개발자와 상호작용하는 쌍방향 정적 분석 시스템

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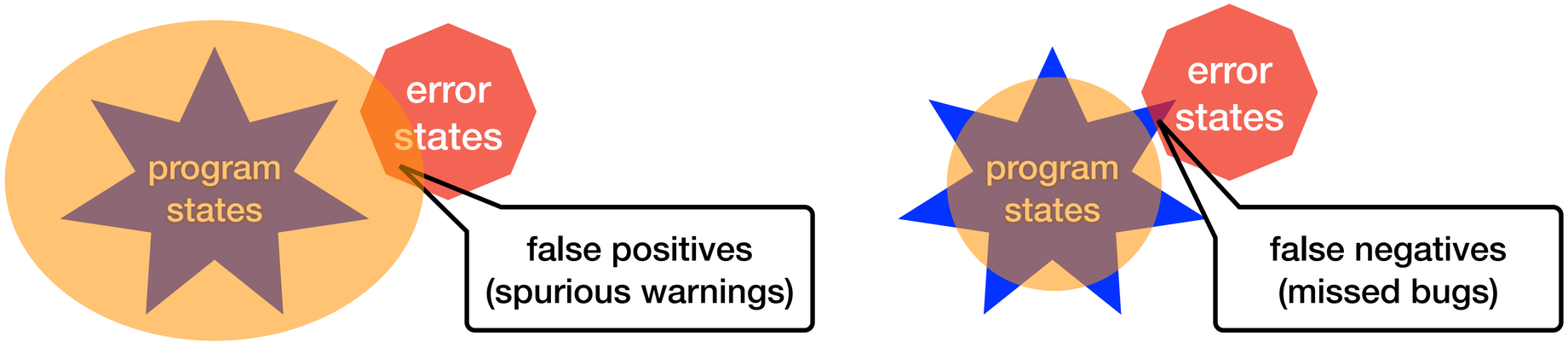
KAIST

소프트웨어 정적 분석

“SW MRI”

- SW 의 동작을 자동으로 예측하는 일반적이고 체계적인 방법
  - 예측: 실행하기 전에 미리 (정적)
  - 자동: 소프트웨어를 분석하는 소프트웨어 (“분석기”)
  - 일반적: 언어와 성질에 국한되지 않음
  - 체계적 : 요약 해석 (abstract interpretation) 이라는 이론에 기반
- 응용: 오류 검출, 검증, 보안, 코드 유지보수, 코드 최적화 등

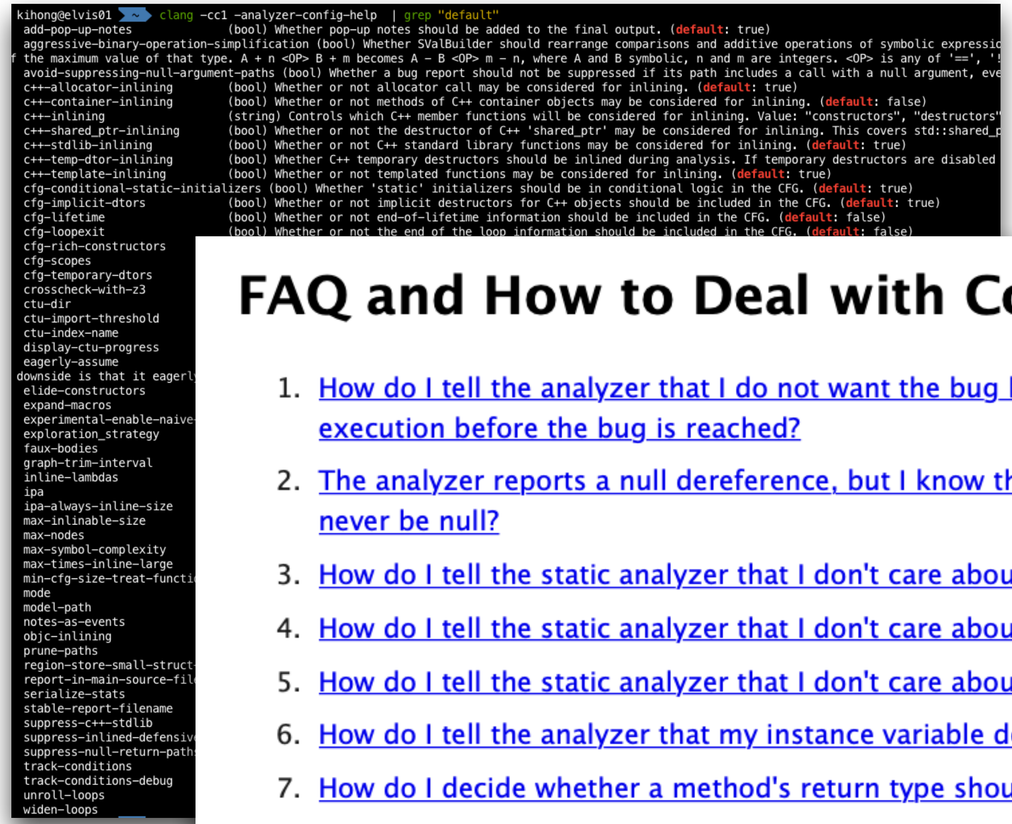
여전한 문제

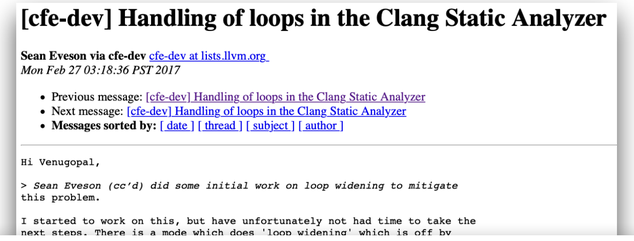


OpenSSL
Cryptography and SSL/TLS Toolkit

> **"…** can be difficult to do without introducing large numbers of ***false positives*****,** or scaling ***performance*** exponentially poorly. In this case, ***balancing*** these … caused us to ***miss the defect*****."**
>
> ***— On Detecting Heartbleed with Static Analysis, (Coverity, 2014)***

정적 분석기 길들이기




[cfe-dev] Handling of loops in the Clang Static Analyzer

Sean Eveson via cfe-dev cfe-dev at lists.llvm.org
Mon Feb 27 03:18:36 PST 2017

- Previous message: [cfe-dev] Handling of loops in the Clang Static Analyzer
- Next message: [cfe-dev] Handling of loops in the Clang Static Analyzer
- **Messages sorted by:** [date] [thread] [subject] [author]

Hi Venugopal,

> *Sean Eveson (cc'd) did some initial work on loop widening to mitigate*
this problem.

I started to work on this, but have unfortunately not had time to take the
next steps. There is a mode which does 'loop widening' which is off by

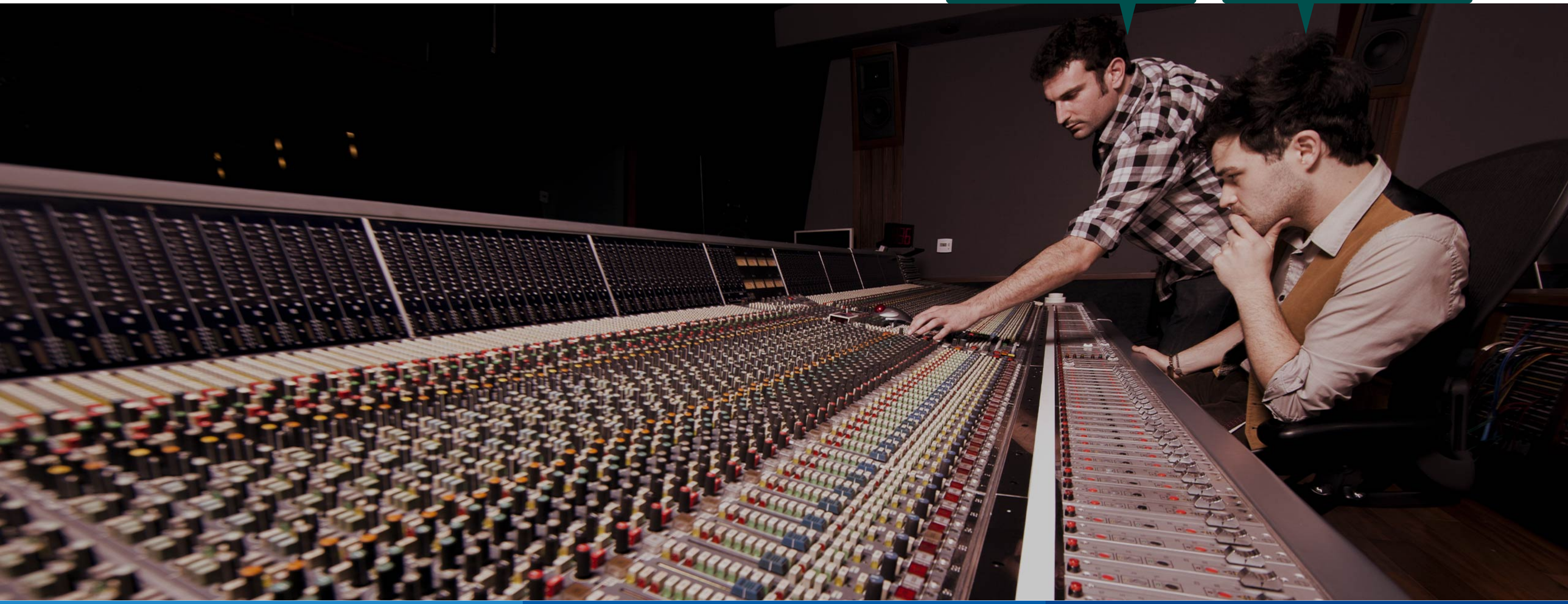
FAQ and How to Deal with Common False Positives

1. How do I tell the analyzer that I do not want the bug being reported here since my custom error handler will safely end the execution before the bug is reached?
2. The analyzer reports a null dereference, but I know that the pointer is never null. How can I tell the analyzer that a pointer can never be null?
3. How do I tell the static analyzer that I don't care about a specific dead store?
4. How do I tell the static analyzer that I don't care about a specific unused instance variable in Objective C?
5. How do I tell the static analyzer that I don't care about a specific unlocalized string?
6. How do I tell the analyzer that my instance variable does not need to be released in -dealloc under Manual Retain/Release?
7. How do I decide whether a method's return type should be _Nullable or _Nonnull?
8. How do I tell the analyzer that I am intentionally violating nullability?
9. The analyzer assumes that a loop body is never entered. How can I tell it that the loop body will be entered at least once?
10. How can I suppress a specific analyzer warning?
11. How can I selectively exclude code the analyzer examines?

