Is the Feature Traceability Problem Already Solved?

Sandra Greiner **Timo Kehrer**

Software Engineering Group, University of Bern, CH
ACP Section, University of Southern Denmark, DK

WSRE, April 2024, Bad Honnef

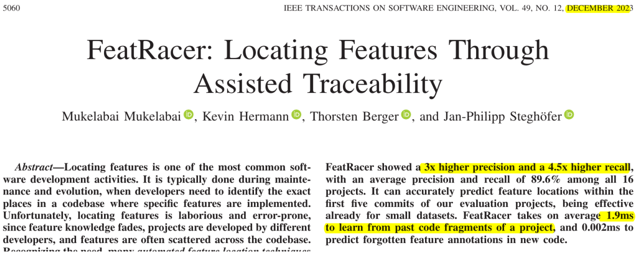
First thought ...

Yes,

First thought ...

Yes,

but ...



FeatRacer: Locating Features Through Assisted Traceability

Mukelabai Mukelabai, Kevin Hermann, Thorsten Berger, and Jan-Philipp Steghöfer

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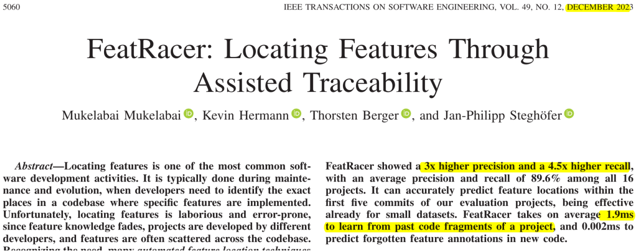

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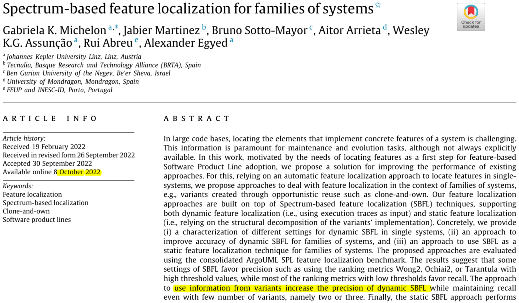

Spectrum-based feature localization for families of systems☆

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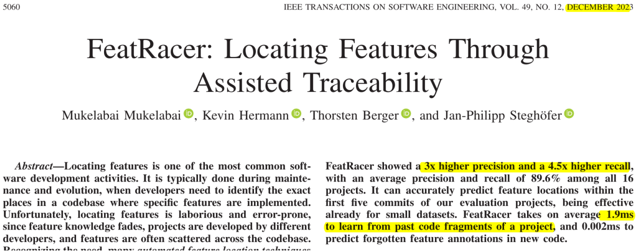

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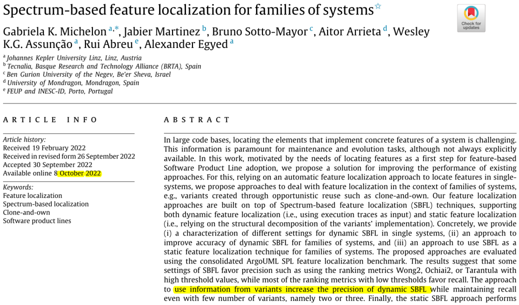

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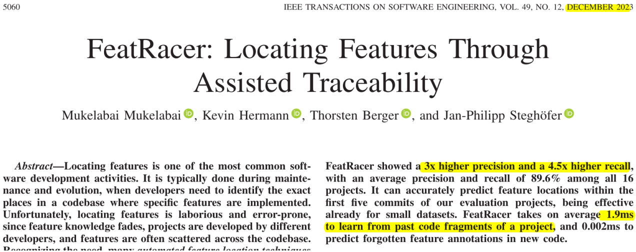

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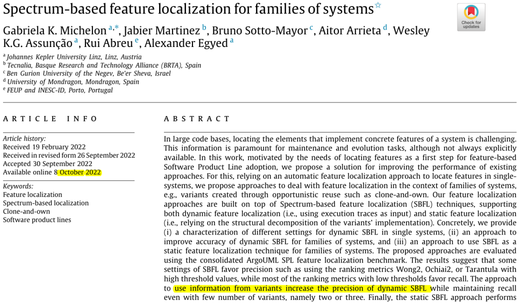

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Feature Traceability

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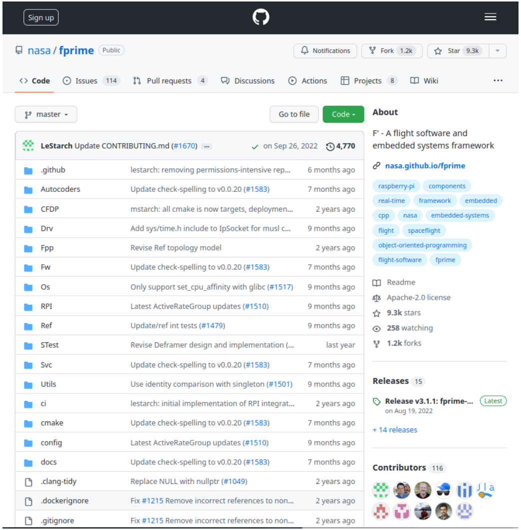
What is it and why should we care?

