Developing Cost-Effective Combinations of Static Analysis Techniques

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October 16, 2025
@ Dagstuhl, Germany

Analysis techniques are usually developed and evaluated **independently**

An **Issue** in the Current Trend of Developing Static Analysis Techniques

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Program

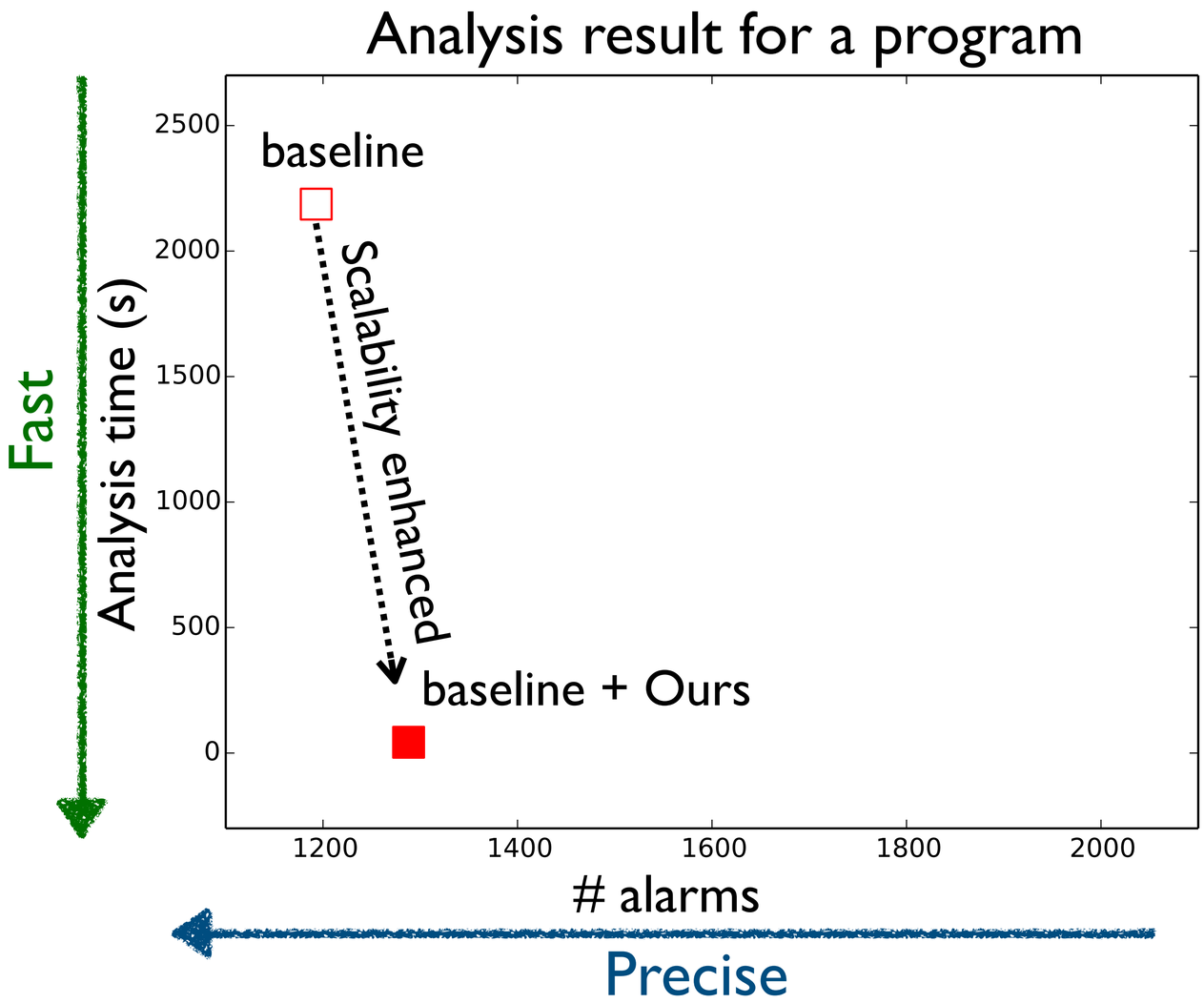
Sound Static Program Analyzer

Precise & Scalable Analysis Results

- Effective static program analyzers require various techniques
  - Partial flow sensitivity techniques [Jeon et al. 2019]
  - Selective context sensitivity techniques [Jeon et al. 2017, 2020]
  - Context tunneling techniques [Jeon et al. 2018, 2022]
  - …

