The 33rd IEEE International Symposium on Software Reliability Engineering (ISSRE 2022)

AexPy: Detecting API Breaking Changes in Python Packages

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Motivation

The Popular Python

Create third-party packages

```
import code
import logging
import os
import pathlib

import click
import yaml
from click import BadArgumentUsage, BadOptionUsage, BadParameter
from click.exceptions import ClickException
```

Use third-party packages

Motivation

Difficulty on Maintaining Packages

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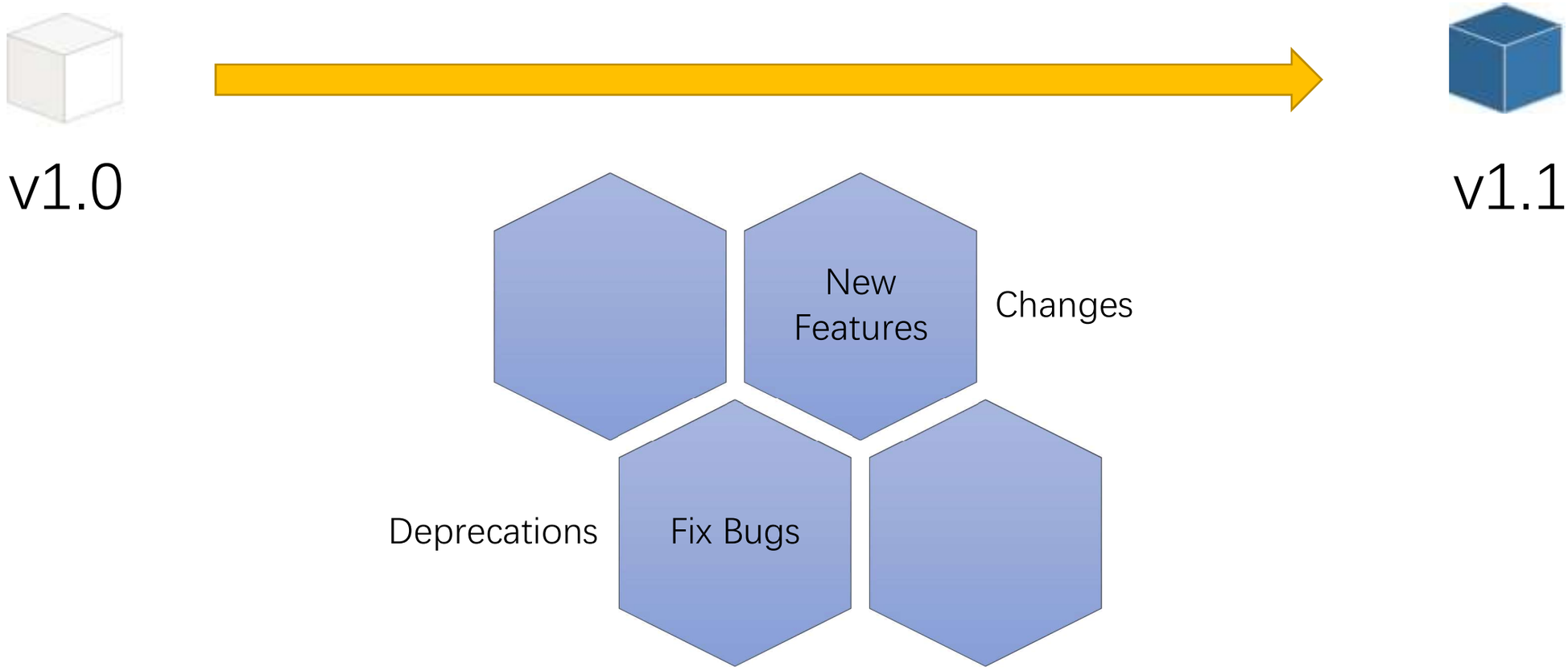

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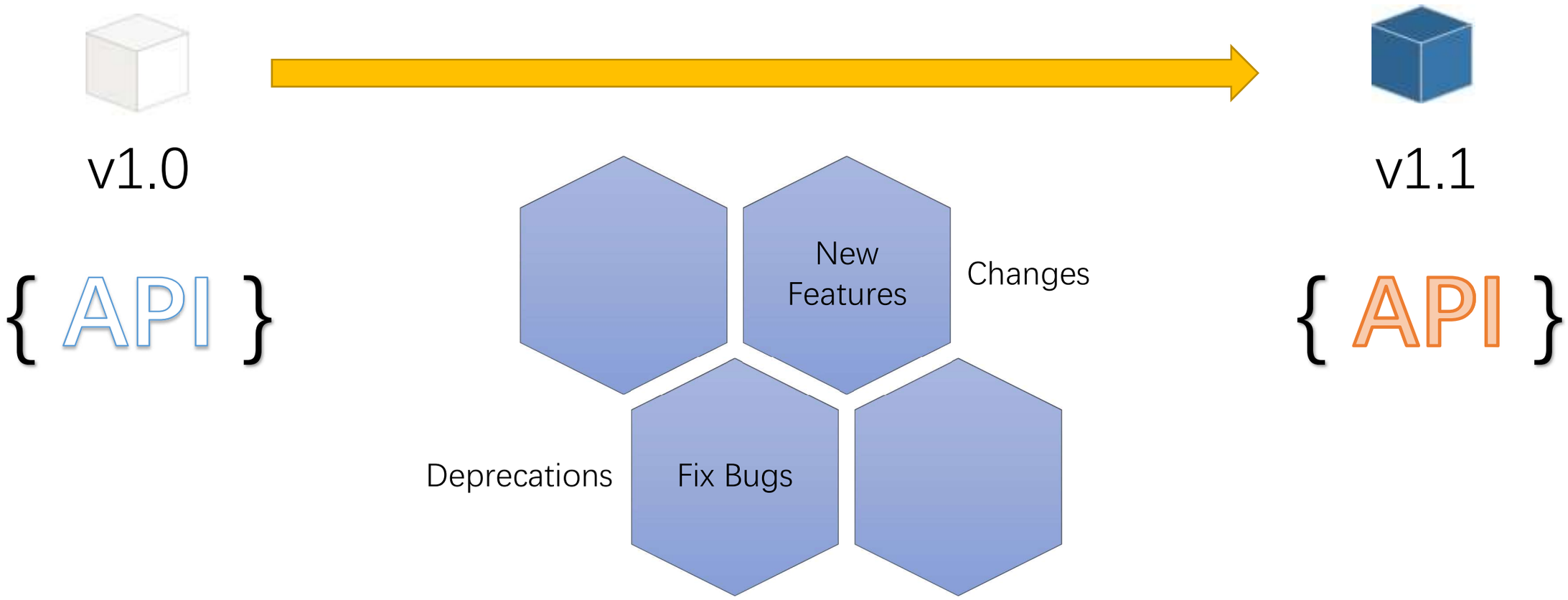

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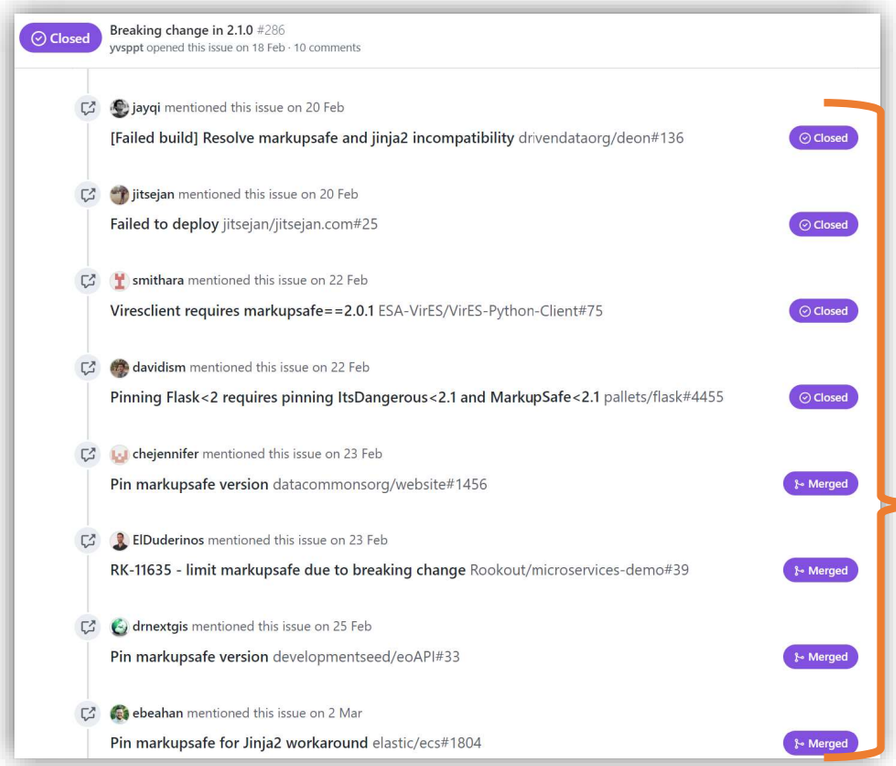
v1.0

{ API }

v1.1

{ API }



Affected clients

Breaking change in 2.1.0 · Issue #286 · pallets/markupsafe (github.com)

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{ API }

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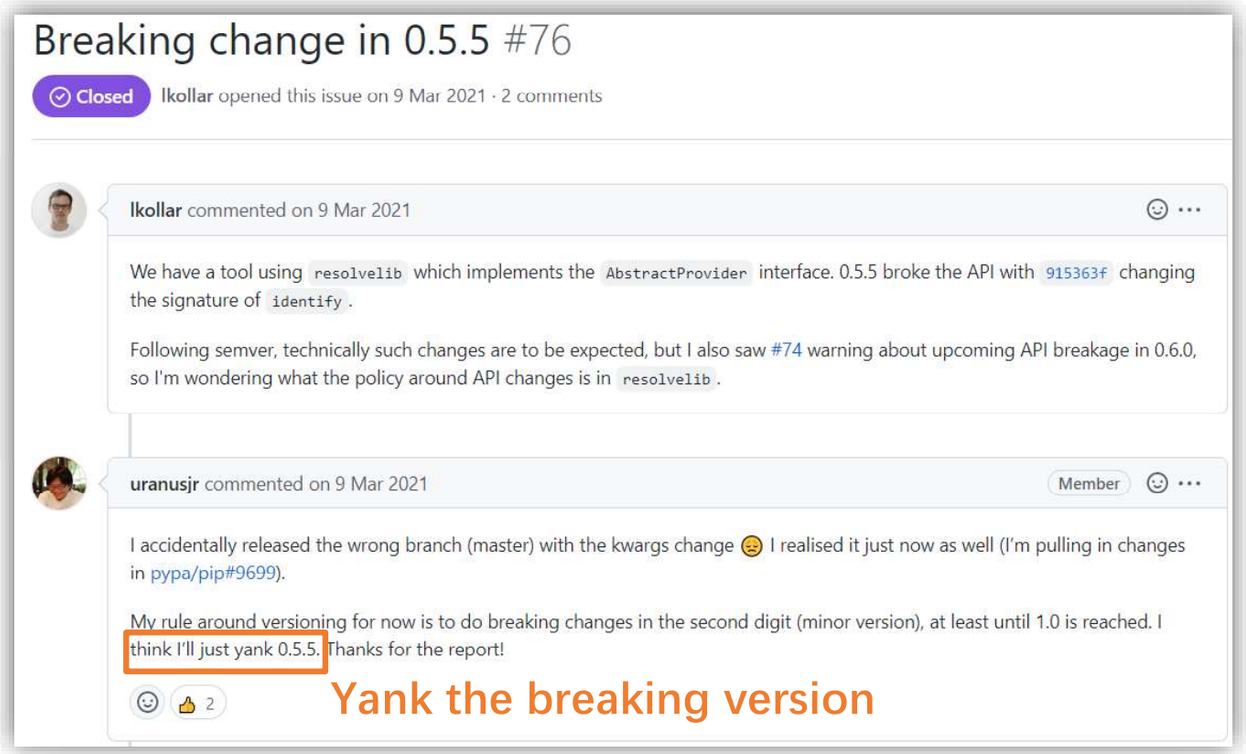

Breaking change in 0.5.5 · Issue #76 · sarugaku/resolvelib (github.com)

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Backward Compatible / **Breaking**?

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{ API }

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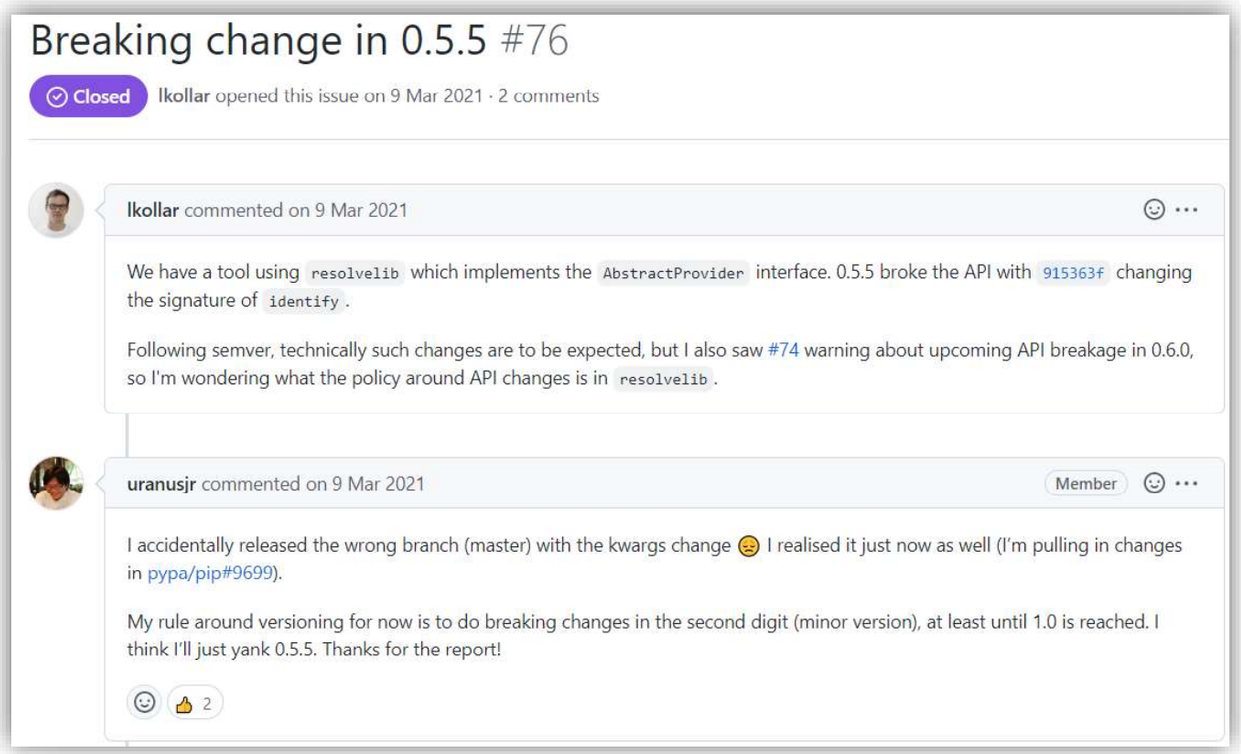

Breaking change in 0.5.5 #76

Closed lkollar opened this issue on 9 Mar 2021 · 2 comments

lkollar commented on 9 Mar 2021

We have a tool using `resolvelib` which implements the `AbstractProvider` interface. 0.5.5 broke the API with `915363f` changing the signature of `identify`.

Following semver, technically such changes are to be expected, but I also saw #74 warning about upcoming API breakage in 0.6.0, so I'm wondering what the policy around API changes is in `resolvelib`.

uranusjr commented on 9 Mar 2021 Member

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Breaking change in 0.5.5 · Issue #76 · sarugaku/resolvelib (github.com)

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Manually check?

