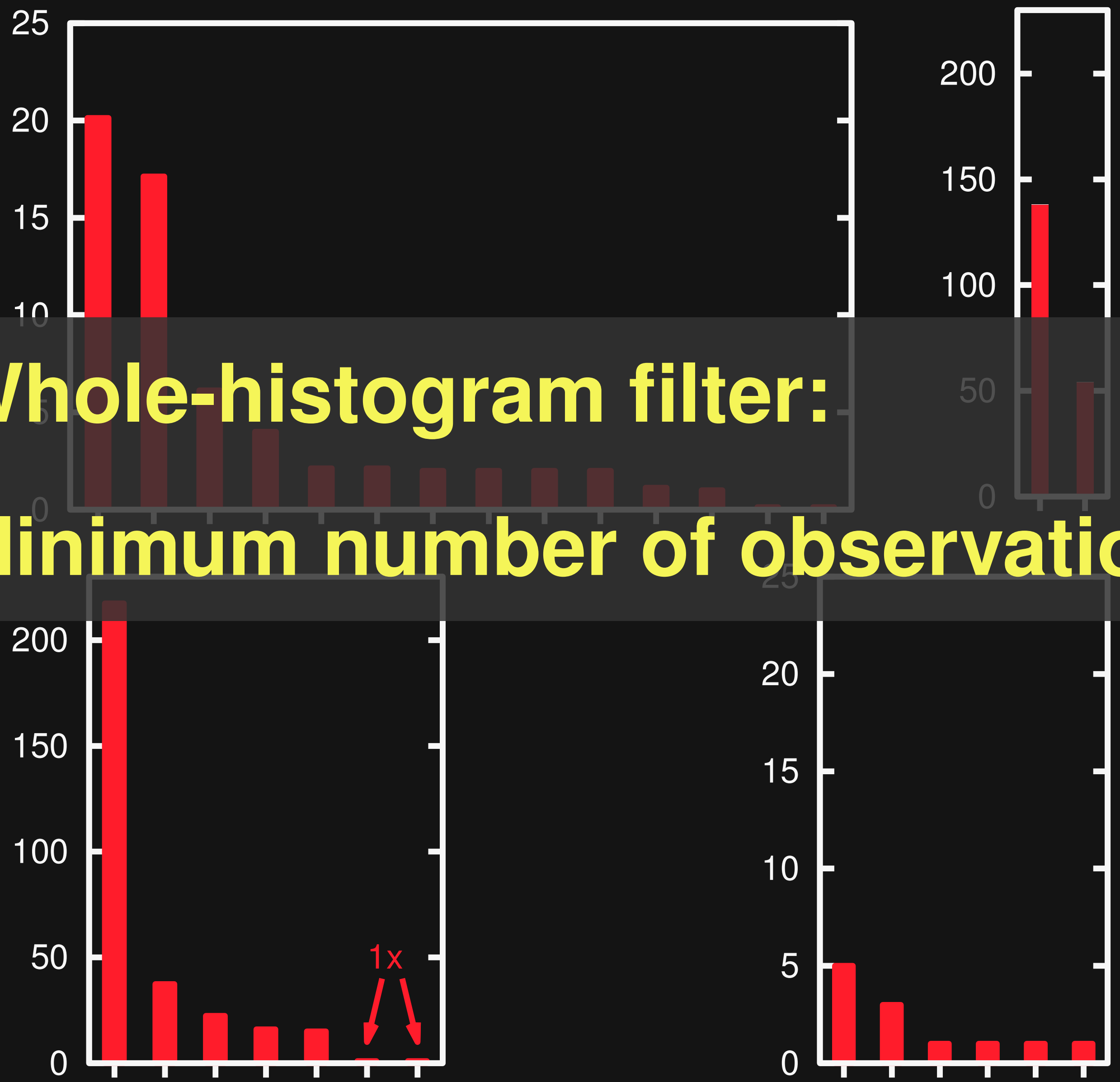
Initial assumption:

All observations are anomalies

Filtering



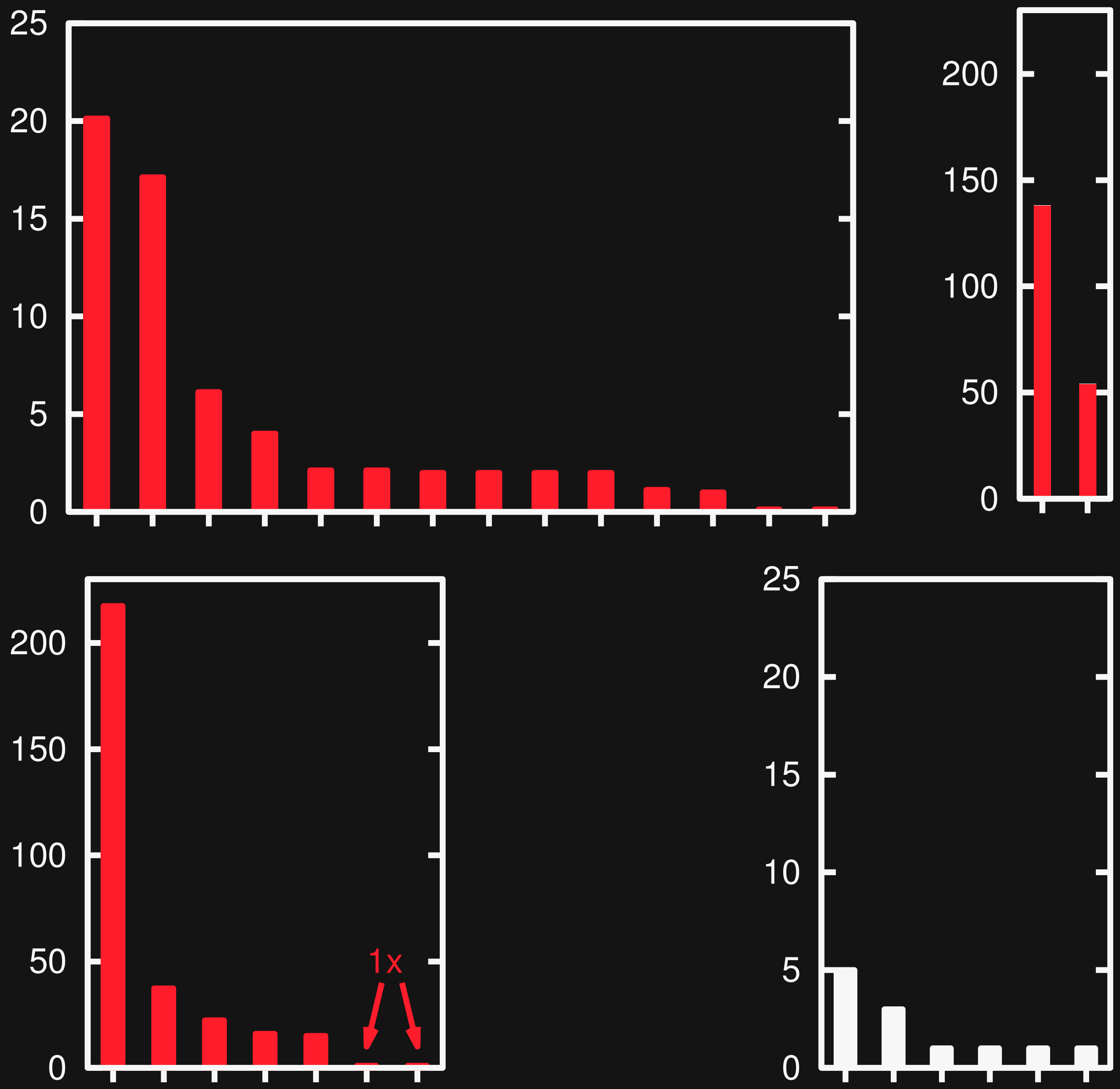
Filtering



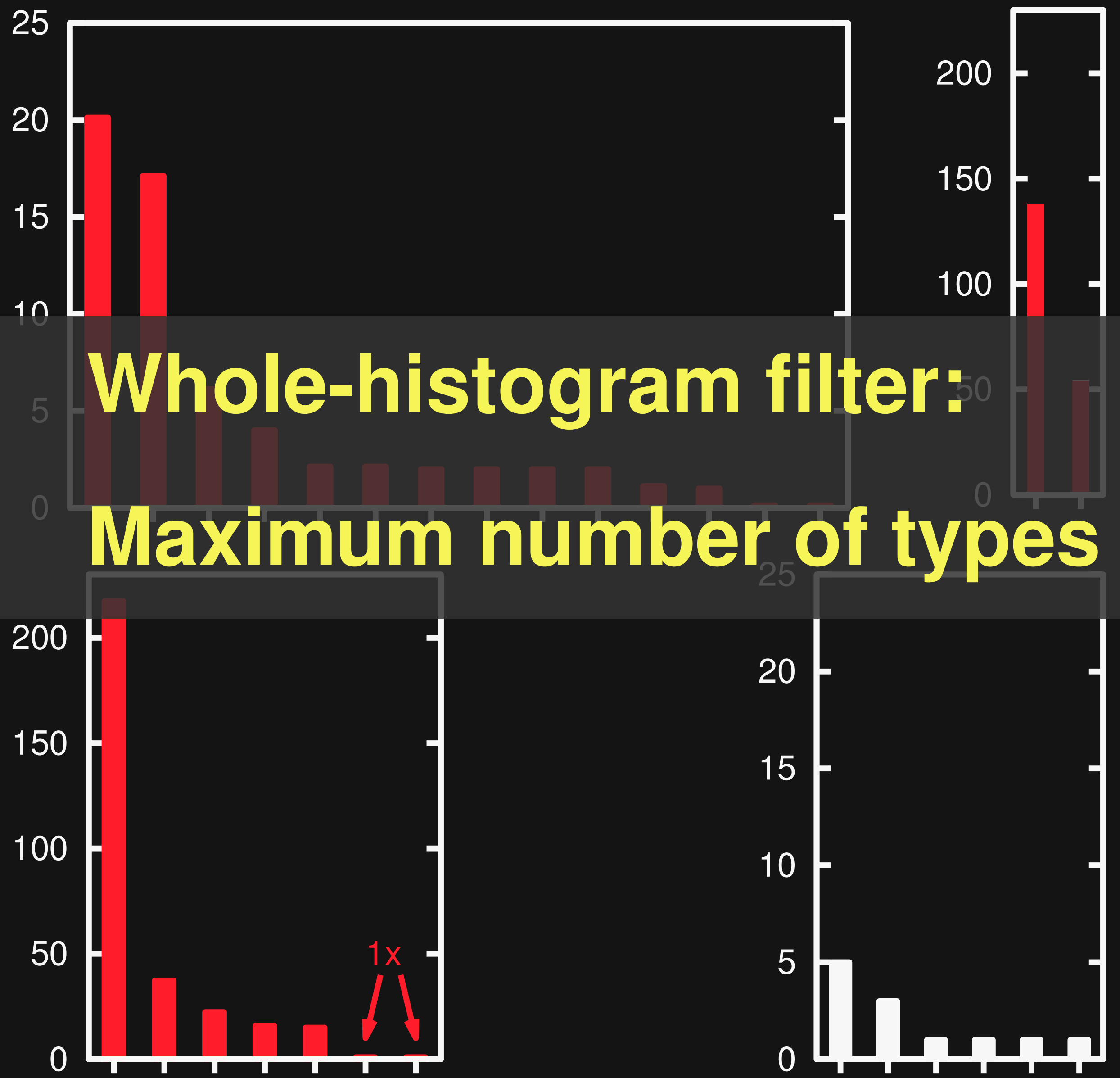
Whole-histogram filter:

Minimum number of observations

Filtering



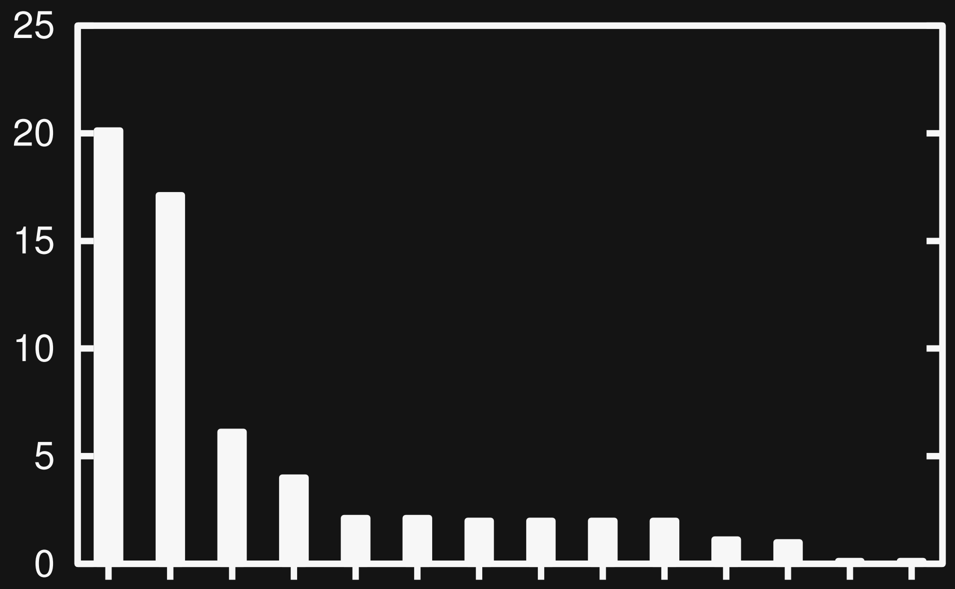
Filtering

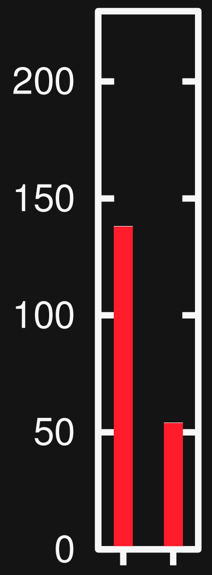


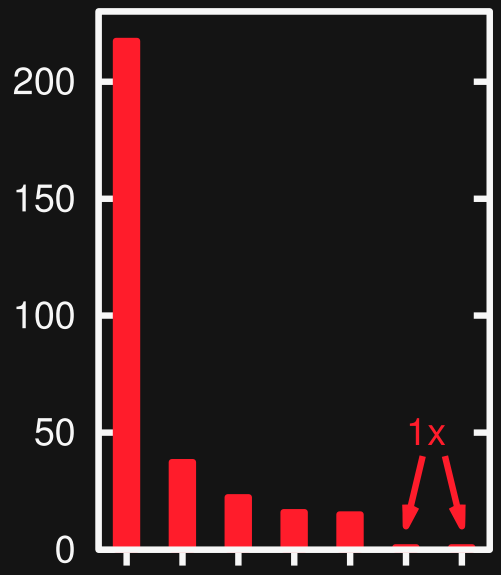
Whole-histogram filter:

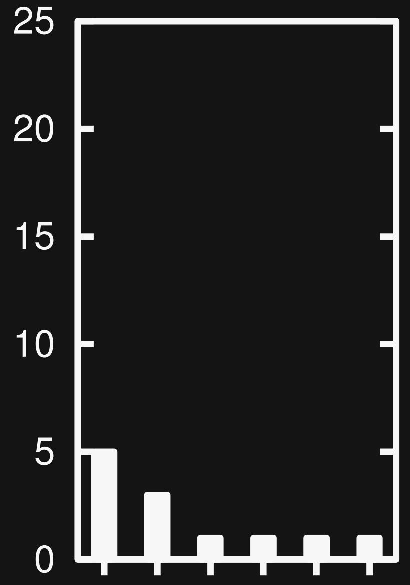
Maximum number of types

Filtering

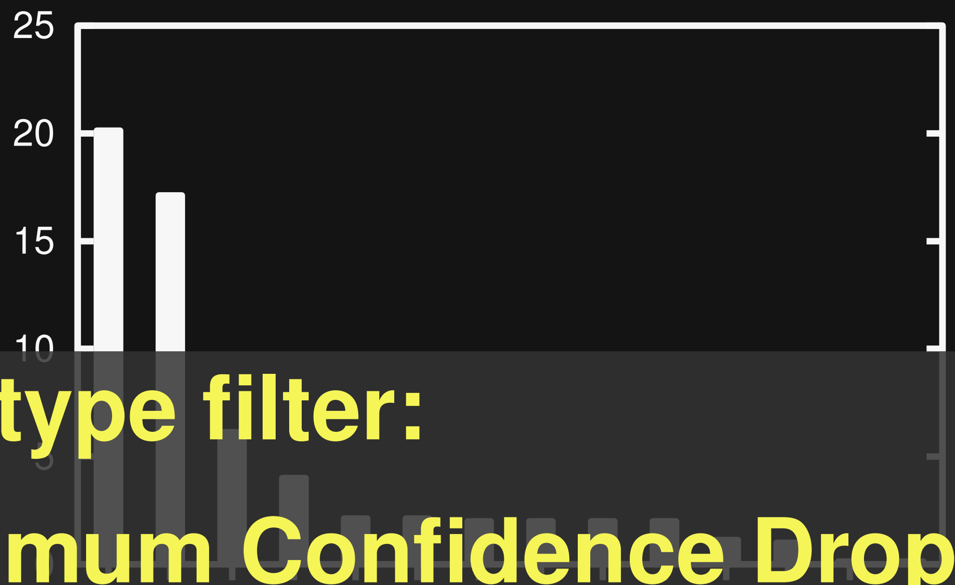


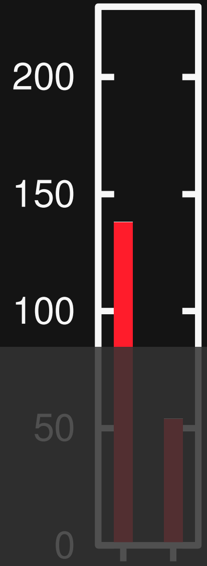






Filtering

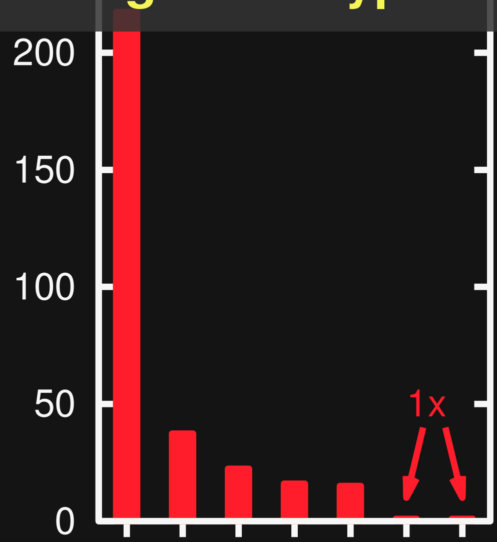


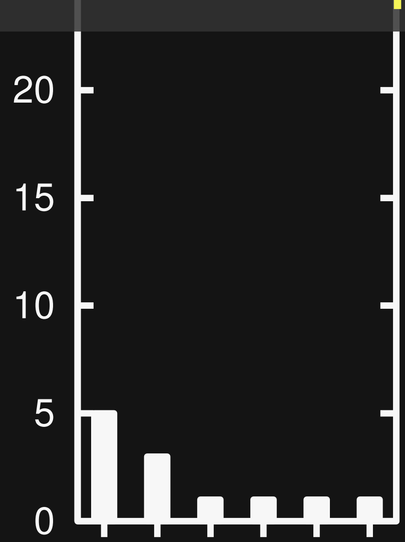


Per-type filter:

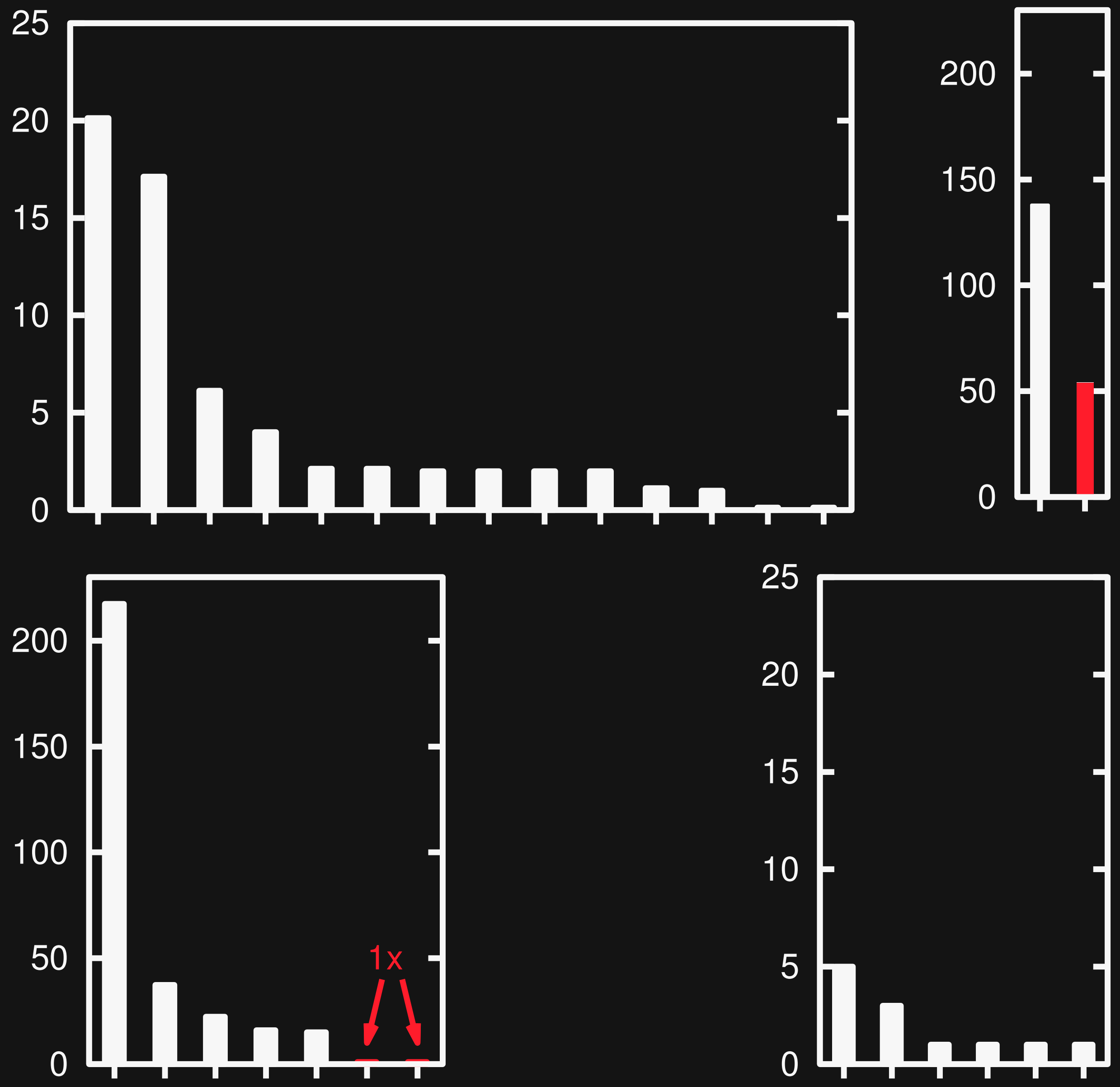
Minimum Confidence Drop

(Does the argument type deviate from an otherwise accepted rule?)