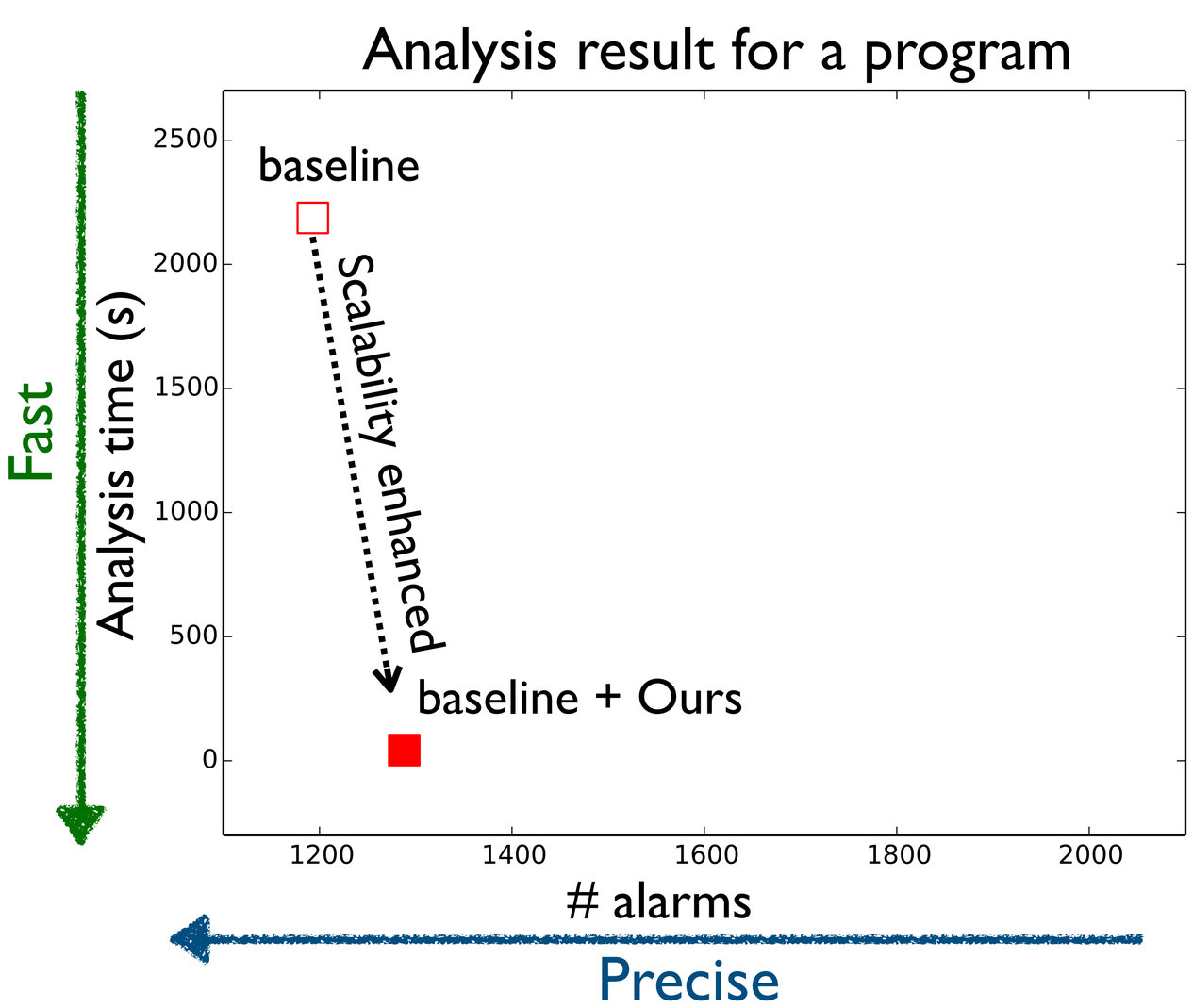
Research Scenario

(1) Develop an analysis technique that enhances the performance of a baseline analysis



Research Scenario

(2) Write a paper showing the effectiveness of our technique when applied to the baseline



Paper Scenario

We present a new static analysis technique

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Our technique enhanced scalability of the **baseline**