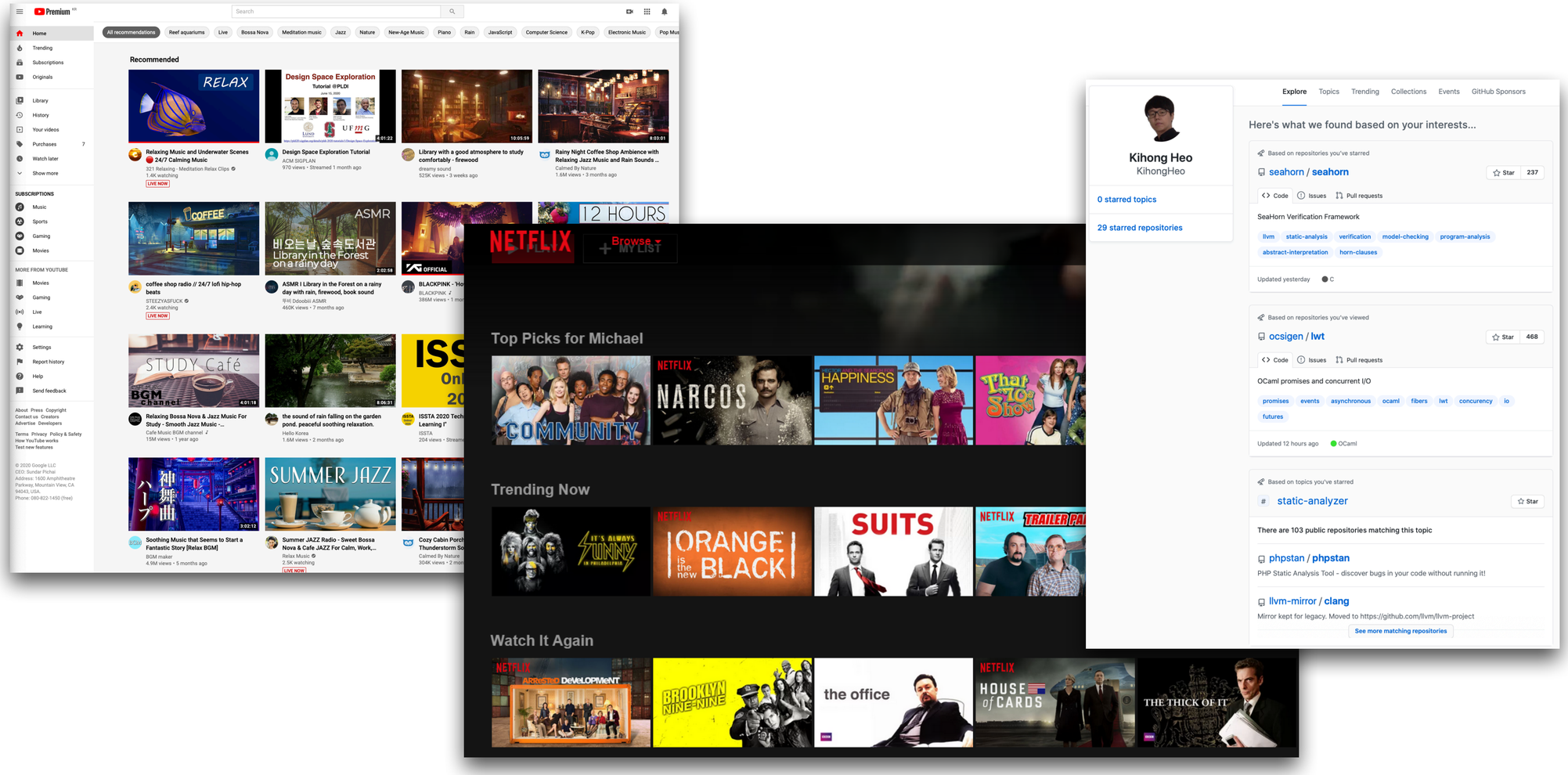
세상에 나쁜 정적 분석은 없다

정적 분석 훈련사

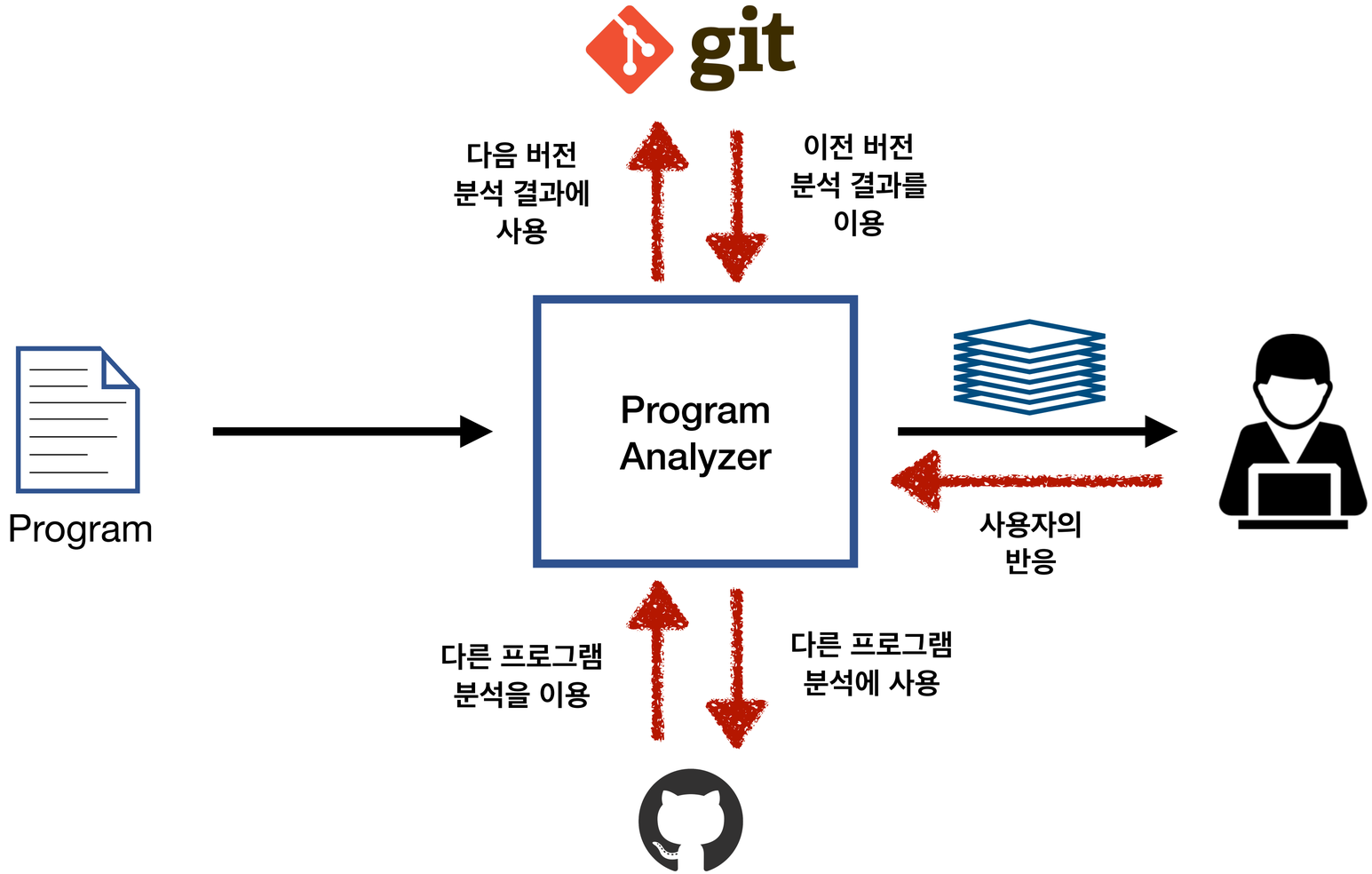
의뢰인 개발자



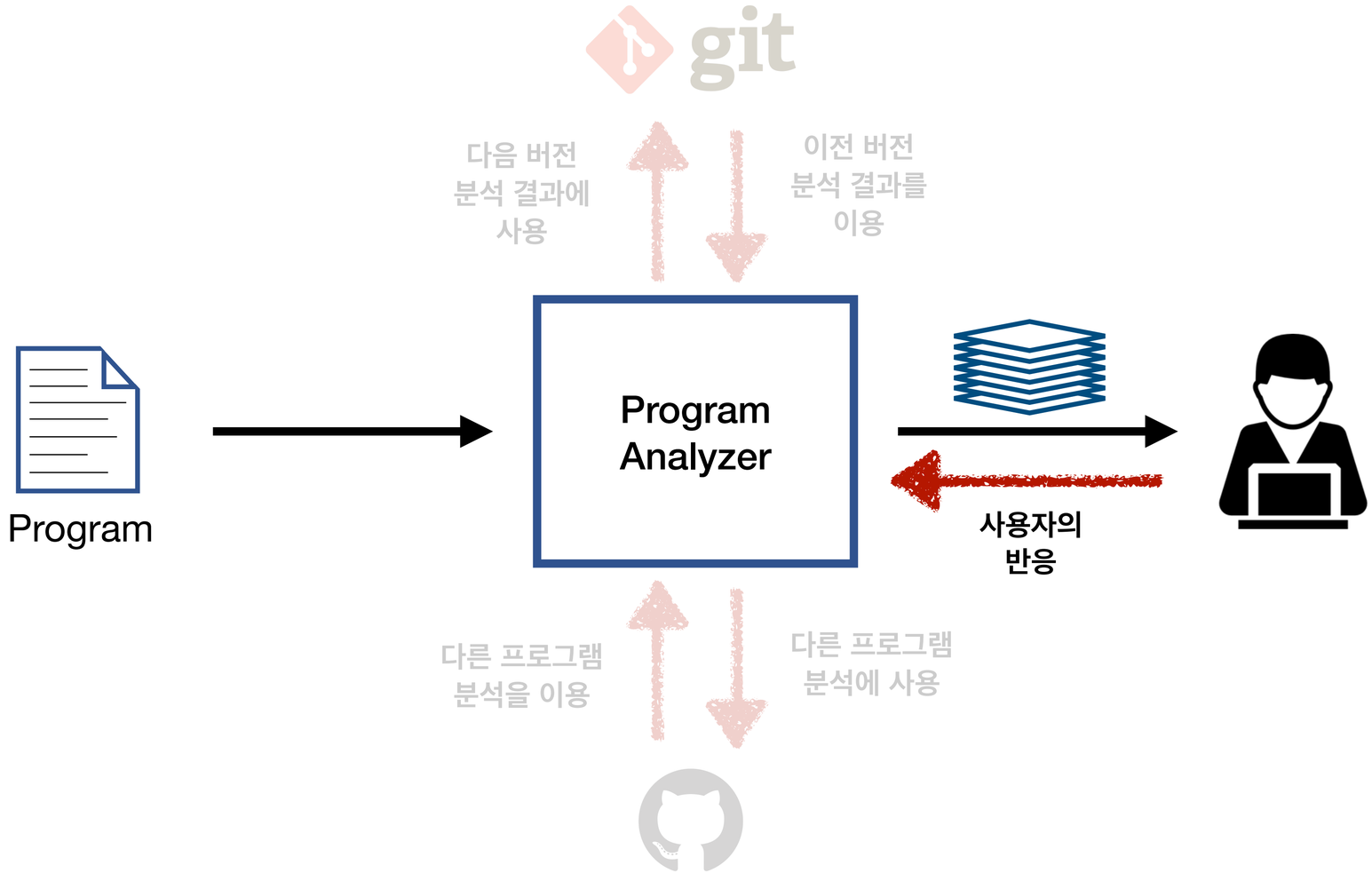
상호작용 시스템 (다른 분야)



정적 분석의 상호 작용


git
다음 버전
분석 결과에
사용
이전 버전
분석 결과를
이용
Program
Program
Analyzer
사용자의
반응
다른 프로그램
분석을 이용
다른 프로그램
분석에 사용

