An Exploratory Study on the Predominant Programming Paradigms in Python Code

Robert Dyer and Jigyasa Chauhan

IN OUR GRIT, OUR GLORY™

Increasing Prevalence of Multi-Paradigm Languages

python

Scala

JavaScript

Increasing Prevalence of Multi-Paradigm Languages

Java

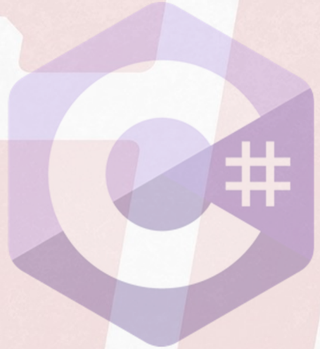
php

python

Scala

JavaScript

Increasing Prevalence of Multi-Paradigm Languages



Java

php

Motivating Example

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

Object-oriented features

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

Object-oriented features

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

Research Questions

RQ1 What is the distribution of predominant paradigms for Python projects on GitHub?

RQ2 What are the most and least used features for some programming paradigms?

RQ3 Are project size and predominant paradigm related?

RQ4 How does predominant paradigm use change over time?

Research Questions

RQ1 What is the distribution of predominant paradigms for Python projects on GitHub?

RQ2 What are the most and least used features for some programming paradigms?

method declarations	2,575,397
class declarations	1,738,668

RQ3 Are project size and predominant paradigm related?

RQ4 How does predominant paradigm use change over time?

Research Questions

RQ1 What is the distribution of predominant paradigms for Python projects on GitHub?

RQ2 What are the most and least used features for some programming paradigms?

method declarations	2,575,397
class declarations	1,738,668
built-in functions (functools/itertools)	990,333
array comprehensions	729,309

RQ3 Are project size and predominant paradigm related?

RQ4 How does predominant paradigm use change over time?

RQ1 What is the distribution of predominant paradigms for Python projects on GitHub?

RQ2 What are the most and least used features for some programming paradigms?

method declarations	2,575,397
class declarations	1,738,668
built-in functions (functools/itertools)	990,333
array comprehensions	729,309

RQ3 Are project size and predominant paradigm related?

RQ4 How does predominant paradigm use change over time?

(it doesn't)

Projects	**101,648**
Revision (with a Python file)	15,254,331
Python Files	7,758,882
(main branch only)	**3,658,391**
Python File Snapshots	68,787,597
ASTs	**105,907,774,611**

Phase 1: Manual Classification

Phase 2: Automated Classification

Phase 1: Manual Classification

Phase 2: Automated Classification

Sample 102 files (out of 98,537)

Phase 1: Manual Classification

Phase 2: Automated Classification

Sample 102 files (out of 98,537)

3 raters: 0.759 kappa (“good” agreement)

Phase 1: Manual Classification

Phase 2: Automated Classification

```
class MyCounter:
    x = 1

    def val(self):
        def wrapper():
            return self.x
        return wrapper

    def __iter__(self):
        self.x = 1
        return self

    def __next__(self):
        if self.x > 50:
            raise StopIteration
        tmp = self.x
        self.x += 1
        return tmp

print([y for y in MyCounter() if y % 2 == 0])
```

Automated Classification

```
class MyCounter:                    #       oo
    x = 1                           #       oo

    def val(self):                  #       oo
        def wrapper():              #       oo
            return self.x           #       oo
        return wrapper              #       oo

    def __iter__(self):             #       oo
        self.x = 1                  #       oo
        return self                 #       oo

    def __next__(self):             #       oo
        if self.x > 50:             #       oo
            raise StopIteration     #       oo
        tmp = self.x                #       oo
        self.x += 1                 #       oo
        return tmp                  #       oo

print([y for y in MyCounter() if y % 2 == 0]) #       oo
```

```
class MyCounter:                    #       ○○
    x = 1                           #       ○○

    def val(self):                  #       ○○
        def wrapper():              #       ○○ proc
            return self.x           #       ○○ proc
        return wrapper              #       ○○

    def __iter__(self):             #       ○○
        self.x = 1                  #       ○○
        return self                 #       ○○

    def __next__(self):             #       ○○
        if self.x > 50:             #       ○○
            raise StopIteration     #       ○○
        tmp = self.x                #       ○○
        self.x += 1                 #       ○○
        return tmp                  #       ○○

print([y for y in MyCounter() if y % 2 == 0]) #       ○○ proc
```

