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Cause Points Analysis for Effective Handling of Alarms

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Motivating Example

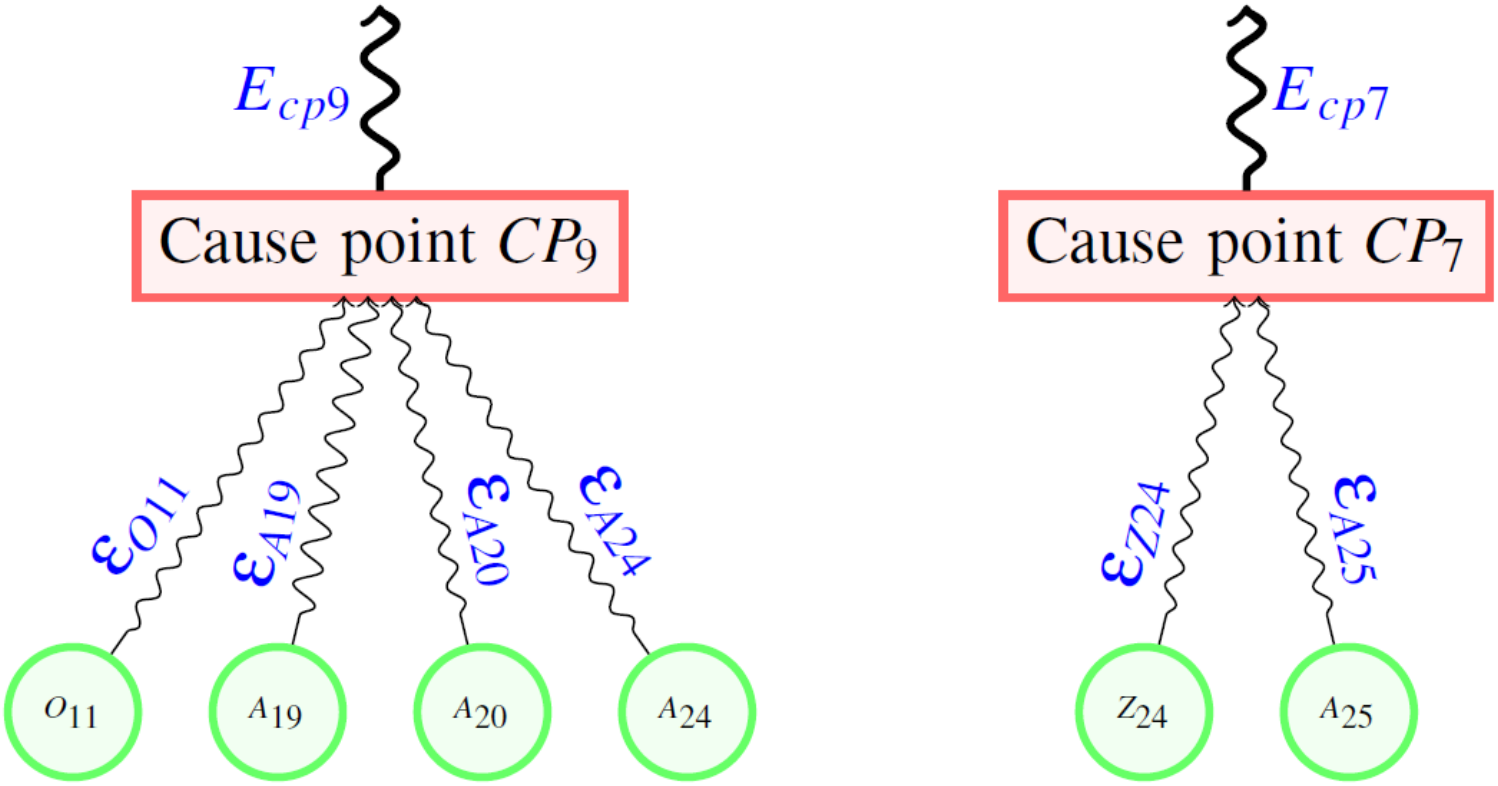
```
1  const int arr1[]={0,3,7,9,14,22,34};
2  char arr2[35], str[20], bound, tmp;
3
4   void foo(){
5   unsigned int i, j, k, length;
6    ... // some code
7   scanf("%s",str);  //Cause point CP7
8   if (i < 7 && j < i)
9      bound=arr1[i]-arr1[j]; //Cause point CP9
10
11   for(k = 0; k <= bound; k++){ //OFUF
12     f1(k);
13   }
14    length = strlen(str);
15    f2(bound, length);
16 }
17
```

```
18  void f1(int p){
19   if(nondet()) arr2[p] = 0; //AIOB
20   else arr2[p] = 1; //AIOB
21  }

22
23 void f2(int p, unsigned int q){
24 arr2[p - 1] = 100 / q; //AIOB, ZD
25 tmp = str[q]; //AIOB
26 }
```