How can we do better?

Today: Large Evolving Software Projects



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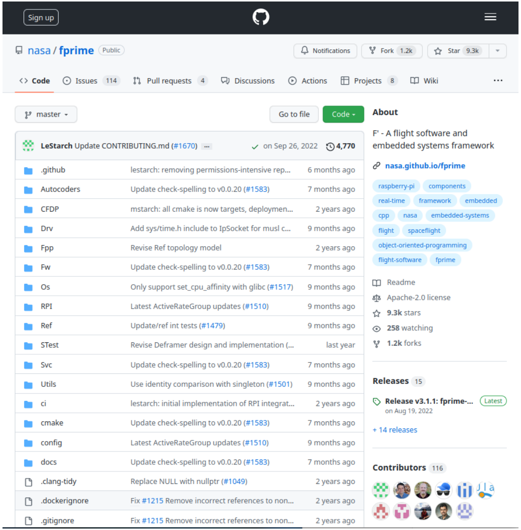

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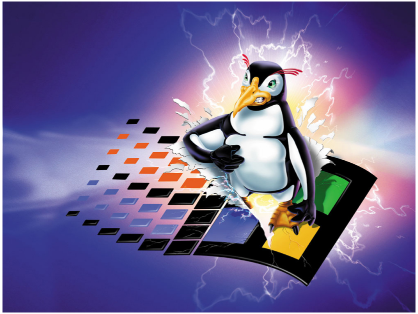

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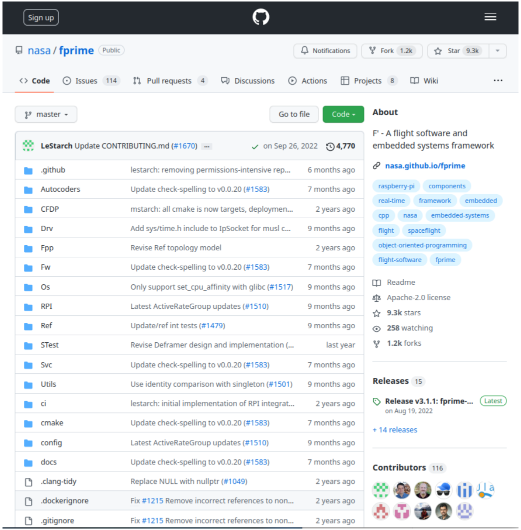

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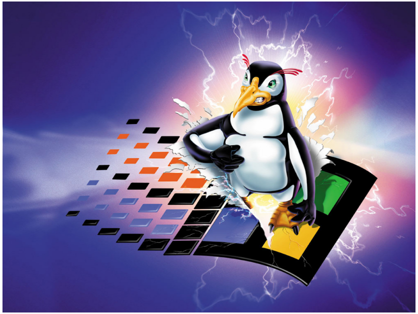

hardly possible to comprehend, analyze, and modernize

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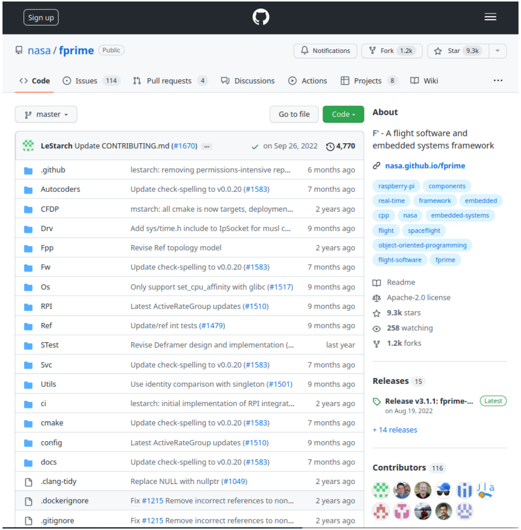