Automated Classification

Automated Classification

```
class MyCounter:                    # func oo
    x = 1                           #      oo

    def val(self):                  #      oo
        def wrapper():              #      oo proc
            return self.x           #      oo proc
        return wrapper              #      oo

    def __iter__(self):             # func oo
        self.x = 1                  #      oo
        return self                 #      oo

    def __next__(self):             # func oo
        if self.x > 50:             #      oo
            raise StopIteration     #      oo
        tmp = self.x                #      oo
        self.x += 1                 #      oo
        return tmp                  #      oo

print([y for y in MyCounter() if y % 2 == 0]) #       oo proc
```

Automated Classification

```
class MyCounter:                    # func oo
    x = 1                           #      oo

    def val(self):                  #      oo
        def wrapper():              #      oo proc
            return self.x           #      oo proc
        return wrapper              # func oo

    def __iter__(self):             # func oo
        self.x = 1                  #      oo
        return self                 #      oo

    def __next__(self):             # func oo
        if self.x > 50:             #      oo
            raise StopIteration     #      oo
        tmp = self.x                #      oo
        self.x += 1                 #      oo
        return tmp                  #      oo

print([y for y in MyCounter() if y % 2 == 0]) #       oo proc
```

Automated Classification

```
class MyCounter:                    # func oo
    x = 1                           #      oo

    def val(self):                  #      oo
        def wrapper():              #      oo proc
            return self.x           #      oo proc
        return wrapper              # func oo

    def __iter__(self):             # func oo
        self.x = 1                  #      oo
        return self                 #      oo

    def __next__(self):             # func oo
        if self.x > 50:             #      oo
            raise StopIteration     #      oo
        tmp = self.x                #      oo
        self.x += 1                 #      oo
        return tmp                  #      oo

print([y for y in MyCounter() if y % 2 == 0]) # func oo proc
```

Automated Classification

```
class MyCounter:                    # func oo
    x = 1                           #      oo      imp

    def val(self):                  #      oo
        def wrapper():              #      oo proc
            return self.x           #      oo proc
        return wrapper              # func oo

    def __iter__(self):             # func oo
        self.x = 1                  #      oo
        return self                 #      oo

    def __next__(self):             # func oo
        if self.x > 50:             #      oo
            raise StopIteration     #      oo
        tmp = self.x                #      oo
        self.x += 1                 #      oo
        return tmp                  #      oo

print([y for y in MyCounter() if y % 2 == 0]) # func oo proc
```

Automated Classification

```
class MyCounter:                    # func oo
    x = 1                           #      oo      imp

    def val(self):                  #      oo
        def wrapper():              #      oo proc
            return self.x           #      oo proc
        return wrapper              # func oo

    def __iter__(self):             # func oo
        self.x = 1                  #      oo
        return self                 #      oo

    def __next__(self):             # func oo
        if self.x > 50:             #      oo
            raise StopIteration     #      oo
        tmp = self.x                #      oo
        self.x += 1                 #      oo
        return tmp                  #      oo

print([y for y in MyCounter() if y % 2 == 0]) # func oo proc
```

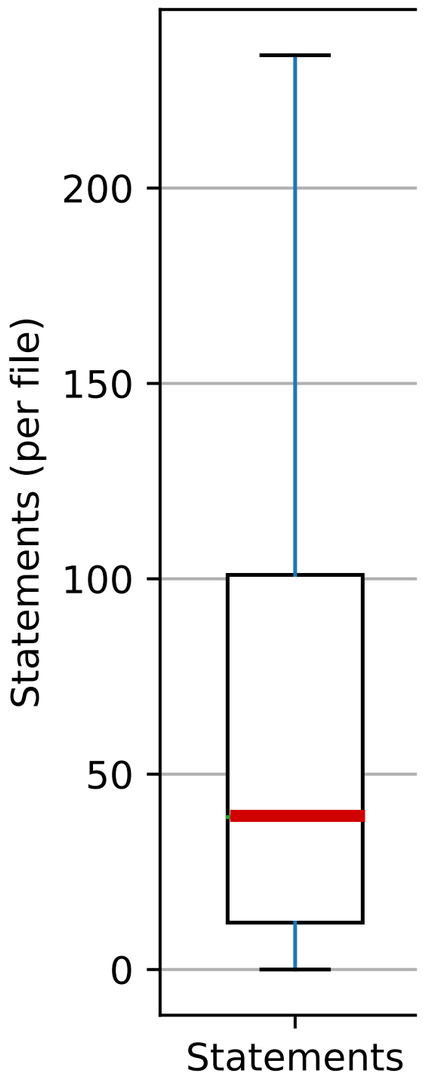
	Count	Percent
Statements	16	100.00%
Functional	5	31.25%
Object-Oriented	16	100.00%
Procedural	3	18.75%
Imperative	1	6.25%