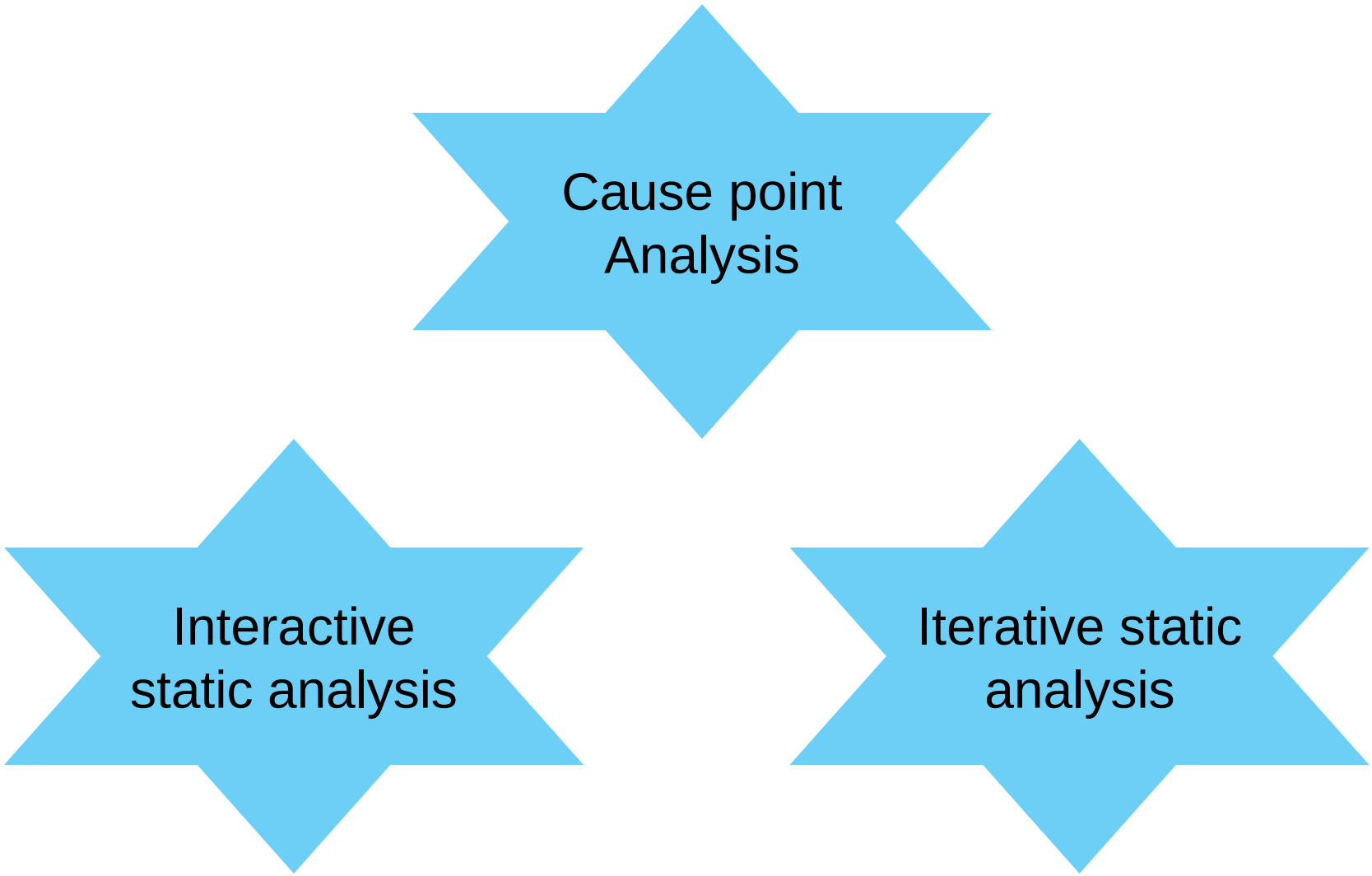
6 alarms due to
2 cause points

Manual Effort



$$\varepsilon_{orig} = ((\varepsilon_{O11}+E_{cp9})+\varepsilon_{A19}+\varepsilon_{A20}+\varepsilon_{A24}) + ((\varepsilon_{Z24}+E_{cp7})+\varepsilon_{A25})$$

Proposed Approach



Motivating Example

```
1  const int arr1[]={0,3,7,9,14,22,34};
2  char arr2[35], str[20], bound, tmp;
3
4   void foo(){
5   unsigned int i, j, k, length;
6    ... // some code
7   scanf("%s",str);  //Cause point CP7
8   if (i < 7 && j < i)