Vanilla analysis

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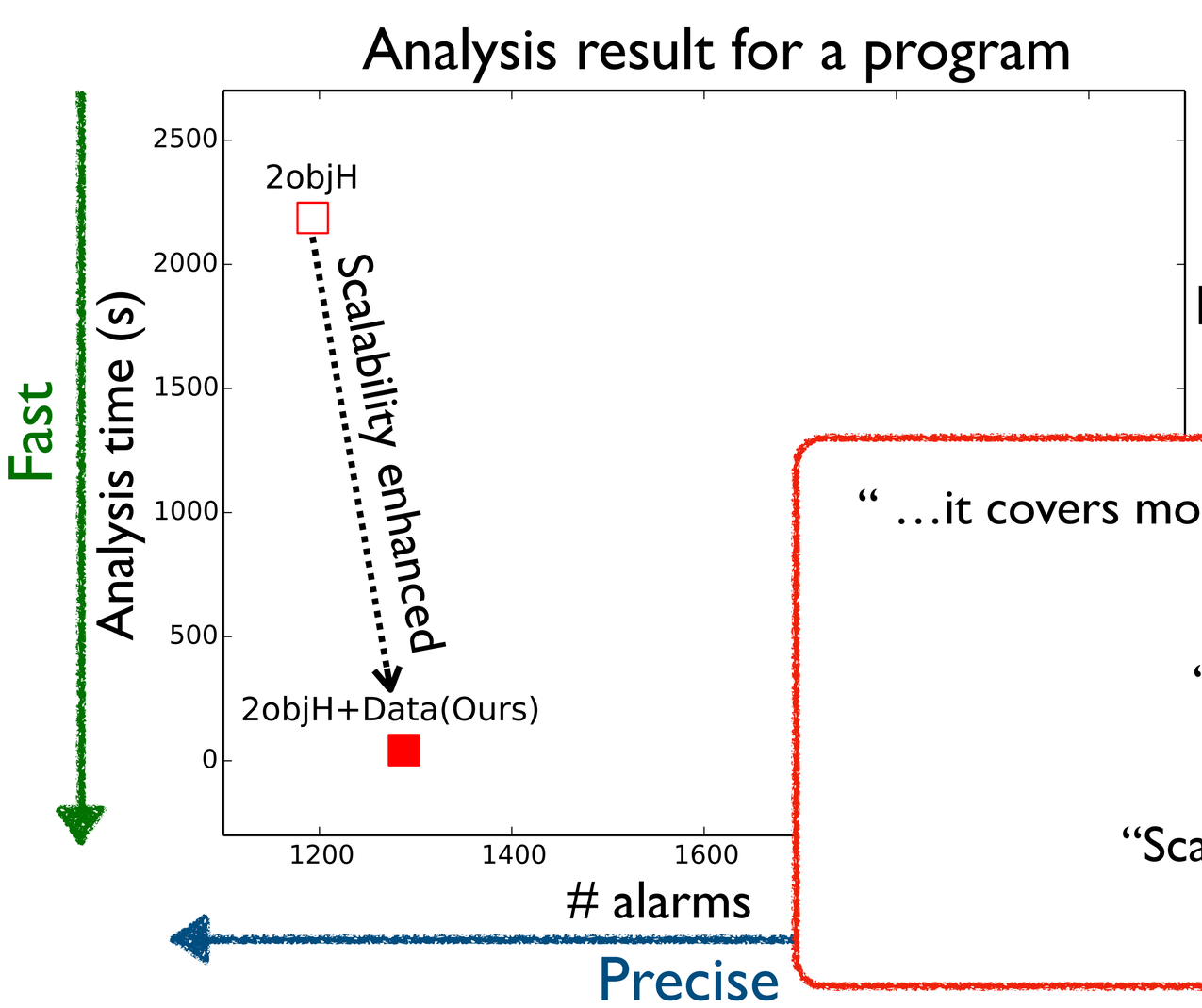

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" …it covers more than two-thirds of the precision advantage of 2objH"

-Smaragdakis et al. [PLDI' 14]

"… 98.8% of the precision of 2obj can be preserved…"