Human and Machine Judgements (on sample)

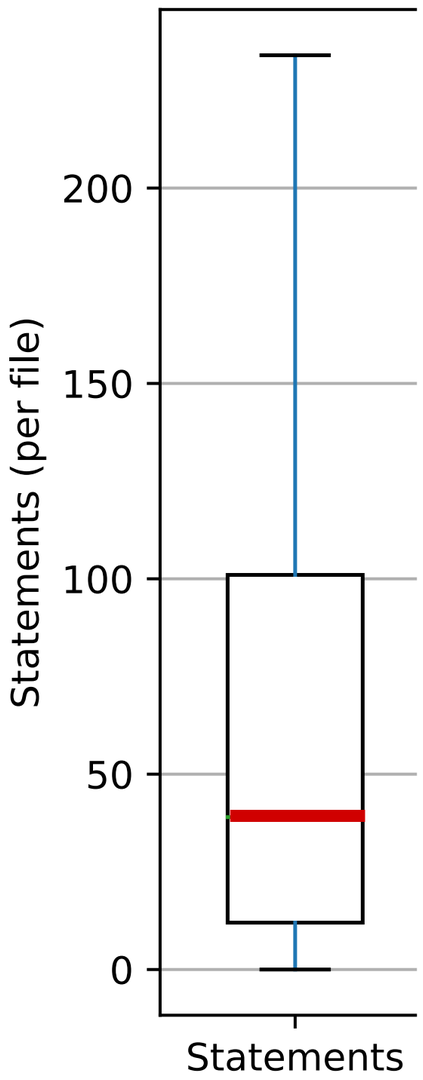
	Human Judgements	Machine Judgements
Imperative	5	8
Mixed	16	10
Object-Oriented	53	55
Procedural	28	29