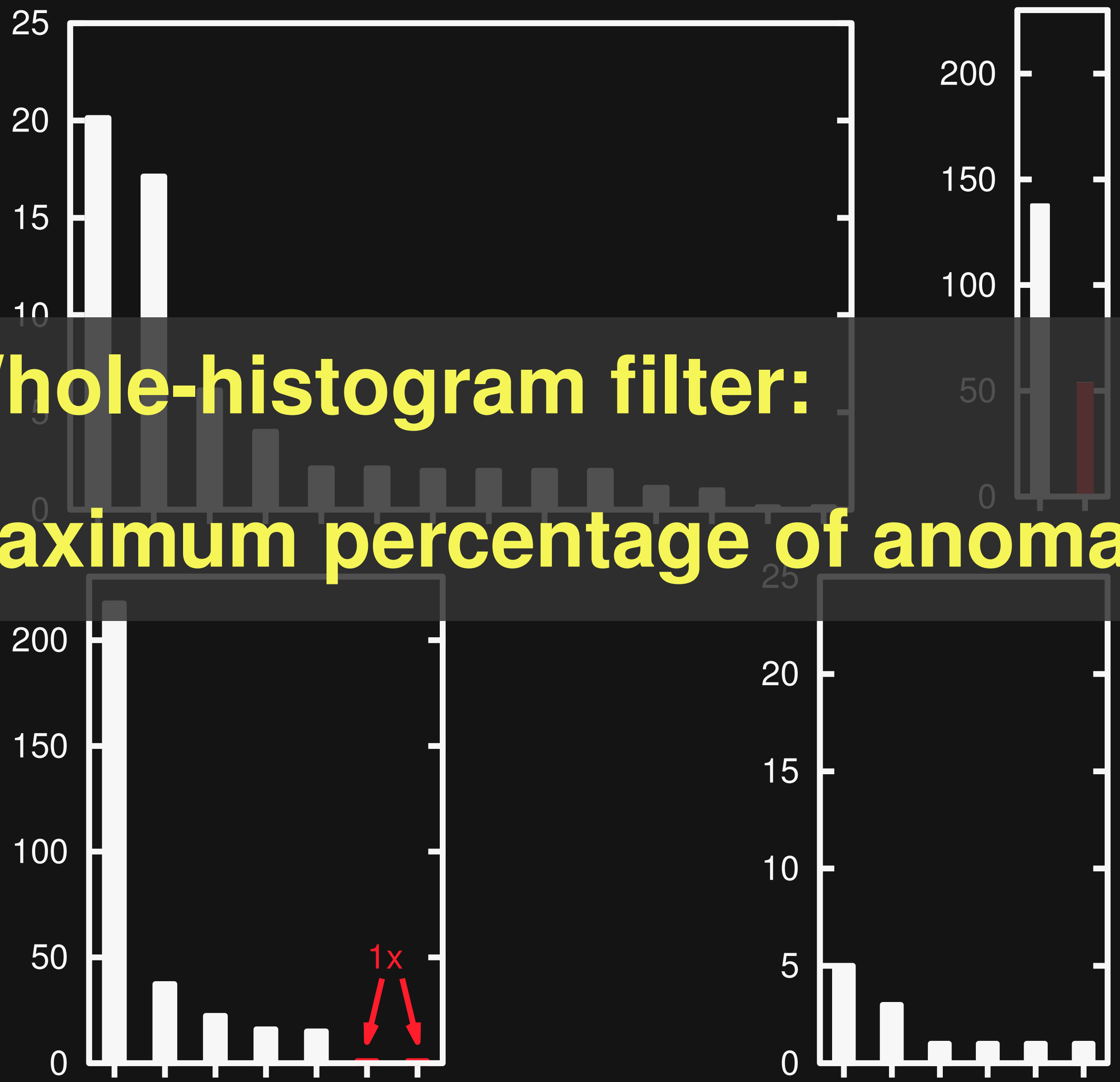




Filtering



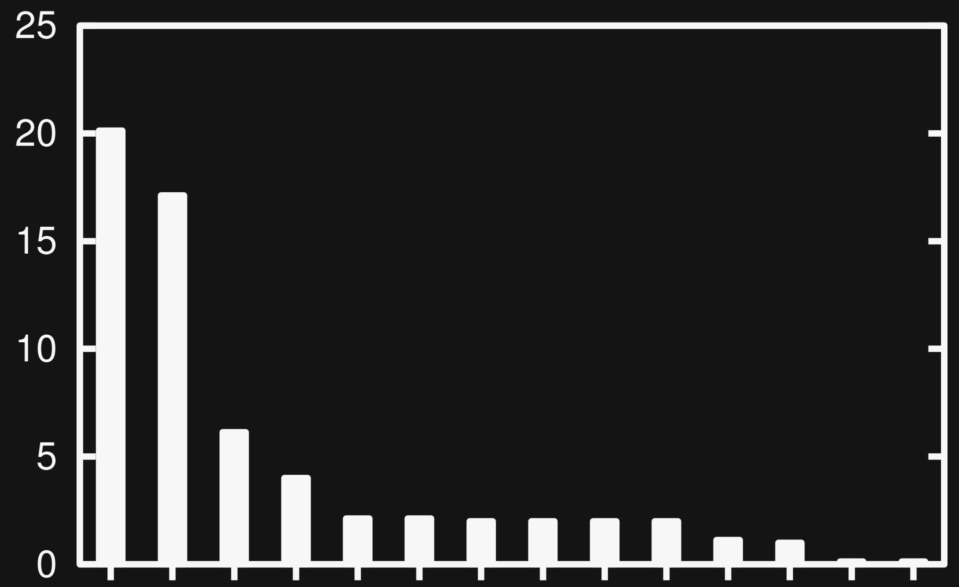
Filtering

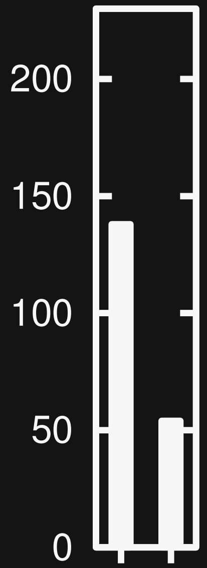


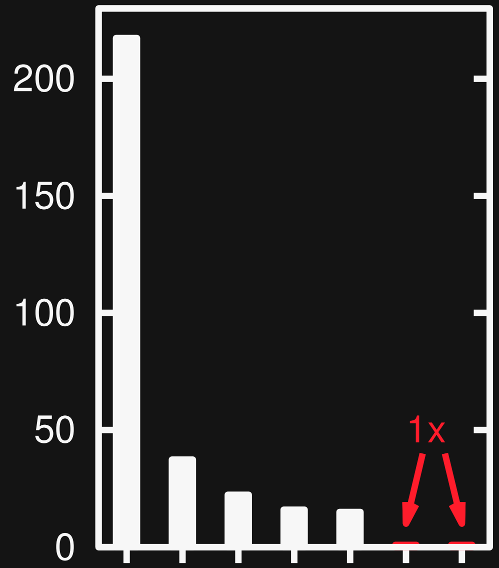
Whole-histogram filter:

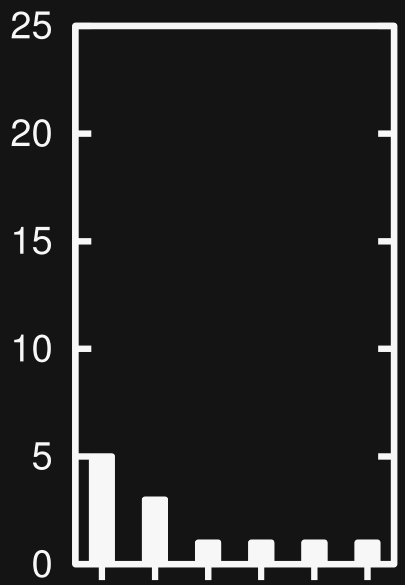
