Evolution-Aware Monitoring-Oriented Programming (eMOP)

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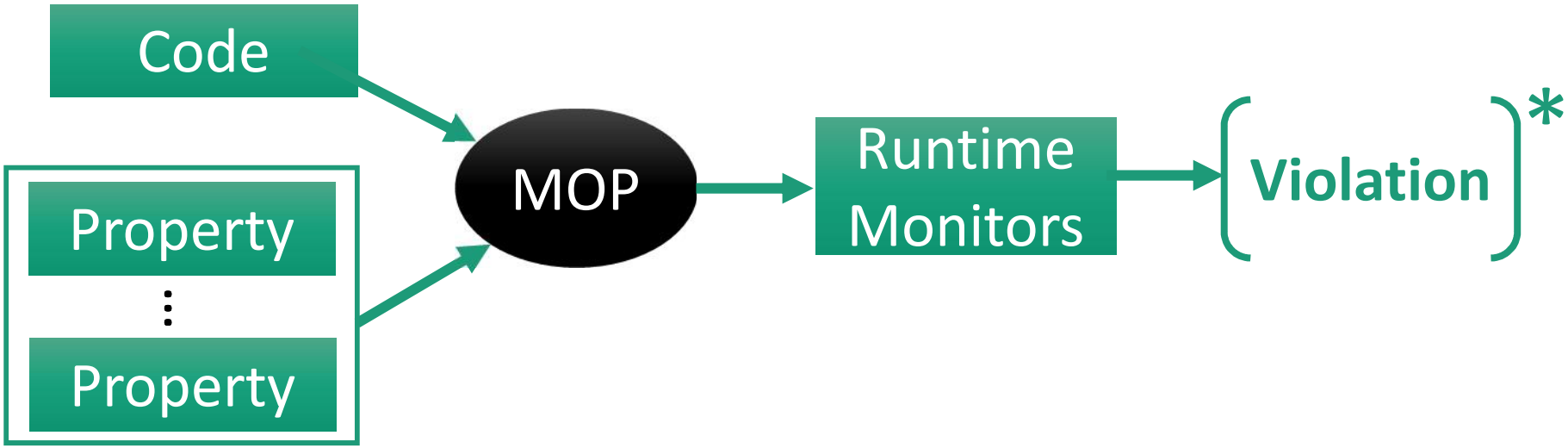
Monitoring-Oriented Programming (MOP)