RQ1: Python files are small

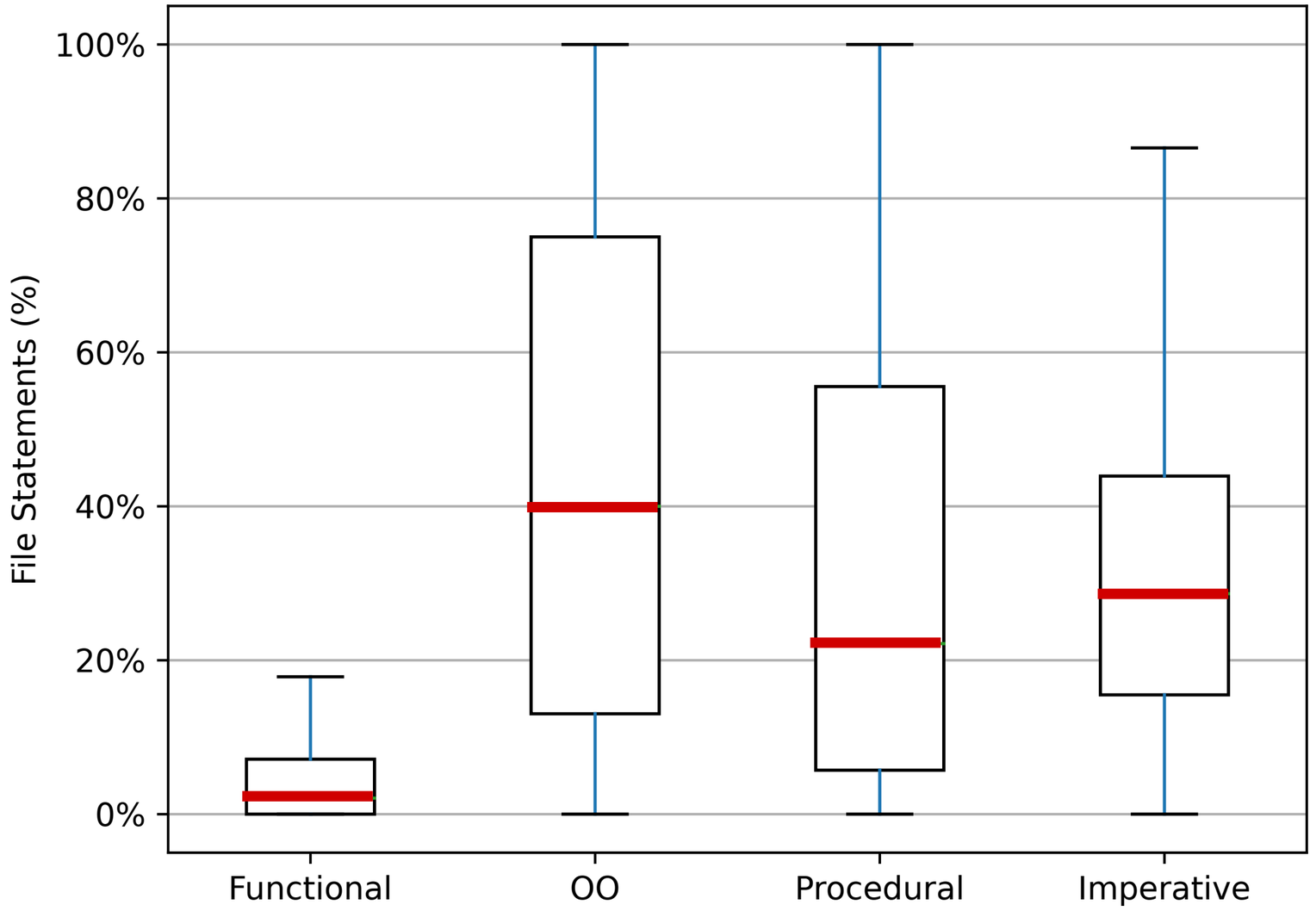
RQ1: Python files are small



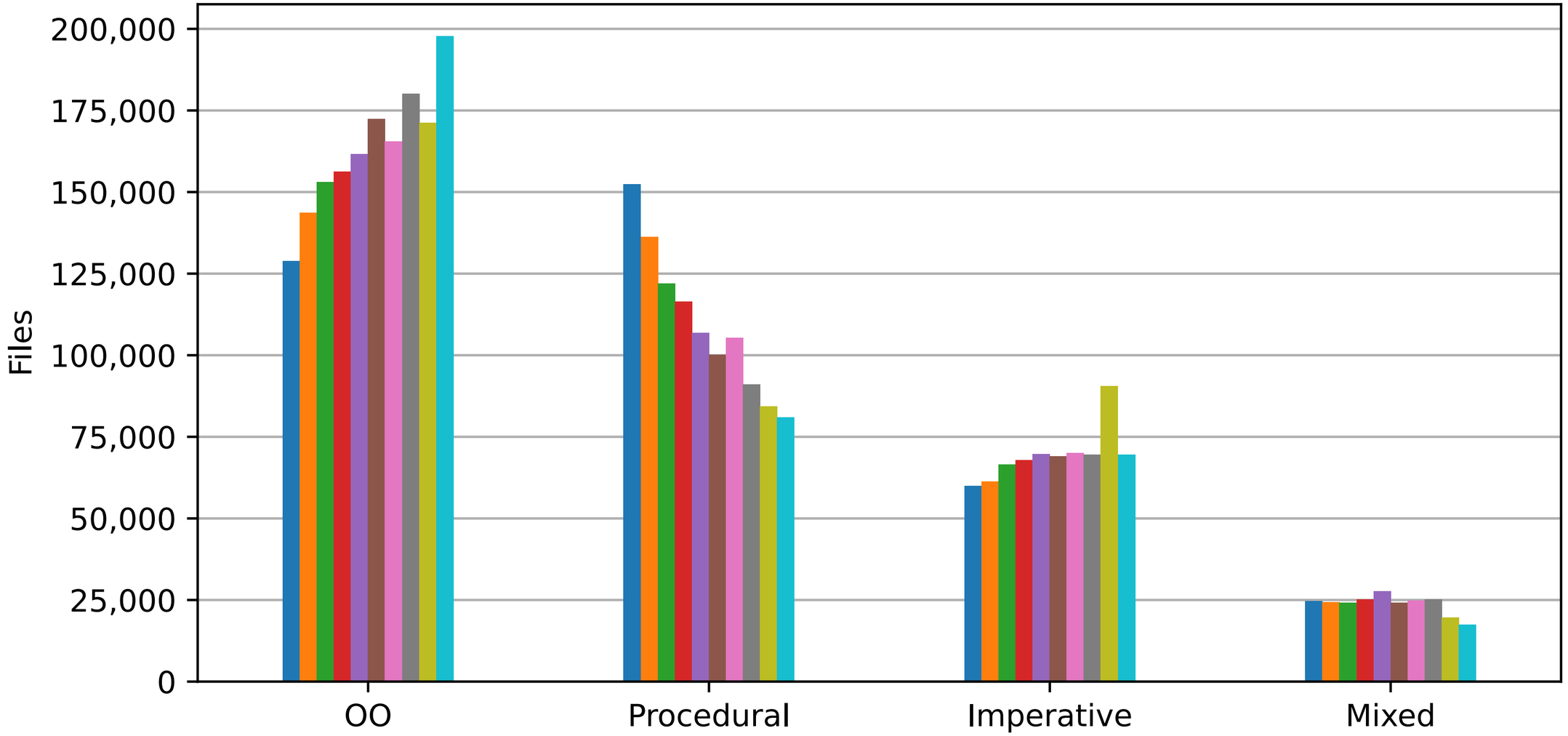
RQ1: Python files are small



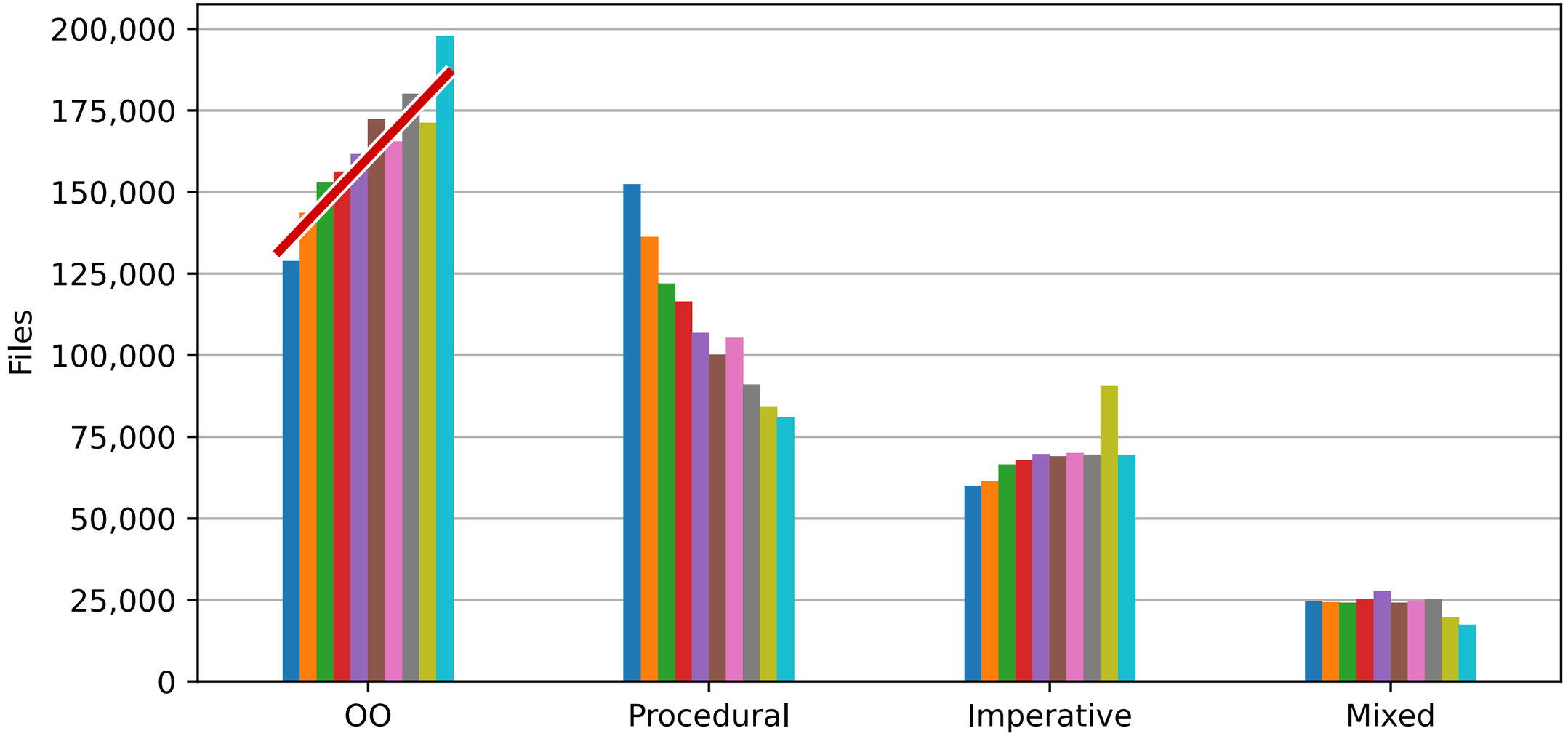
RQ1: Python is Truly Multi-Paradigm



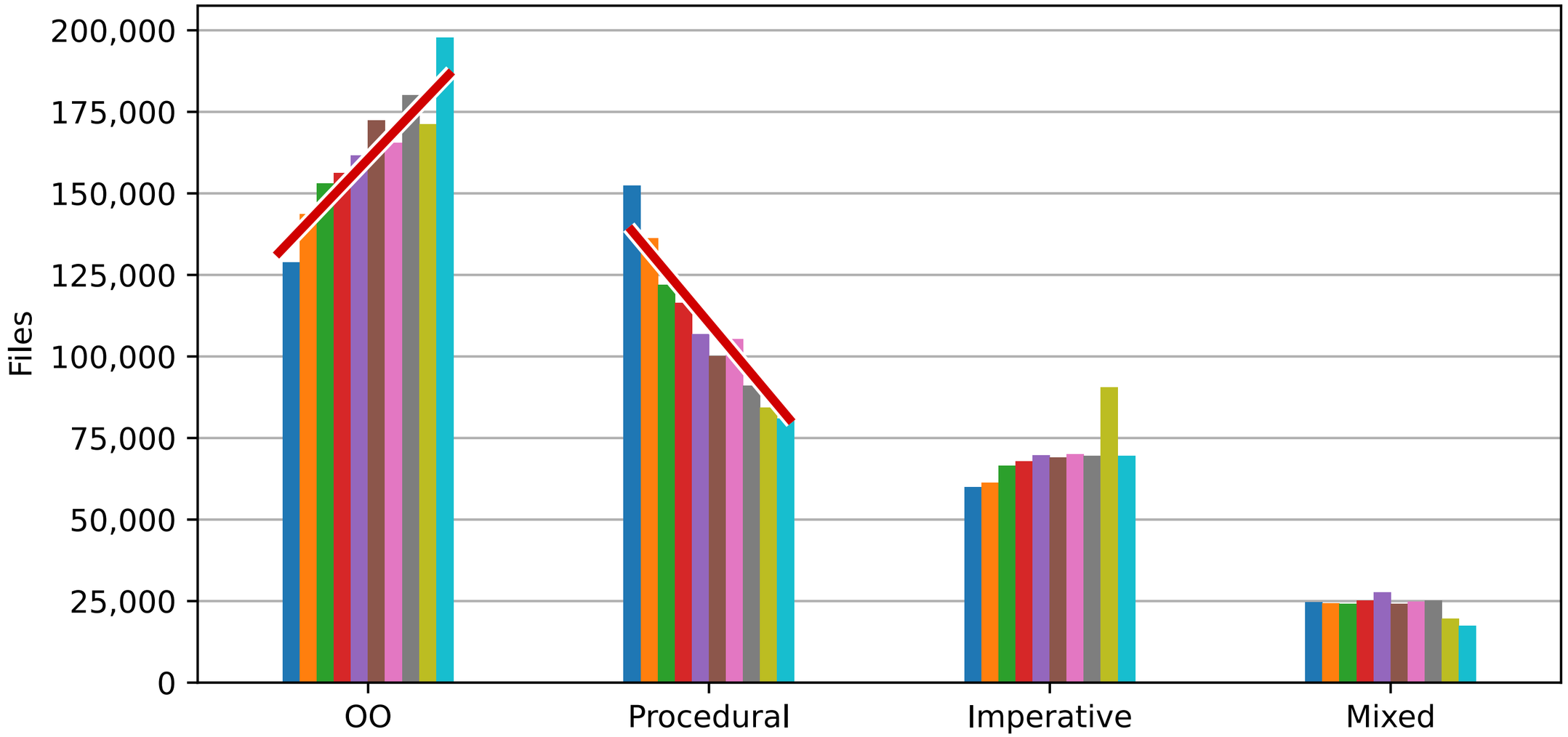
RQ3: Correlating # Statements with Predominant Paradigm



RQ3: Correlating # Statements with Predominant Paradigm



RQ3: Correlating # Statements with Predominant Paradigm



COLLEGE OF
ENGINEERING

Projects	**101,648**
Revision (with a Python file)	15,254,331
Python Files	7,758,882
(main branch only)	**3,658,391**
Python File Snapshots	68,787,597
ASTs	**105,907,774,611**

COLLEGE OF ENGINEERING

Projects	**101,648**
Revision (with a Python file)	15,254,331
Python Files	7,758,882
(main branch only)	**3,658,391**
Python File Snapshots	68,787,597
ASTs	**105,907,774,611**