정적 분석의 상호 작용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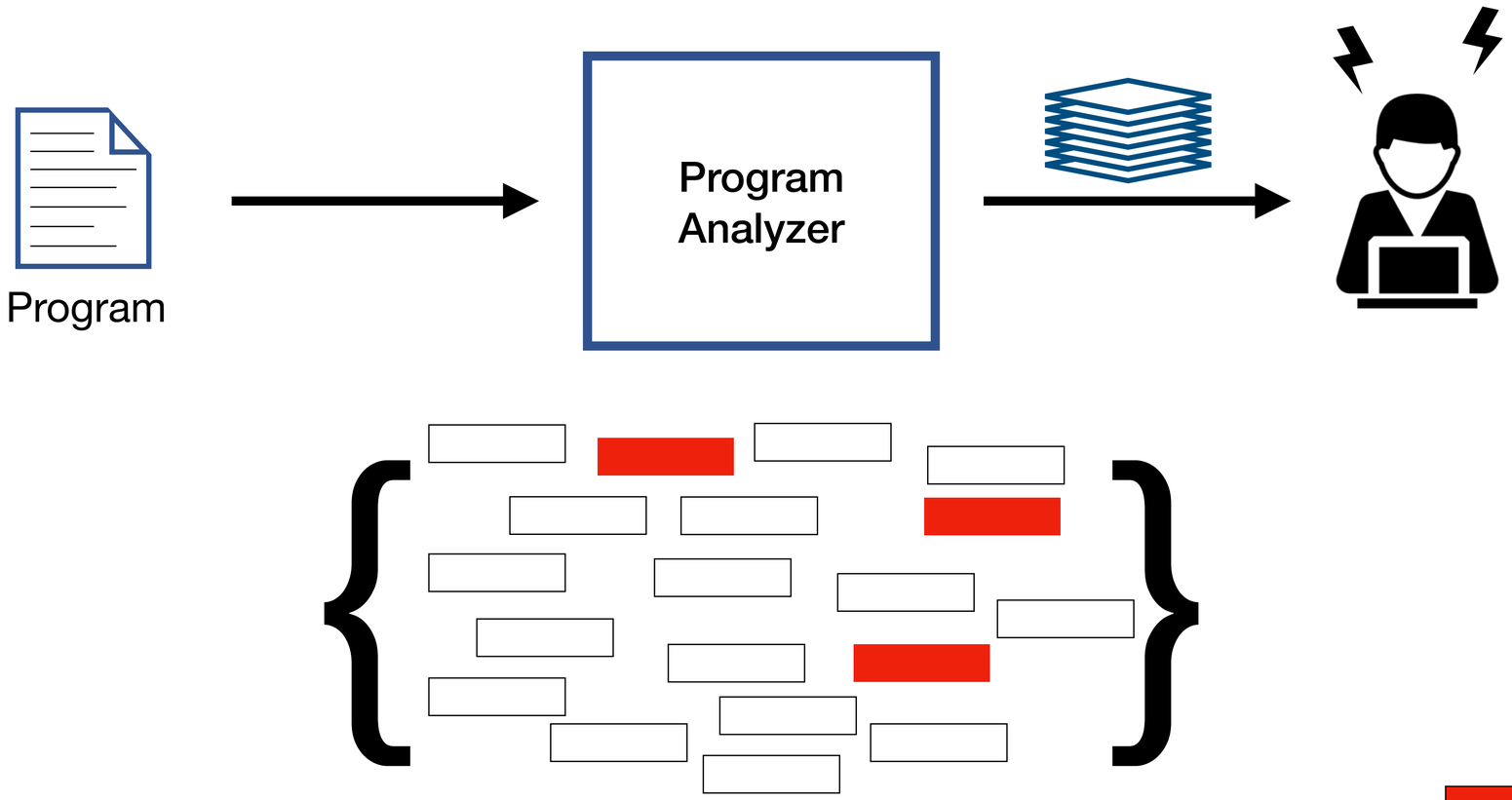
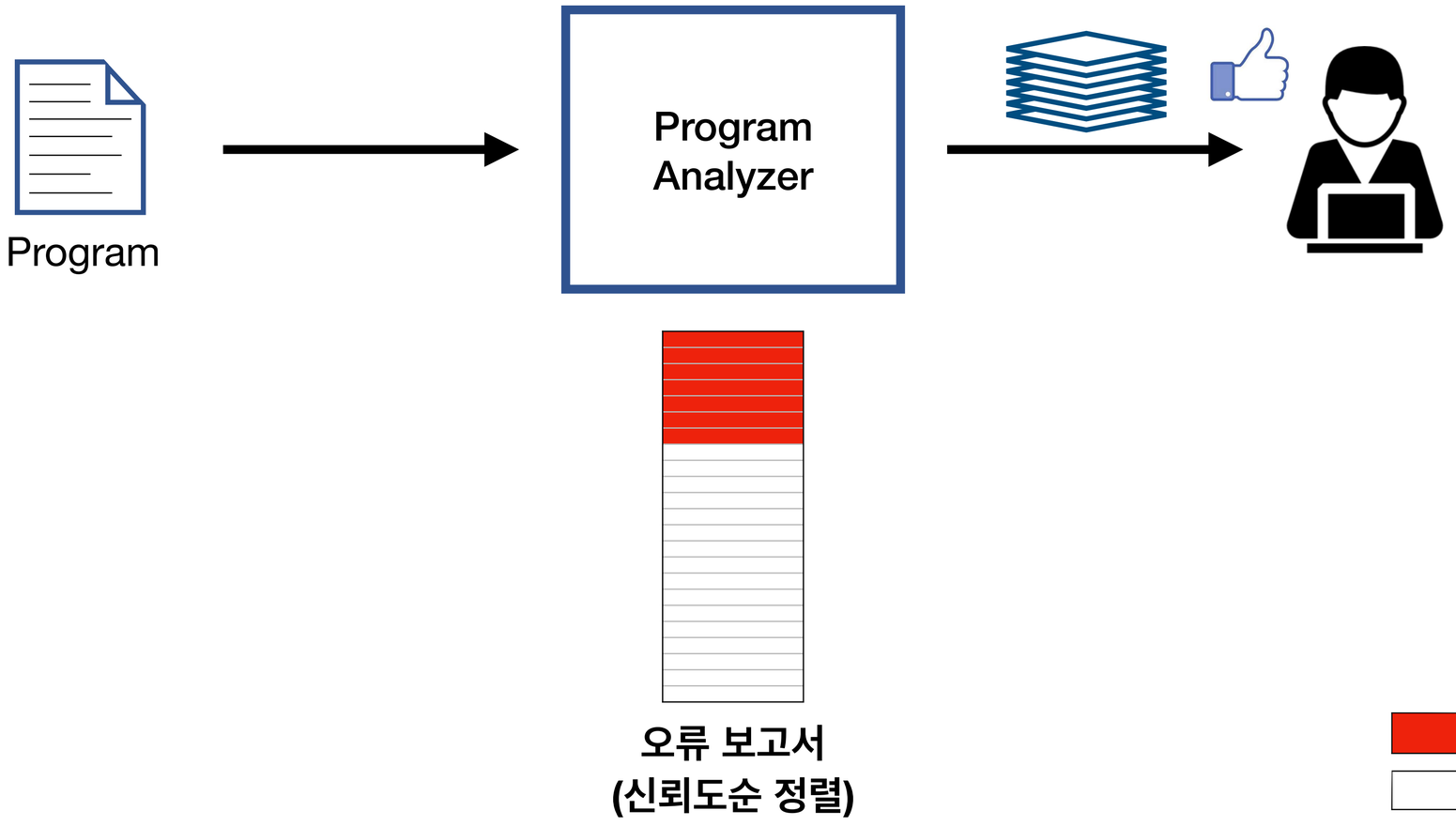
분석에 사용

Bingo: 사용자와 상호작용하는 정적 분석 [PLDI'18]