9     bound=arr1[i]-arr1[j]; //Cause point CP9
10
11  for(k = 0; k <= bound; k++){ //OFUF
12    f1(k);
13  }
14   length = strlen(str);
15   f2(bound, length);
16 }
17
```

Get values for unknowns from user

Re-analyze the code using inputs

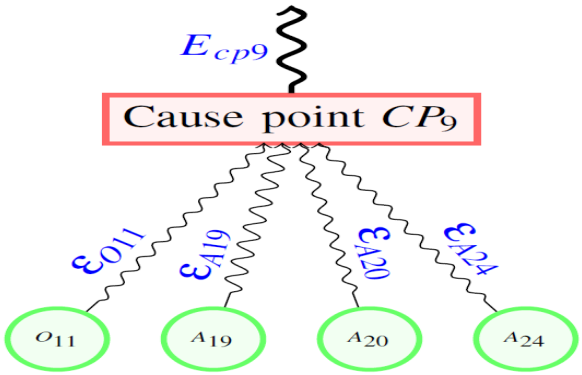
No alarm is generated

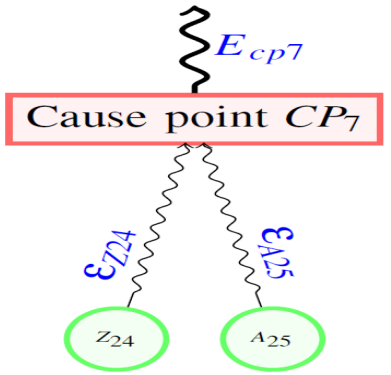
```
18  void f1(int p){
19   if(nondet()) arr2[p] = 0; //AIOB
20   else arr2[p] = 1; //AIOB
21  }

22
23 void f2(int p, unsigned int q){
24 arr2[p - 1] = 100 / q; //AIOB, ZD
25 tmp = str[q]; //AIOB
26 }
```