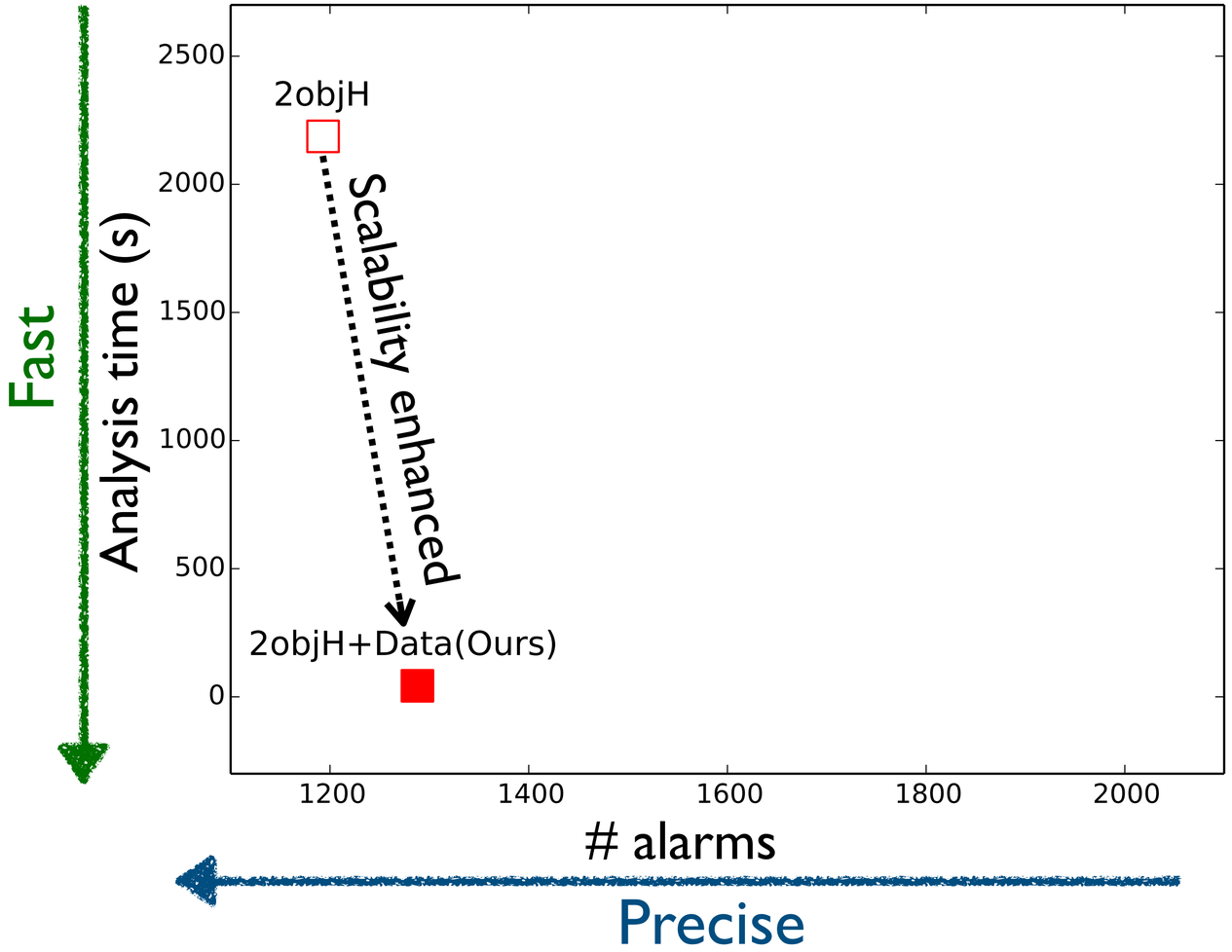
-Li et al. [OOPSLA' 18]

"Scaler still attains most of the precision gains of 2obj …"

-Li et al. [FSE' 18]

Research Scenario

(3) Get review comments and incorporate them into the revision



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Check whether the idea is interesting

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Check whether the technique sufficiently enhances **baseline**