Maximum percentage of anomalies

Filtering









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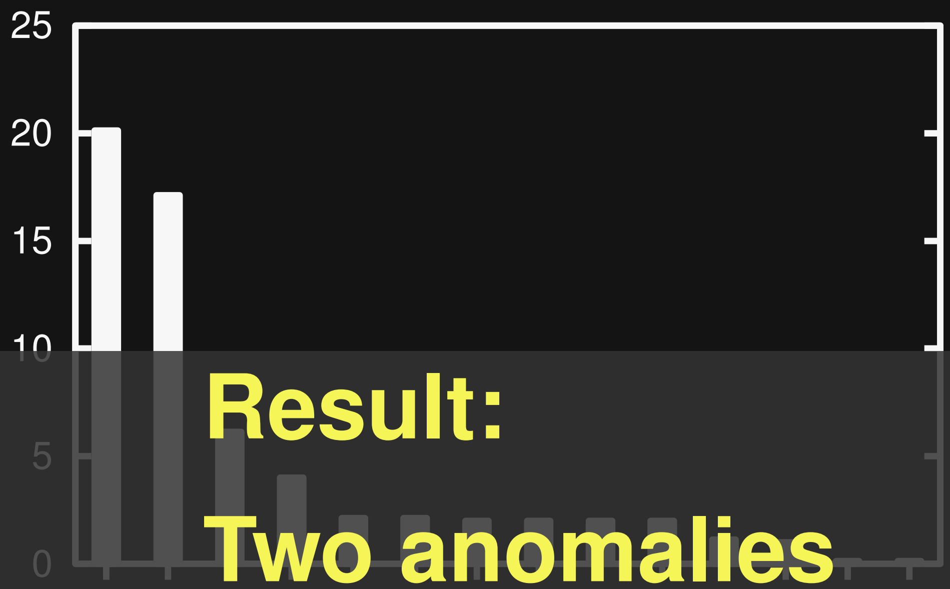
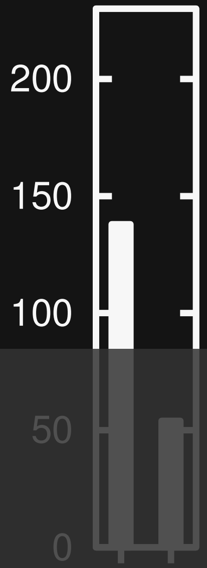
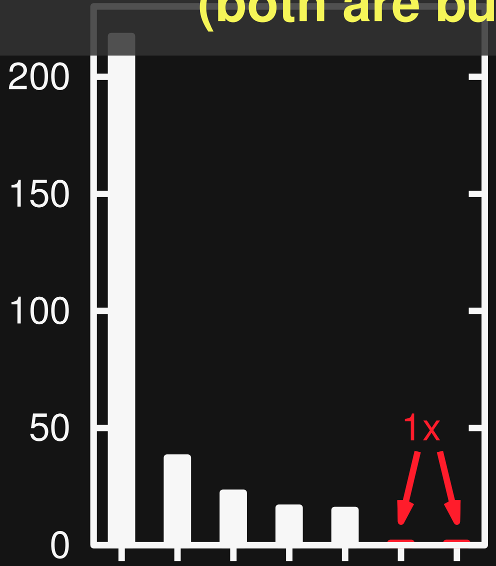