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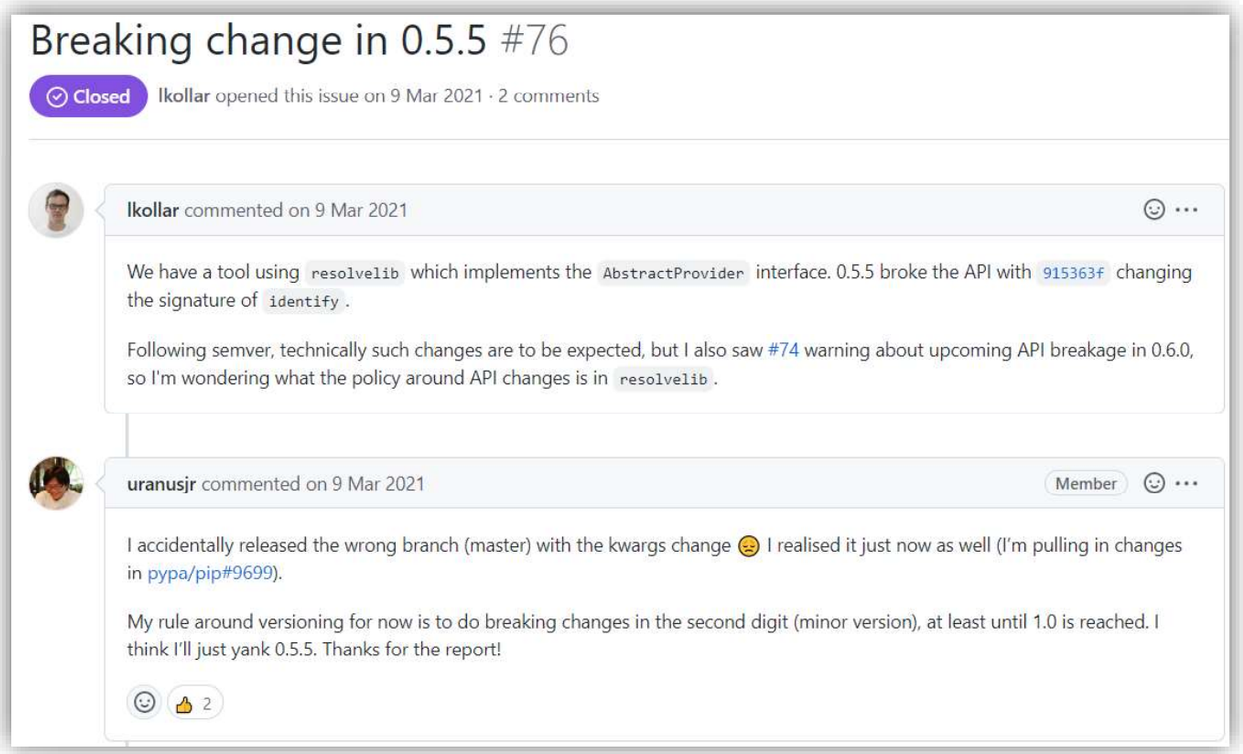

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Automatically check by AexPy!

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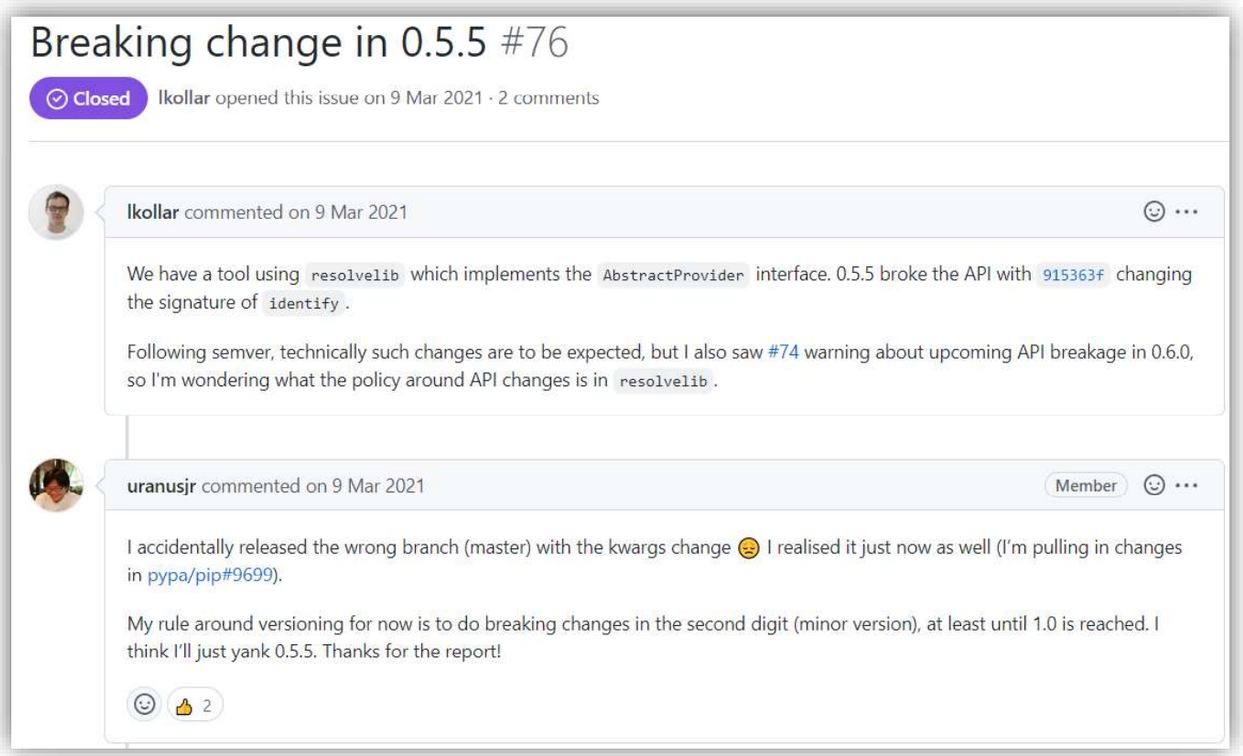

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Dynamic Language Features

- Programming behaviors at runtime
- Dynamic type system with duck-typing

Complex API References

- Importing and renaming
- Same API but different names

Fake Private Members

- Fuzzy API accessibility / visibility
- Custom naming-conventions in case of aliasing

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- Required or optional parameters
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Attributes in constructor

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Decorators to modify APIs at runtime

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Duck-typing: class A is a virtual subclass of Iterable

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Optional type annotations

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data._store
write

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Developers' convention, but still accessible for clients

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Different visibilities of aliases

data._store (private)
write (public)

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    test(1, 2)   Positional


def test(pos, /, posOrKw, *args, kw = None, **kwargs):
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    test(1, 2)   Positional
    test(1, posOrKw=2, kw=3)   Keyword


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    test(1, 2)   Positional
    test(1, posOrKw=2, kw=3)   Keyword
    test(1, 2, 3, other=4)   Variadic

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API Description

Extraction Method

Comparing Algorithm

Change Severities

AexPy's Approach

Overview

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Detailed API Model

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Detailed API Model

Hybrid Analysis

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Constraint Checking

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Breaking Levels

AexPy's Approach

Overview

Detection

Grading

- API model
- Dynamic reflection
- Static analysis

- Change classification
- API and parameter pairing
- Constraint-based comparing

- Breaking levels
- API scope and change content
- Type compatibility

Detailed API Model

Hybrid Analysis

Constraint Checking

Breaking Levels

AexPy's Approach

Extraction – API Model

```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
        return c

    @property
    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
    pass
```

Module

Membership

Aliases

Class

Inheritance

Abstract base classes (ABCs)

{ API }

Attribute

Instance attributes

Type

Function

Parameters

Return type

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members(M).values

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members(M).values

members(M).keys

```
{
    "opt",
    "func",
    "_share",
    "A",
    "B",
    "C"
}
```

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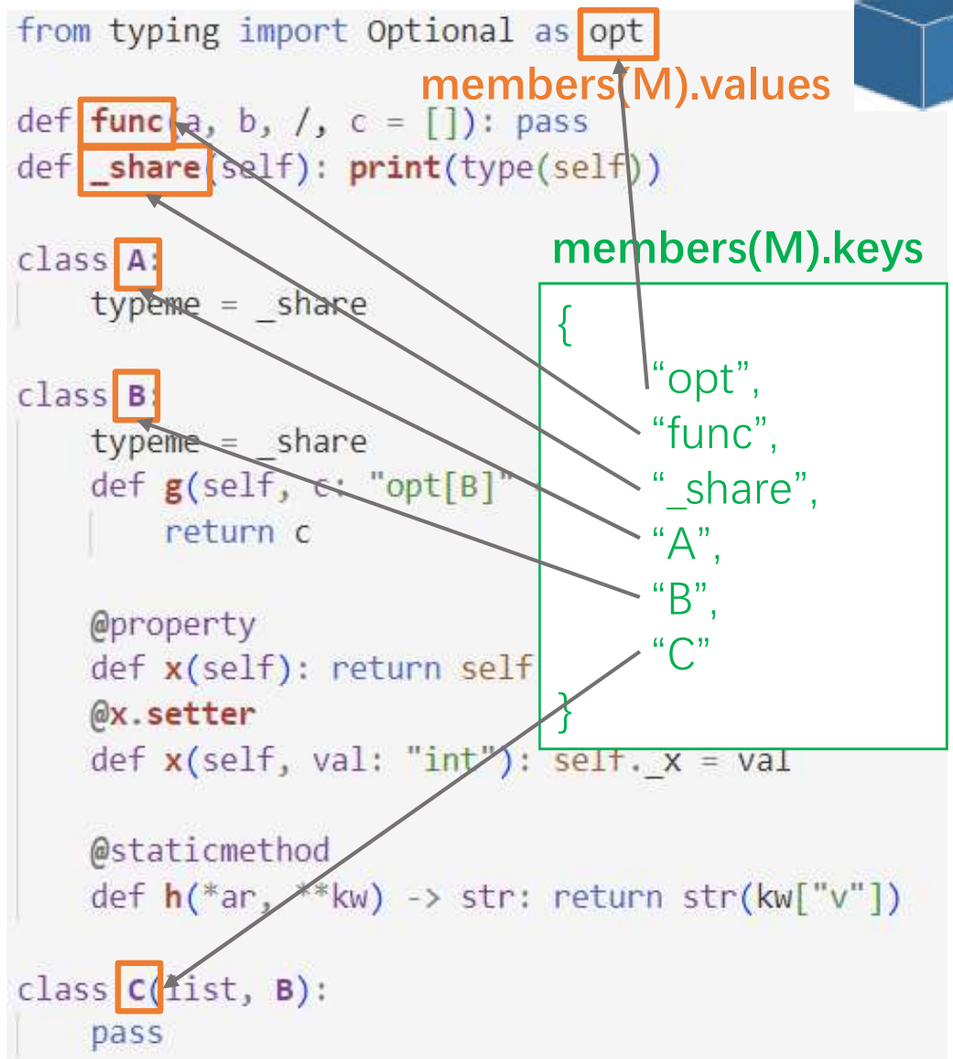

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bases(C) abcs(C)

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Sequence
Iterable

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def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share  # Normal attributes

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
        return c

    @property  # Instance attributes
    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
    pass
```

Module

Membership

Aliases

Class

Inheritance

Abstract base classes (ABCs)

{ API }

Attribute

Instance attributes

Type

Function

Parameters

Return type

AexPy's Approach

Extraction – API Model

```python
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def func(a, b, /, c = []): pass
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    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw["v"])
class C(list, B):
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```

Optional parameter

Variadic parameters

Return type

Module

Membership

Aliases

Class

Inheritance

Abstract base classes (ABCs)

{ API }

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Instance attributes

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Function

Parameters

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AexPy's Approach

Extraction – API Model

```python
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def func(a, b, /, c = []): pass
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class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
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    @property
    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
    pass
```
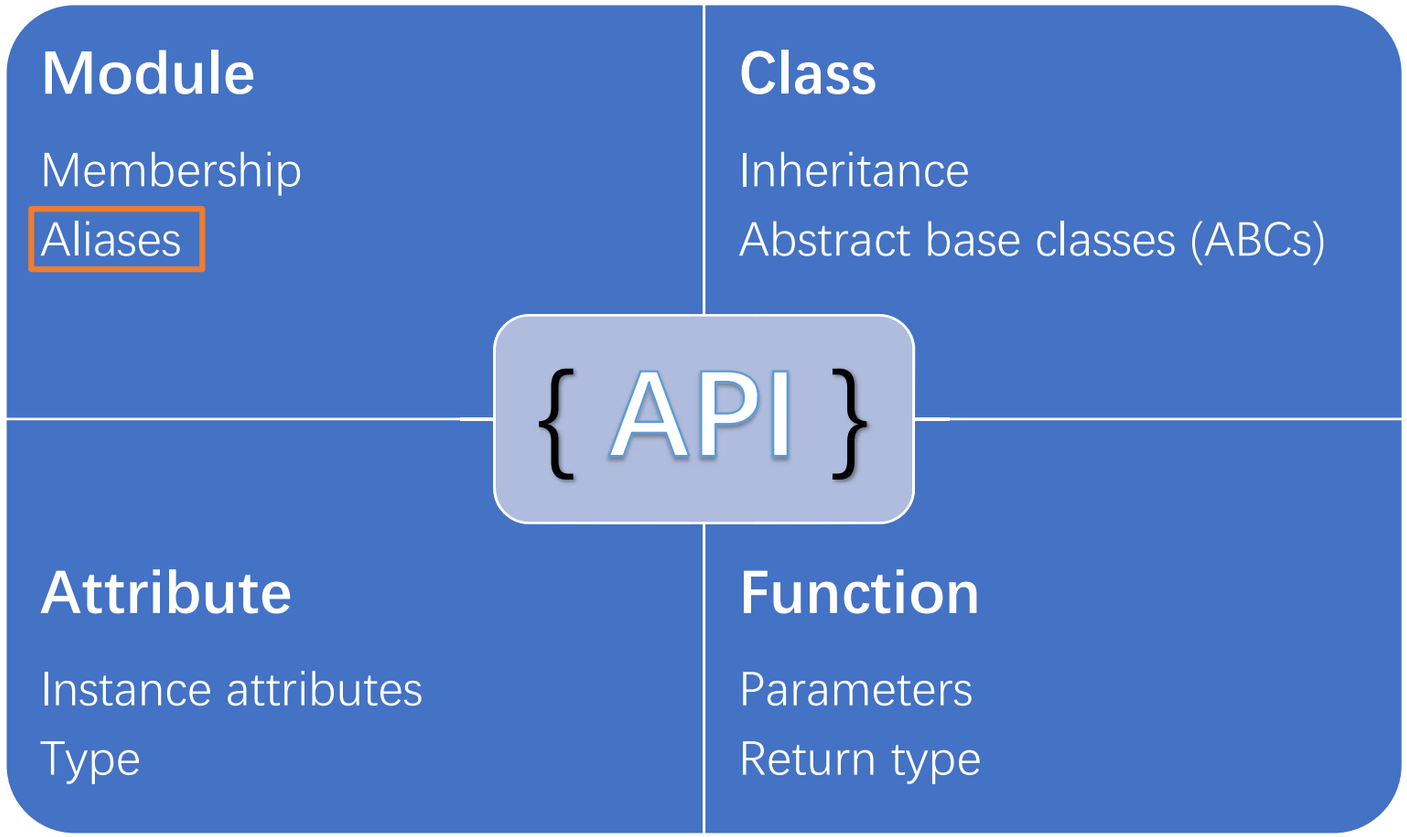

aliases(_share)

A.typeme
B.typeme



AexPy's Approach

Extraction – API Model

```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
        return c
    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
    pass
```

Sum: $T_1 + T_2 + \cdots + T_n,$

Product: $T_1 \times T_2 \times \cdots \times T_n,$

Callable: $T_{args} \to T_{ret},$

Generic: $T_{base}(T_1, T_2, \ldots, T_n)$

Module

Membership

Aliases

Class

Inheritance

Abstract base classes (ABCs)

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AexPy's Approach

Extraction – API Model

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from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

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    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
        return c
    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
    pass
```

type(c) = **B** + **none**

Sum: $T_1 + T_2 + \cdots + T_n,$

Product: $T_1 \times T_2 \times \cdots \times T_n,$

Callable: $T_{args} \to T_{ret},$

Generic: $T_{base}(T_1, T_2, \ldots, T_n)$

Module

Membership

Aliases

Class

Inheritance

Abstract base classes (ABCs)

{ API }

Attribute

Instance attributes

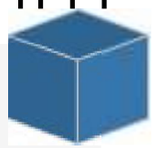
Type

Function

Parameters

Return type

AexPy's Approach
Extraction – Algorithm



```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
        return c

    @property
    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
    pass
```

Dynamic Reflection

- Breadth-first search
- Inspect live objects

Static Analysis

- Traverse ASTs
- Gain types from Mypy

AexPy's Approach

Extraction – Algorithm

```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share

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    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
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    def x(self): return self._x
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    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
    pass
```

Dynamic Reflection

Breadth-first search

Static Analysis