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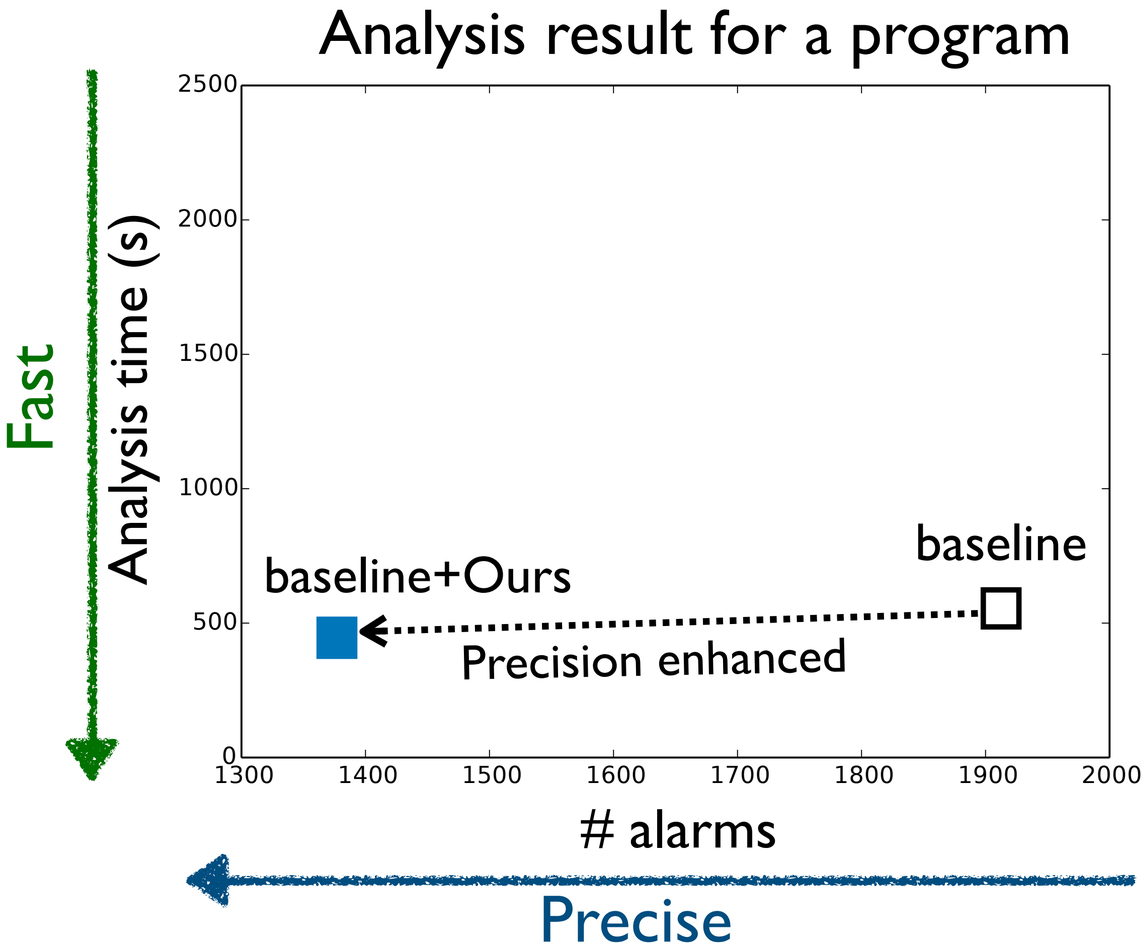

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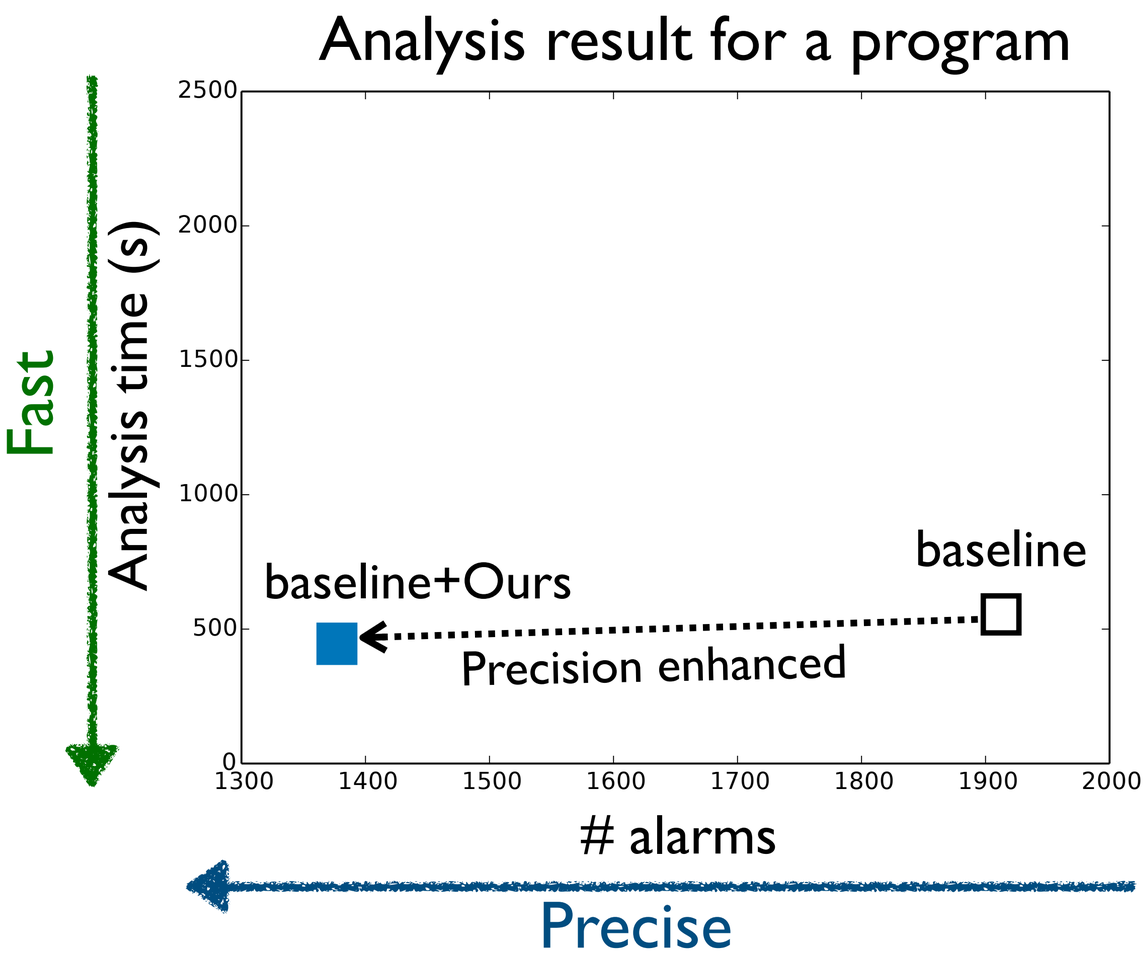