Runtime monitoring of software against formal properties

- **Existing technique** targeted at single program version

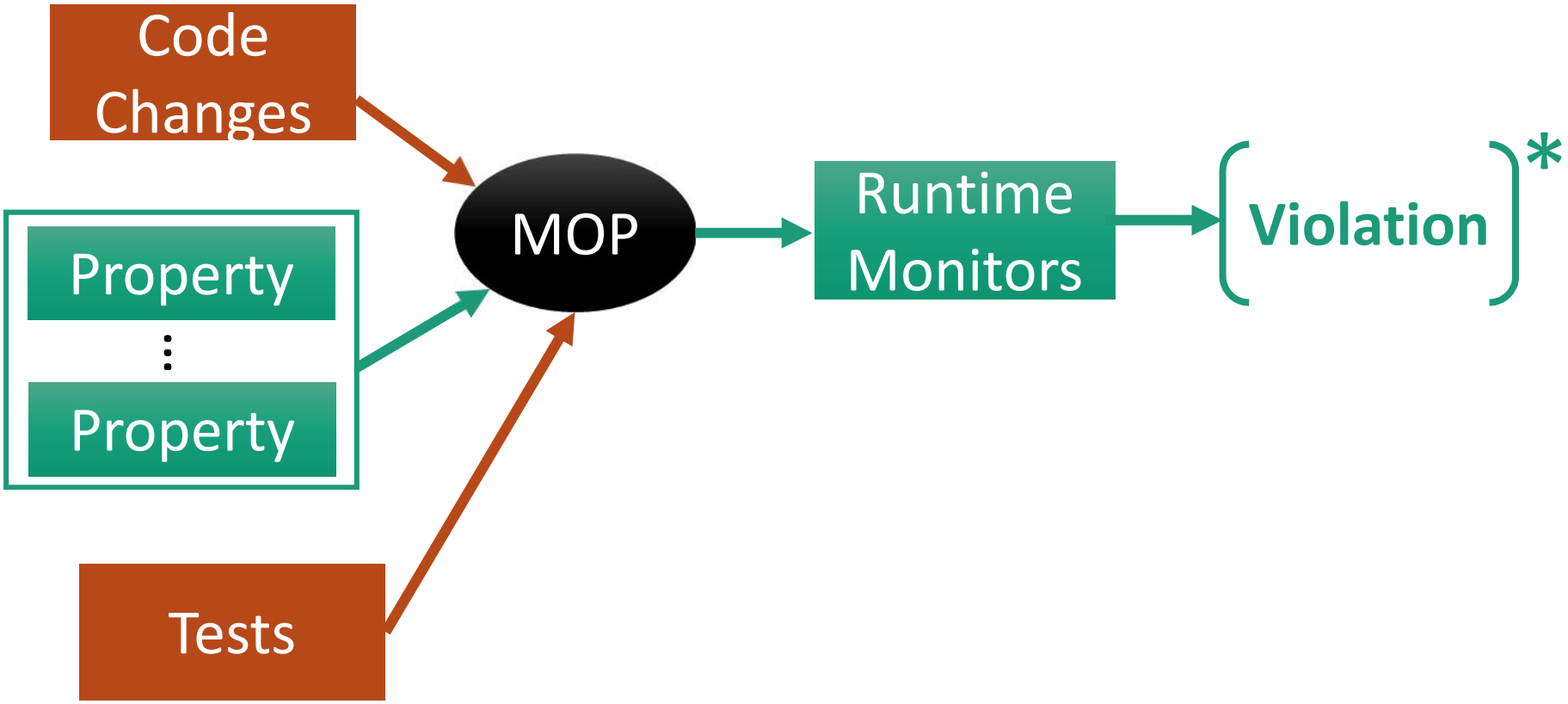


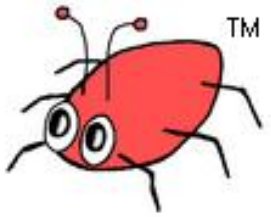
Problems: High overhead and too many violations shown during evolution across many versions

Evolution-Aware MOP (eMOP)

Make MOP **faster** and **show fewer violations** during evolution

- **Proposed**





Input: (Potentially Buggy) Code

```
1 public boolean m(List a, List b) {
2   ...
3   for(Iterator i = a.iterator(); i.hasNext();){
4     ...
5     for(Iterator i2 = b.iterator(); i.hasNext();){
6       ... i2.next() ...
7     }
8   } return ...
9 }
```

Line 5 should be ***i2.hasNext()***

Mimics two real bugs found in older AspectJ code

Input: Formally Specified Properties

1. When to fire Events

after **Iterator.*hasNext() == true,*** before **Iterator.*next()***

2. Specification over Events

Iterator.hasNext() == true precedes every **Iterator.next()**

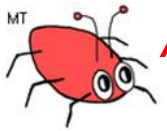
3. Handler code

User-defined action when specification is violated

Many properties can be monitored at once

Output

```
1 public boolean find(List a, List b) {
2   ...
3   for(Iterator i = a.iterator(); i.hasNext();){
4     ...
5     for(Iterator i2 = b.iterator(); i.hasNext();){
        // event: "before Iterator.next()"
6       ... i2.next() ...
7     }
8   } return ...
9 }
```



Violation: *next()* was called without calling ***hasNext()***

Current State of MOP Research

- Many papers, focus on reducing runtime overhead
- Many bugs found in well-used, well-tested code
- **All prior research focused on one version**
  - Recurring costs of monitoring are high, e.g.,

Run	Properties Monitored	Total Violations	Time(s)
No MOP v1	n/a	n/a	8.4
MOP v1	180	**27,895**	**164.1**
MOP v2	180	**27,904**	**231.8**

Evolution-Aware MOP (eMOP)

- Improve MOP during software evolution
  - **Faster:** re-monitor based on parts affected by changes
  - **Show fewer violations:** show only violations due to changes
- We propose three techniques
  - Can be used separately or combined
  - **Property selection**
  - **Monitor selection**
  - **Test selection**