```
modules:

classes:

attributes:
```

```
functions:
```

AexPy's Approach

Extraction – Algorithm

```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
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class A:
    typeme = _share

class B:
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    def g(self, c: "opt[B]" = None) -> "B | None":
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class C(list, B):
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```

Dynamic Reflection

Breadth-first search

Static Analysis

```yaml
modules:
  M:
    members:
      opt: <external>typing.Optional
      func: M.func
      _share: M._share
      A: M.A
      B: M.B
      C: M.C
classes:
  M.A:
    members:
      typeme: M._share
  M.B:
    members:
      typeme: M._share
      g: M.B.g
      x: M.B.x
      h: M.B.h
  M.C:

attributes:
  M.B.x:
```

```yaml
functions:
  M.func:

  M._share:
    aliases: [M.A.typeme, M.B.typeme]

  M.B.g:
```

AexPy's Approach

Extraction – Algorithm

```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
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class C(list, B):
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Dynamic Reflection → **Static Analysis**

Breadth-first search

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      h: M.B.h
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AexPy's Approach

Extraction – Algorithm

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Dynamic Reflection → **Static Analysis**

Breadth-first search

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attributes:
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```

```
functions:
  M.func:

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AexPy's Approach

Extraction – Algorithm

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Dynamic Reflection

Inspect live objects

Static Analysis

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      typeme: M._share
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    members:
      typeme: M._share
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attributes:
  M.B.x:
```

```yaml
functions:
  M.func:

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```

AexPy's Approach

Extraction – Algorithm

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Dynamic Reflection

Inspect live objects

Static Analysis

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      B: M.B
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classes:
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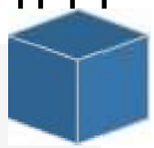
    members:
      typeme: M._share
  M.B:
    members:
      typeme: M._share
      g: M.B.g
      x: M.B.x
      h: M.B.h
  M.C:
    bases: [list, M.B]
    abcs: [Sequence, Iterable]
attributes:
  M.B.x:
    scope: instance
```

```yaml
functions:
  M.func:
    parameters:
      - name: a
        kind: Positional
      - name: b
        kind: Positional
      - name: c
        kind: PositionalOrKeyword
        optional: true
        default: <object>
  M._share:
    aliases: [M.A.typeme, M.B.typeme]
    parameters:
      - name: self
        kind: PositionalOrKeyword
  M.B.g:
    parameters:
      - name: self
        kind: PositionalOrKeyword
      - name: c
        kind: PositionalOrKeyword
        optional: true
```

AexPy's Approach

Extraction – Algorithm



Dynamic Reflection

Static Analysis

Traverse ASTs

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def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B | None":
        return c

    @property
    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw["v"])

class C(list, B):
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```yaml
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      C: M.C
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  M.A:
    members:
      typeme: M._share
  M.B:
    members:
      typeme: M._share
      g: M.B.g
      x: M.B.x
      h: M.B.h
  M.C:
    bases: [list, M.B]
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  M.B.x:
    scope: instance
  M.B._x:
    scope: instance
```

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      - name: b
        kind: Positional
      - name: c
        kind: PositionalOrKeyword
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        default: <object>
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    parameters:
      - name: self
        kind: PositionalOrKeyword
  M.B.g:
    parameters:
      - name: self
        kind: PositionalOrKeyword
      - name: c
        kind: PositionalOrKeyword
        optional: true
```

AexPy's Approach

Extraction – Algorithm

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Dynamic Reflection → Static Analysis

Gain types from Mypy

```yaml
modules:
  M:
    members:
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      B: M.B
      C: M.C
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  M.A:
    members:
      typeme: M._share
  M.B:
    members:
      typeme: M._share
      g: M.B.g
      x: M.B.x
      h: M.B.h
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    bases: [list, M.B]
    abcs: [Sequence, Iterable]
attributes:
  M.B.x:
    scope: instance
  M.B._x:
    scope: instance
```

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functions:
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    parameters:
      - name: a
        kind: Positional
      - name: b
        kind: Positional
      - name: c
        kind: PositionalOrKeyword
        optional: true
        default: <object>
  M._share:
    aliases: [M.A.typeme, M.B.typeme]
    parameters:
      - name: self
        kind: PositionalOrKeyword
  M.B.g:
    parameters:
      - name: self
        kind: PositionalOrKeyword
      - name: c
        kind: PositionalOrKeyword
        optional: true
        type:
          category: union
          components: [B, none]
    return:
      category: union
      components: [B, none]
```

AexPy's Approach

Detection – Classification

	Module	Class	Function	Attribute	Parameter	Alias
Addition						
Removal						
Modification						

AexPy's Approach

Detection – Classification

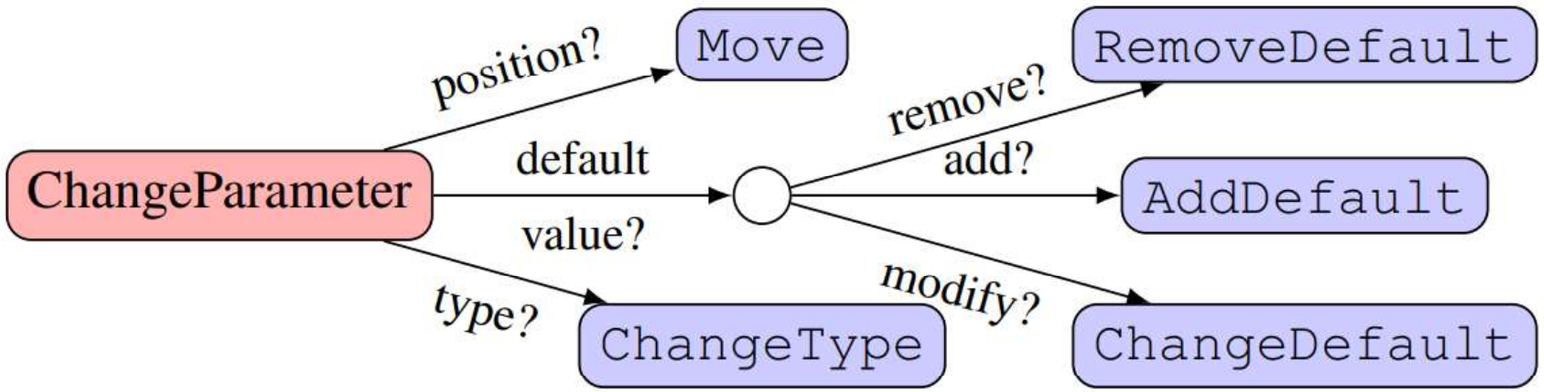
	Module	**Class**	**Function**	**Attribute**	**Parameter**	**Alias**
Addition	AddModule	AddClass	AddFunction	AddAttribute	*AddParameter*[*]	AddAlias
Removal	*RemoveModule*	*RemoveClass*	*RemoveFunction*	*RemoveAttribute*	*RemoveParameter*	*RemoveAlias*
Modification	-[†]	*ChangeInheritance*	*ChangeReturnType*	*ChangeAttributeType*	*ChangeParameter*	ChangeAlias

AexPy's Approach

Detection – Classification

42 change patterns

	Module	Class	Function	Attribute	Parameter	Alias
Addition	AddModule	AddClass	AddFunction	AddAttribute	*AddParameter*[*]	AddAlias
Removal	*RemoveModule*	*RemoveClass*	*RemoveFunction*	*RemoveAttribute*	*RemoveParameter*	*RemoveAlias*
Modification	-[†]	*ChangeInheritance*	*ChangeReturnType*	*ChangeAttributeType*	*ChangeParameter*	ChangeAlias



AexPy's Approach

Detection – Algorithm

Paring → Comparing

Simulate name resolution and argument passing

```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) ->
        return c

    @property
    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x =

    @staticmethod
    def h(*ar, **kw) -> str: return st

class C(list, B):
    pass
```

```yaml
modules:
  M:
    members:
      opt: <external>typing.Optional
      func: M.func
      _share: M._share
      A: M.A
      B: M.B
      C: M.C
classes:
  M.A:
    members:
      typeme: M._share
  M.B:
    members:
      typeme: M._share
      g: M.B.g
      x: M.B.x
      h: M.B.h
  M.C:
    bases: [list, M.B]
    abcs: [Sequence, Iterable]
attributes:
  M.B.x:
    scope: instance
  M.B._x:
    scope: instance
```

```python
from typing import Optional as opt

def func(b, a, /, c = []): pass
def _share(self, obj = None): print(type(

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B
        return c

    @property
    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw

class C(B):
    def g(self, c: "opt[C]" = None) -> "C
```

```yaml
modules:
  M:
    members:
      opt: <external>typing.Optional
      func: M.func
      _share: M._share
      A: M.A
      B: M.B
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    members:
      typeme: M._share
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    members:
      typeme: M._share
      g: M.B.g
      x: M.B.x
      h: M.B.h
  M.C:
    bases: [M.B]
    abcs: []
attributes:
  M.B.x:
    scope: instance
  M.B._x:
    scope: instance
```

AexPy's Approach

Detection – Algorithm

Paring

Comparing

Simulate name resolution and argument passing

```python
from typing import Optional as opt

def func(a, b, /, c = []): pass
def _share(self): print(type(self))

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) ->
        return c

    @property
    def x(self): return self._x
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    def h(*ar, **kw) -> str: return st

class C(list, B):
    pass
```

```
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  M:
    members:
      opt: <external>typing.Optional
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      A: M.A
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classes:
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    members:
      typeme: M._share
  M.B:
    members:
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```

```python
from typing import Optional as opt

def func(b, a, /, c = []): pass
def _share(self, obj = None): print(type(

class A:
    typeme = _share

class B:
    typeme = _share
    def g(self, c: "opt[B]" = None) -> "B
        return c

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    def x(self): return self._x
    @x.setter
    def x(self, val: "int"): self._x = val

    @staticmethod
    def h(*ar, **kw) -> str: return str(kw

class C(B):
    def g(self, c: "opt[C]" = None) -> "C
```

```
modules:
  M:
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  M.B.x:
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    scope: instance
```

AexPy's Approach

Detection – Algorithm

Paring → Comparing

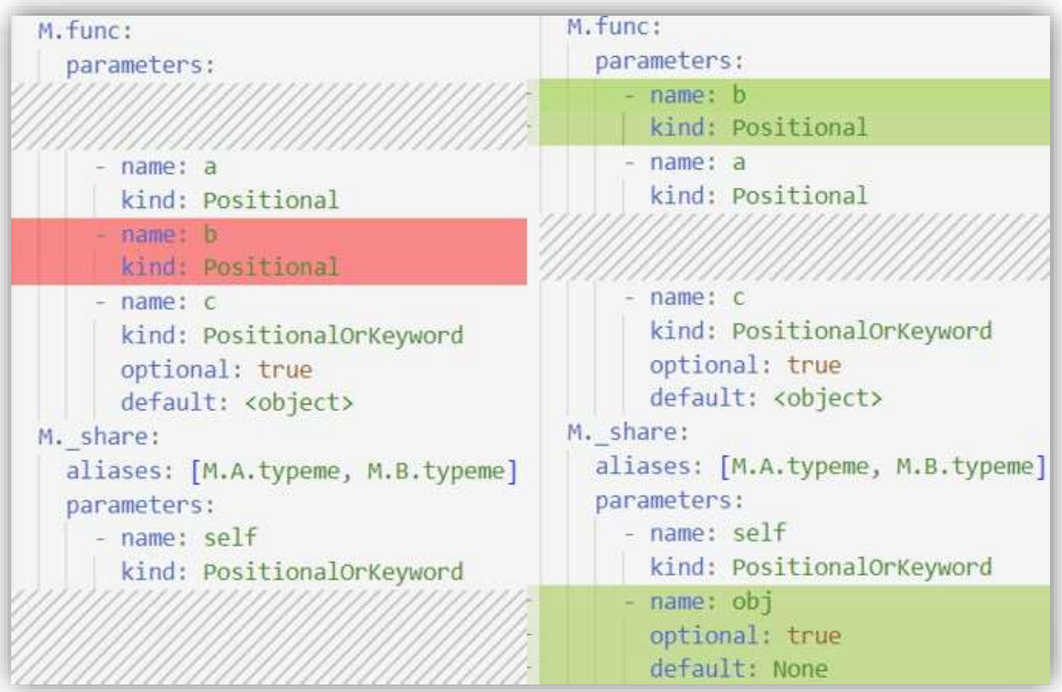
Simulate name resolution and argument passing

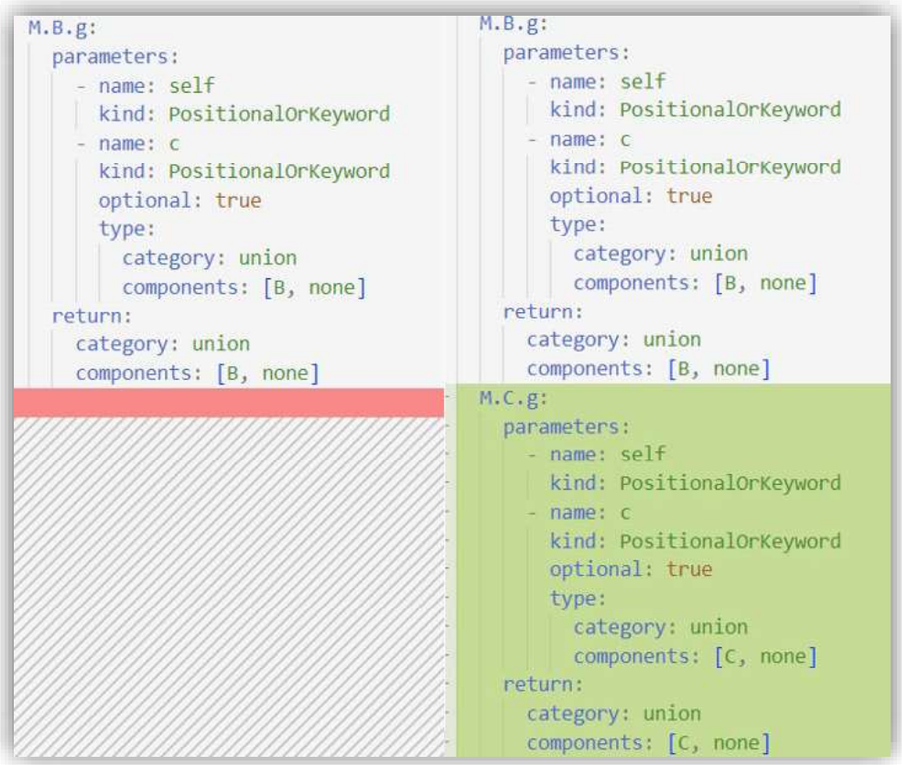
```
def func(a, b, /, c = []): pass
def _share(self): print(type(self))
```

```
def func(b, a, /, c = []): pass
def _share(self, obj = None): print(type(obj or self))
```

```
class C(list, B):
    pass
```

```
class C(B):
    def g(self, c: "opt[C]" = None) -> "C | None": return c
```





AexPy's Approach

Detection – Algorithm

Paring → Comparing

Simulate name resolution and argument passing

```
def func(a, b, /, c = []): pass
def _share(self): print(type(self))
```

```
def func(b, a, /, c = []): pass
def _share(self, obj = None): print(type(obj or self))
```

