Paralegal: Practical Static Analysis for Privacy Bugs

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Problem

Existing tools are not practical enough to help developers find subtle privacy bugs.

Practical tools must meet these challenges:

1. Support for relevant privacy policies
2. No changes to code, behavior & performance
3. Policy robust against source code changes
4. Support libraries w/o needing complex models

Approach	1. Flexible	2. Non-invasive	3. Robust	4. Libraries
IFC	✗	✗	✓	✗
Specialized Bug Finder	✗	✓	✓	✓
Runtime Checks	✓	✗	✓	✓
Code Query Engine	✓	✓	✗	✗
Paralegal	✓	✓	✓	✓

Policy: expressive first-order logic policies with legal-document-like syntax

Succinct and auditable

```
Somewhere:
1. For each "data type" marked user_data:
  A. There is a "source"
      that produces "data type" where:
    a. There is a "delete query" marked deletes:
      i) "source" goes to "delete query"
```

Markers: Semantically meaningful terms that connect policy and application code

```
#[paralegal::marker(user_data)]
struct Post { ... }
#[paralegal::marker(user_data)]
struct Comment { ... }
```

Policy does not need to change when code does

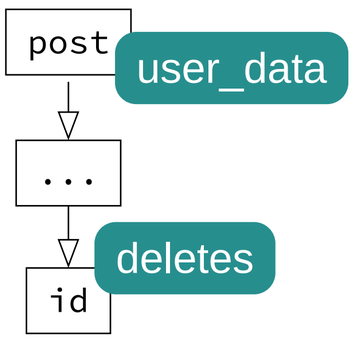
Real bug in Plume app: Devs forgot to delete `Comment`s

Link

Application Code

Receives

Representation: Program Dependence Graph with markers



Handles library modeling, scaling and FFI

Paralegal

Emits

Fixes

Application Developer

Paralegal

```
'Deletion Policy' not satisfied.
No entrypoints satisfied rule 1.A

Entrypoint `delete_user`
  Did not satisfy Rule 1.A
    There is a "source"
    that produces "data type"

  for the "data type" type: `Comment` (Rule 1)
```

Approximation: Rusts types let Paralegal approximate a PDG for any function.

```
fn HashMap::get_mut<'a, 'k, K, V>(&'a mut self,
        key: &'k K) -> Option<'a mut V>
```

- `mut` tells Paralegal only `self` is modified, not `key`
- lifetimes `'a` and `'k` tell Paralegal that `self` and `key` cannot alias

Paralegal finds subtle privacy bugs in real code bases by

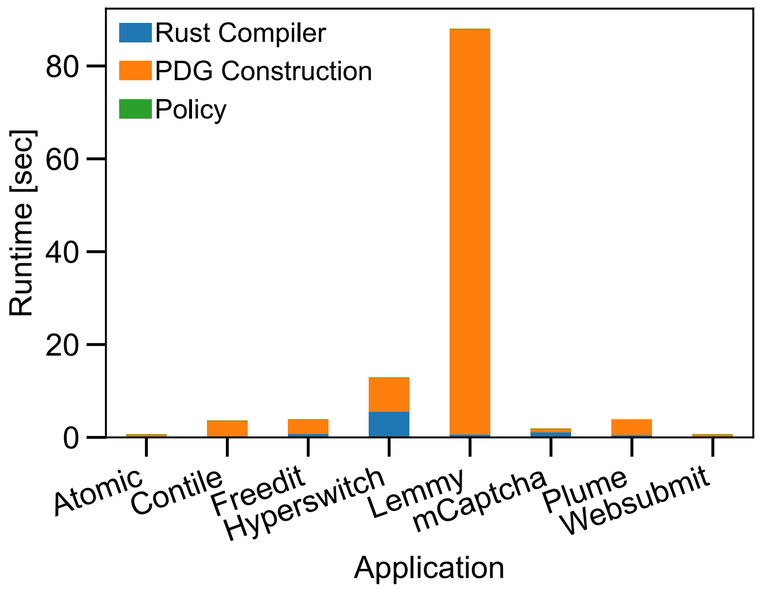
1. **separating concerns between policy writers and developers; and**
2. **leveraging Rust for precise approximations**

Evaluation

Setup: 8 Applications and **11 Policies** (Access Control, Purpose Limitation, Data Deletion, Credential Security, …)

Bugs: Found **7** subtle bugs. **2** new, **5** previously known

Related Work Comparison: IFC fails to express half of the policies. CodeQL only finds half the bugs



Performance

- Full codebase check: <90 seconds
  ⟹ fast enough for CI
- Incremental check: <5 seconds
  ⟹ fast enough for IDE

Paralegal is open source.

github.com/brownsys/paralegal