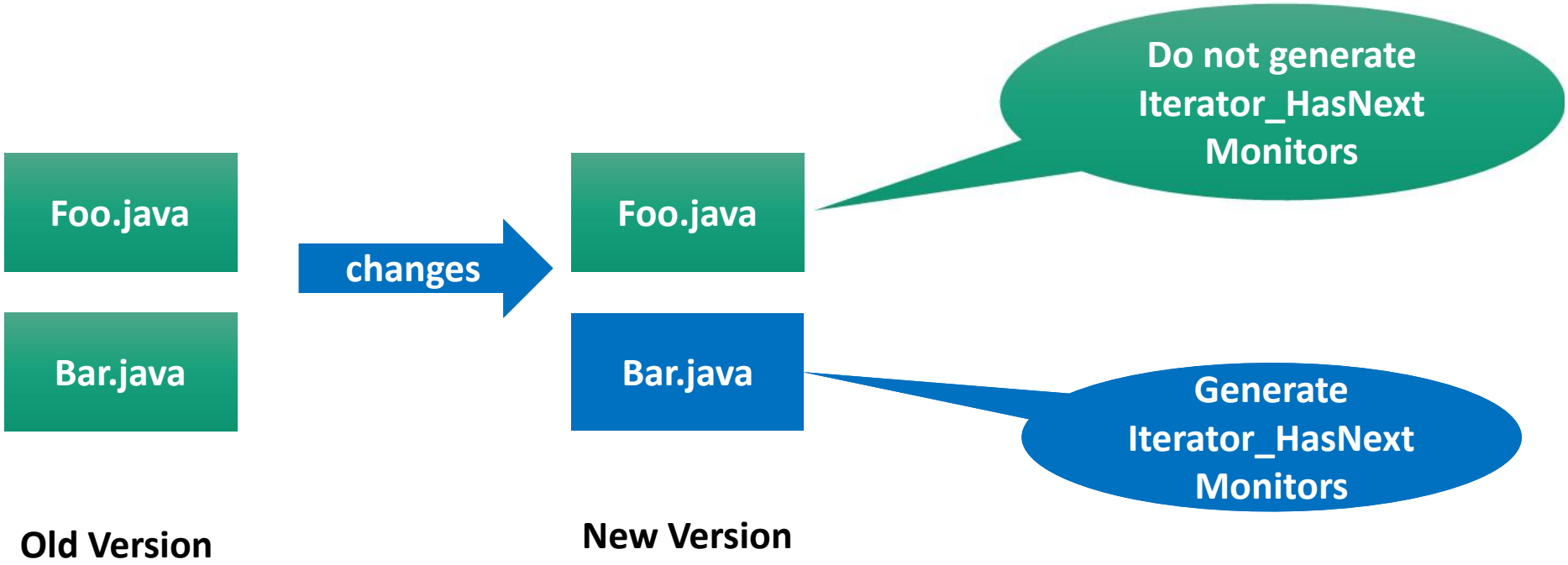
Technique: Property Selection

- What subset of properties to re-monitor in new version?
- Preliminary evaluation by seeding **i2.next()** bug :
  - Only ***Iterator_HasNext*** is affected by changes

Run	Properties Monitored	Properties Violated	HasNext Violations	Total Violations	Time(s)
No MOP v1	n/a	n/a	n/a	n/a	8.4
MOP v1	180	6	0	27,895	164.1
MOP v2	180	7	9	**27,904**	**231.8**
eMOP v2	1	1	9	**9**	**8.8**