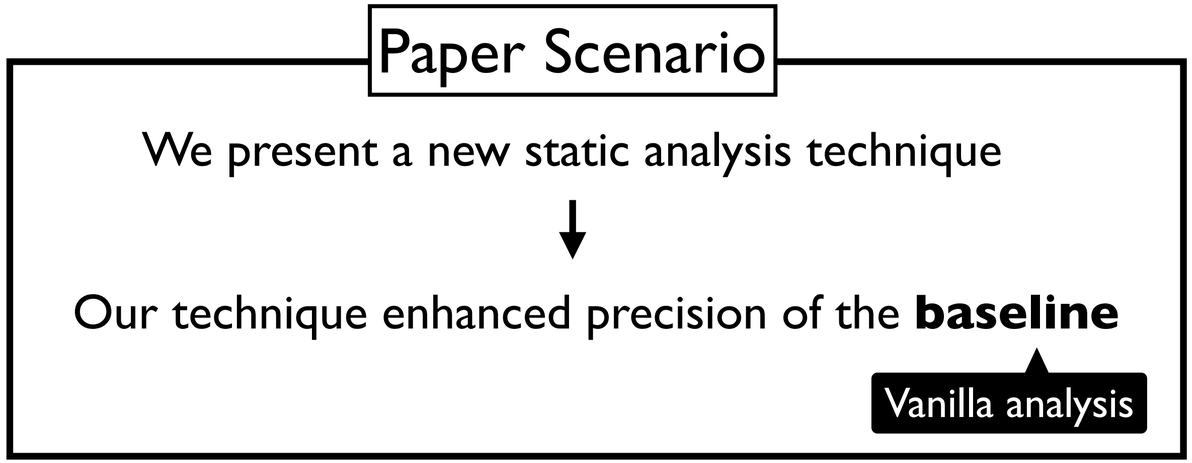

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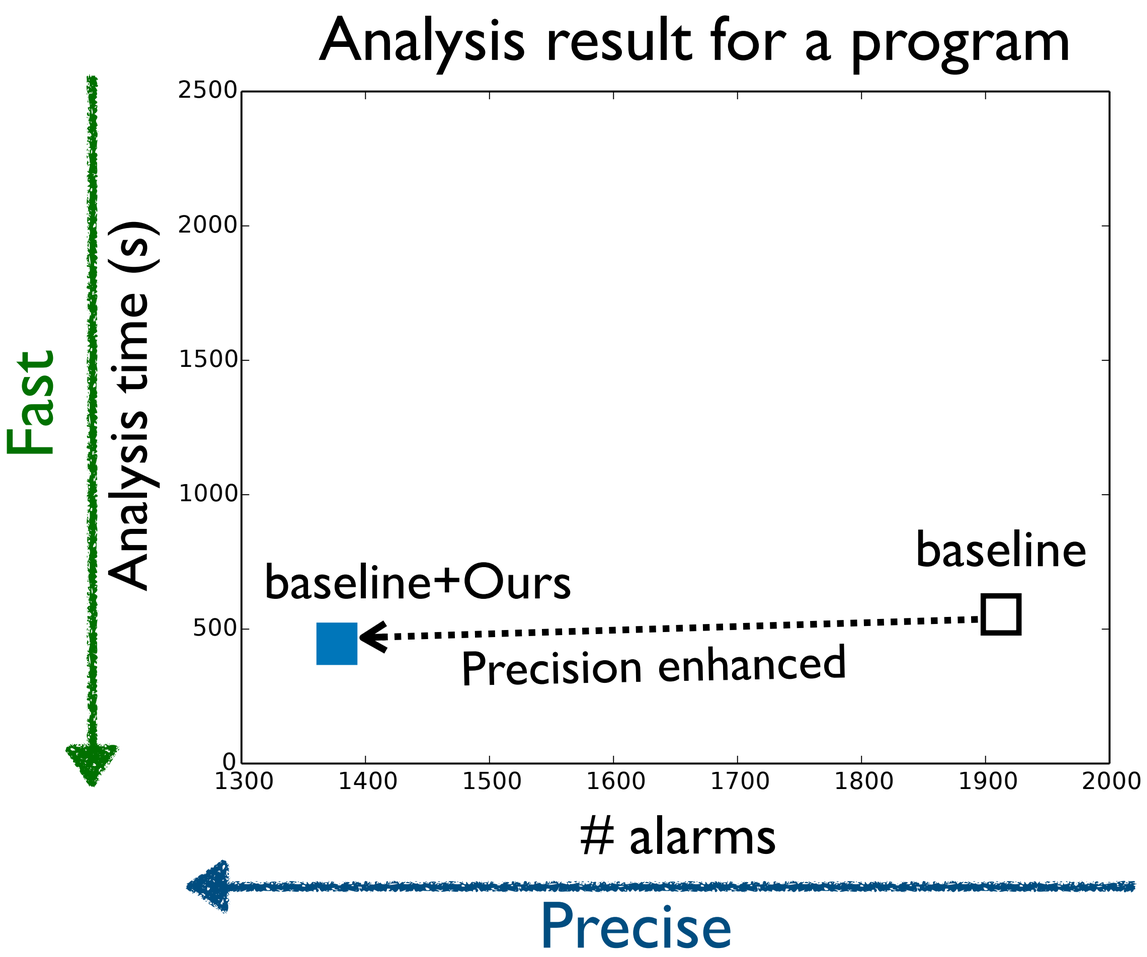