```
class C(list, B):
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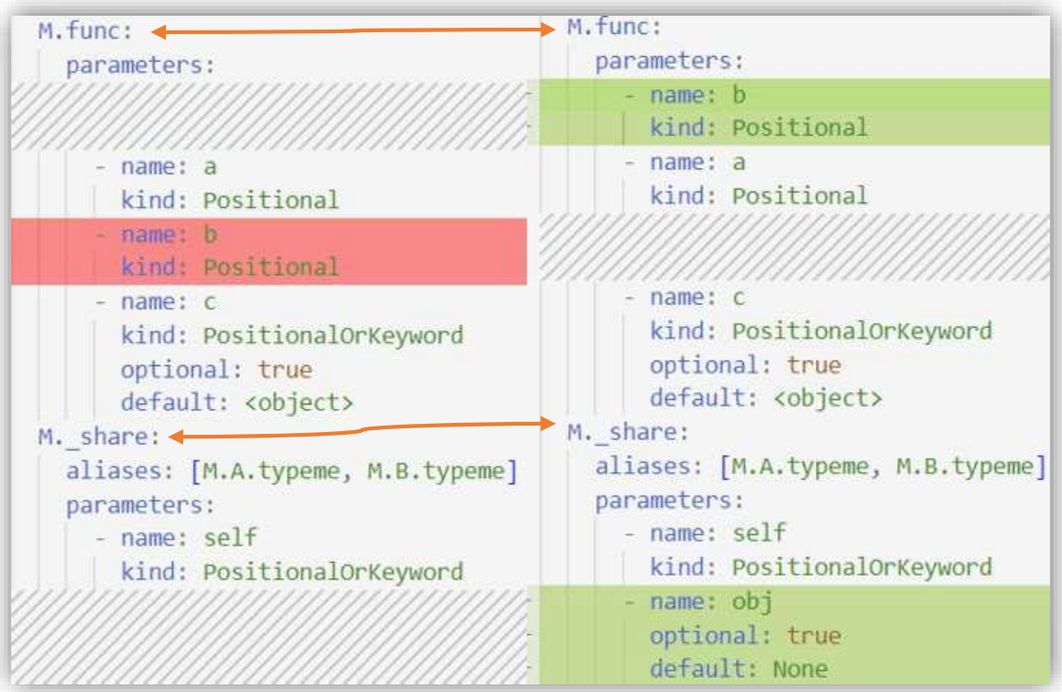

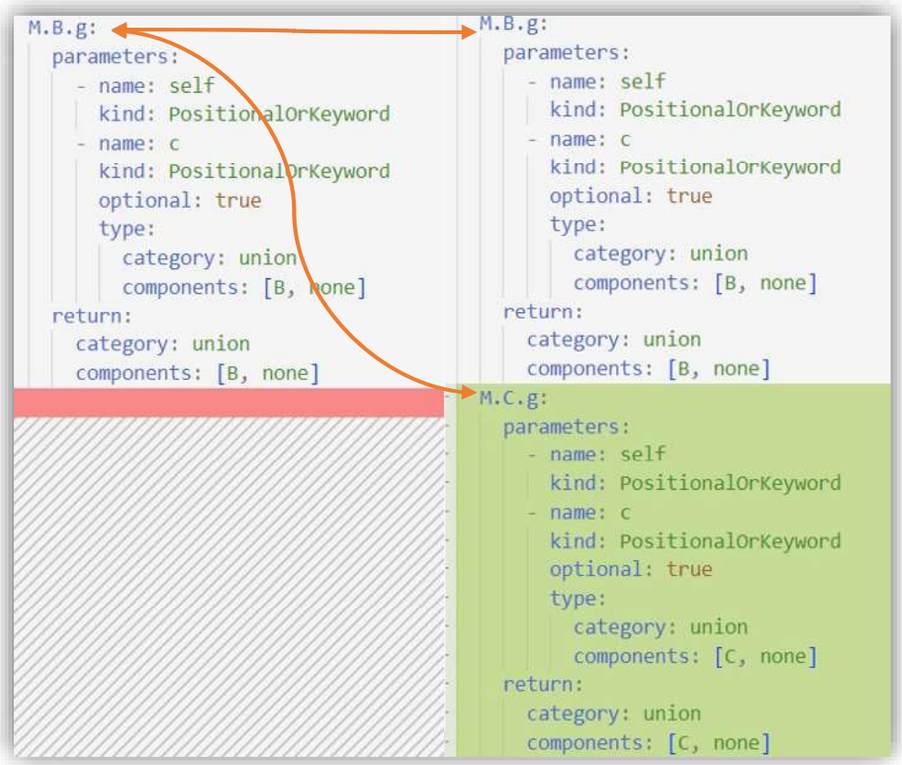

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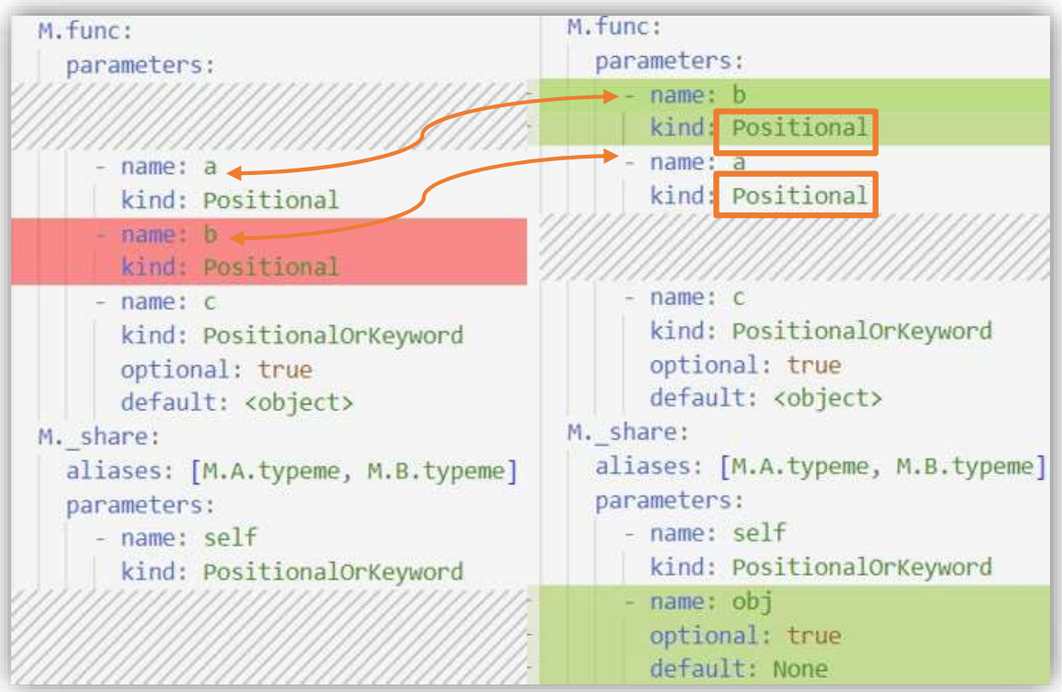
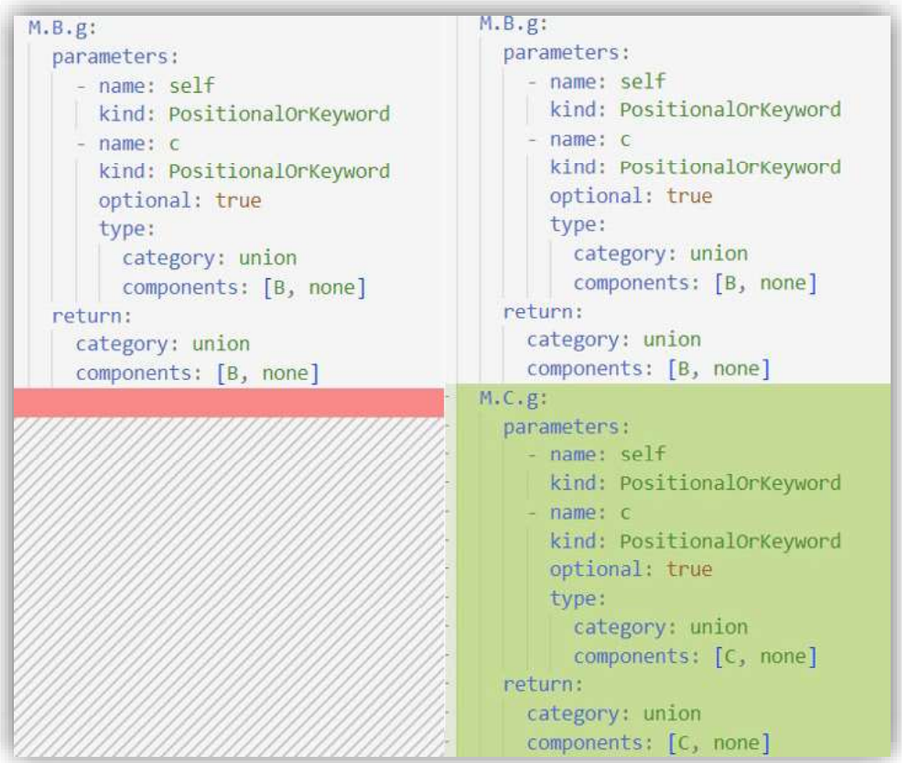




AexPy's Approach

Detection – Algorithm

Paring → Comparing

Define and judge constraints on API pairs

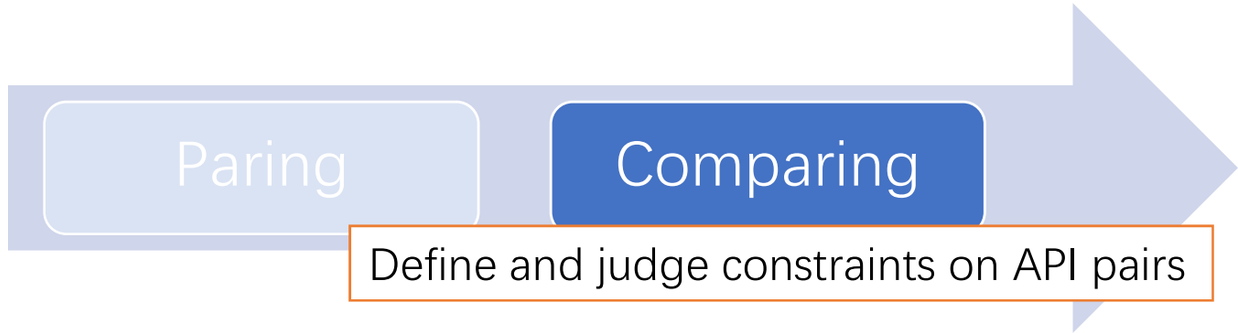
42 change patterns → **42 constraints**

Pattern	Constraint
AddModule	$e = \bot \wedge e' \in M$
RemoveFunction	$e \in F \wedge e' = \bot \wedge \textbf{scope}(e) = \text{Static}$
RemoveBaseClass	$e, e' \in C \wedge \textbf{bases}(e) \not\subseteq \textbf{bases}(e')$
ChangeReturnType	$e, e' \in F \wedge \textbf{return}(e) \neq \textbf{return}(e')$
AddRequiredParameter	$p = \bot \wedge p' \neq \bot \wedge \neg\textbf{optional}(p')$
MoveParameter	$p \neq \bot \wedge p' \neq \bot \wedge \textbf{position}(p) \neq \textbf{position}(p')$
RemoveVarKeywordCandidate	$p \neq \bot \wedge p' = \bot \wedge \textbf{kind}(p) = \text{VarKeywordCandidate}$
RemoveAlias	$e, e' \in M \cup C \wedge (\exists (n, t), t \in E \wedge n \in \textbf{aliases}(t) \wedge (n, t) \in (\textbf{members}(e) - \textbf{members}(e')))$
RemoveExternalAlias	$e, e' \in M \cup C \wedge \exists n, (n, \bot) \in (\textbf{members}(e) - \textbf{members}(e'))$

Full list is at Specification of Changes – AexPy (https://aexpy.netlify.app/change-spec).

AexPy's Approach

Detection – Algorithm



RemoveBaseClass

$$e, e' \in C \wedge \mathbf{bases}(e) \not\subseteq \mathbf{bases}(e')$$

```
M.C:
  bases: [list, M.B]
  abcs: [Sequence, Iterable]
```

```
M.C:
  bases: [M.B]
  abcs: []
```

AexPy's Approach

Detection – Algorithm

Paring → Comparing

Define and judge constraints on API pairs

MoveParameter

$$p \neq \bot \wedge p' \neq \bot \wedge \mathbf{position}(p) \neq \mathbf{position}(p')$$

position(a) = **0**
position(b) = **1**

```
M.func:
  parameters:
    - name: a
      kind: Positional
    - name: b
      kind: Positional
    - name: c
      kind: PositionalOrKeyword
      optional: true
      default: <object>
```

```
M.func:
  parameters:
    - name: b
      kind: Positional
    - name: a
      kind: Positional
    - name: c
      kind: PositionalOrKeyword
      optional: true
      default: <object>
```

position(a) = **1**
position(b) = **0**

AexPy's Approach
Grading

Weak constraints on Python APIs

Lack of compilation checking

Difficulty on restricting client usage

New matplotlib breaking change · Issue #1172 · polyaxon/polyaxon (github.com)

AexPy's Approach
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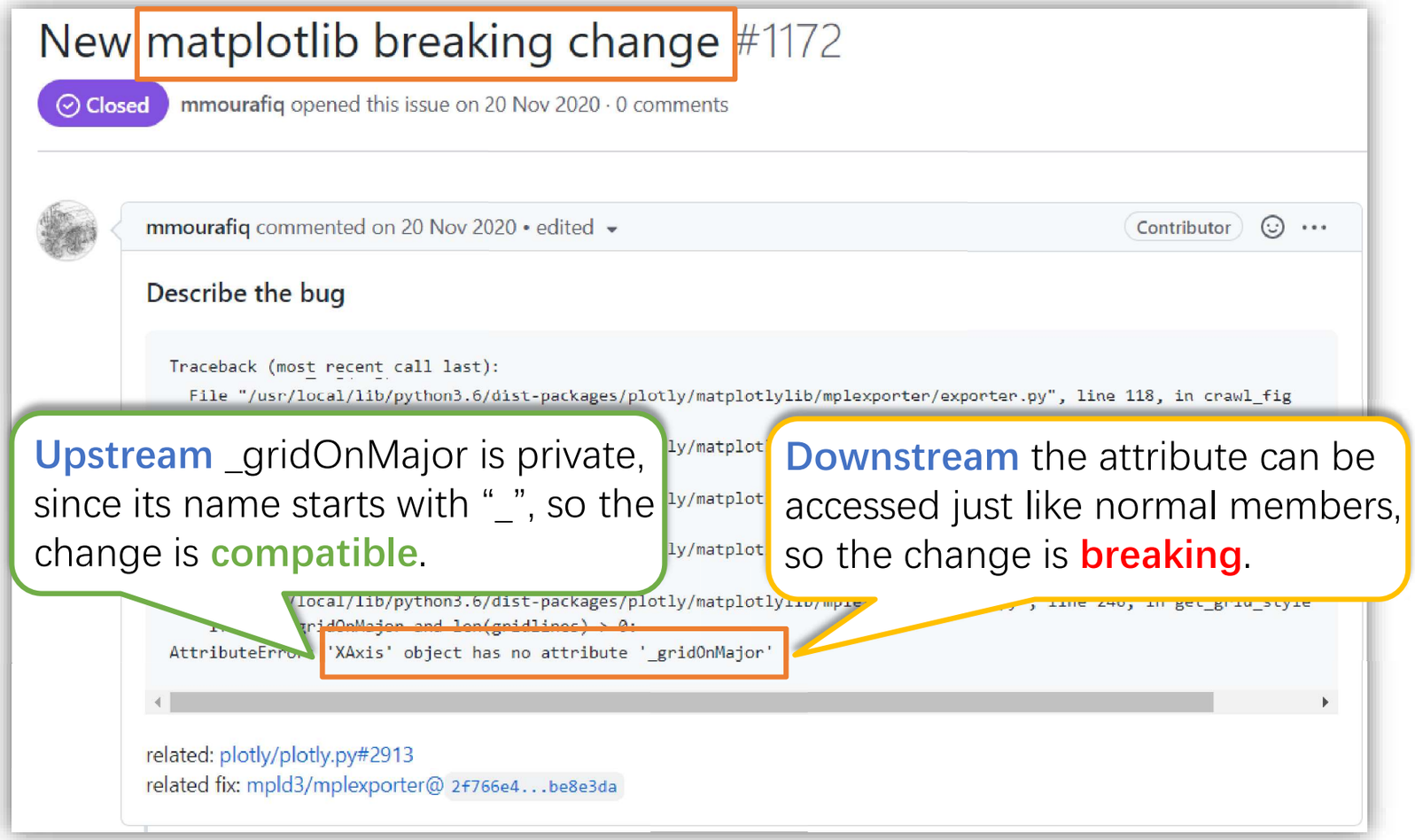

New matplotlib breaking change · Issue #1172 · polyaxon/polyaxon (github.com)