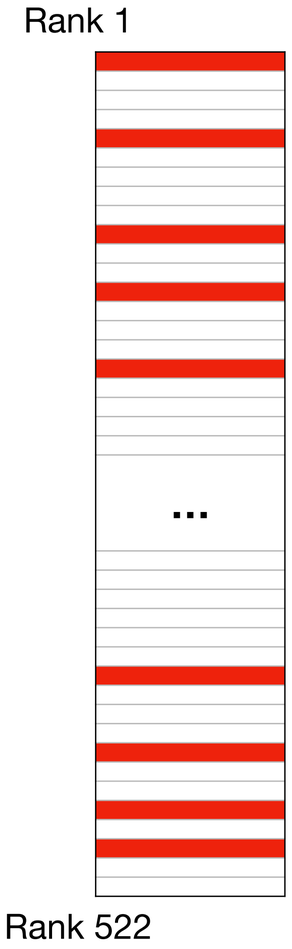
고질적인 문제점



목표



반응형 오류 보고

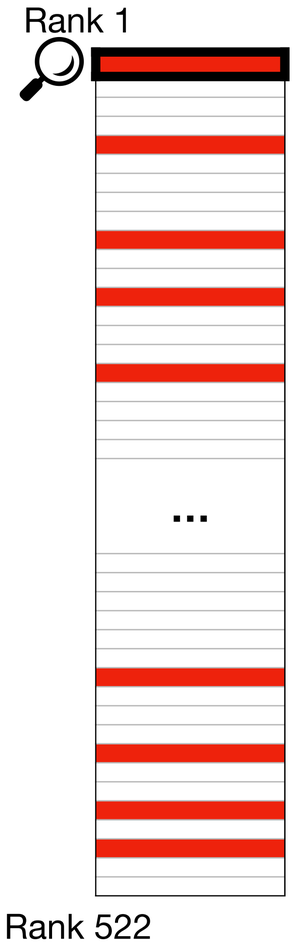


152KLOC
75 Datarace Bugs
522 Total Alarms

Bug

False Alarm

반응형 오류 보고



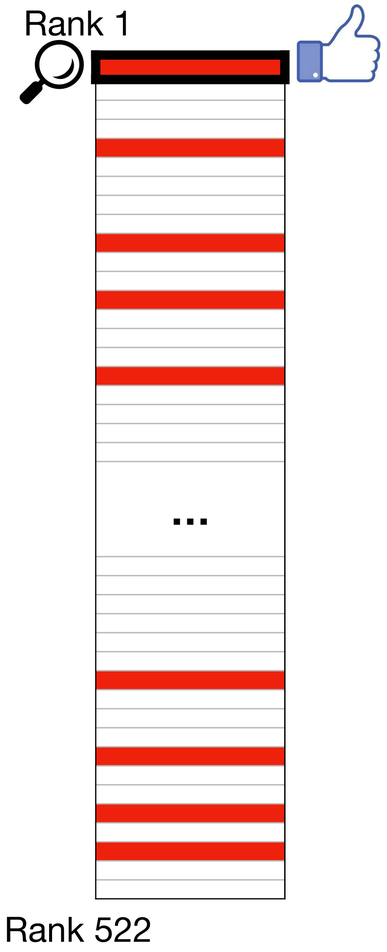
Apache FtpServer

152KLOC
75 Datarace Bugs
522 Total Alarms

Bug

False Alarm

반응형 오류 보고



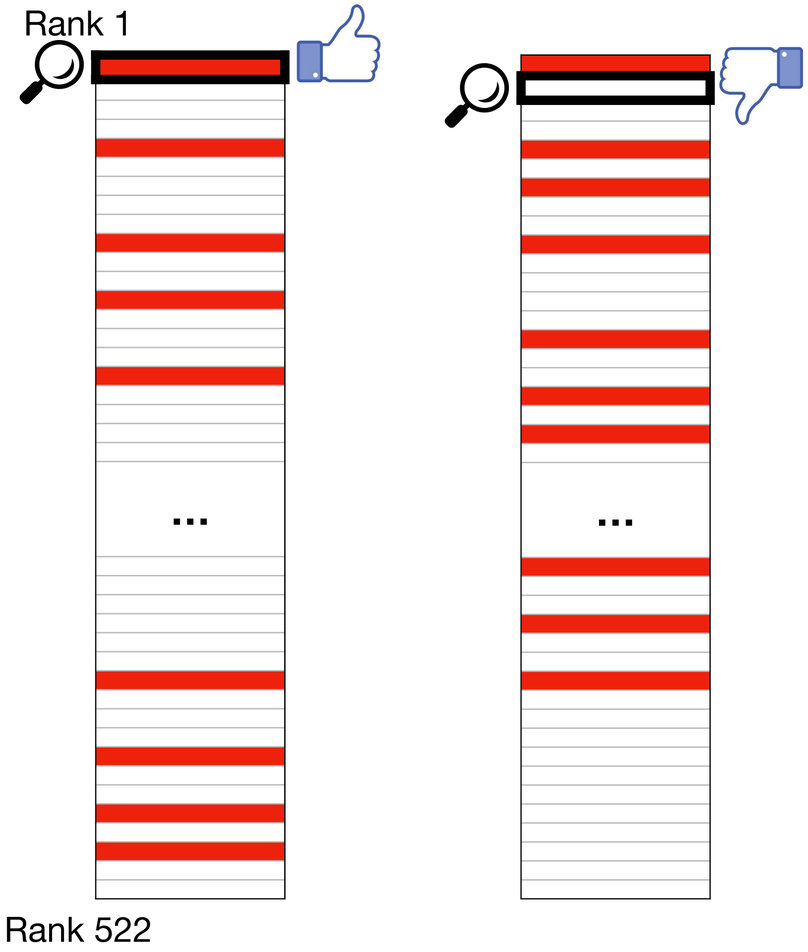
Apache FtpServer

152KLOC
75 Datarace Bugs
522 Total Alarms

Bug

False Alarm

반응형 오류 보고

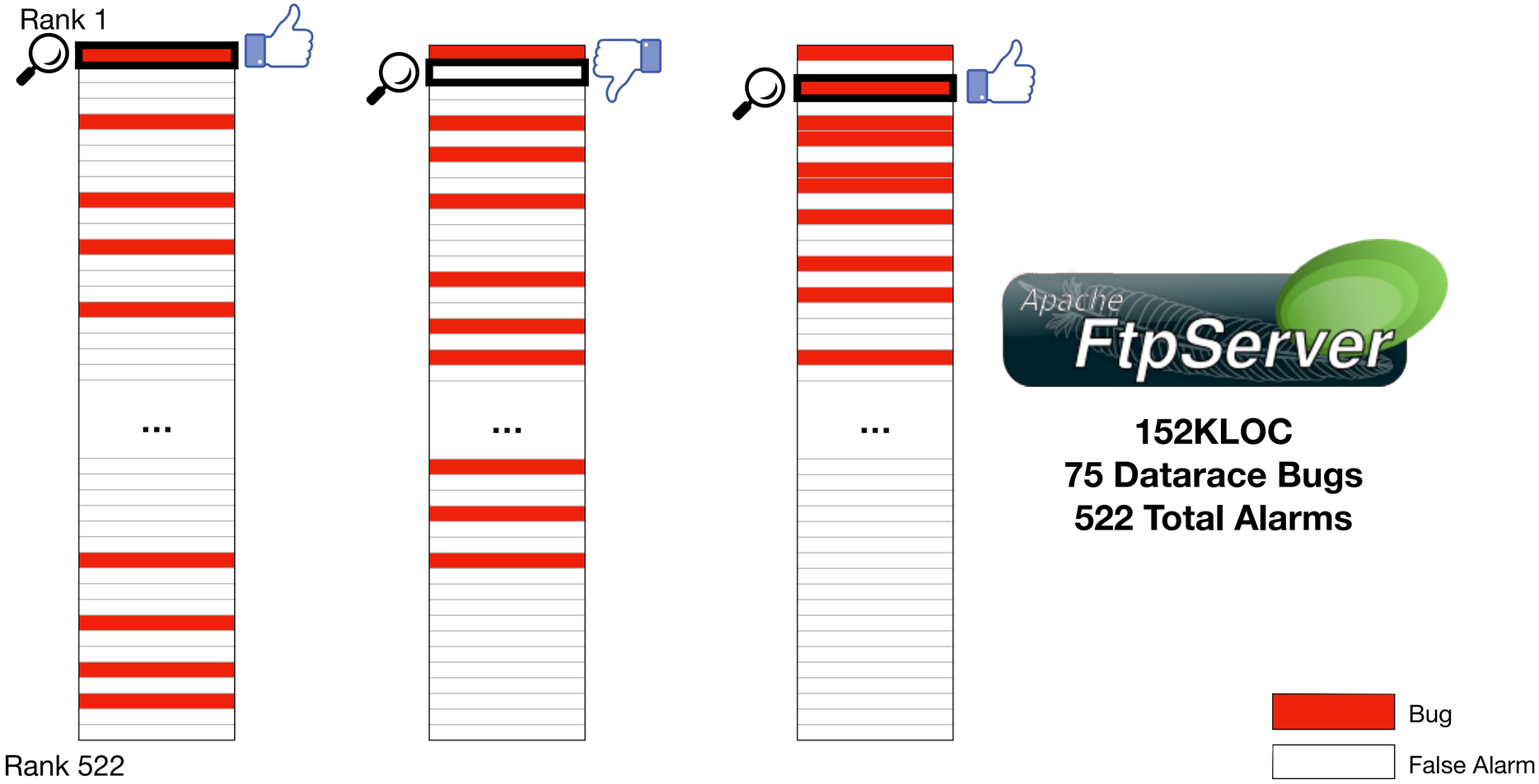


152KLOC
75 Datarace Bugs
522 Total Alarms

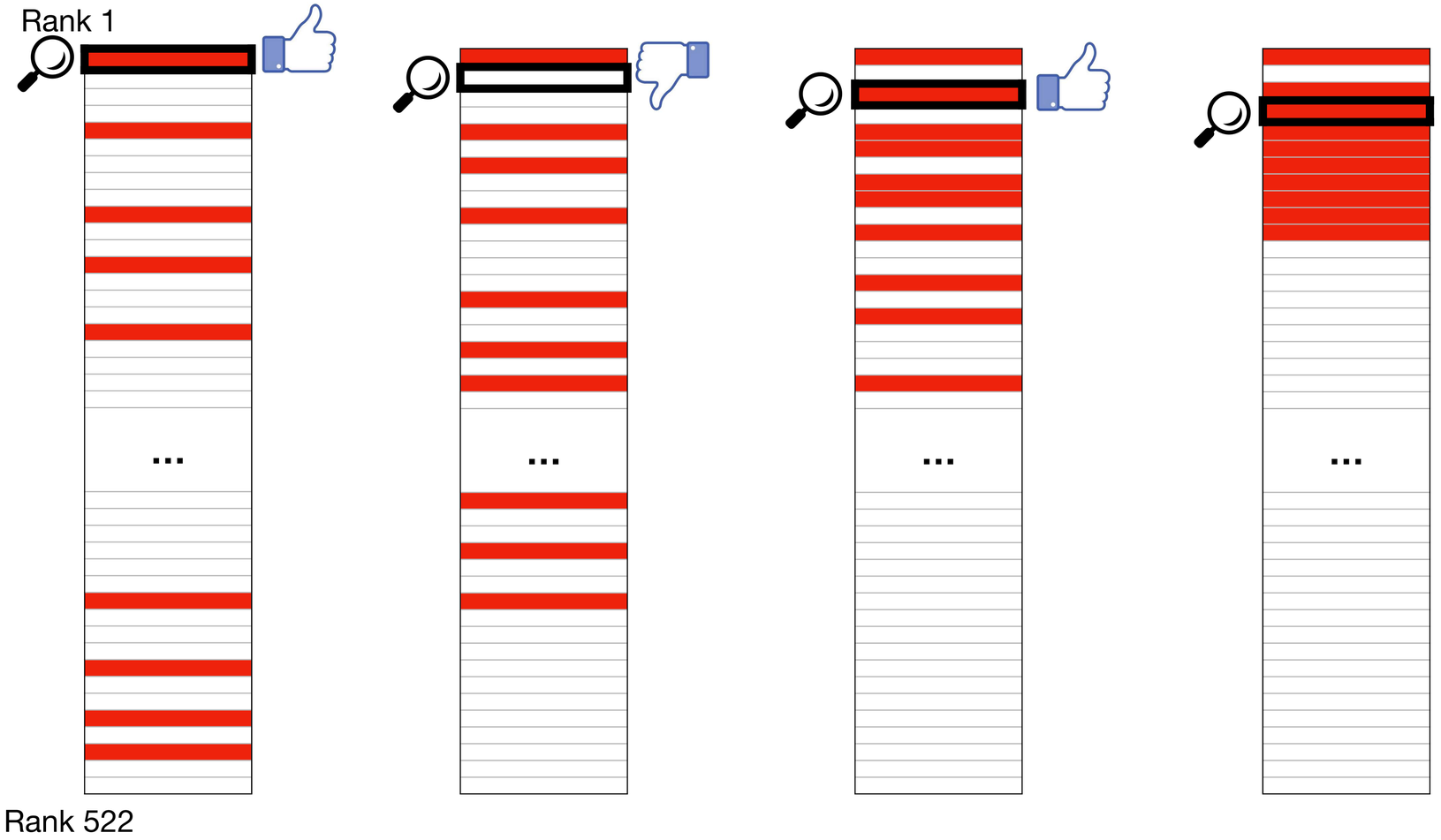
Bug

False Alarm

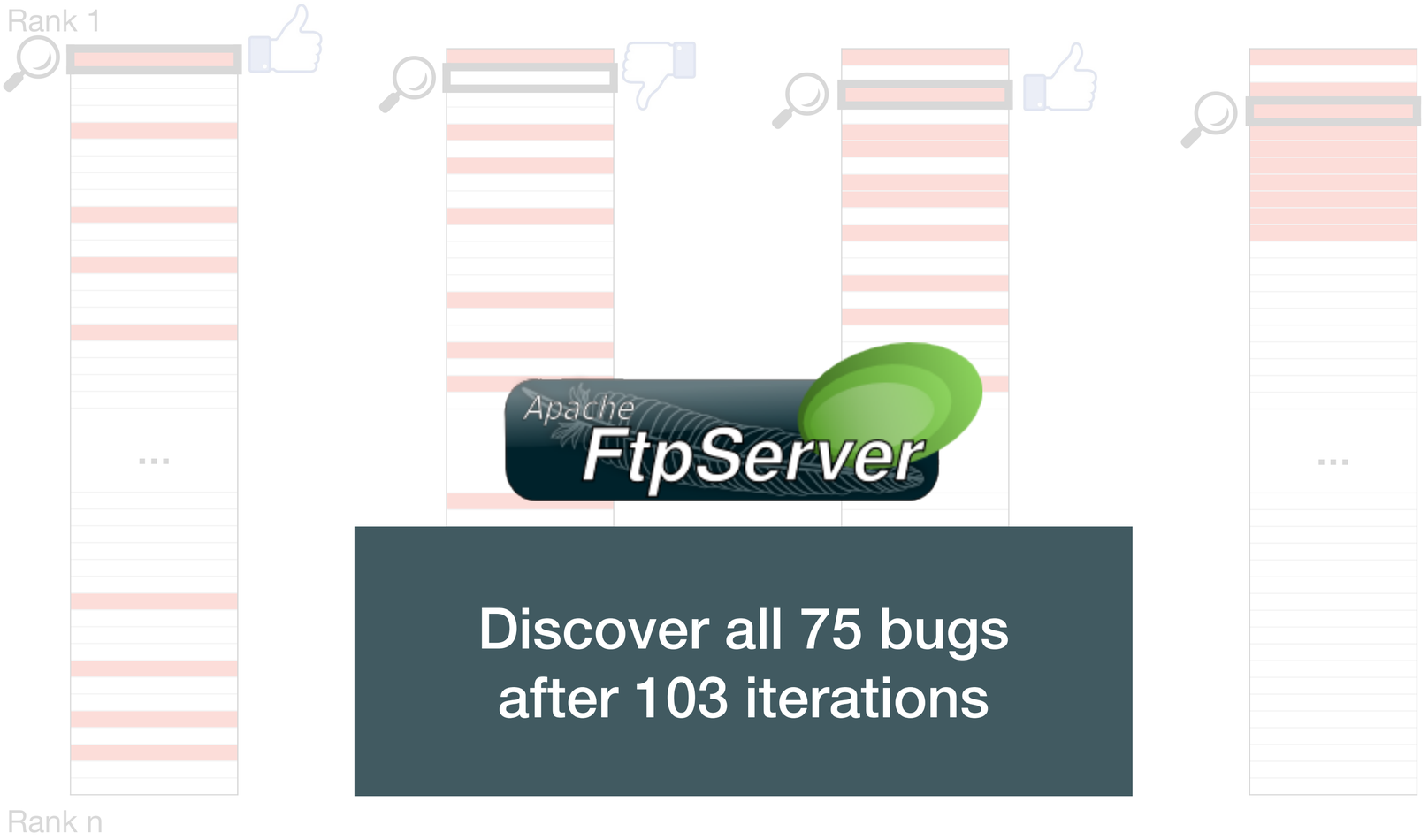
반응형 오류 보고


Rank 1
...
...
...
Rank 522
Apache
FtpServer
152KLOC
75 Datarace Bugs
522 Total Alarms
Bug
False Alarm