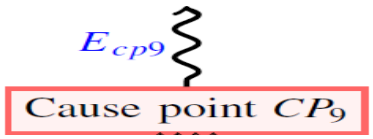
Manual Effort Reduction

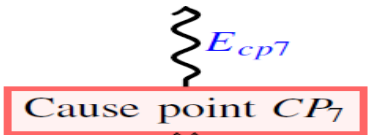
ε_{orig} =



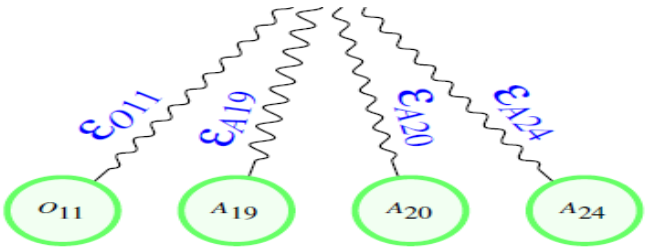


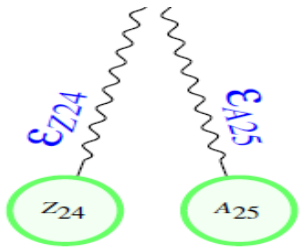
ε_{new} =



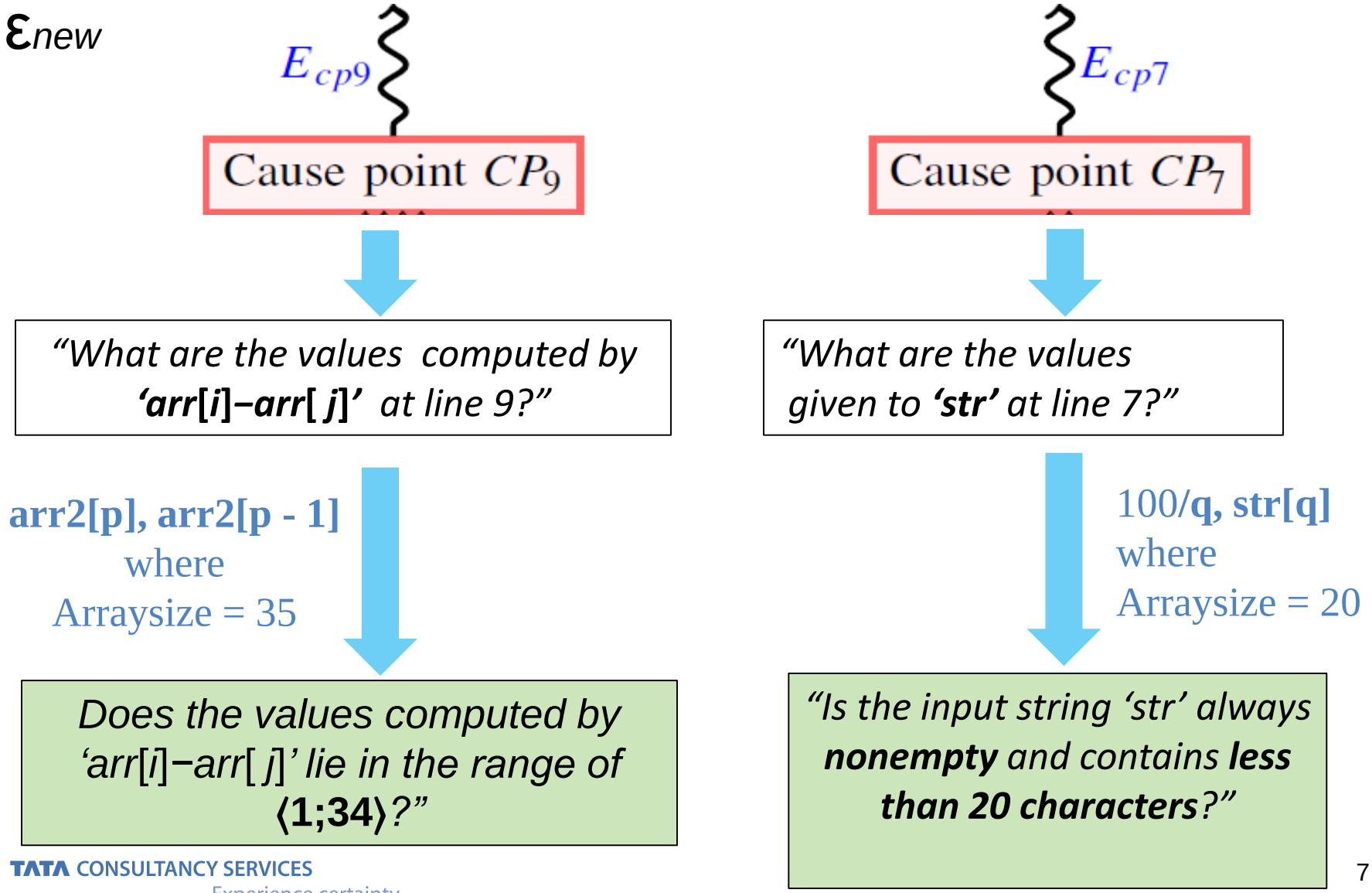


ε_{saved} =





Cause Points-specific Queries



Modeling of Cause Points

- Unknowns of various types
  - *i-unknowns* e.g. scanf("%s", str);
  - *c-unknowns* e.g. ratio * a * b + size
  - *loop-unknowns* e.g. for(i=0; i < 10 || foo(); i++){…}
  - *ds-unknowns* e.g. arr[i], pop();
  - *lib-unknowns* e.g. lib();
  - *p-unknowns*
- Cause point = Unknown + program point + unknown-type

Ranking of Cause Points

1. Unknown types

   input > library > path > loop > computational > data-structure