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Grading

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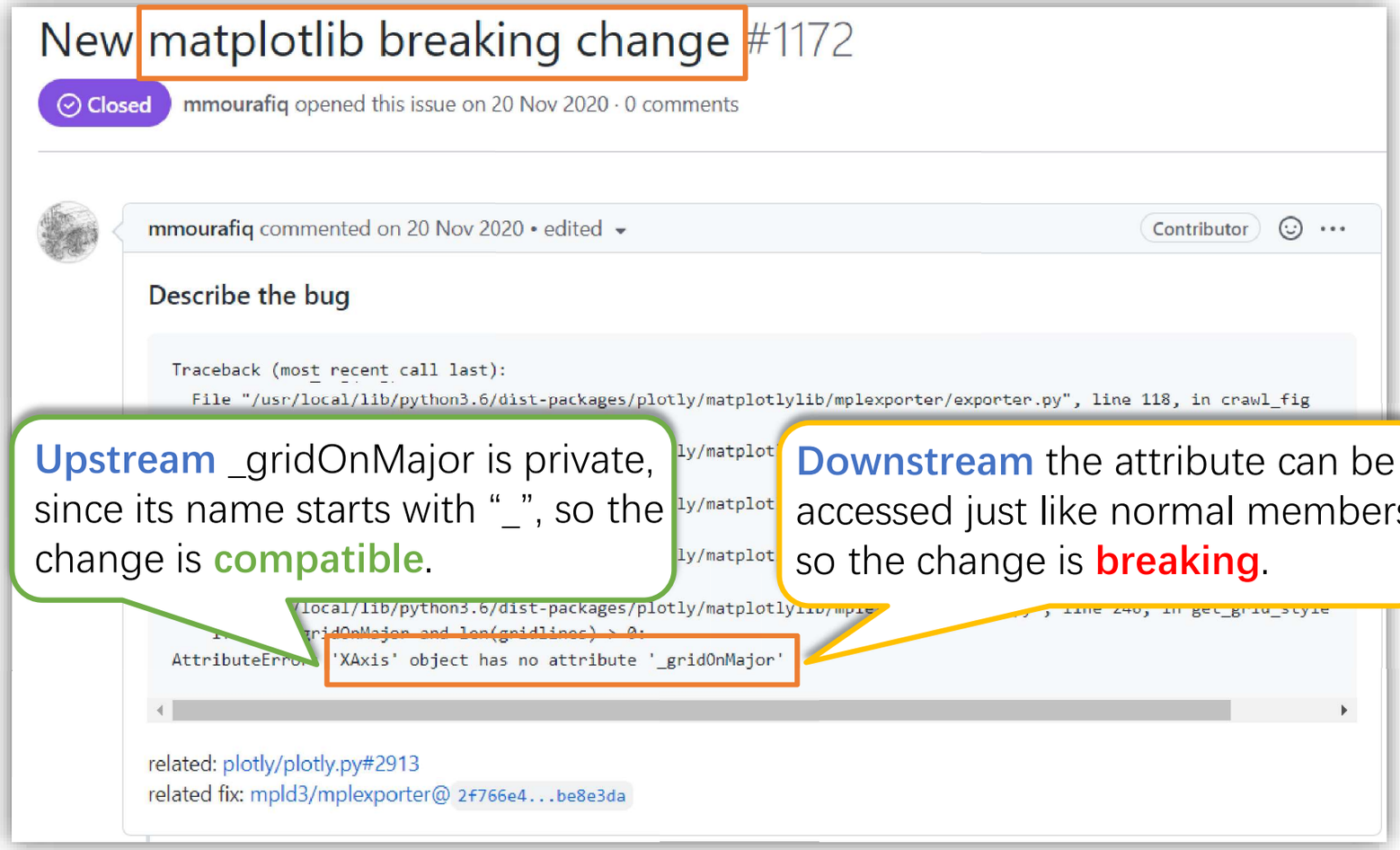
Backward Compatible / **Breaking**?



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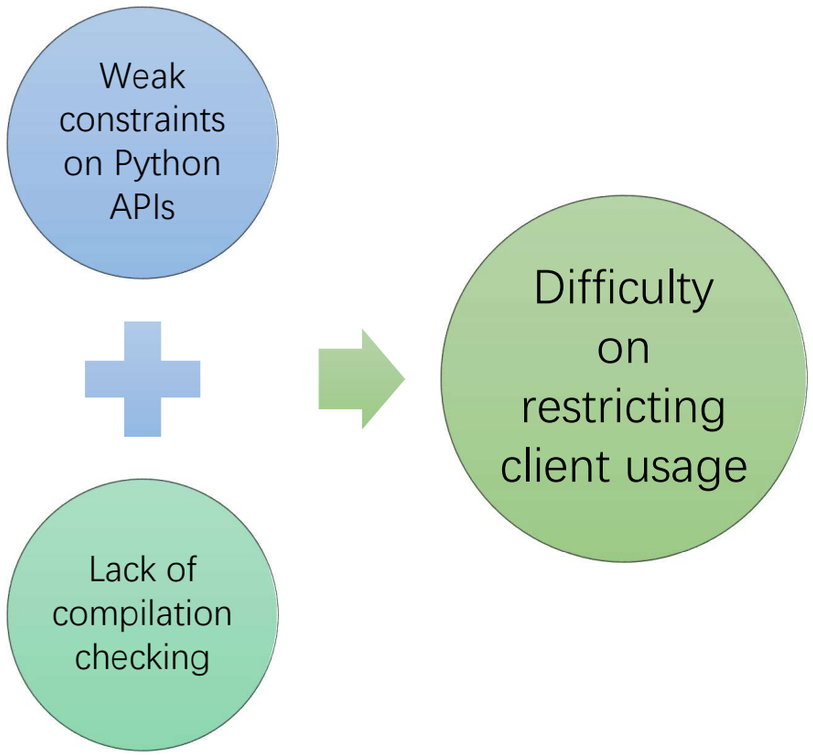
AexPy's Approach

Grading

Backward Compatible / **Breaking**?



High

- Directly breaking usability
- API removals

Medium

- Limited impact
- Type incompatibility

Low

- Fake private members
- References to external

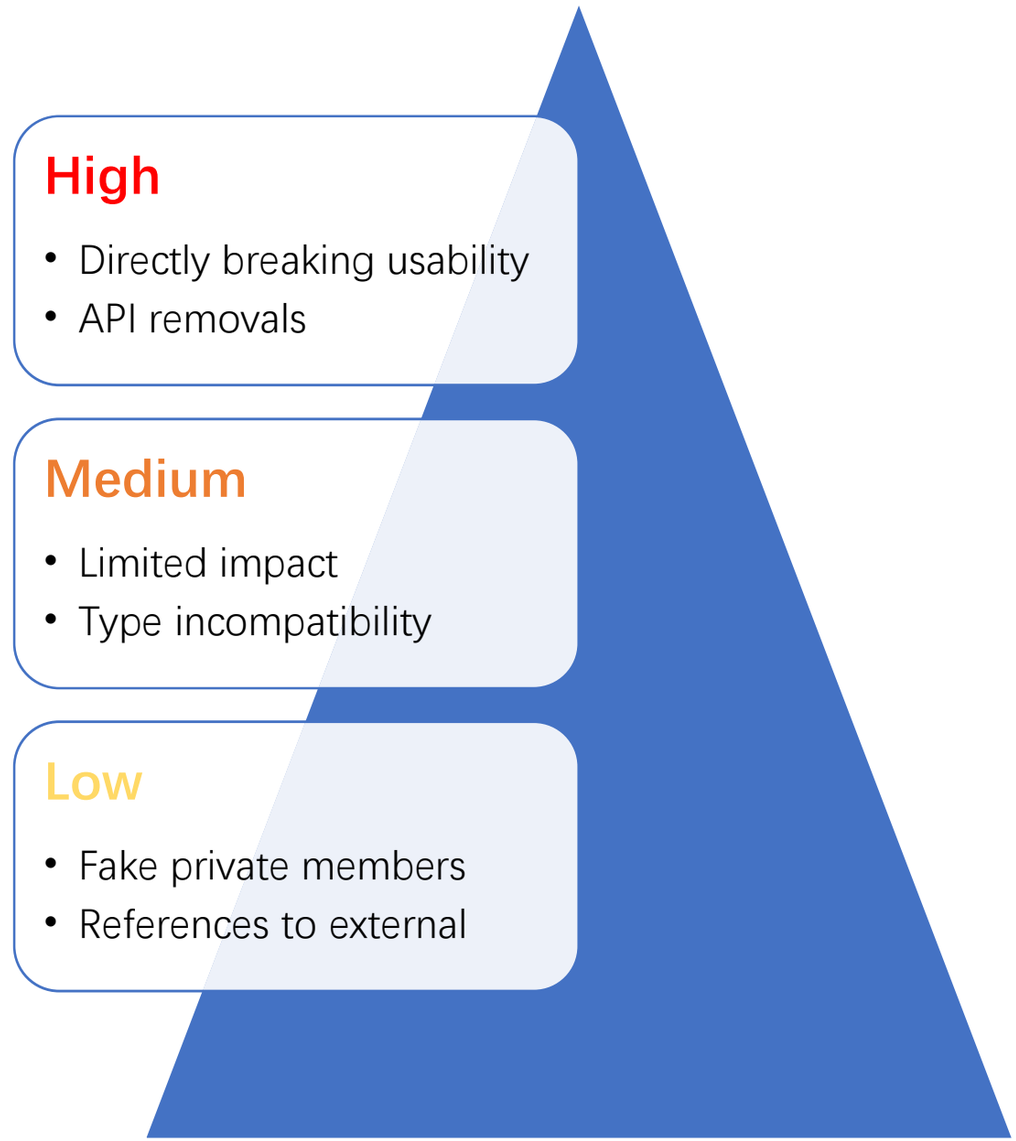
AexPy's Approach

Grading

High Remove base class "list" of class "C".

High Reorder parameter "a" and "b" of "func".

Backward Compatible / **Breaking**?



AexPy's Approach

Grading

Backward Compatible / **Breaking**?

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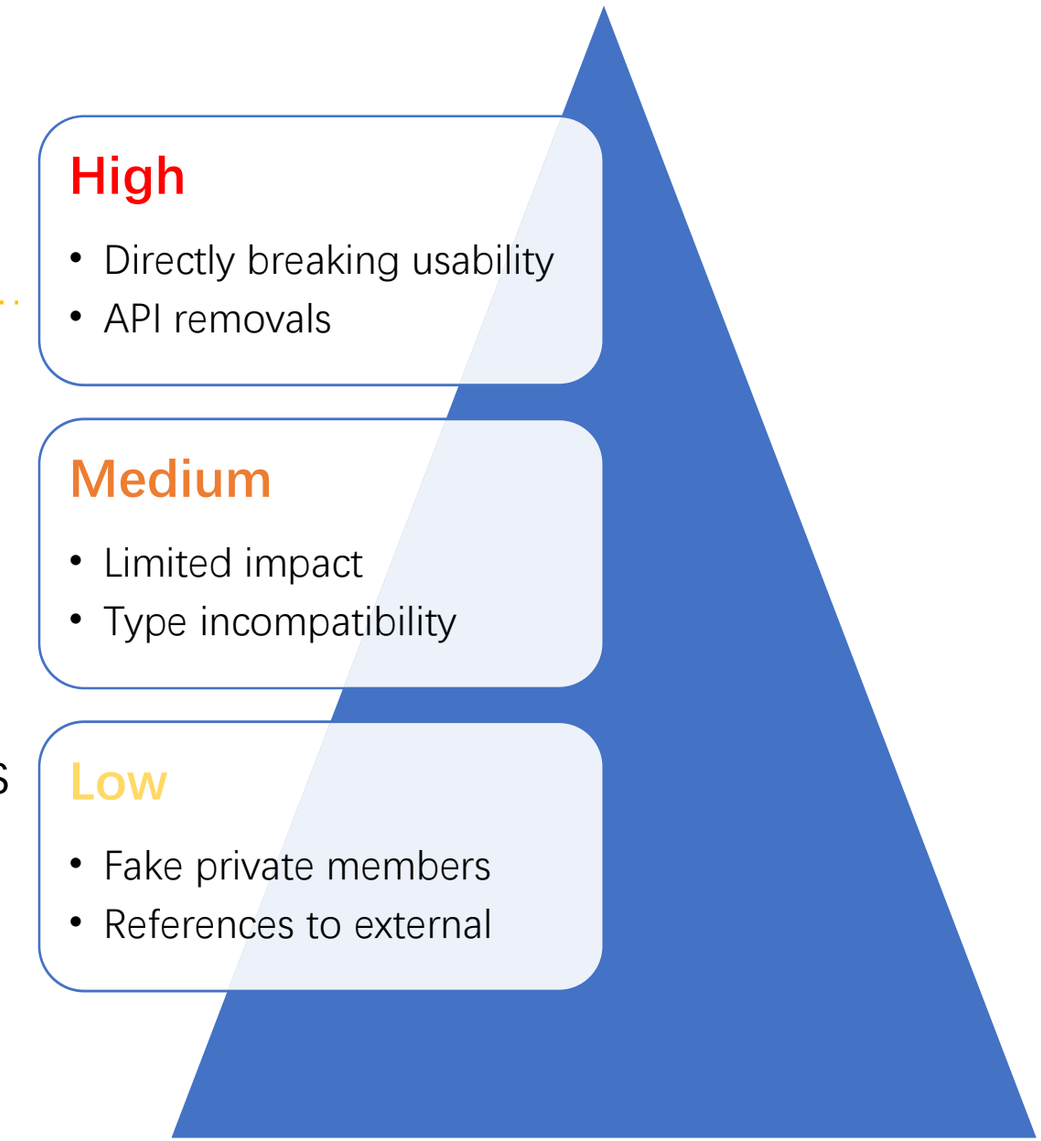
Change type of parameter "c" of function "C.g", which no longer accepts "B".

Change return type of "C.g", which returns "C", a subclass of old return type "B".



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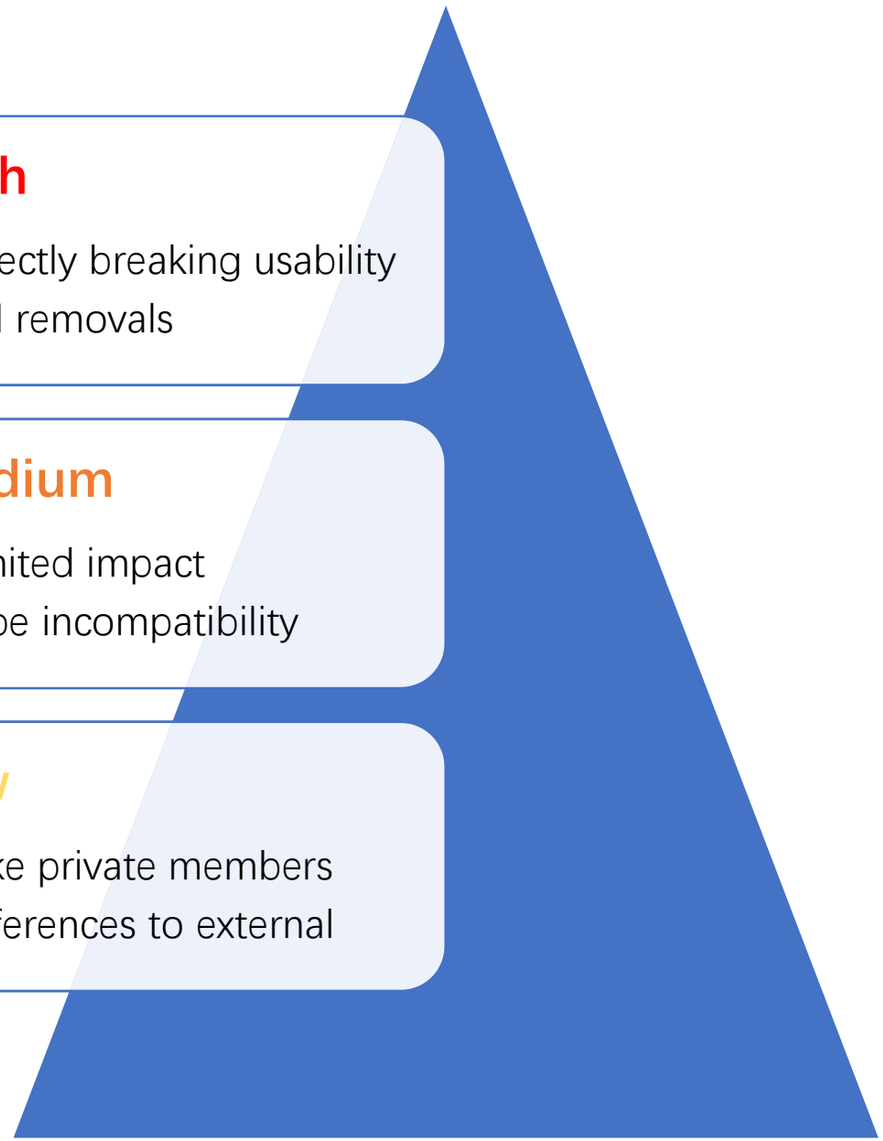

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$$\textsc{Callable:}\ \frac{T_{args} \subseteq S_{args} \qquad S_{ret} \subseteq T_{ret}}{T_{args} \to T_{ret} \subseteq S_{args} \to S_{ret}}$$

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Compatible Change return type of "C.g", which returns "C", **a subclass of old return type** "B".