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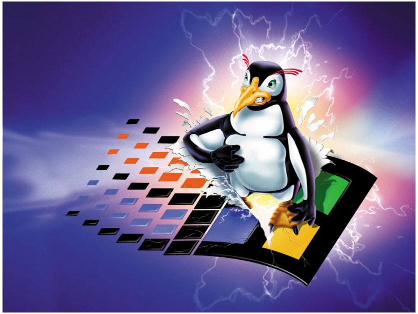

hardly possible to comprehend, analyze, and modernize

particularly, if highly configurable

Problem Statement: Large Evolving Highly-Configurable Software Projects

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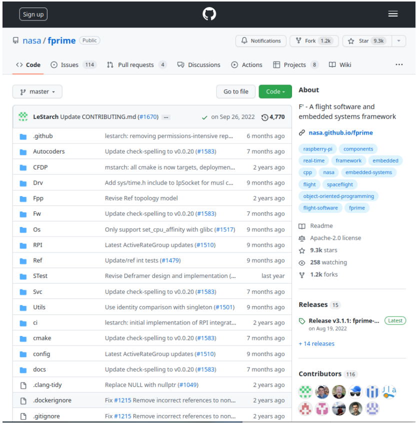

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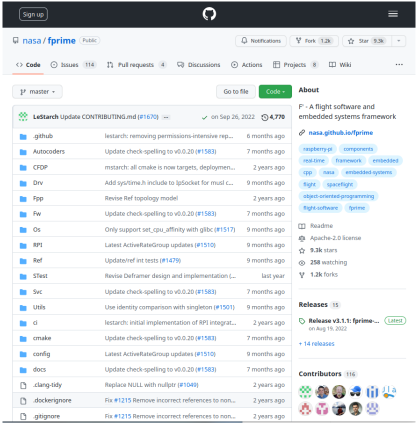

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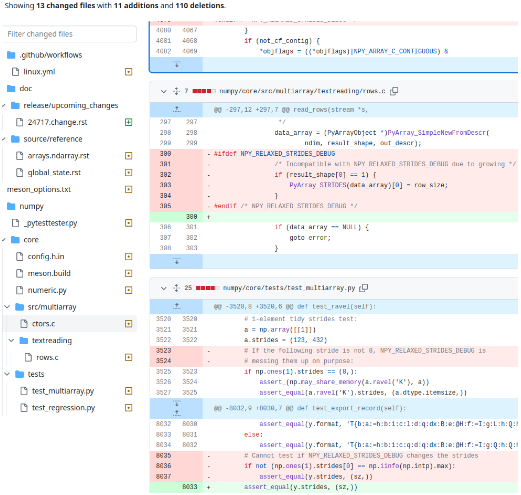

Showing **13 changed files** with **11 additions** and **110 deletions**.

Filter changed files

- .github/workflows
  - linux.yml
- doc
  - release/upcoming_changes
    - 24717.change.rst
  - source/reference
    - arrays.ndarray.rst
    - global_state.rst
- meson_options.txt
- numpy
  - _pytesttester.py
  - core
    - config.h.in
    - meson.build
    - numeric.py
    - src/multiarray
      - ctors.c
      - textreading
        - rows.c
    - tests
      - test_multiarray.py
      - test_regression.py

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                }
                if (not_cf_contig) {
                    *objflags = ((*objflags)|NPY_ARRAY_C_CONTIGUOUS) &
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7 numpy/core/src/multiarray/textreading/rows.c

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@@ -297,12 +297,7 @@ read_rows(stream *s,
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-                       /* Incompatible with NPY_RELAXED_STRIDES_DEBUG due to growing */
-                       if (result_shape[0] == 1) {
-                           PyArray_STRIDES(data_array)[0] = row_size;
-                       }
- #endif /* NPY_RELAXED_STRIDES_DEBUG */
+
                        if (data_array == NULL) {
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```