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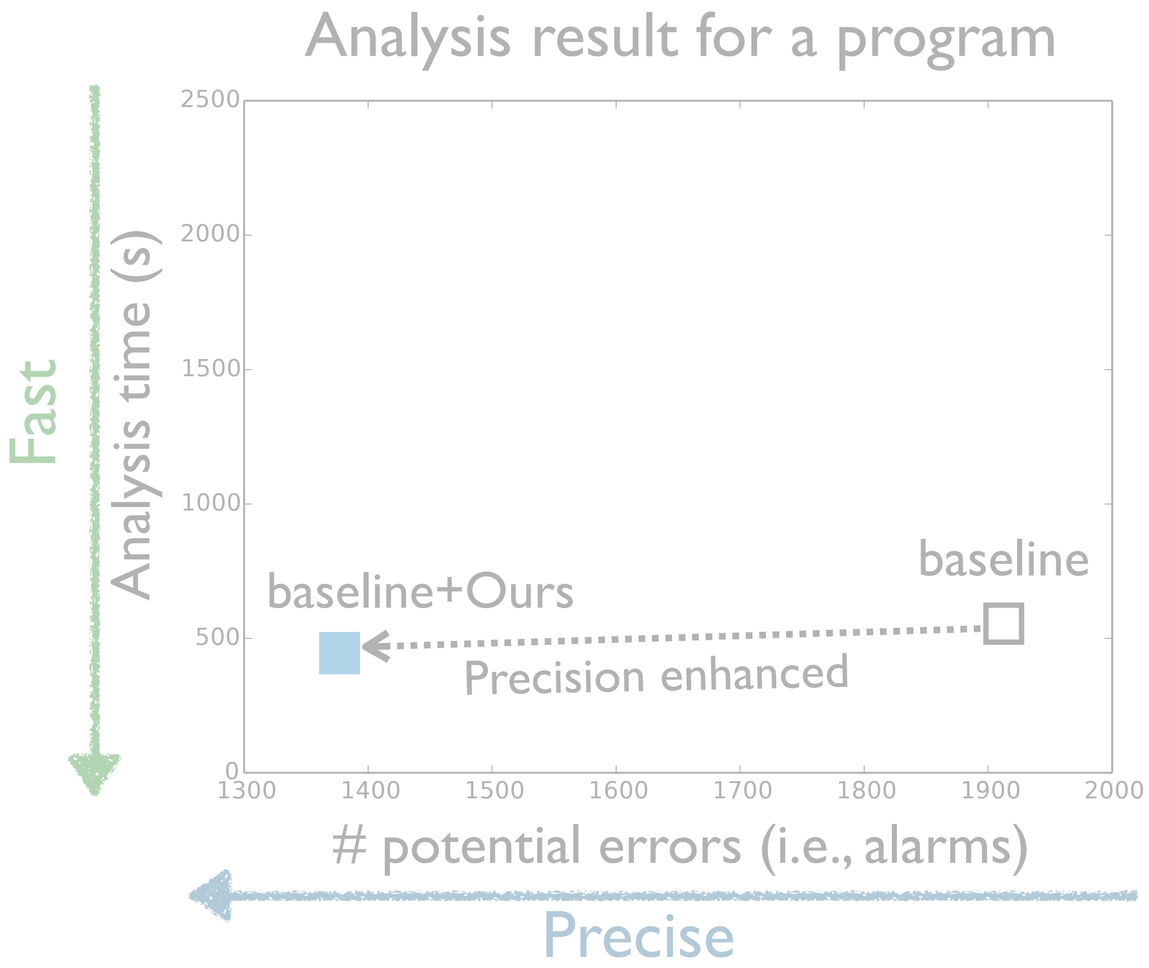