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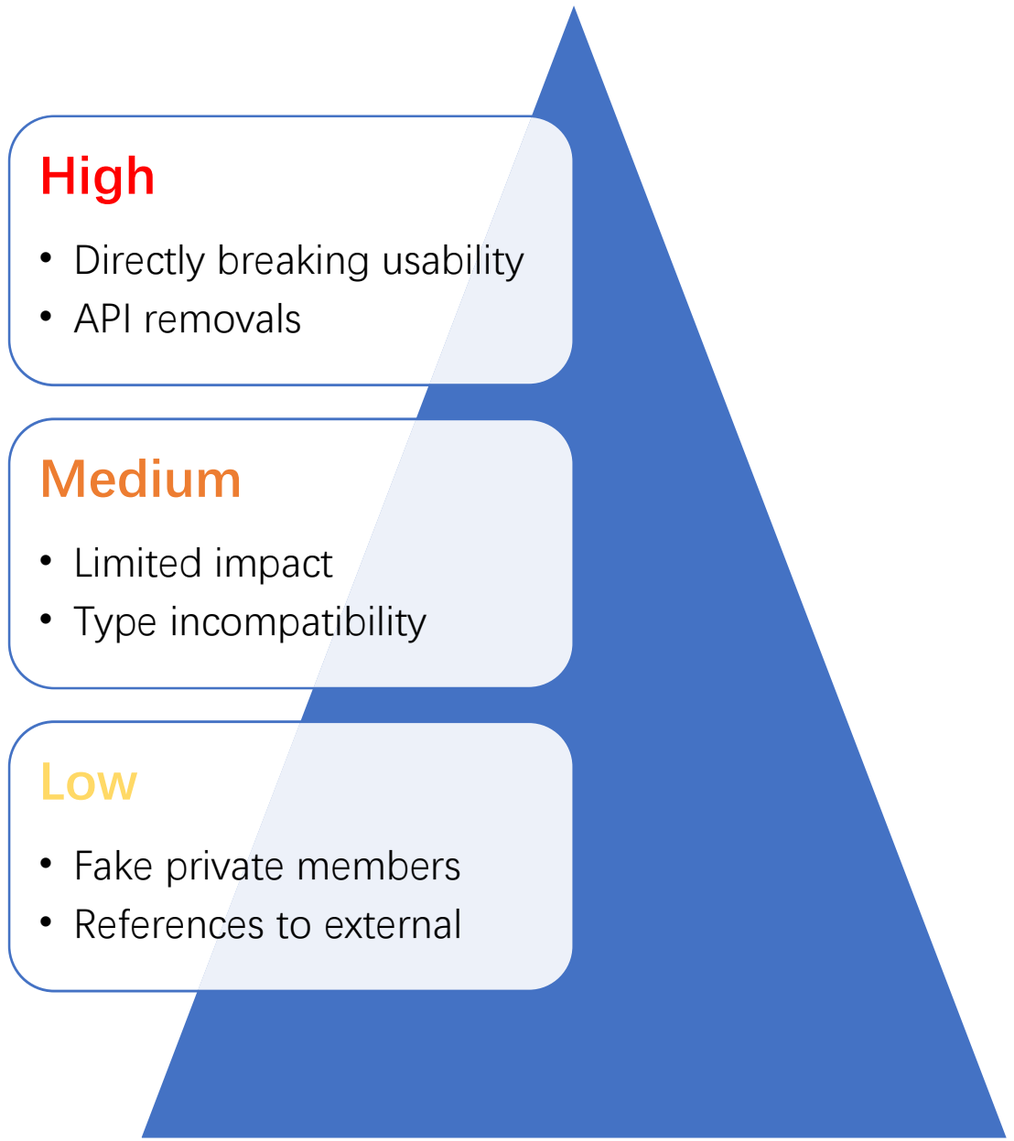
Medium Change type of parameter "c" of function "C.g", which no longer accepts "B".

Compatible Change return type of "C.g", which returns "C", a subclass of old return type "B".

Low Add optional parameter "obj" to "_share".



AexPy's Approach
Summary

Dynamic Language Features

- Dynamic reflection
- Static analysis

Complex API References

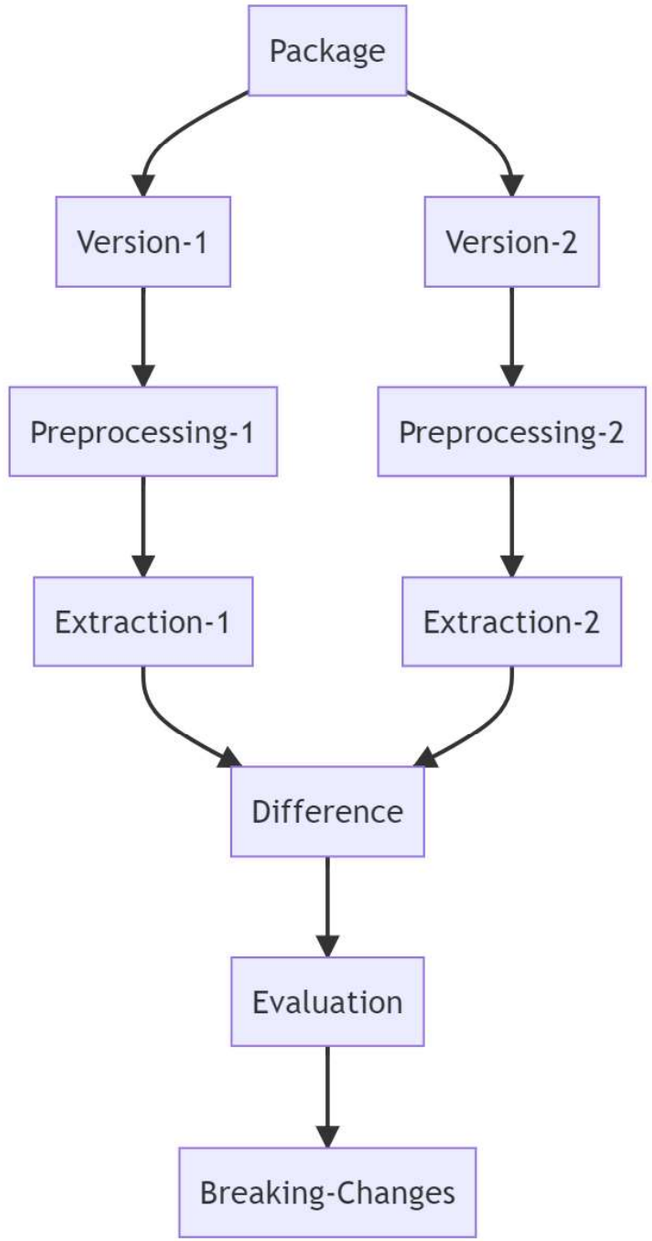
- Import and inspect
- Identify aliases by runtime objects

Fake Private Members

- Breadth-first search for accessible APIs
- Identify by API aliases and grade to low level

Flexible Argument Passing

- Model parameter kinds
- Match parameters in diff algorithm



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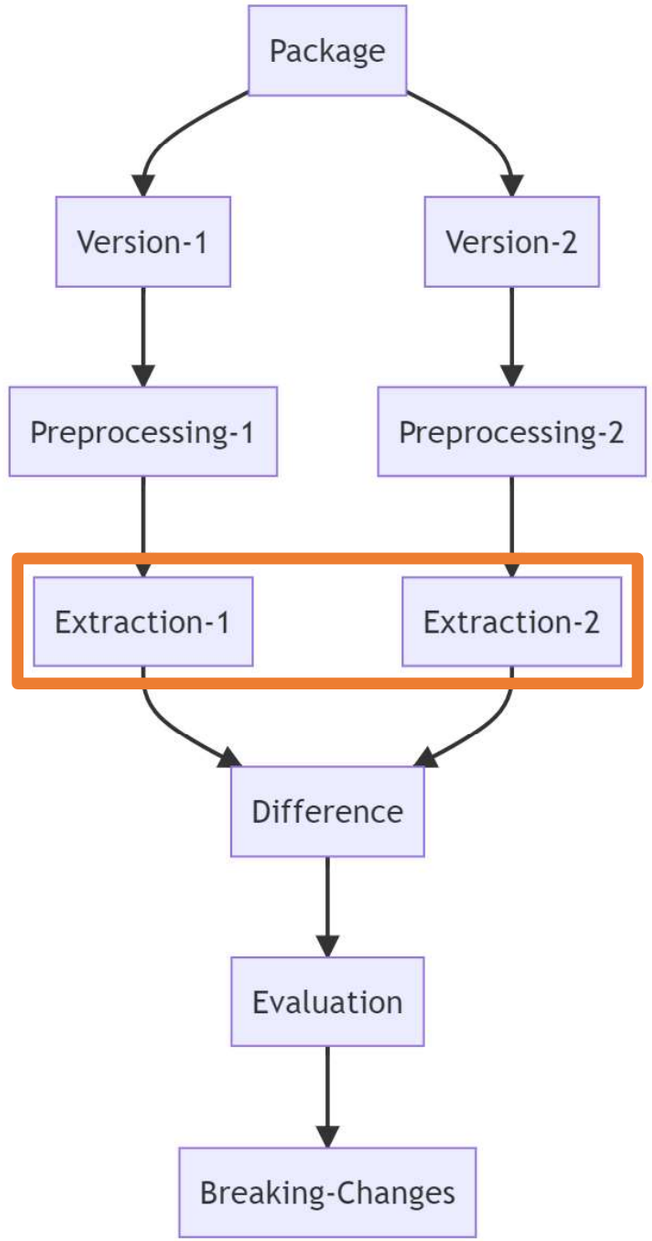

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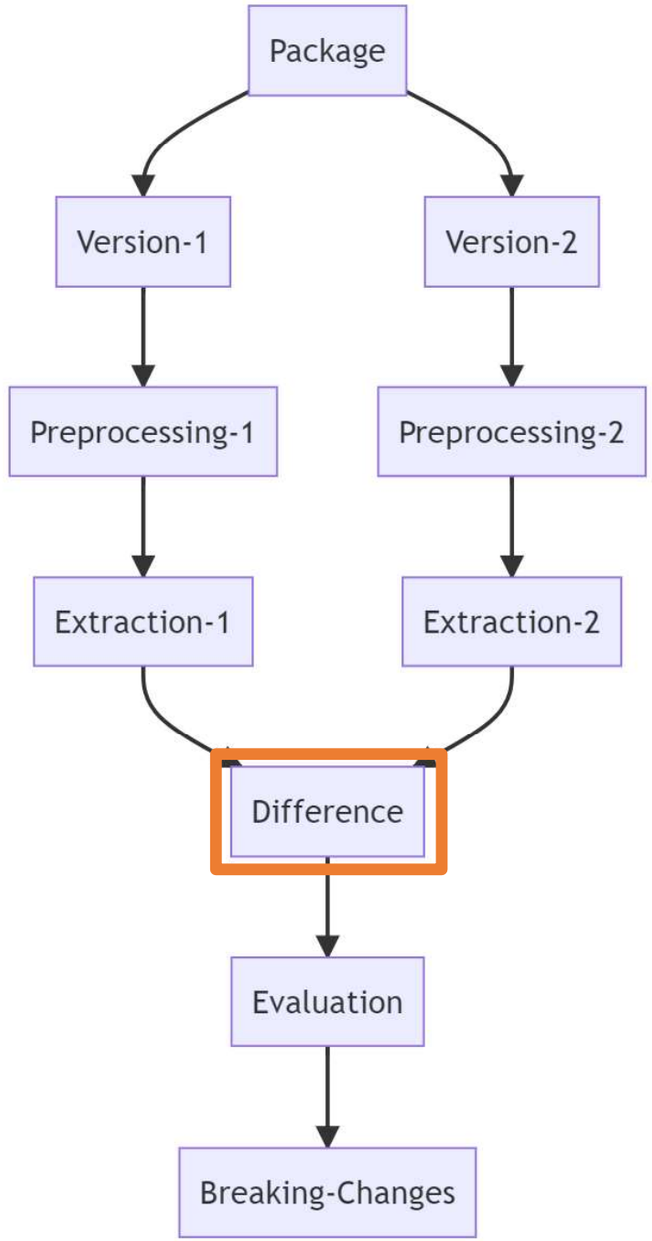

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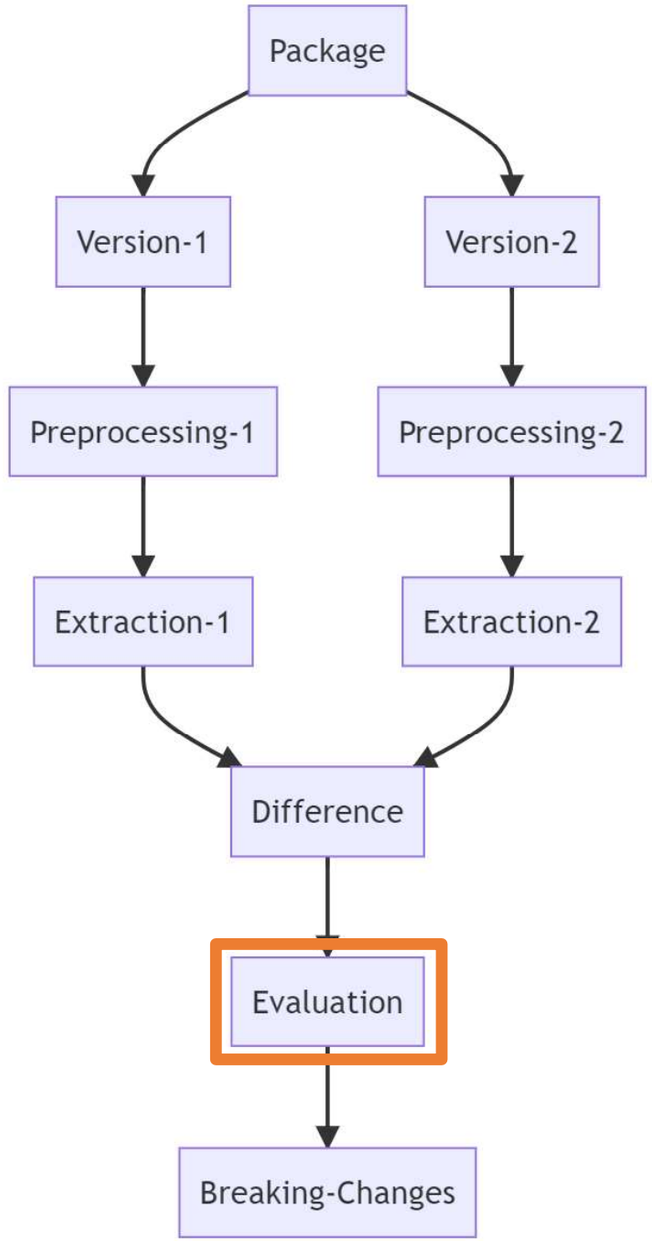