25 numpy/core/tests/test_multiarray.py

```
@@ -3520,8 +3520,6 @@ def test_ravel(self):
                # 1-element tidy strides test:
                a = np.array([[1]])
                a.strides = (123, 432)
-               # If the following stride is not 8, NPY_RELAXED_STRIDES_DEBUG is
-               # messing them up on purpose:
                if np.ones(1).strides == (8,):
                    assert_(np.may_share_memory(a.ravel('K'), a))
                    assert_equal(a.ravel('K').strides, (a.dtype.itemsize,))
@@ -8032,9 +8030,7 @@ def test_export_record(self):
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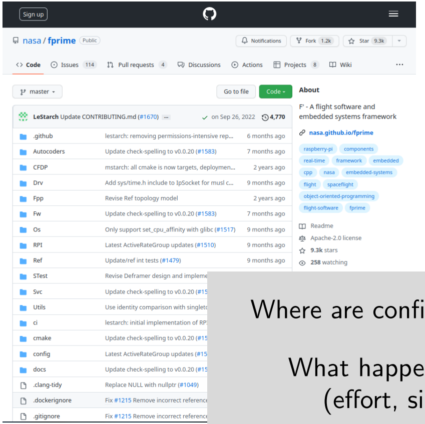
Problem Statement: Large Evolving Highly-Configurable Software Projects

FPrime



LeStarch Update CONTRIBUTING.md (#1670) ... ✓ on Sep 26, 2022 4,770

.github	lestarch: removing permissions-intensive rep...	6 months ago
Autocoders	Update check-spelling to v0.0.20 (#1583)	7 months ago
CFDP	mstarch: all cmake is now targets, deploymen...	2 years ago
Drv	Add sys/time.h include to IpSocket for musl c...	9 months ago
Fpp	Revise Ref topology model	2 years ago
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.clang-tidy	Replace NULL with nullptr (#1049)	
.dockerignore	Fix #1215 Remove incorrect reference	
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About

F' - A flight software and embedded systems framework

nasa.github.io/fprime

raspberry-pi components real-time framework embedded cpp nasa embedded-systems flight spaceflight object-oriented-programming flight-software fprime

Readme
Apache-2.0 license
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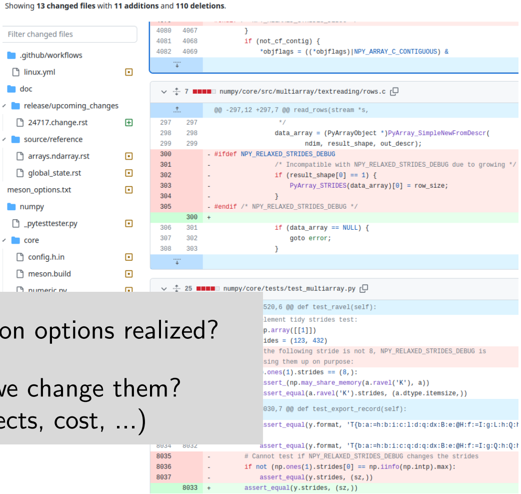
numpy



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What happens if we change them?
(effort, side effects, cost, ...)

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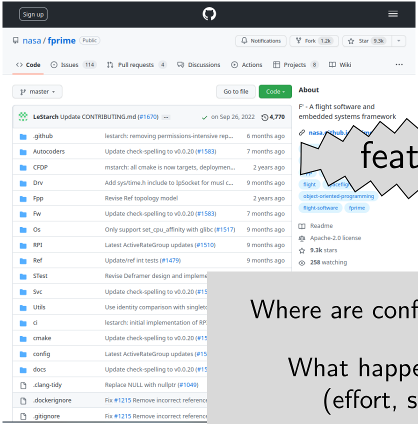

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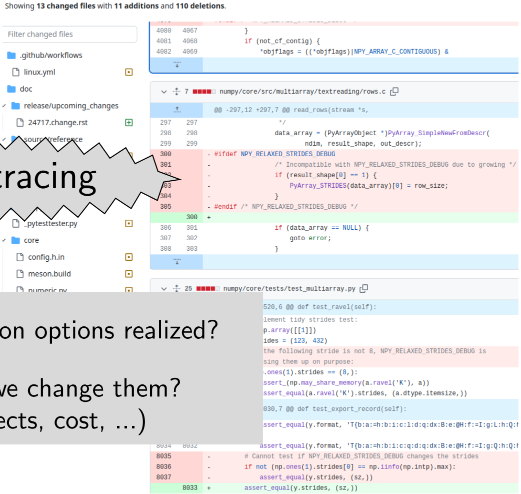

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feature tracing

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Background

How does feature tracing work?

Example: Configurable (?) Graph Implementations

Example: Configurable (?) Graph Implementations

single system

```
public class Graph {

  List<Node> getNodes(Color c) { ... }
  List<Edge> getIncomEdges(Node n) { ... }

  // #IFDEF Weighted
  List<Edge> getEdges(double w)
    { ... }
  // #ENDIF

  Graph subGraph(double w)  { ... }
}

public class Node{}

// #IFDEF Color
public class Color {}
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```

multiple variants

Example: Configurable (?) Graph Implementations

single system

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multiple variants

```java
/// V1: {G, E, W}
// FEAT: Graph
interface Graph {
  List<Node> nodes();
  // FEAT: E
  List<Edge> edges();
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```

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interface Graph {
  List<Node> nodes();
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}
```

```
/// V2: {G, E, C}
interface Graph {
  List<Node> nodes();
  // FEAT: C
  List<Node> nodes(Color c);
  List<Edge> edges();
  Graph subGraph(Color c);
}
```

Example: Configurable (?) Graph Implementations

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  List<Edge> edges();
  Graph subGraph(Color c);
}
```