2. Grouping of Cause points

   A. *Lexical Similarity-based Grouping* e.g. malloc();

   B. *Proximity-based Grouping* e.g. same file or function

3. Contribution score-based ranking

   $tc\text{-}score(cp) = k * fc\text{-}score(cp) + pc\text{-}score(cp)$

Approach Benefits

Manual review effort reduction

Reviewing as many as **alarms** possible in a given time

Identifying as many as **errors** possible in a given time

Experimental Evaluation

RQ1: What is the reduction in the manual effort using the proposed approach?

RQ2: What is the contribution of cause points in generating the alarms and how are they distributed in practice?

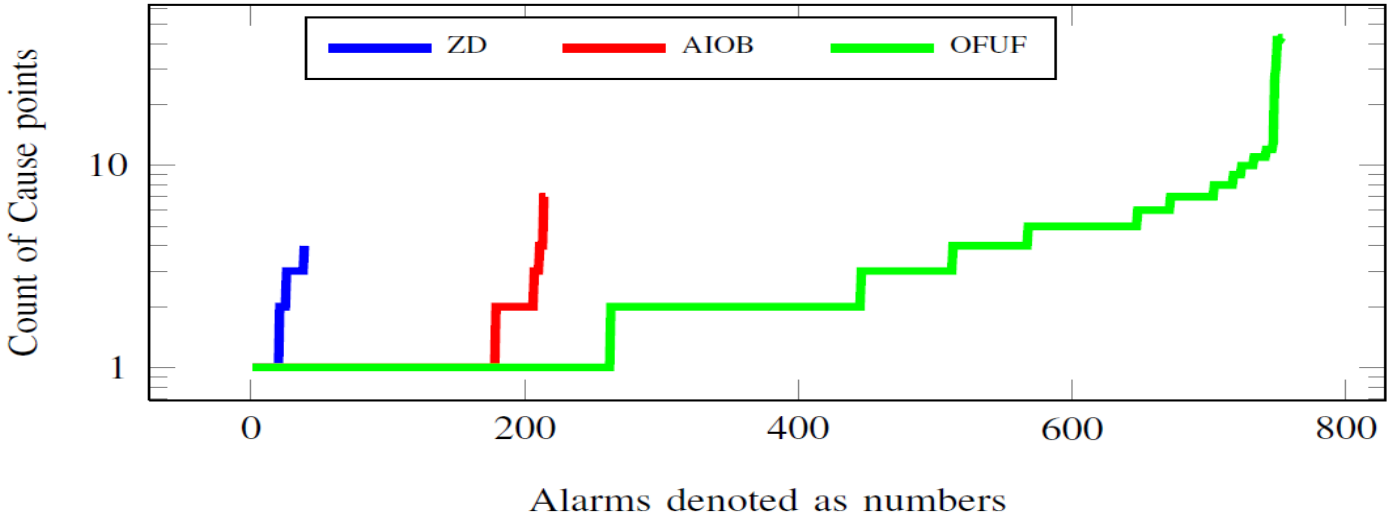
RQ3: How effective are the metrics used in the ranking of cause points?