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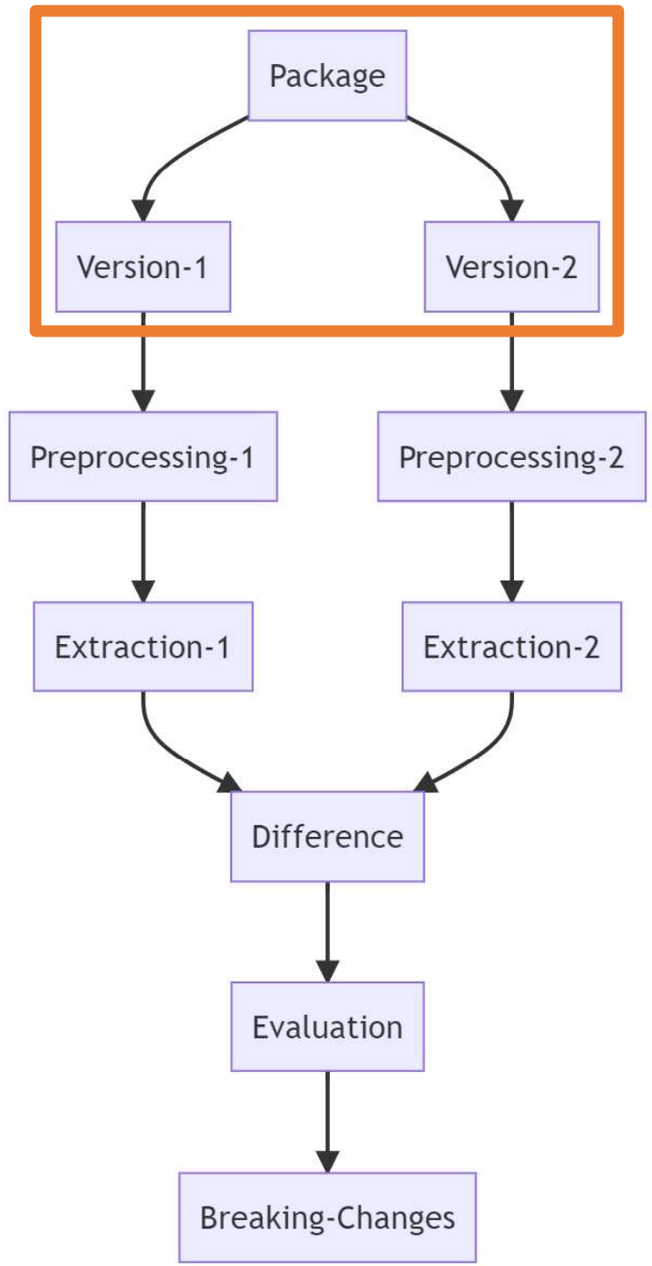

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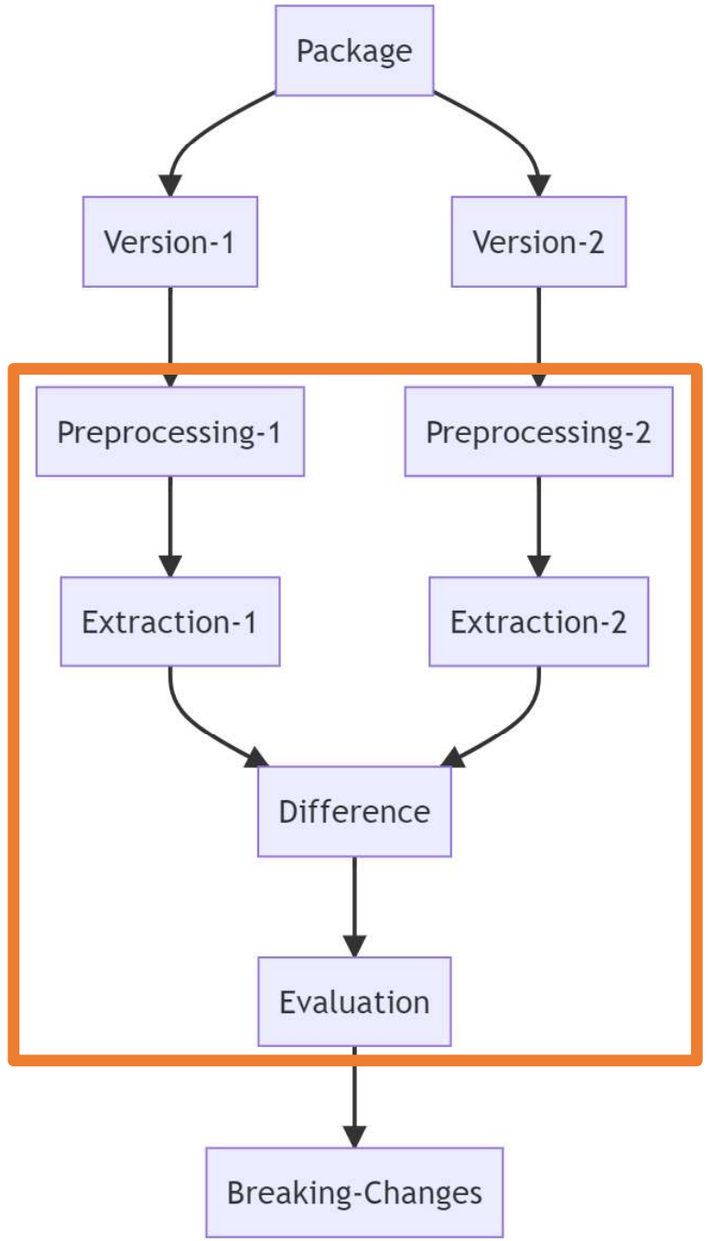

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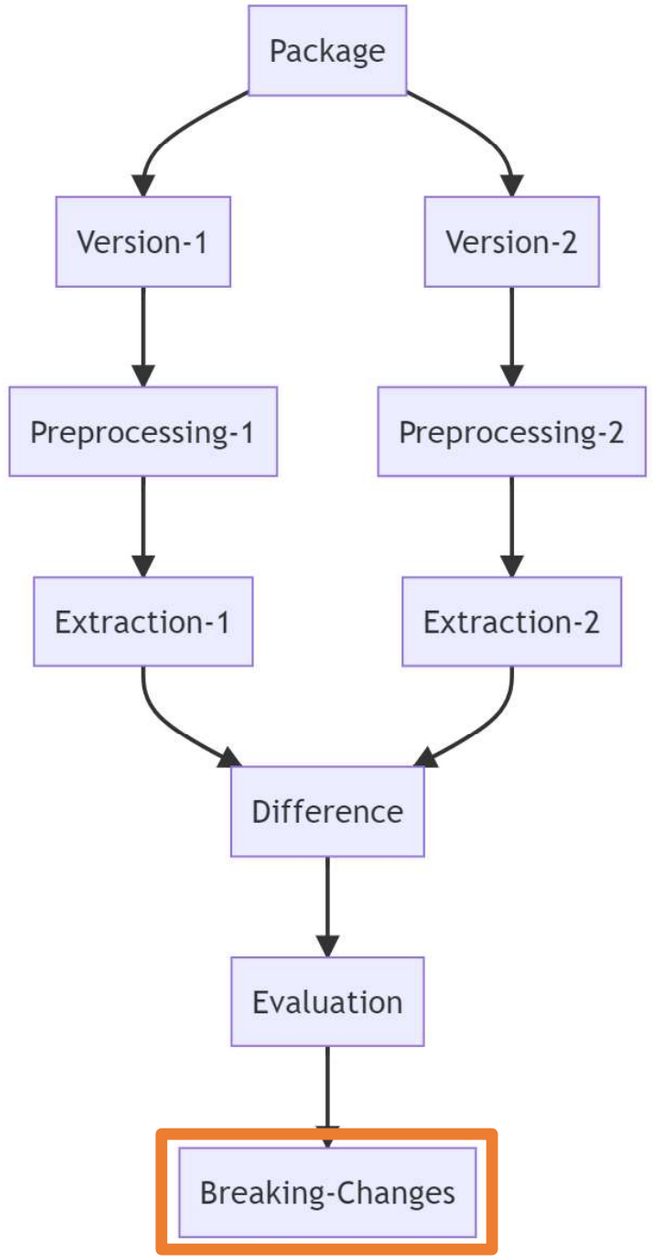
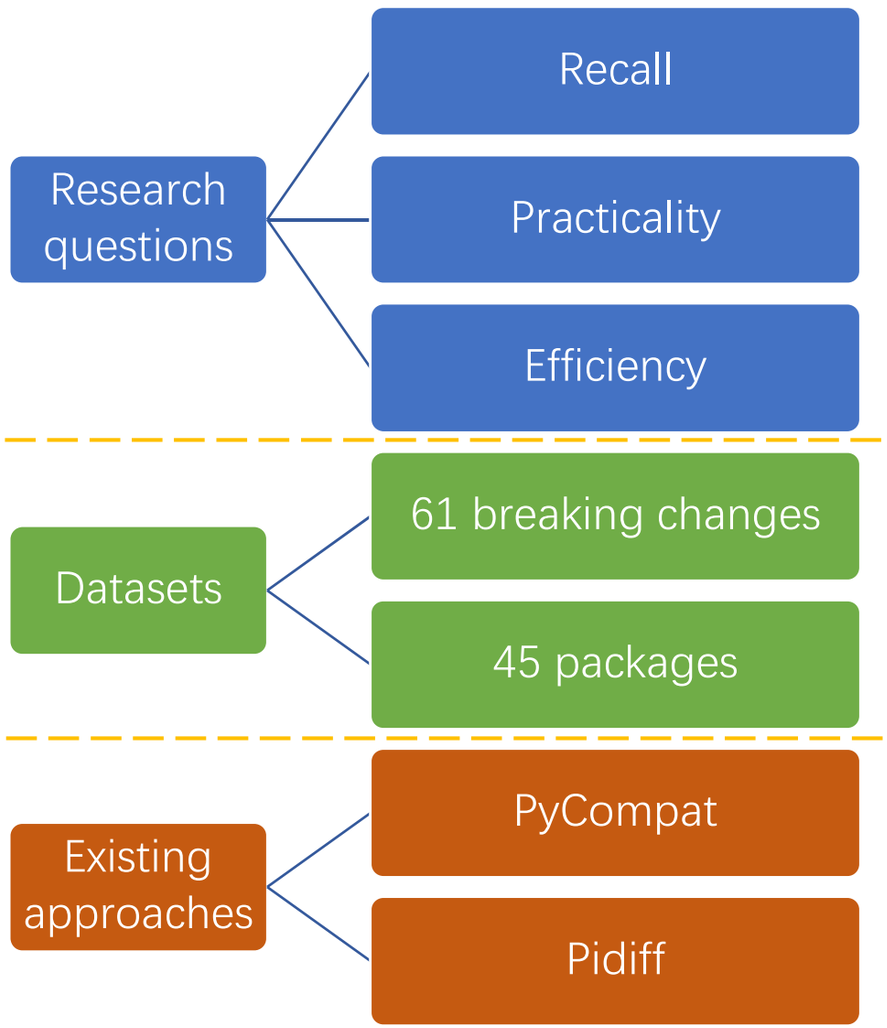


Evaluation
Setup



Does AexPy detect more **known** breaking changes than existing approaches?

Can AexPy find potential **unknown** breaking changes?

What is the **time** performance of AexPy?

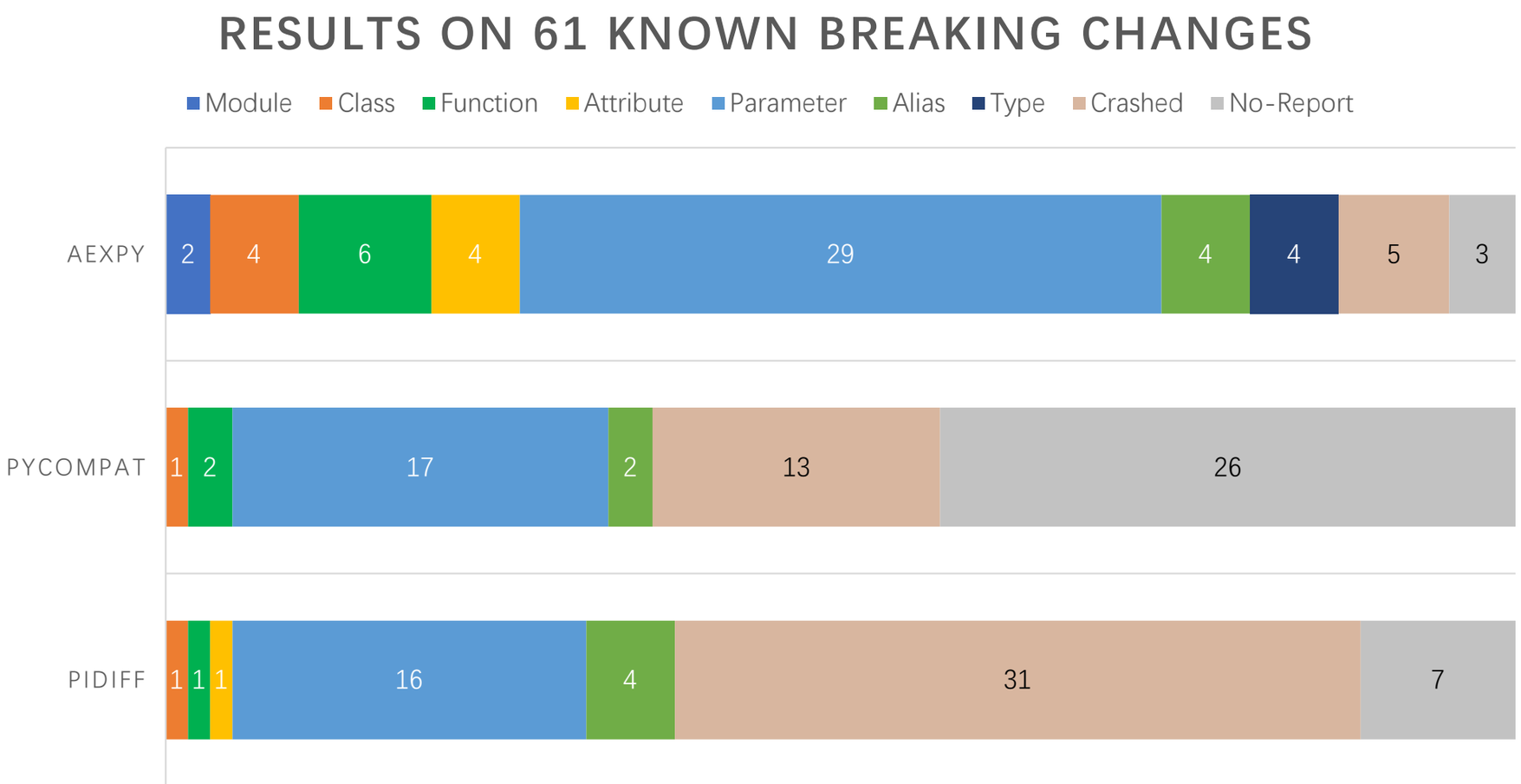
From resolved GitHub issues and 10 popular packages' changelogs

An API misuse detector with its own change detector

A semantic versioning checker for Python packages

Evaluation

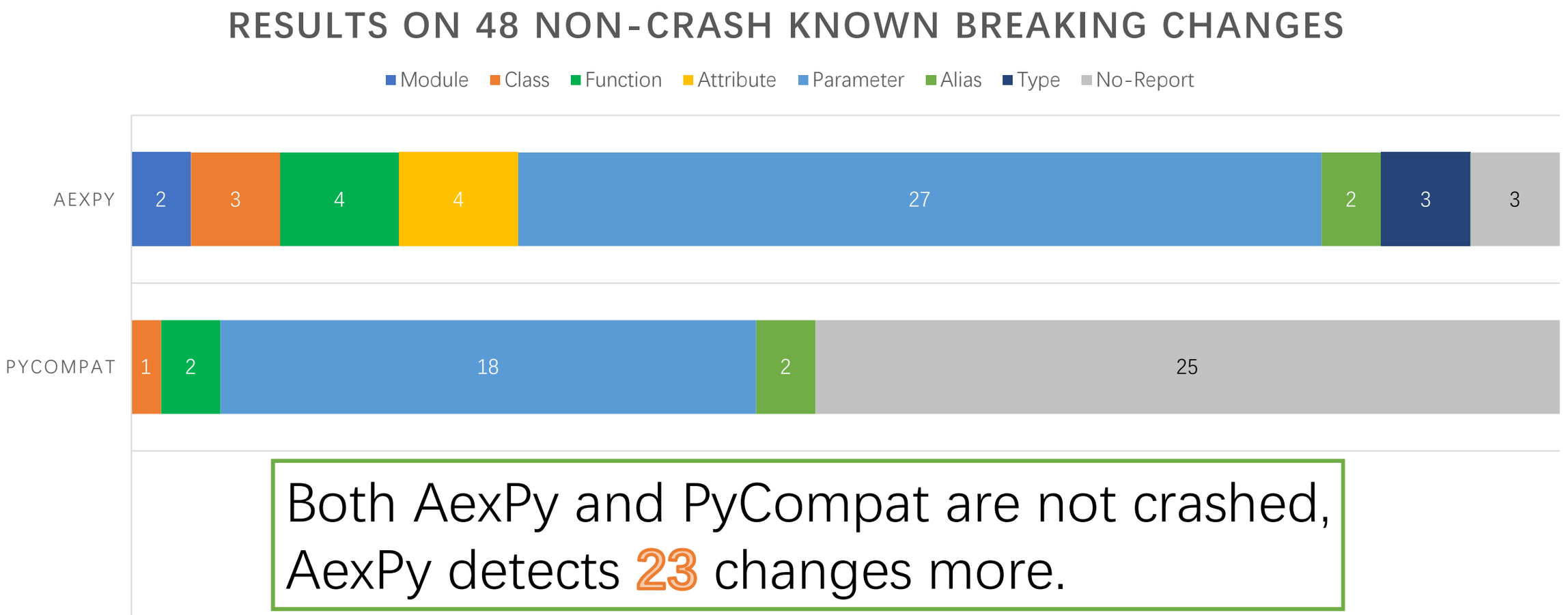
Does AexPy detect more known breaking changes than existing approaches?