```java
/// V3: {G, E, D}
interface Graph {
  List<Node> nodes();
  List<Edge> edges();
  List<Edge> incomEdges(Node n);
  // FEAT: C
  Graph subGraph(Color c);
}
```

Proactive Tracing

through

commit messages

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requires

discipline
development practices and guidelines
remains a **manual** task

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⇒ often neglected

⇒ missed opportunity

Retroactive Tracing

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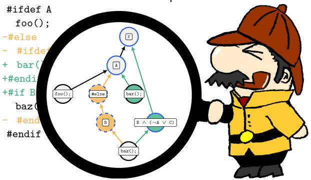

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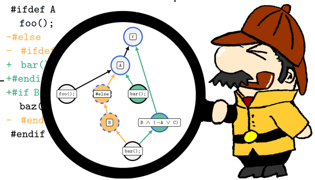

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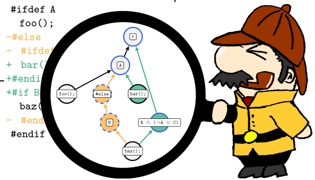

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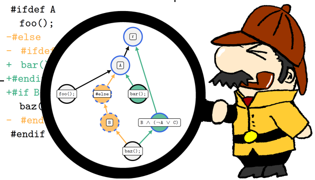

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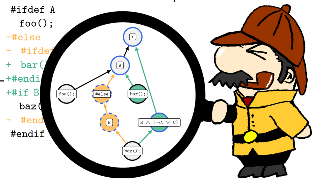

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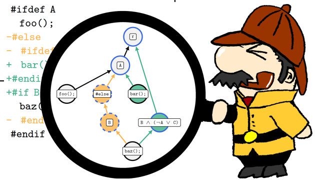

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- execution effort and data
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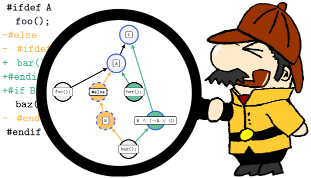

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pin-pointed

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without immediate benefit

additional documentation burden

(*exclude uncertainty, feature interactions...)

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manual vs. automated

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manual vs. automated

automated: static or dynamic or hybrid

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⇒ less reliable

⇒ many techniques, but not optimal

Feature Traceability

Feature Traceability

What is it and why should we care?

How can we do better?

Proactive + Retroactive Feature Tracing

How can retroactive feature tracing benefit from proactive traces?

Proactive + Retroactive Feature Tracing

How can retroactive feature tracing benefit from proactive traces?

Results from experimenting with comparison-based feature location

Comparison-Based Feature Location

```
/// V1: {G, E, W}
// FEAT: Graph
interface Graph {
  List<Node> nodes();
  // FEAT: E
  List<Edge> edges();
  List<Node> nodes(double w);
}
```

```
/// V3: {G, E, D}
interface Graph {
  List<Node> nodes();
  List<Edge> edges();
  List<Edge> incomEdges(Node n);
  // FEAT: C
  Graph subGraph(Color c);
}
```