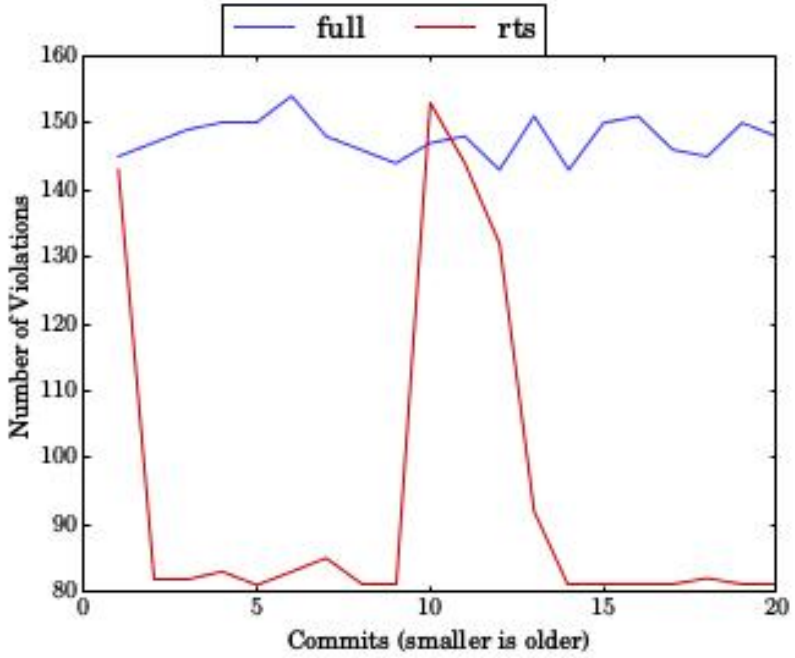
Technique: Monitor Selection

- Generate monitors for parts of code affected by change
- Example: ***Foo.java*** and ***Bar.java*** both use Iterator

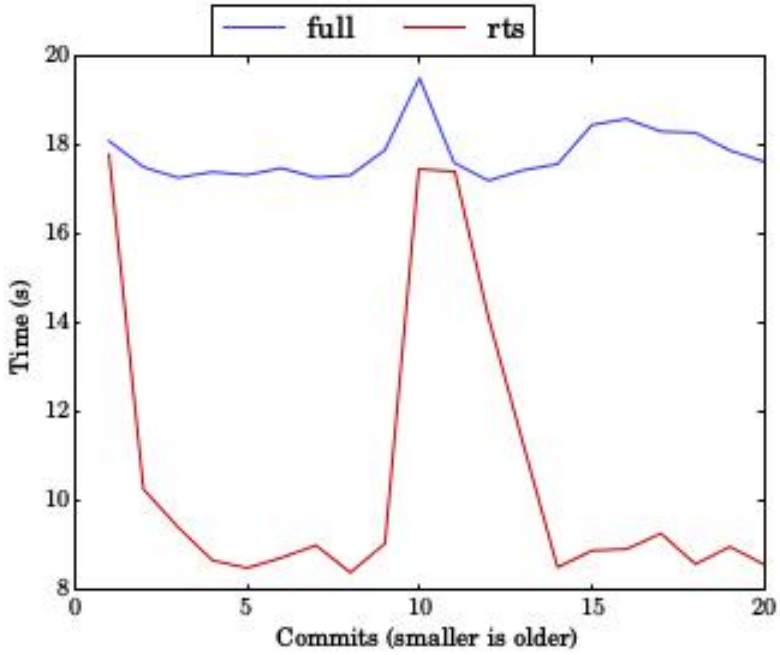


Technique: Test Selection (MOP + RTS)

- In eMOP we monitor execution of tests
  - RTS selects **subset** of tests that can be affected by code changes
  - If fewer tests are run, fewer violations and less overhead



(a) Violation Counts for one project

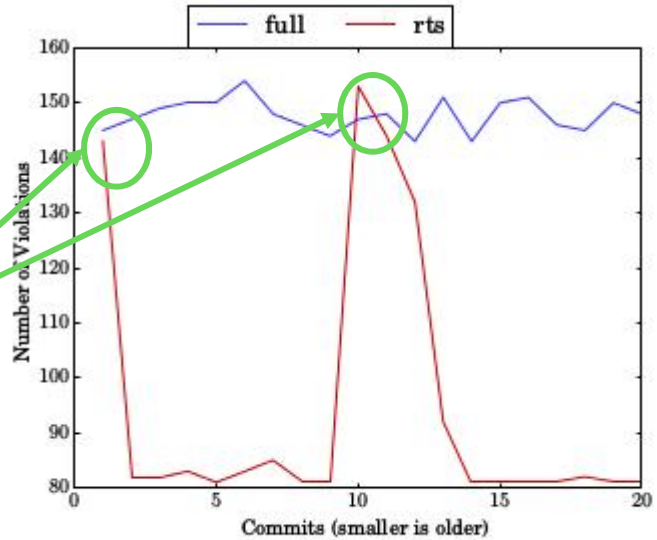


(b) Monitoring Times for one project

Some Challenges

- Safely determining properties/monitors/tests that can't have new violations
- Non-determinism, e.g.,

In these versions, the same tests are run, but different number of violations



(a) Violation Counts for one project

Conclusions

- All prior research on MOP targeted single code versions
- **eMOP** aims to adapt MOP to software evolution
  - Make MOP **faster** between versions of software
  - **Show only violations** due to changes between versions
- We proposed three techniques for eMOP
  - **Property selection**
  - **Monitor selection**
  - **Test selection**