AexPy detects **53** changes, increasing by ~**50%** recall.

Evaluation

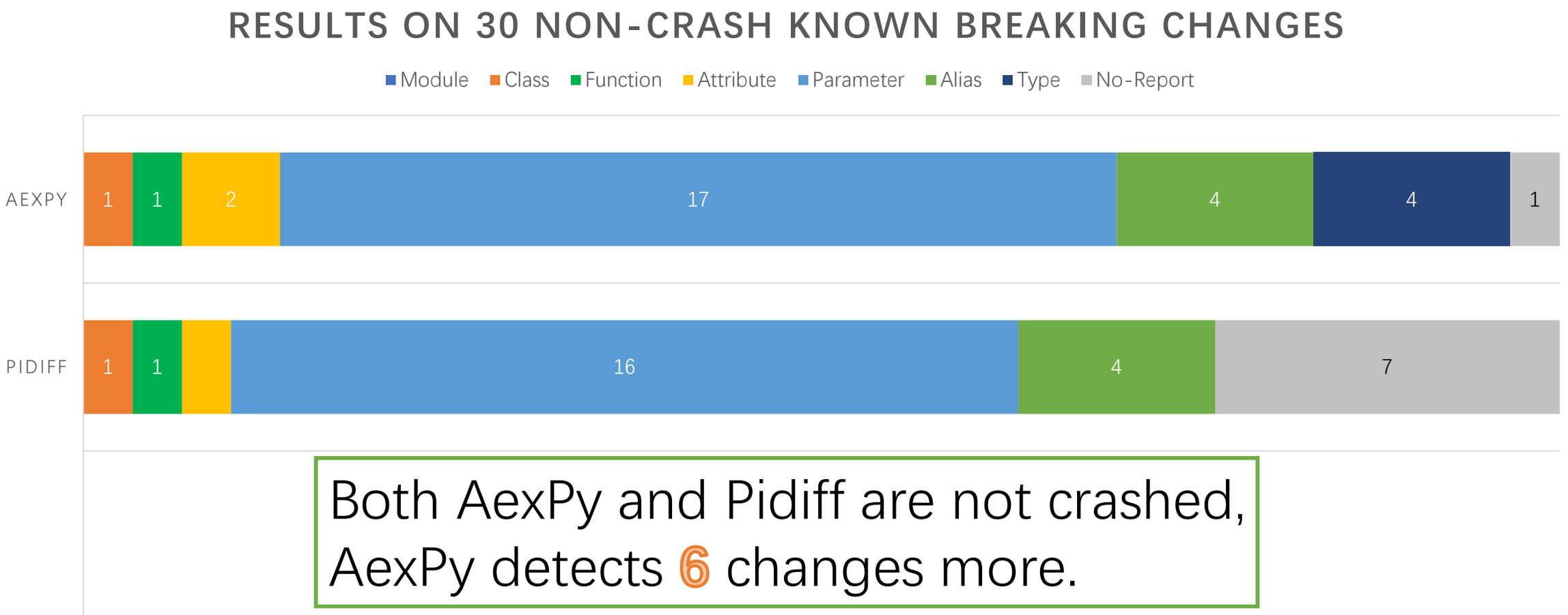
Does AexPy detect more known breaking changes than existing approaches?



Both AexPy and PyCompat are not crashed, AexPy detects 23 changes more.

Evaluation

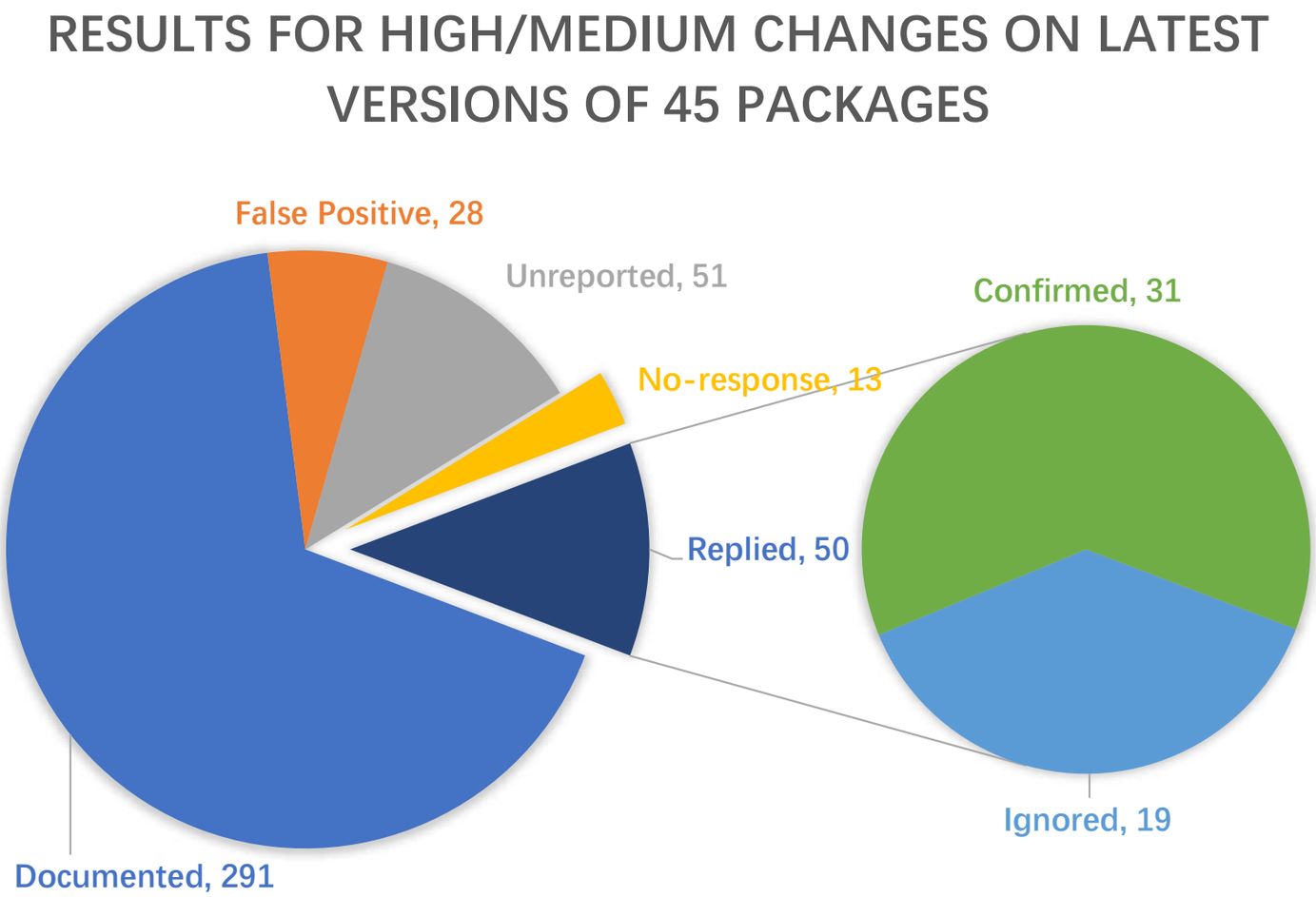
Does AexPy detect more known breaking changes than existing approaches?



Both AexPy and Pidiff are not crashed, AexPy detects 6 changes more.

Evaluation

Can AexPy find potential unknown breaking changes?



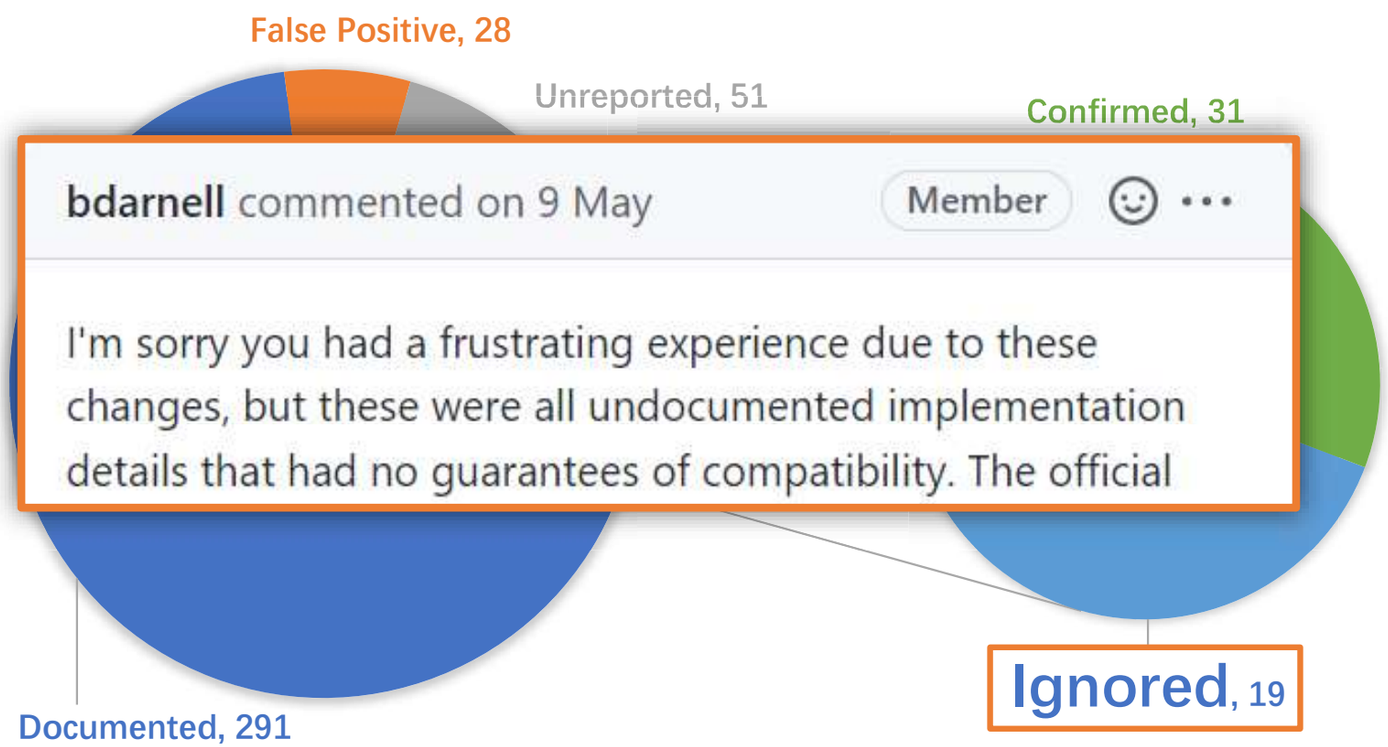
AexPy detects 433 high/medium changes, **405** are true.

Among 63 reported potential changes, **31** are confirmed by developers.

Evaluation

Can AexPy find potential unknown breaking changes?

RESULTS FOR HIGH/MEDIUM CHANGES ON LATEST VERSIONS OF 45 PACKAGES



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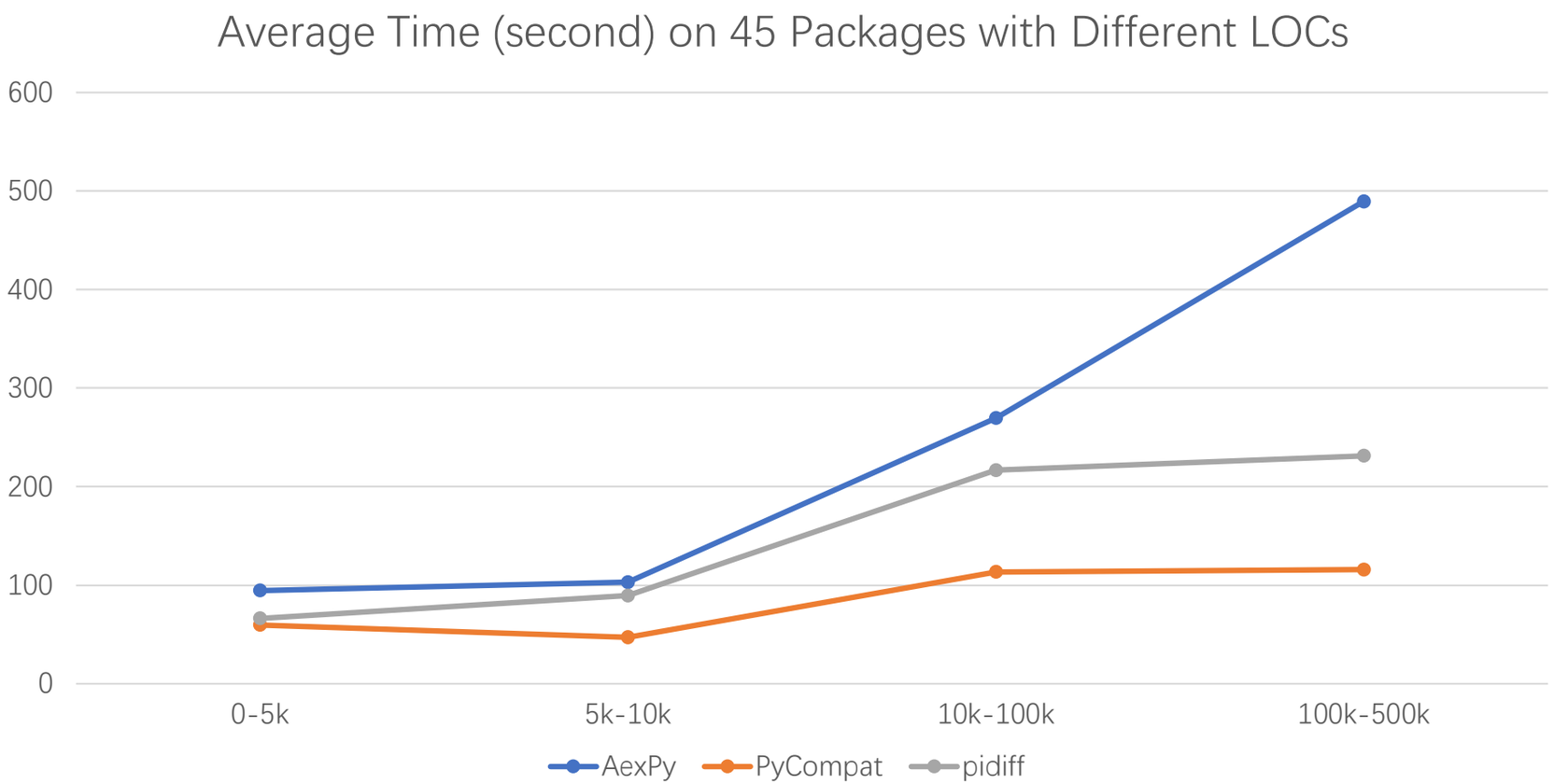
Evaluation

What is the time performance of AexPy?



Experiment Environment
Containers on a Ubuntu 18.04, 12 CPUs of 3.8GHz, 64 GBs RAM
Limited in 50GBs RAM, 1 hour, for each version pair

The time performances of the three tools are **in the same order of magnitude**.

Contributions

AexPy: Detecting API Breaking Changes in Python Packages

An API breaking change detection approach for Python packages

- High recall and strong robustness
- Detecting potential breaking changes
- Comparable time performance

Key ideas

- Detailed model for APIs, changes, and breaking levels
- Hybrid analysis to enhance API extraction
- Constraint-based method to detect and grade API changes

Future works

- Study more applications of the built API and change knowledge base
- Consider more aspects of breaking changes including API semantics

Contributions

AexPy: Detecting API Breaking Changes in Python Packages

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Jun Ma
majun@nju.edu.cn

https://github.com/**StardustDL/aexpy**

https://pypi.org/project/**aexpy**/

https://hub.docker.com/r/**stardustdl/aexpy**