```
/// V2: {G, E, C}
interface Graph {
  List<Node> nodes();
  // FEAT: C
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  Graph subGraph(Color c);
}
```

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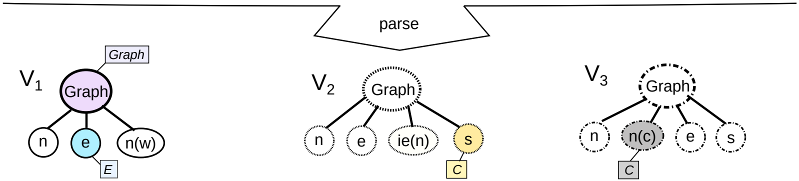

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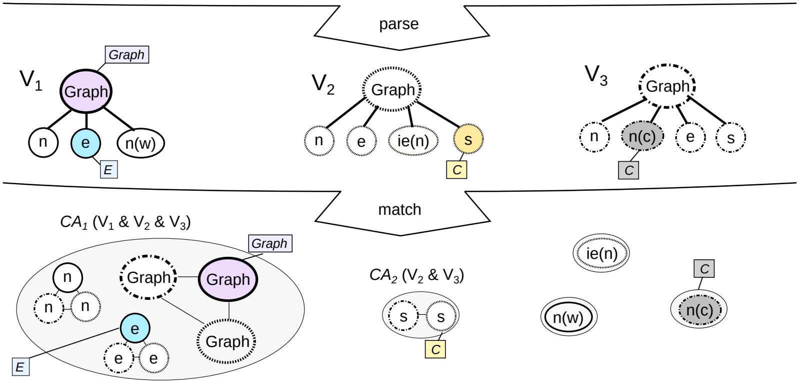
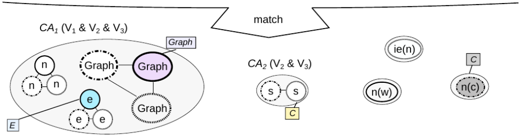


Comparison-Based Feature Location

annotation per node (based on features in configurations)



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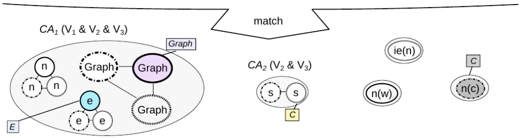

Feature Trace

Comparison-Based Feature Location

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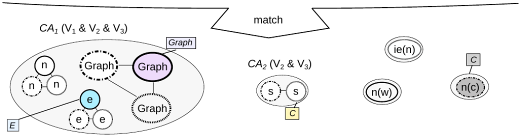

Feature Trace

Graph ∧ Edge	interface Graph, nodes(), edges(), subGraph()
Weighted	nodes (double w)
Colored	nodes(Color c)
Directed	incomingEdges(Edge e)

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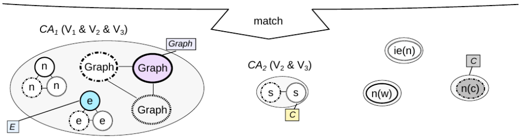

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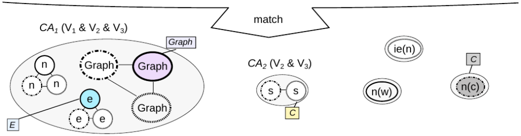

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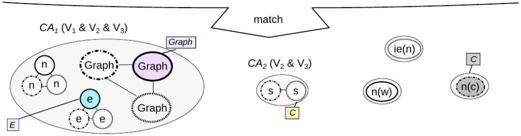

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- measure quantitatively
    - effect of adding proactive mappings per variant
    - effect of number of compared variants

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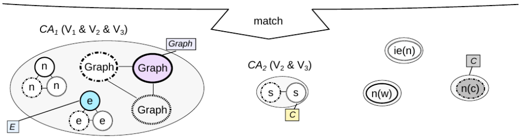

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effect of number of compared variants

⇒ increase in accuracy?

⇒ invest in exploiting proactive knowledge?

Setup

Subject Systems: Marlin, ArgoUML, VIM; OpenVPN, BusyBox

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Groundtruth: VEVOS, Benchmark generator for highly configurable software

Measure:

Agreement between ground truth and computed mapping to keep a line of code in variant

Compute: precision, recall, F1-Score

Results : Busybox (precision & recall (row), 3 and 7 variants (columns))

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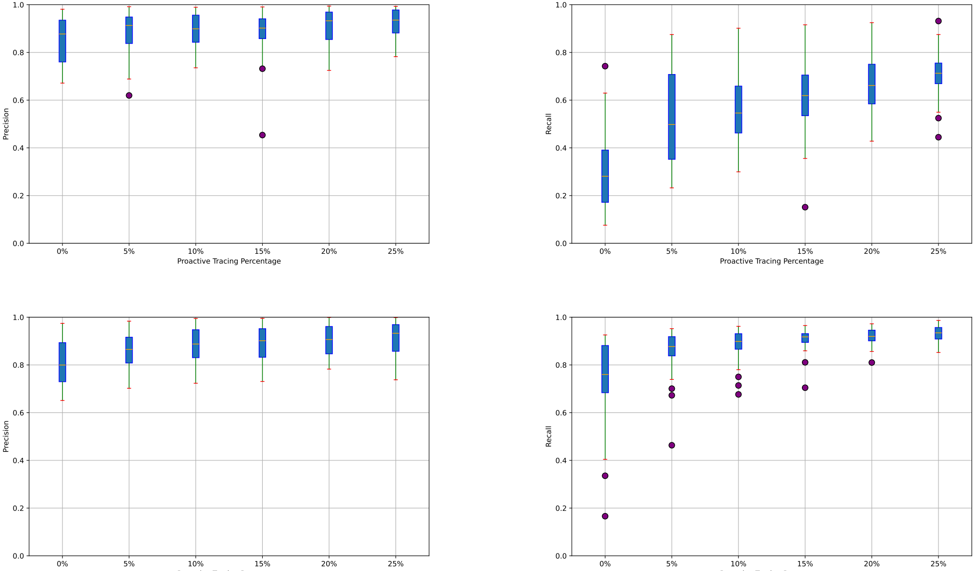