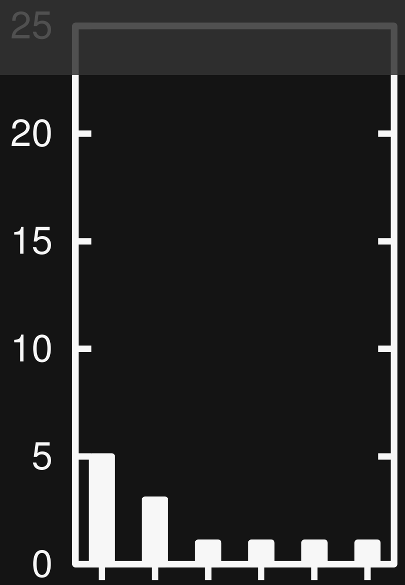


Result:

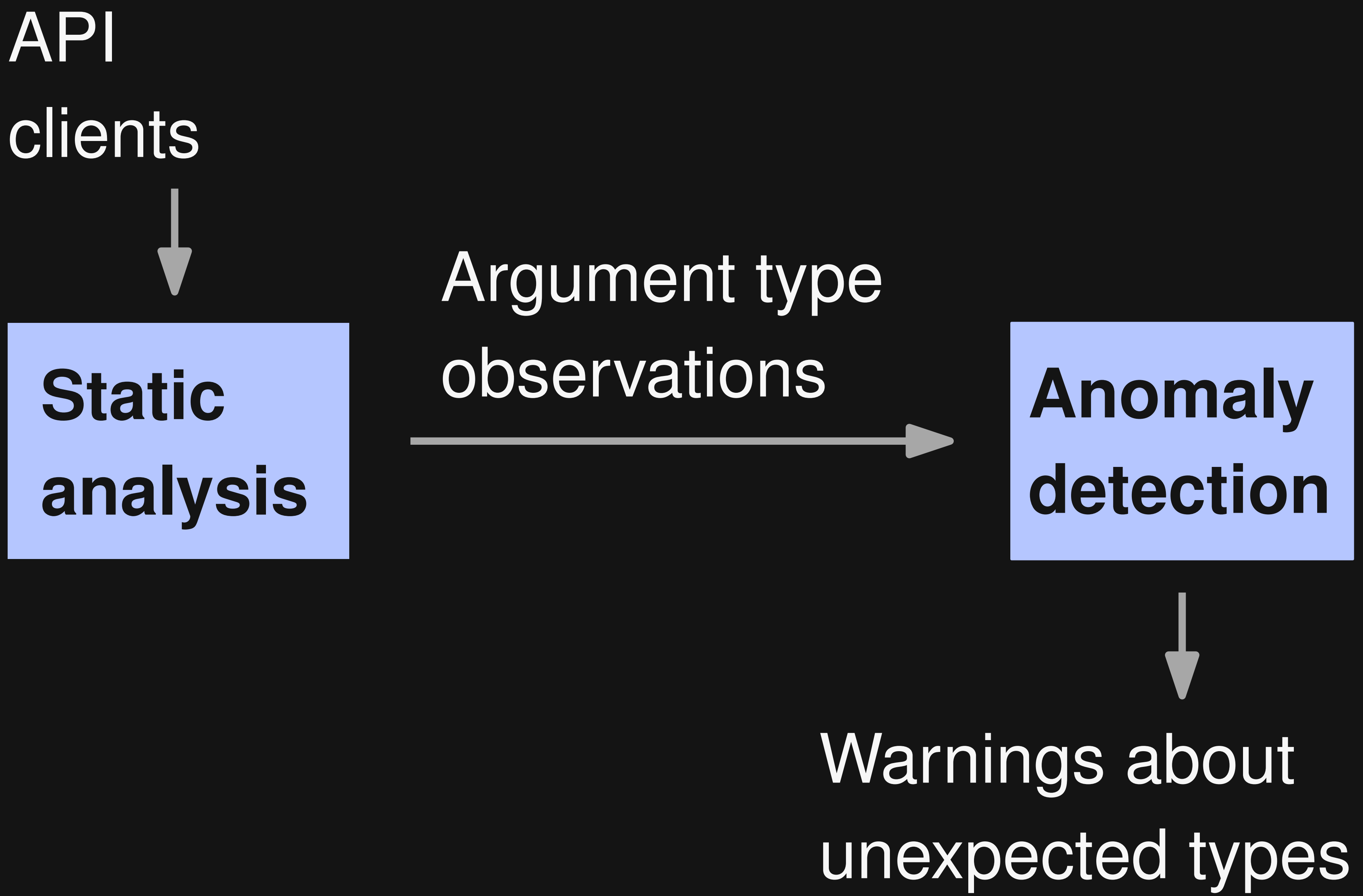
Two anomalies

(both are bugs)





Summary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Evaluation

- 21 programs (650 kLoC)
- AWT/Swing API
- Bugs - code smells - false positives

Example: Bug in jEdit

```
class FilteredListModel extends AbstractListModel {
  void setFilter(String filter) {
    Runnable runner = new Runnable() {
      public void run() {
        fireContentsChanged(this, 0, getSize()-1);
      }
    };
  }
}
```

Confirmed as a bug and fixed within a day. See bug #3477759.