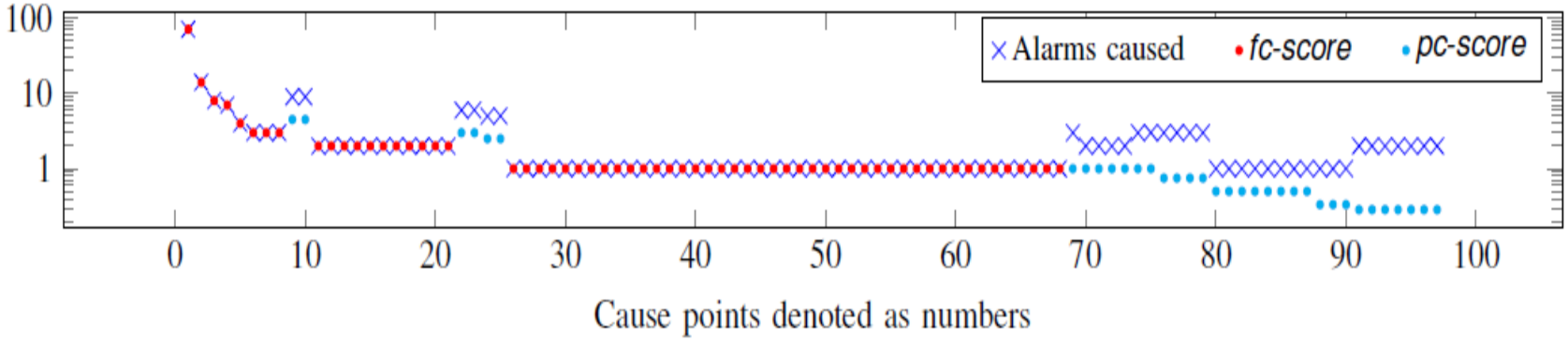
- Implementation using TCS ECA analysis framework

Effort Reduction (RQ1)

App.	Tool used	Verification Property & alarms	Reviewers		Manual Effort (Hrs)		% ε_{saved}
			Original	Proposed	ε_{orig}	ε_{new}	
A1(C)	TCS ECA	AIOB(215)	R1#	R3#	2.41	1.30	**46.05**
	TCS ECA	AIOB (215)	R6	R6	6.83	3.48	**49.04**
	TCS ECA	AIOB+OFUF+ZD(1000)	R2#	R2#	9.15	6.36	**30.49**
A2(C)	TCS ECA	AIOB(196)	R5 + R6	R5 + R6	3.29	2.53	**23.10**
A3(C)	TCS ECA	AIOB+ZD (243)*	R7	R8	12.15	7.50	**38.27**
A4(C)	TCS ECA	IDP (2000)*	R1	R2	2.74	1.24	**54.74**
A5 (C++)	Polyspace Code Prover	AIOB+ZD (85)	R4	R4	3.53	2.40	**32.01**
A6 (Java)	NPEDetector	NDP (555)*	R3#	R2#	5.68	1.58	**72.18**

Distribution/Contribution (RQ2)





Ranking Effectiveness (RQ3)

$$\text{Error cause rate (t)} = \frac{\textit{Errors uncovered in alarms caused by Cause Points of type t}}{\textit{Total alarms caused by Cause Points of type t}}$$

	Cause point (unknown) types					
	inputs	Library	Path	Loop	Computation	Data Structure
No. of cause points	7	7	6	16	10	11
Alarms caused	11	7	6	56	12	21
Errors caused	11	7	3	20	0	2
% Error cause Rate	**100**	**100**	**50**	**35**	**0**	**9**

Summary

Motivation

Simplifying manual inspections of alarms

Proposed Approach

Cause point Analysis

Iterative static analysis

Thank You!

Approach Benefits

Manual review effort reduction

Reviewing as many as **alarms** possible in a given time

Identifying as many as **errors** possible in a given time

Experimental Evaluation

RQ1: What is the reduction in the manual effort using the proposed approach?
Answer: 42 %

RQ2: What is the contribution of cause points in generating the alarms and how are they distributed in practice?
Answer: 80-20 principle in causing the alarms

RQ3: How effective are the metrics used in the ranking of cause points?
Answer: Validated our hypothesis in cause points ranking