반응형 오류 보고

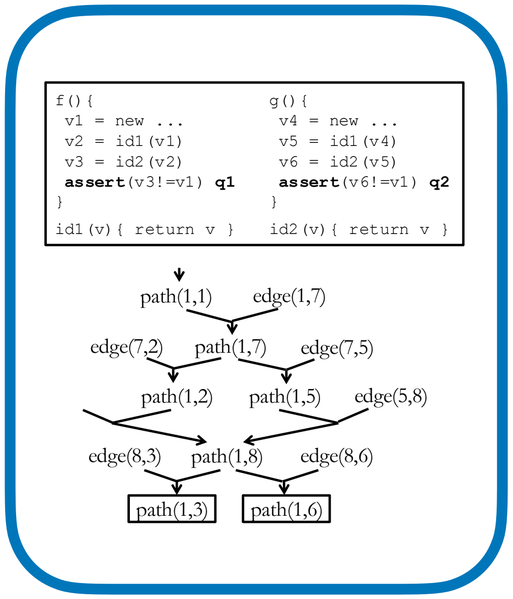


반응형 오류 보고

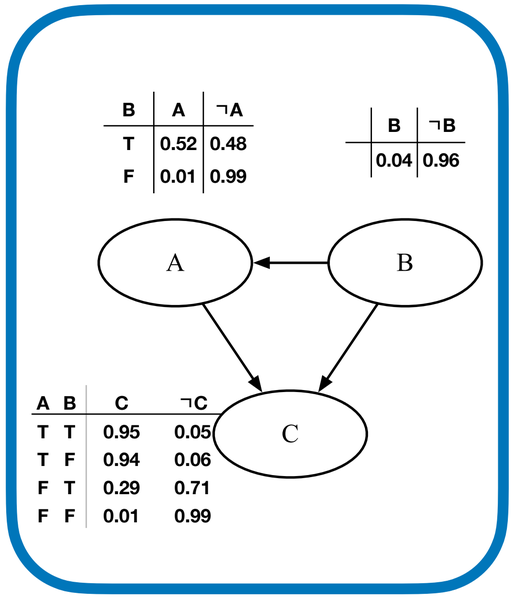

Rank 1
...
Rank n
Apache
FtpServer
...
Discover all 75 bugs
after 103 iterations

핵심 기술

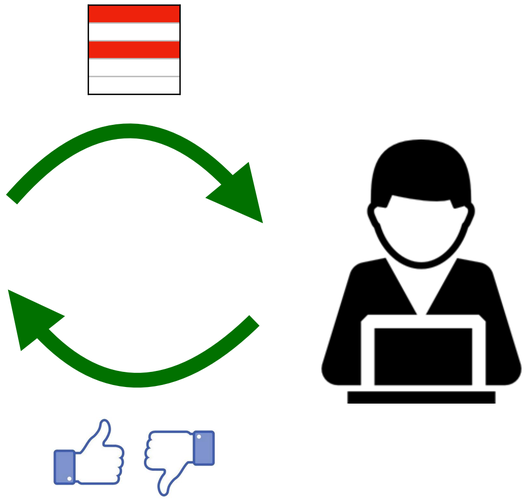
인간-분석 상호 작용 + 베이지안 추론 (Bayesian inference)



분석 결과



확률 모델
(e.g., Bayesian Network)



사용자

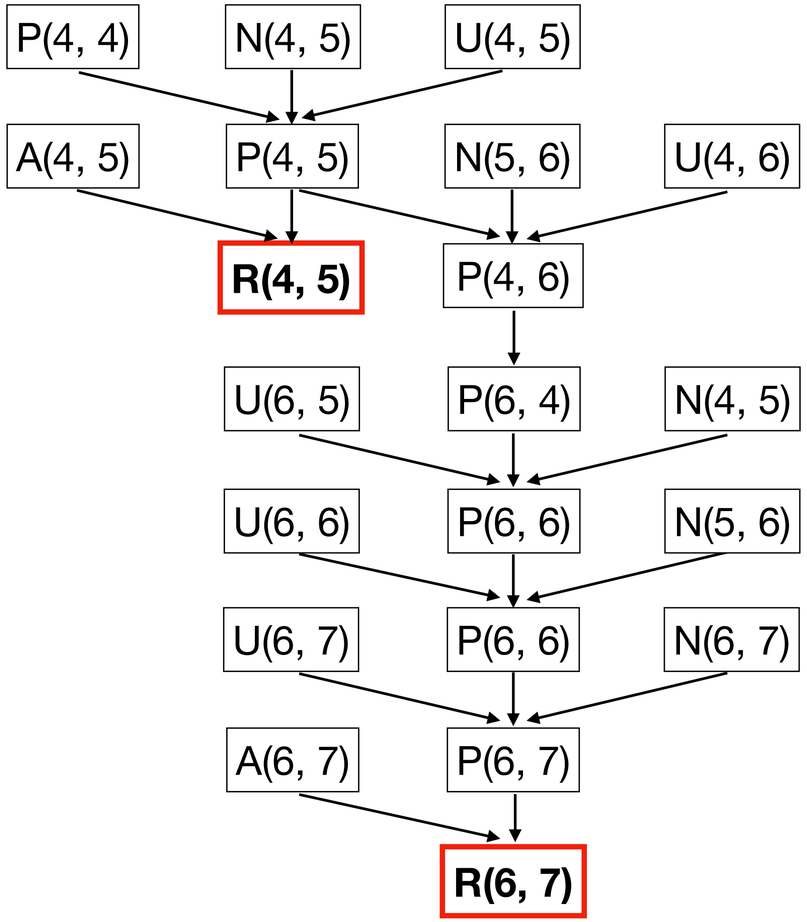
순위 기반 오류 보고서

```
public class RequestHandler {
 private FtpRequest request;

 public FtpRequest getRequest() {
  return request;                    //L0
 }

 public void close() {
  synchronized (this) {              //L1
   if (isClosed) return;             //L2
   isClosed = true;                  //L3
  }
  controlSocket.close();             //L4
  controlSocket = null;              //L5
  request.clear();                   //L6
  request = null;                    //L7
 }
}
```

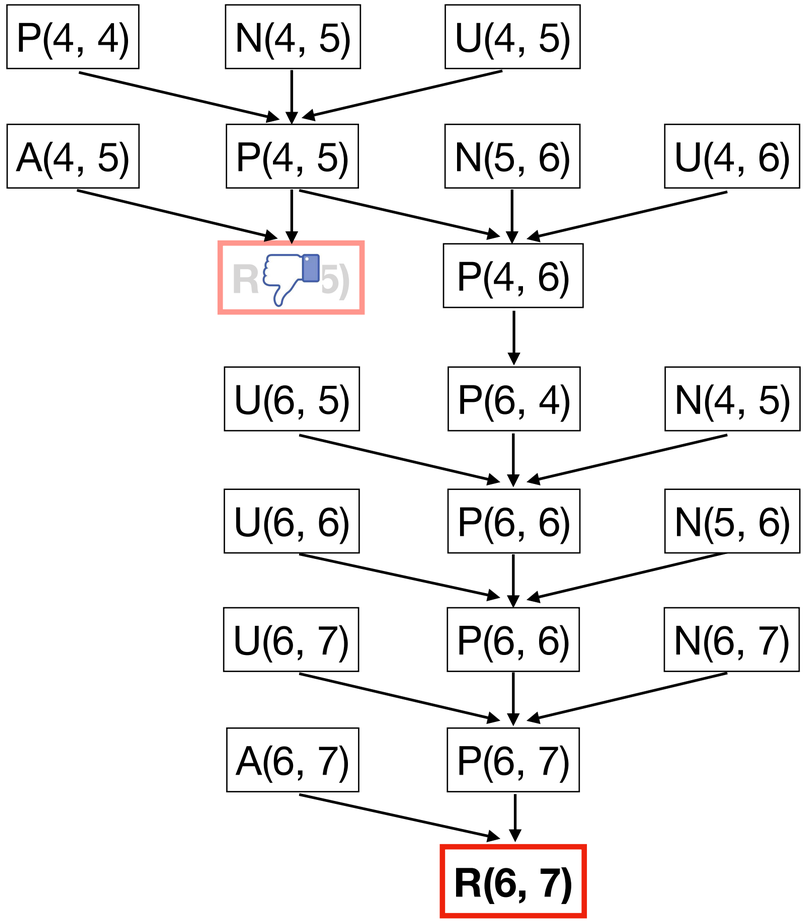
Ranking	Alarm	Confidence
1	R(4, 5)	0.398
2	R(5, 5)	0.378
3	R(6, 7)	0.324
4	R(7, 7)	0.308
5	R(0, 7)	0.279

Q: What are the probabilities of the other alarms when R(4,5) is false?

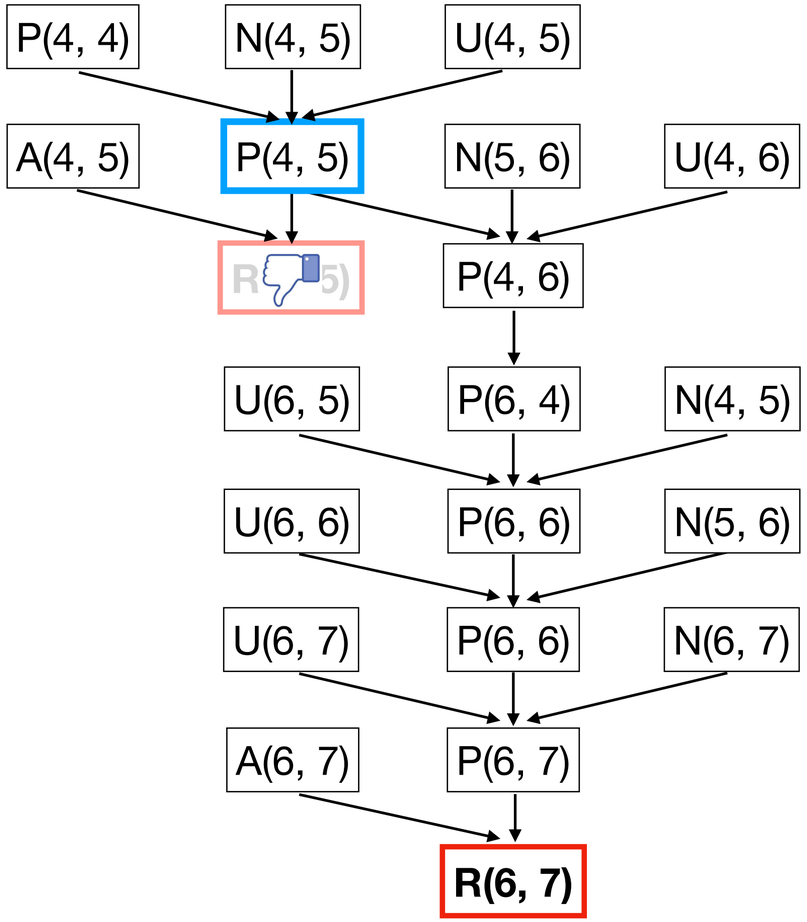
사용자의 반응에 따른 변화



사용자의 반응에 따른 변화

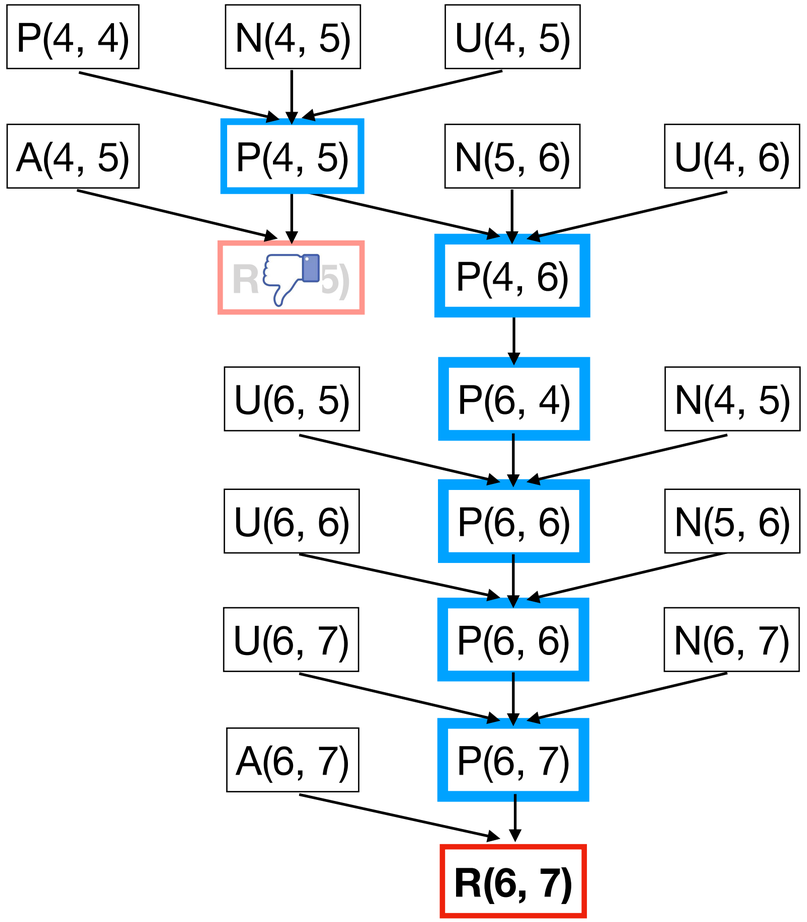


사용자의 반응에 따른 변화



Pr(P(4,5) | ¬R(4,5))
= *Pr*(¬R(4,5) | P(4,5)) *
Pr(P(4,5)) / *Pr*(¬R(4,5))
= 0.03