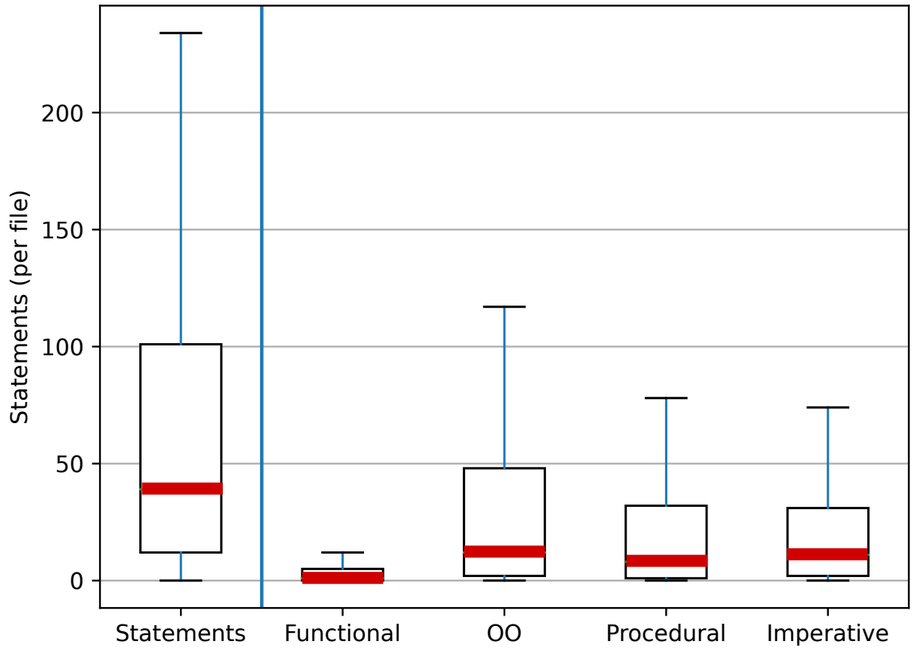
Phase 1: Manual Classification

Phase 2: Automated Classification

Projects	**101,648**
Revision (with a Python file)	15,254,331
Python Files	7,758,882
(main branch only)	**3,658,391**
Python File Snapshots	68,787,597
ASTs	**105,907,774,611**