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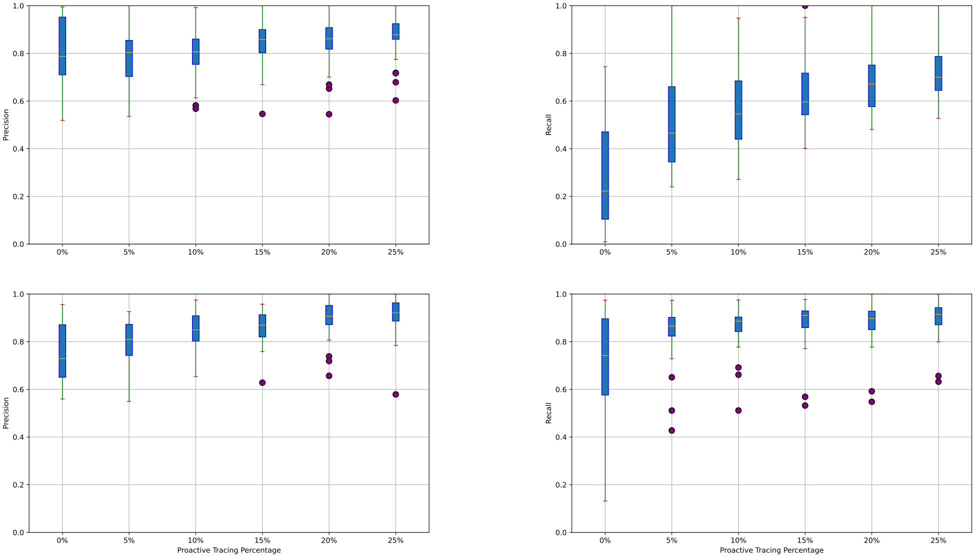

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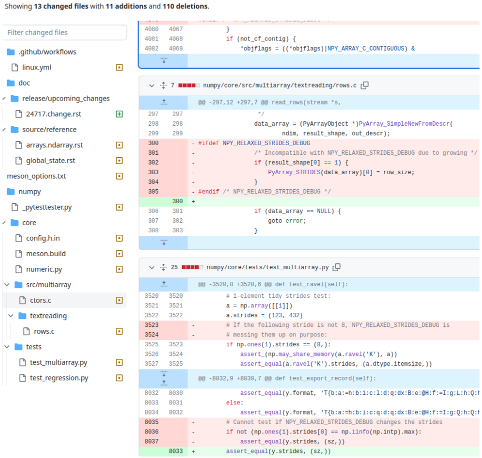
the more variants, the higher the accuracy (with and without added traces)

⇒ potential to exploit proactive traces further

⇒ examine the effect in further techniques, also qualitatively

⇒ optimize retroactive techniques but also inform semi-automated tracing (e.g. for machine learning)

Summary



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                    if (data_array == NULL) {
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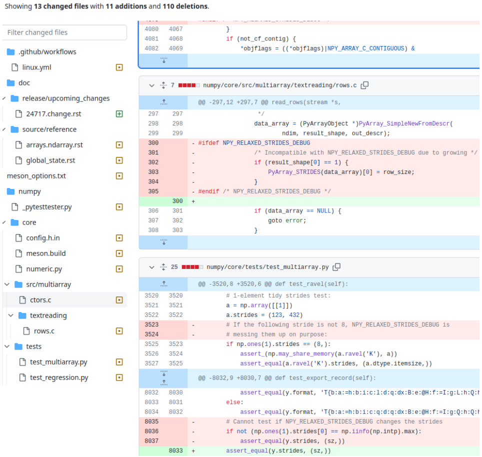

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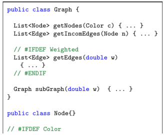

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public class Node{}

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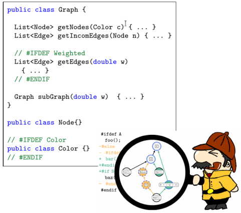
Retroactive Tracing



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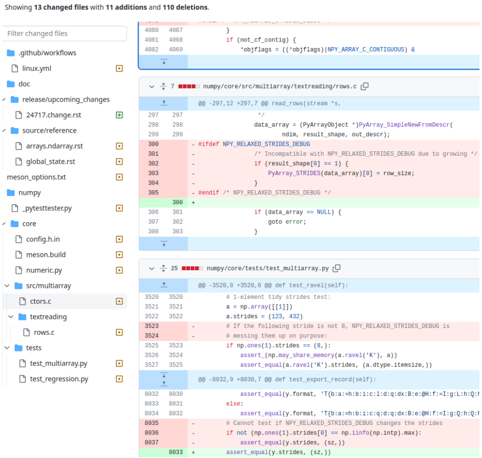

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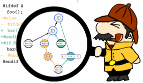
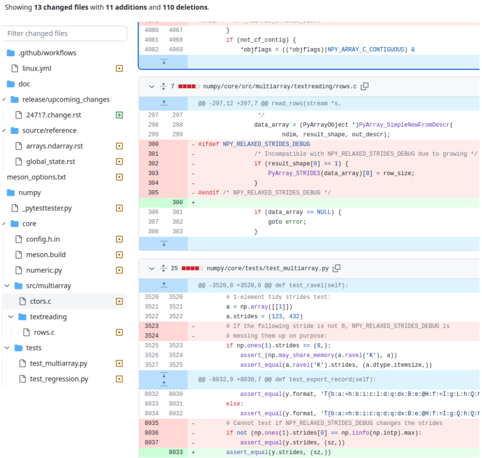


feature traceability comes with plenty of techniques

Summary



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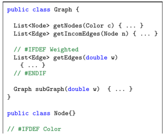

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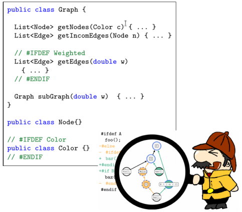

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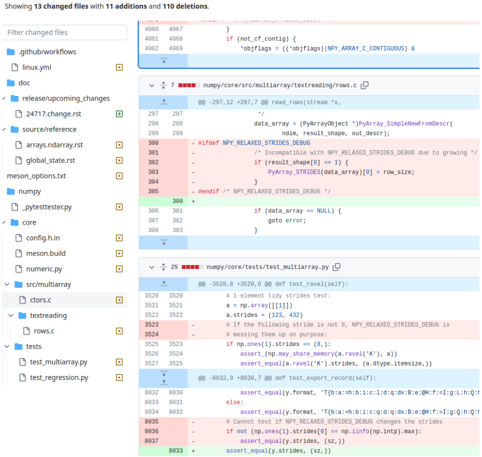
no optimal solution (we examined proactive potentials)

Summary



Showing **13 changed files** with **11 additions** and **110 deletions**.

Filter changed files

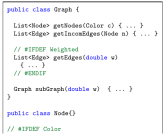
- .github/workflows
  - linux.yml
- doc
  - release/upcoming_changes
    - 24717.change.rst
  - source/reference
    - arrays.ndarray.rst
    - global_state.rst
- meson_options.txt
- numpy
  - _pytesttester.py
  - core
    - config.h.in
    - meson.build
    - numeric.py
    - src/multiarray
      - ctors.c
      - textreading
        - rows.c
    - tests
      - test_multiarray.py
      - test_regression.py