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    };
  }
}
```

- **Declared:** `Object`
- **Expected:** `*ListModel`
- **Here:** `Runnable`

Confirmed as a bug and fixed within a day. See bug #3477759.

Example: Bug in JFtp

```
...
JScrollPane scrollPane = new JScrollPane(list);
container.add(new JScrollPane(scrollPane));
...
```

Confirmed as a bug and fixed. See bug #3484625.

Example: Bug in JFtp

```
...
JScrollPane scrollPane = new JScrollPane(list);
container.add(new JScrollPane(scrollPane));
...
```

- **Declared:** `Component`
- **Expected:** `JList`, `JTextArea`, ...
- **Here:** `JScrollPane`

Confirmed as a bug and fixed. See bug #3484625.

Characteristics of Issues

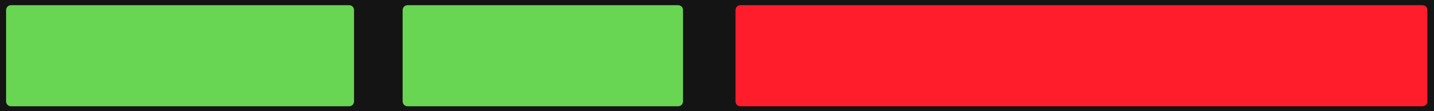
Common to all issues found:

- Subtle problems (no exception etc.)
- Visual glitches
- GUI misbehavior

Hard to find with traditional testing

Precision

Default filtering: 47%



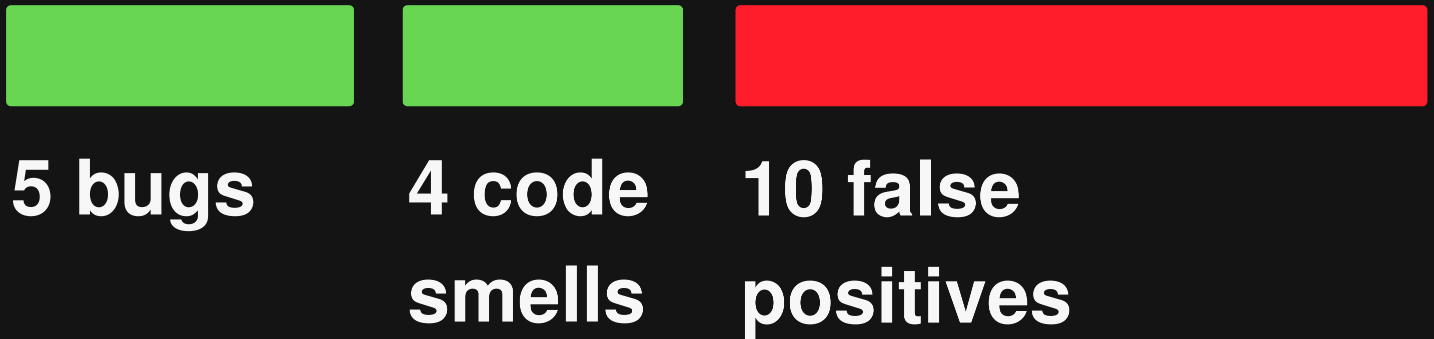
5 bugs

4 code smells

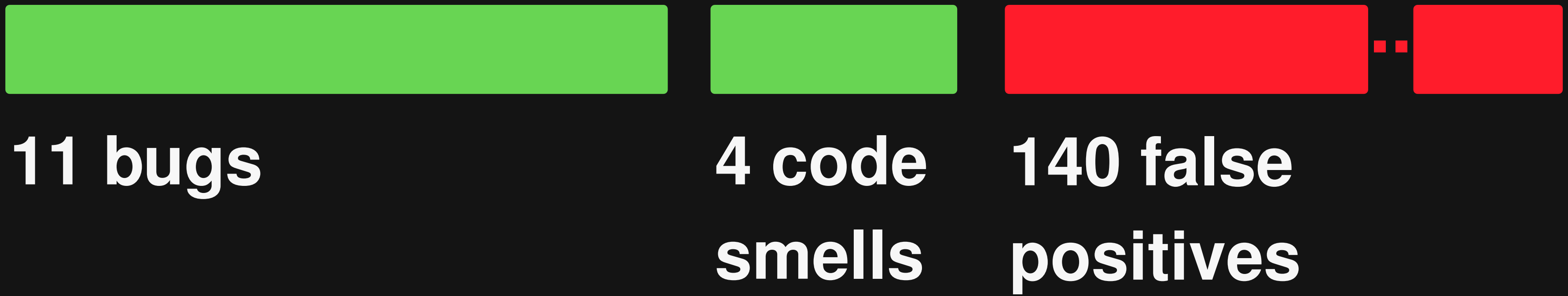
10 false positives

Precision

Default filtering: 47%



Recall-focused filtering: 11%



Recall

Randomly seeded bugs
(for known brittle parameters)

- Default filtering: 83%
- Recall-focused filtering: 94%

Influence of Points-to Analysis

Benefits of using points-to analysis

- **Find two more bugs**
  (recall-focused configuration, original programs)
- **Increased precision: 76% $\rightarrow$ 83%**
  (default configuration, seeded bugs)

Influence of Points-to Analysis

Benefits of using points-to analysis

- Find two more bugs
  (recall-focused configuration, original programs)
- Increased precision: 76% $\rightarrow$ 83%
  (default configuration, seeded bugs)

Beneficial but not crucial

Performance

Good performance for automatic analysis

- All 21 programs: 23 minutes
- 99.9% of time: Static analysis

Intel Core 2 Duo with 3.16 GHz, 2.5 GB memory

Conclusion

Powerful analysis that finds subtle errors where traditional testing fails

Lessons learned:

- Brittle parameters: Real problem that deserves attention
- Simple analysis: Effective in practice
- Many-client analysis: Key to success

Thank you!

Implementation and experimental data:
http://mp.binaervarianz.de/issta2012/

Static Detection of Brittle Parameter Typing
Michael Pradel, Severin Heiniger, and Thomas R. Gross