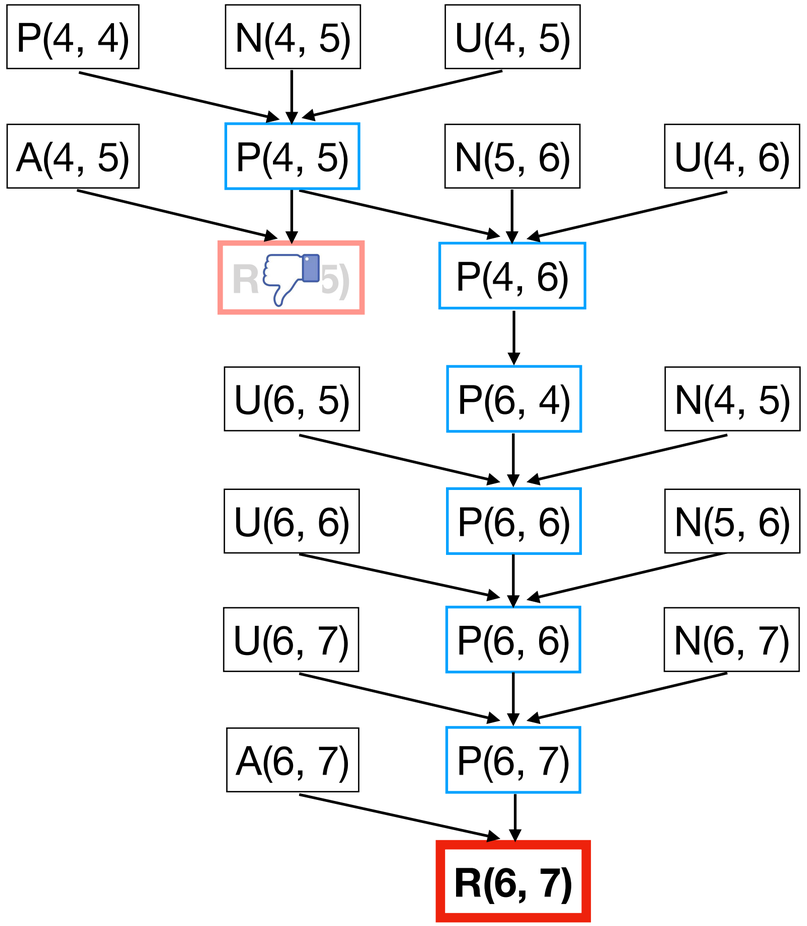
사용자의 반응에 따른 변화



Pr(P(4,5) | ¬R(4,5))
= *Pr*(¬R(4,5) | P(4,5)) *
Pr(P(4,5)) / *Pr*(¬R(4,5))
= 0.03

By Bayes's Rule:
Pr(A|B) = *Pr*(B|A) * *Pr*(A) / *Pr*(B)

사용자의 반응에 따른 변화



Pr(P(4,5) | ¬R(4,5))
= *Pr*(¬R(4,5) | P(4,5)) *
Pr(P(4,5)) / *Pr*(¬R(4,5))
= 0.03

By Bayes's Rule:
***Pr*(A|B) = *Pr*(B|A) * *Pr*(A) / *Pr*(B)**

Pr(R(6,7) | ¬R(4,5))
= *Pr*(R(6,7) | P(4,5)) *
Pr(P(4,5)) | ¬R(4,5))
= 0.03

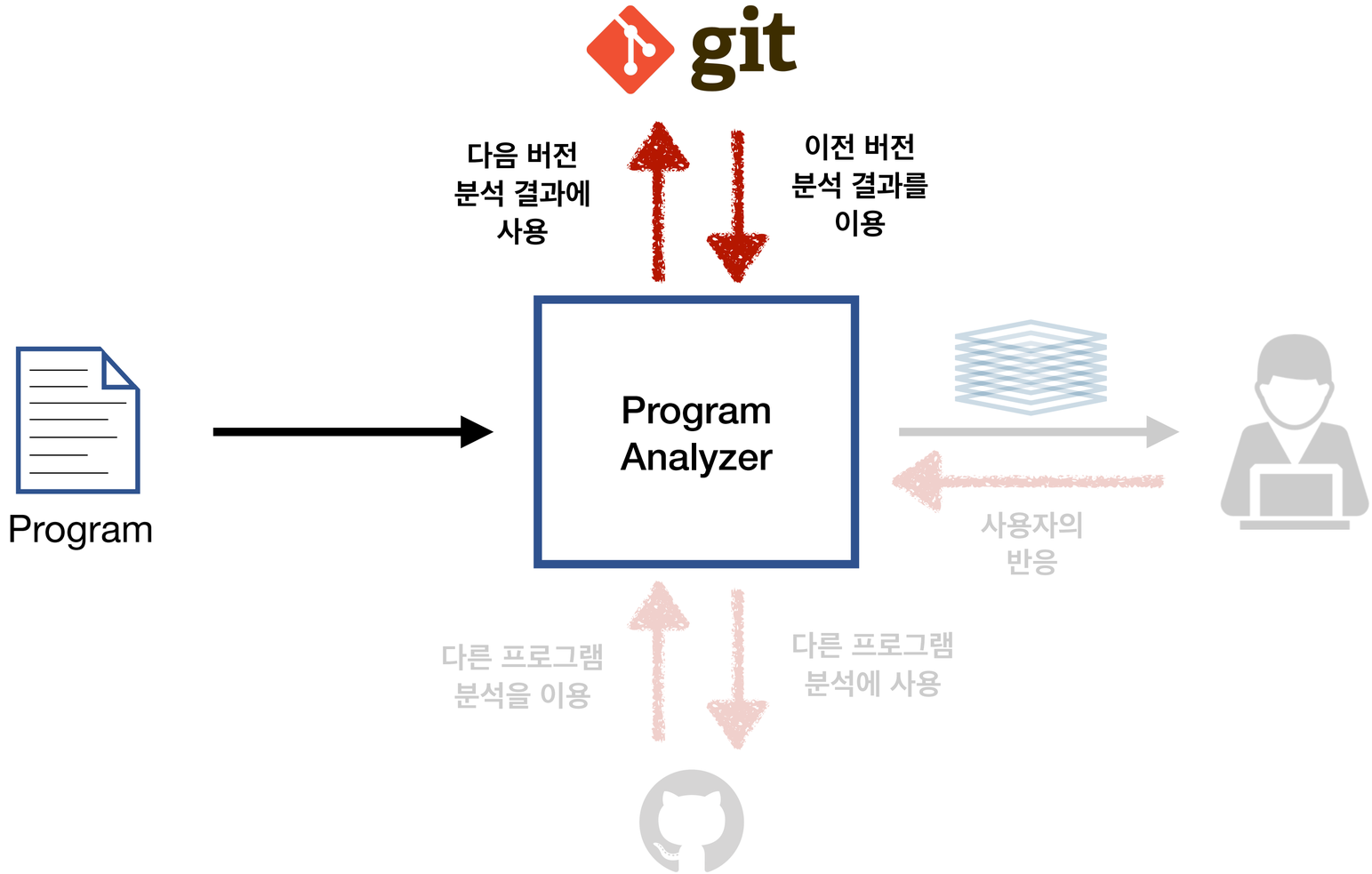
기존 순위

Ranking	Alarm	Confidence
1	R(4, 5)	0.398
2	R(5, 5)	0.378
3	R(6, 7)	0.324
4	R(7, 7)	0.308
5	R(0, 7)	0.279

개선된 순위

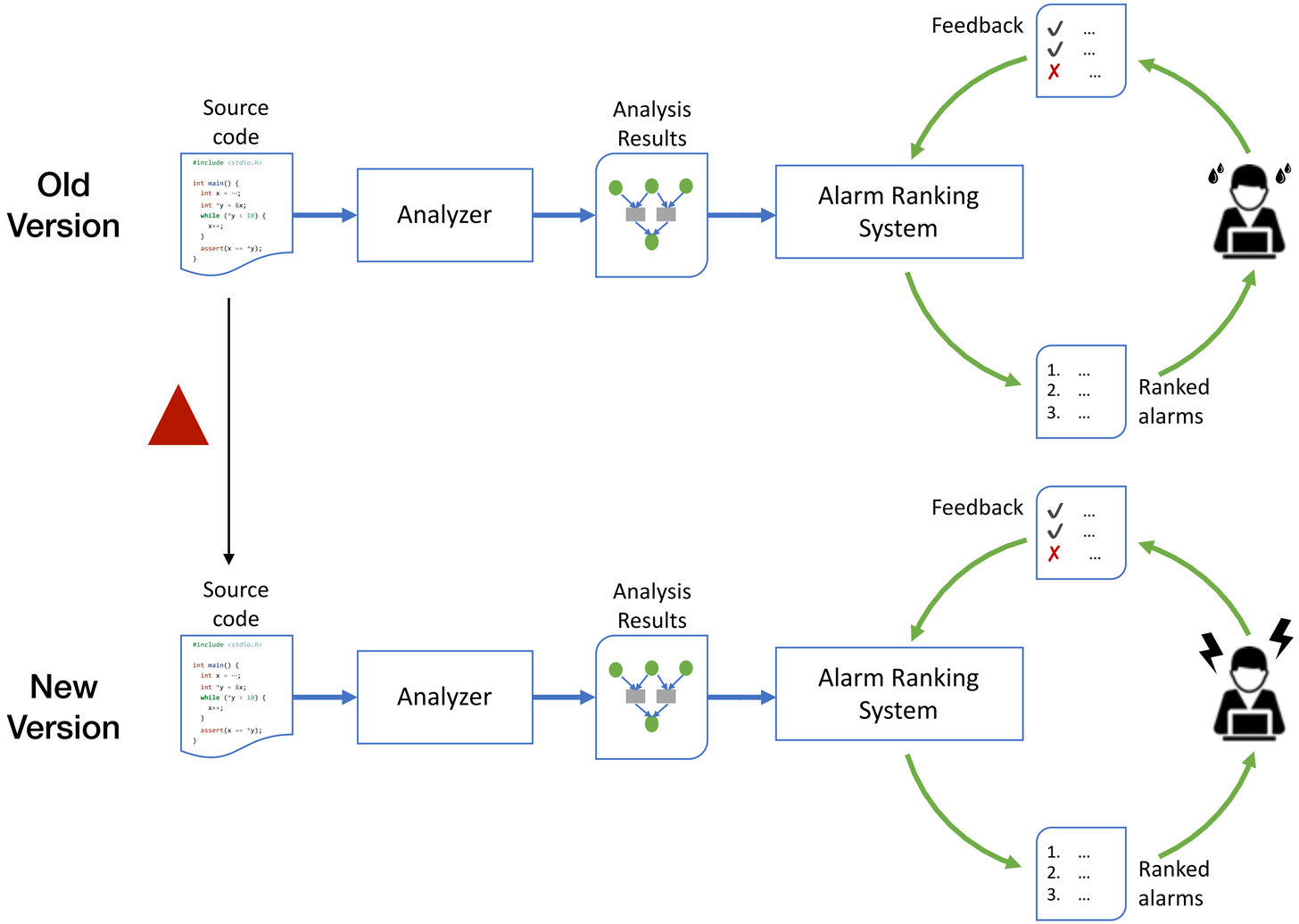
Ranking	Alarm	Confidence
1	R(0, 7)	0.279
2	R(5, 5)	0.035
3	R(6, 7)	0.030
4	R(7, 7)	0.028
5	R(4, 5)	0