Phase 1: Manual Classification

Phase 2: Automated Classification

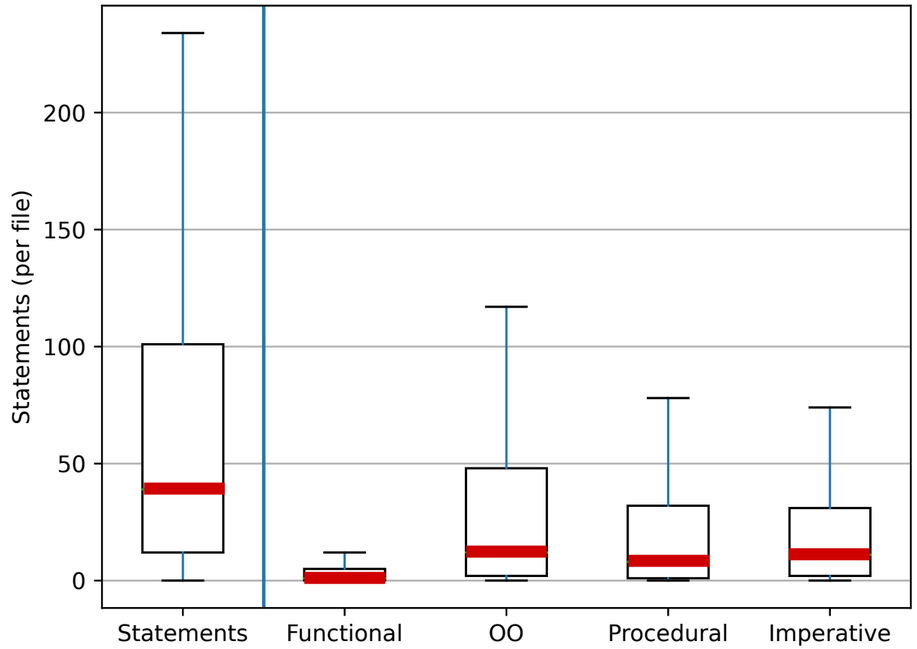


COLLEGE OF ENGINEERING

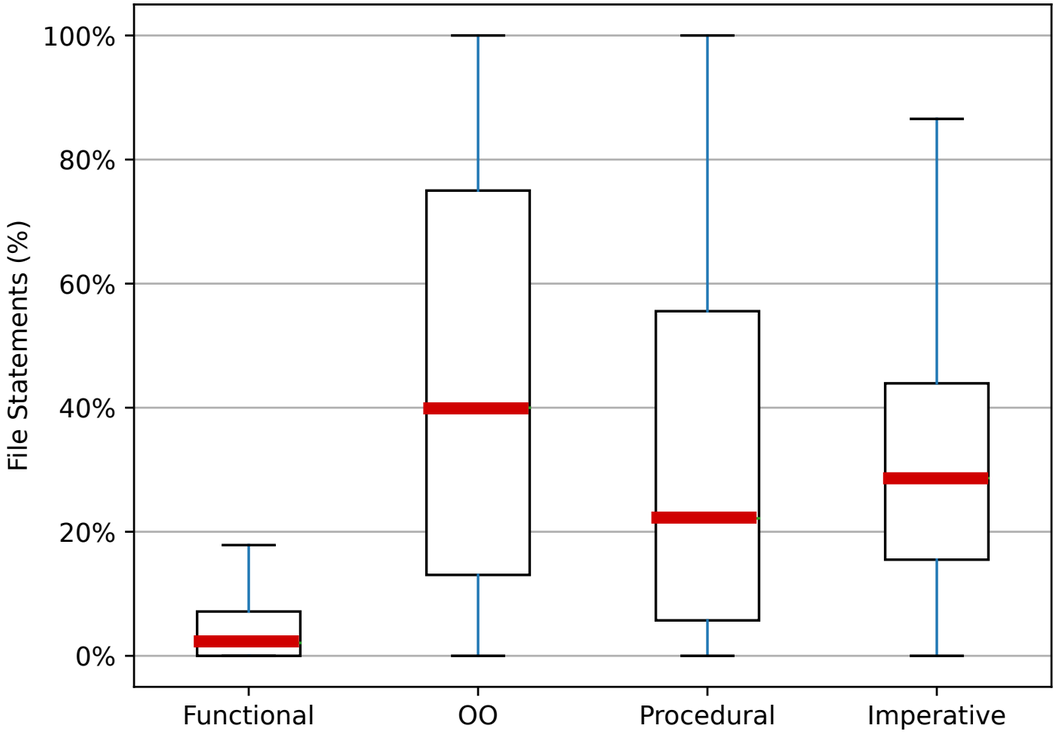
Projects	**101,648**
Revision (with a Python file)	15,254,331
Python Files	7,758,882
(main branch only)	**3,658,391**
Python File Snapshots	68,787,597
ASTs	**105,907,774,611**

Phase 1: Manual Classification

Phase 2: Automated Classification



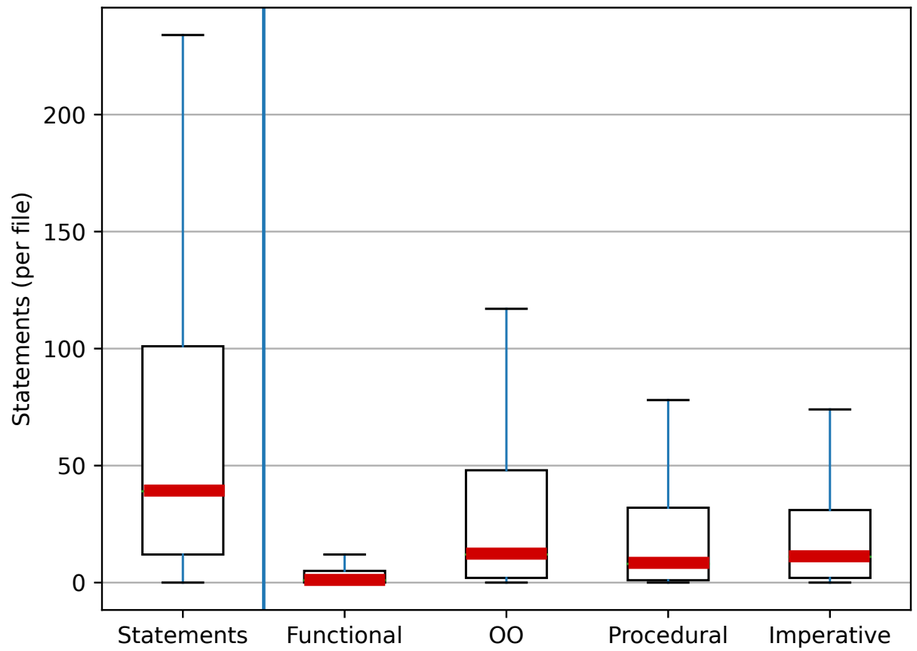
COLLEGE OF ENGINEERING



Projects	**101,648**
Revision (with a Python file)	15,254,331
Python Files	7,758,882
(main branch only)	**3,658,391**
Python File Snapshots	68,787,597
ASTs	**105,907,774,611**

Phase 1: Manual Classification

Phase 2: Automated Classification



COLLEGE OF ENGINEERING