```
            }
            if (not_cf_contig) {
                *objflags = ((*objflags)|NPY_ARRAY_C_CONTIGUOUS) &
```

```
7 numpy/core/src/multiarray/textreading/rows.c
@@ -297,12 +297,7 @@ read_rows(stream *s,
                         */
                        data_array = (PyArrayObject *)PyArray_SimpleNewFromDescr(
                                ndim, result_shape, out_descr);
- #ifdef NPY_RELAXED_STRIDES_DEBUG
-                       /* Incompatible with NPY_RELAXED_STRIDES_DEBUG due to growing */
-                       if (result_shape[0] == 1) {
-                           PyArray_STRIDES(data_array)[0] = row_size;
-                       }
- #endif /* NPY_RELAXED_STRIDES_DEBUG */
+
                        if (data_array == NULL) {
                            goto error;
                        }
```

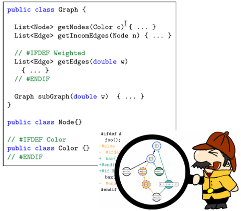
```
25 numpy/core/tests/test_multiarray.py
@@ -3520,8 +3520,6 @@ def test_ravel(self):
        # 1-element tidy strides test:
        a = np.array([[1]])
        a.strides = (123, 432)
-       # If the following stride is not 8, NPY_RELAXED_STRIDES_DEBUG is
-       # messing them up on purpose:
        if np.ones(1).strides == (8,):
            assert_(np.may_share_memory(a.ravel('K'), a))
            assert_equal(a.ravel('K').strides, (a.dtype.itemsize,))
@@ -8032,9 +8030,7 @@ def test_export_record(self):
            assert_equal(y.format, 'T{b:a:=h:b:i:c:l:d:q:dx:B:e:@H:f:=I:g:L:h:Q:h
        else:
            assert_equal(y.format, 'T{b:a:=h:b:i:c:q:d:q:dx:B:e:@H:f:=I:g:Q:h:Q:h
-       # Cannot test if NPY_RELAXED_STRIDES_DEBUG changes the strides
-       if not (np.ones(1).strides[0] == np.iinfo(np.intp).max):
-           assert_equal(y.strides, (sz,))
+       assert_equal(y.strides, (sz,))
```

Proactive Tracing



```
public class Graph {

  List<Node> getNodes(Color c) { ... }
  List<Edge> getIncomEdges(Node n) { ... }

  // #IFDEF Weighted
  List<Edge> getEdges(double w)
    { ... }
  // #ENDIF

  Graph subGraph(double w)  { ... }
}

public class Node{}

// #IFDEF Color
```

Retroactive Tracing



```
public class Graph {

  List<Node> getNodes(Color c) { ... }
  List<Edge> getIncomEdges(Node n) { ... }

  // #IFDEF Weighted
  List<Edge> getEdges(double w)
    { ... }
  // #ENDIF

  Graph subGraph(double w)  { ... }
}

public class Node{}

// #IFDEF Color
public class Color {}
// #ENDIF
```

feature traceability comes with plenty of techniques

no optimal solution (we examined proactive potentials)

potentials in machine learning, necessity for maintenance over time and different artifacts

Thanks!

Feedback, Questions, ...?

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