정적 분석의 상호 작용


git
다음 버전
분석 결과에
사용
이전 버전
분석 결과를
이용
Program
Program
Analyzer
사용자의
반응
다른 프로그램
분석을 이용
다른 프로그램
분석에 사용

Drake: 프로그램의 변화를 감지하는 정적 분석
[PLDI'19]

일괄형 (batch-mode) 분석



연속적 (continuous) 분석

"We only display results for most analyses on ***changed lines*** *by default; this keeps analysis results* ***relevant*** *to the code review at hand", - Google, 2015*

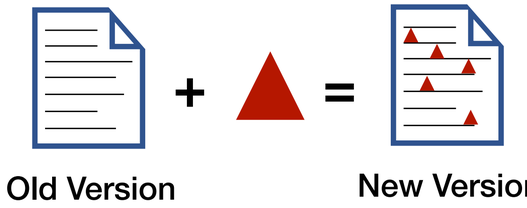
"The vast majority of Infer's impact to this point is attributable to ***continuous reasoning at diff time****", - Facebook, 2016*

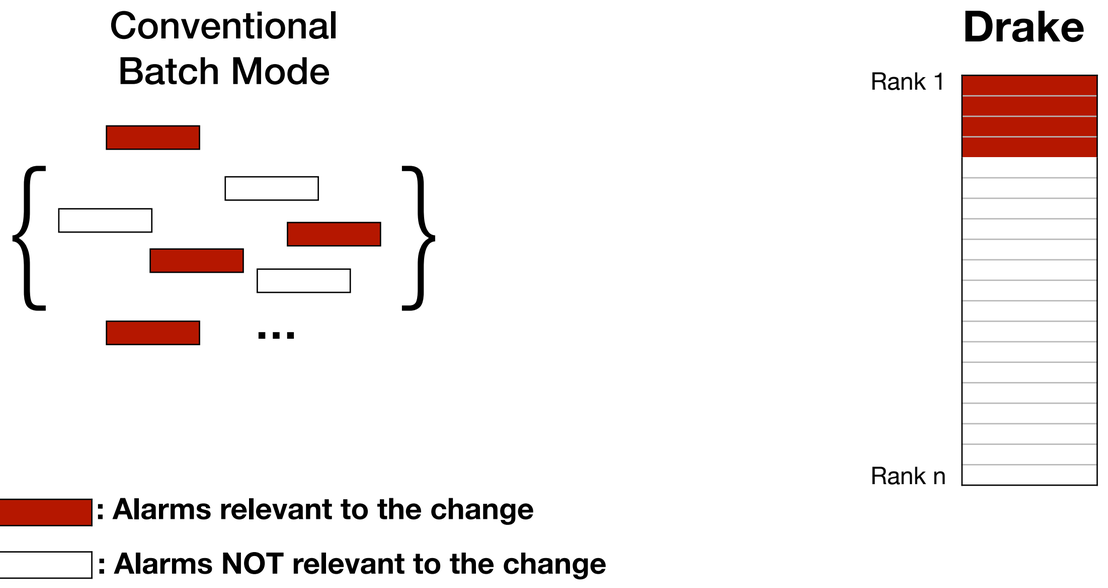
"… is the ability to analyze a ***changelist (a.k.a. a commit) rather than the entire codebase****. This functionality can help developers assess the quality and impact of a change …", - Microsoft, 2016*

"In order to realize the goal, verification must continue to work with low effort ***as developers change the code****. … Neither of these approaches would work for Amazon as s2n is under* ***continuous development****.", - Amazon, 2018*

목표

- 코드 변화와 관련이 있는 순으로 정렬해주는 오류 보고 시스템

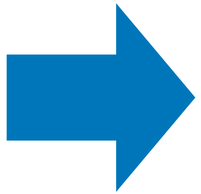




예제

Old Version

```
 1: x = input();
 2: y = input();
 3: x = opaque_dec(x);
-4: y = opaque_dec(y);
 5: x++;  // Alarm
 6: y++;  // Alarm
```



New Version

```
 1: x = input();
 2: y = input();
 3: x = opaque_dec(x);
+4: y = identity(y);
 5: x++;  // Alarm
 6: y++;  // Alarm
```

예제

Old Version

```
 1: x = input();
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 5: x++;  // Alarm
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New Version

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 1: x = input();
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+4: y = identity(y);
 5: x++;  // Alar
 6: y++;  // Ala rm
```
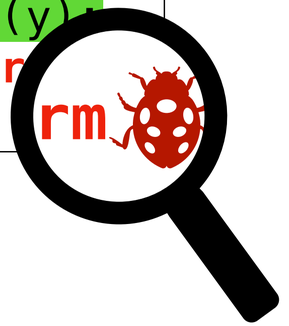
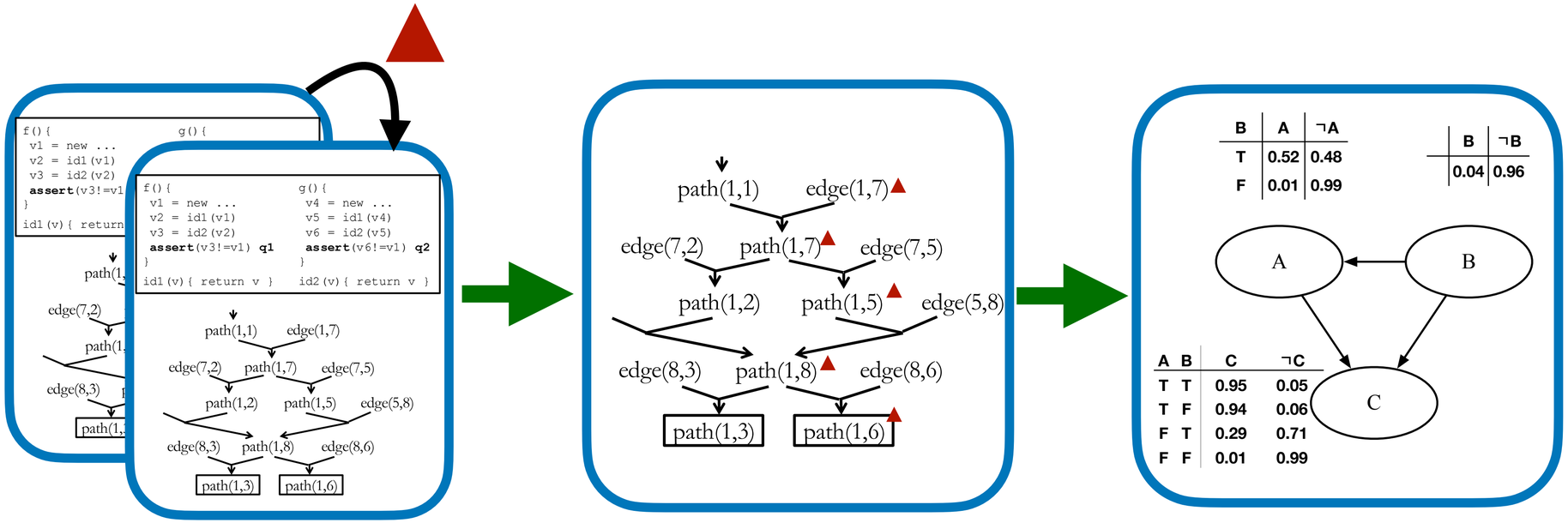



Q: How to emphasize the alarm at 6 that is relevant to this change?

핵심 기술

변화 감지 분석 결과 + 베이지안 추론 (Bayesian inference)



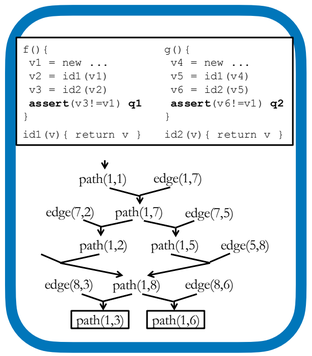
두 버전의 분석 결과

코드 변화를 감지하는 분석 결과

확률 모델
(Bayesian Network)

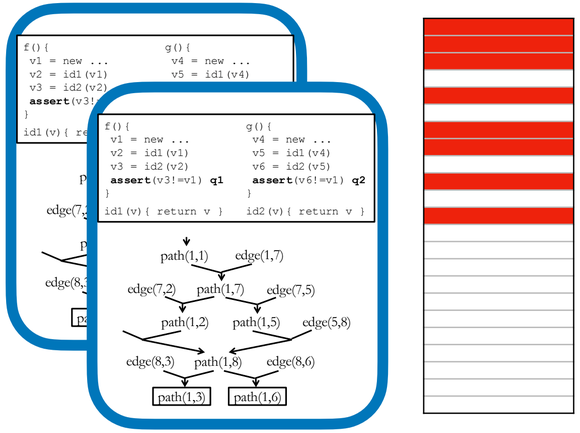
효과

평균 3개 버그를 찾기 위한 드는 노력의 평균을 측정



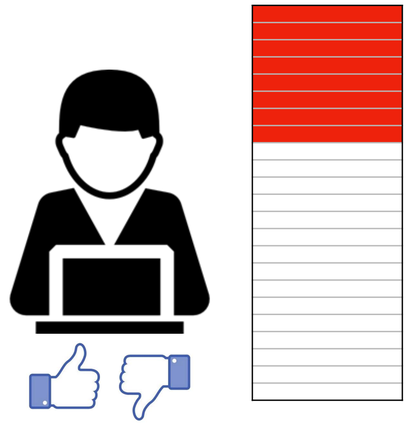
일괄형

563 개 경보 사이에
모든 버그가 산재



관련성 기반 순위

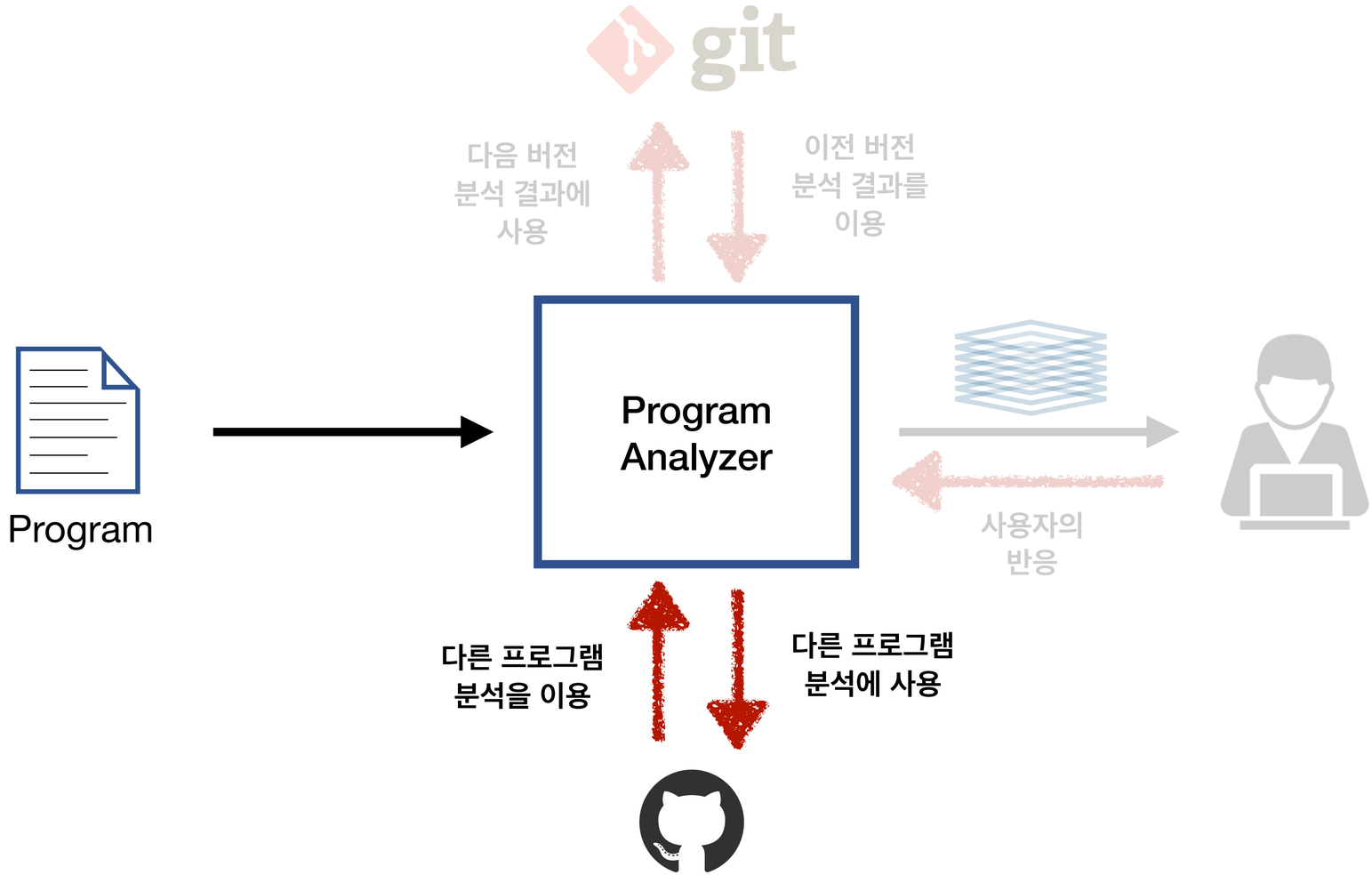
최대 순위 94 위 이내에
모든 버그 위치



+ 상호 작용 기반 순위

상호 작용 30 회 이내에
모든 버그 검출

정적 분석의 상호 작용

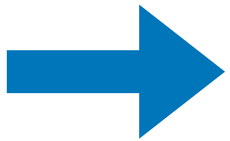

git
다음 버전
분석 결과에
사용
이전 버전
분석 결과를
이용
Program
Program
Analyzer
사용자의
반응
다른 프로그램
분석을 이용
다른 프로그램
분석에 사용

BayeSmith: 다른 프로그램 분석에서 배우는 정적 분석
[현재 진행]

잘못된 일반화

```
/* GNU sort-7.2 */
1: size_t avoid_trashing_input (struct sortfile *files, size_t ntemps, …) {
2:   for (i = ntemps; i < nfiles; i++) {
3:     if (/* file[i] is the same as outfile */) {
4:       while (i + num_merged < nfiles) {
5:         num_merged += mergefiles (&files[i], 0, nfiles - i, tftp, temp);
6:         files[i].name = temp;                          // false alarm
7:         files[i].pid = pid;                            // false alarm
8:         memmove(&files[i], &files[i + num_merged],     // true alarm
9:             num_merged * sizeof *files);
10:        ntemps += 1;
11:        nfiles -= num_merged - 1;;
12:        i += num_merged;
13:      }
14:    }
15:  }
16: }
```

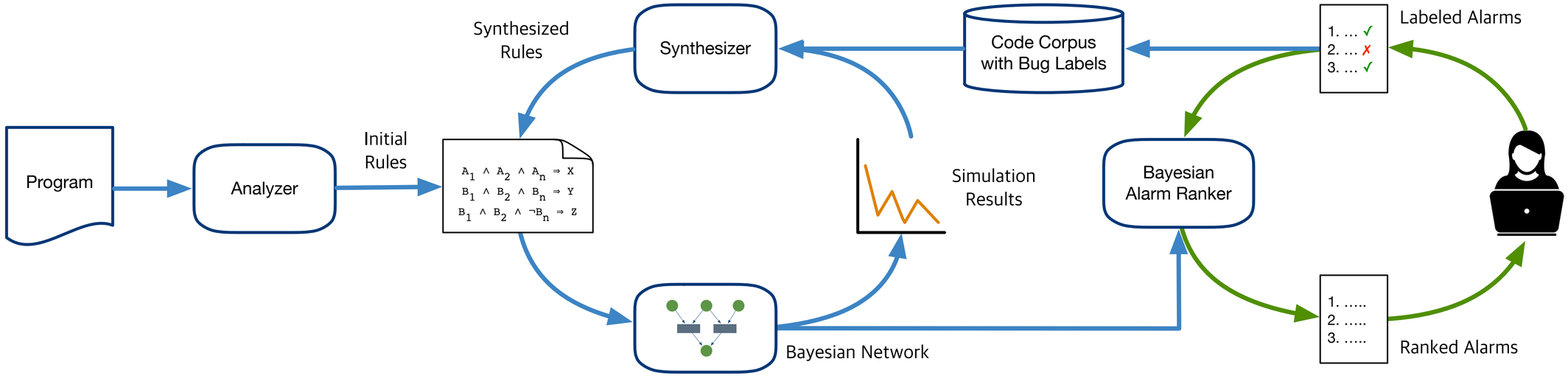
Ranking	Alarm	Confidence
1	LIne 6	0.93
2	Line 7	0.92
3	Line 8	0.91
…		



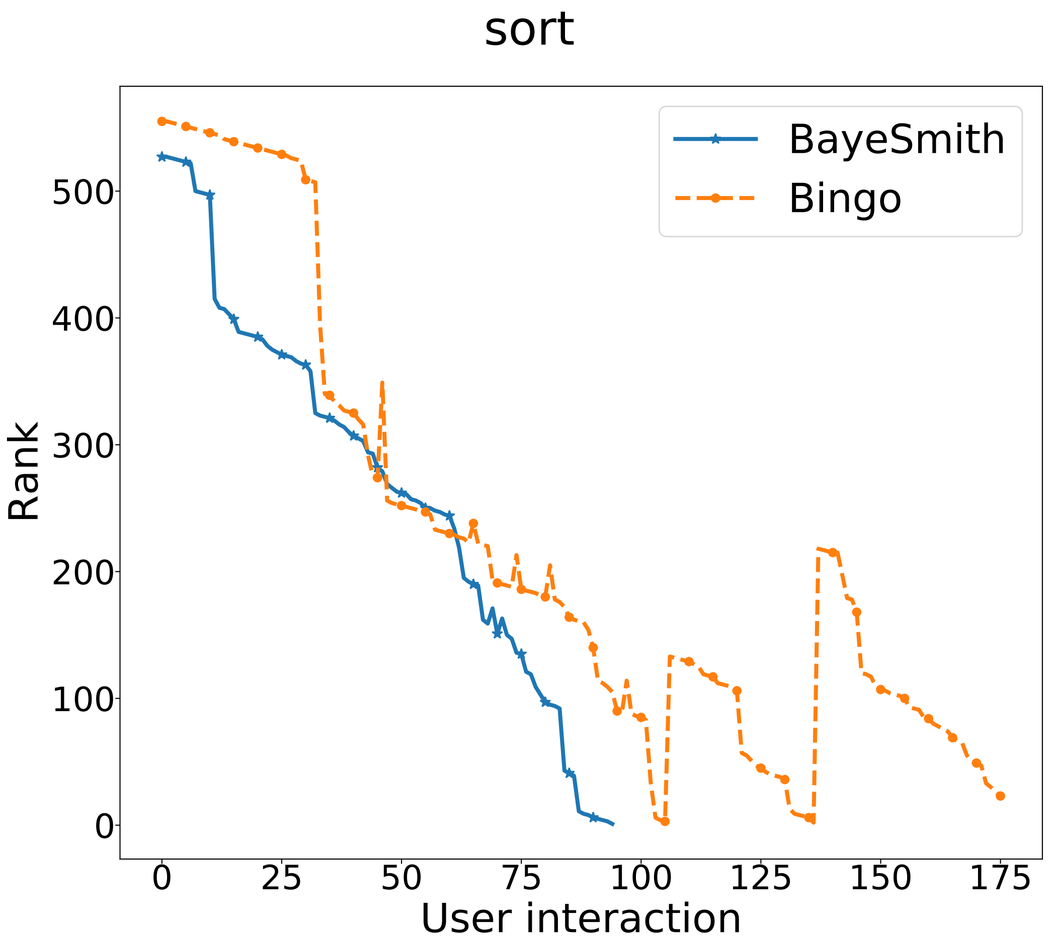
Ranking	Alarm	Confidence
…		
132	Line 7	0.41
133	Line 8	0.40
…		

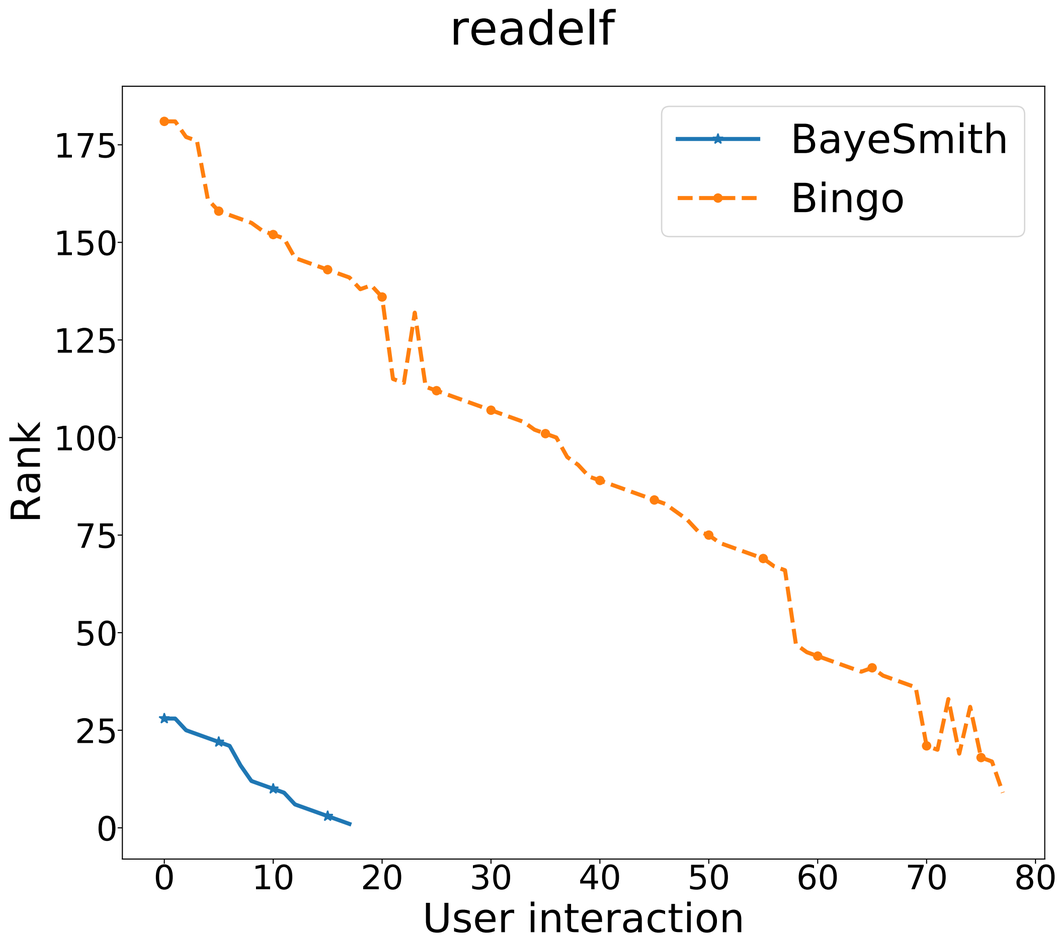
핵심 기술

프로그램 합성 + 베이지안 추론 (Bayesian inference)



성능


sort
BayeSmith
Bingo
Rank
User interaction
0
100
200
300
400
500
0
25
50
75
100
125
150
175


readelf
BayeSmith
Bingo
Rank
User interaction
0
25
50
75
100
125
150
175
0
10
20
30
40
50
60
70
80

결론

- 사용자가 정적 분석을 이해해야 하는 시대 → 정적 분석이 사용자를 이해하는 시대
- 여러 가지 방식으로 상호작용
  - Bingo: 사용자와 직접 상호작용
  - Drake: 이전 버전과 상호작용
  - BayeSmith: 다른 프로그램의 분석 결과 상호작용
- 핵심 기술: 정적 분석 + 프로그램 합성 + 통계적 추론