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Our technique enhanced precision of the **baseline**

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This paper presents a new technique

↓

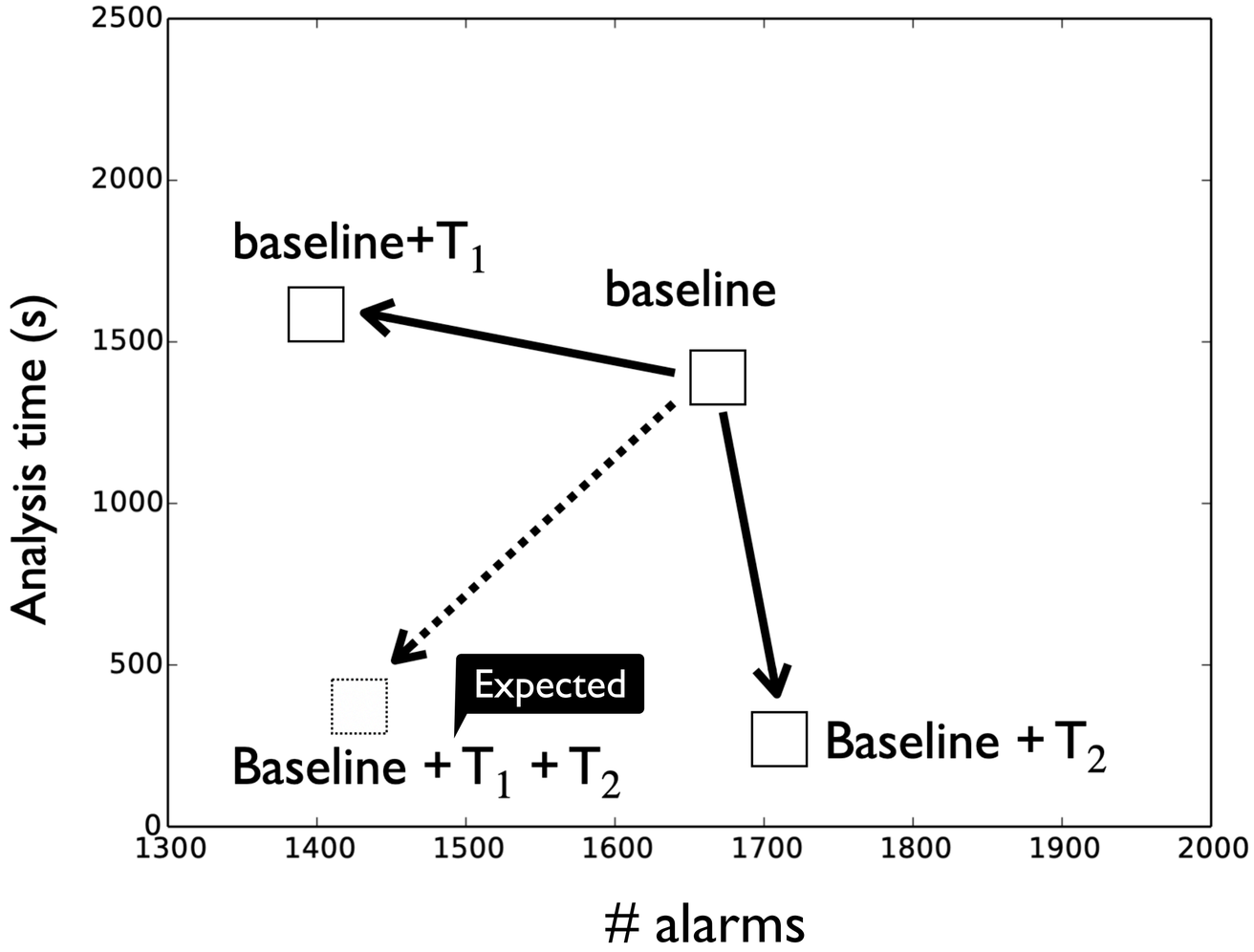
Excellent improvements in precision

Underlying assumption

Individually optimized techniques will also perform effective when combined.

Research Question

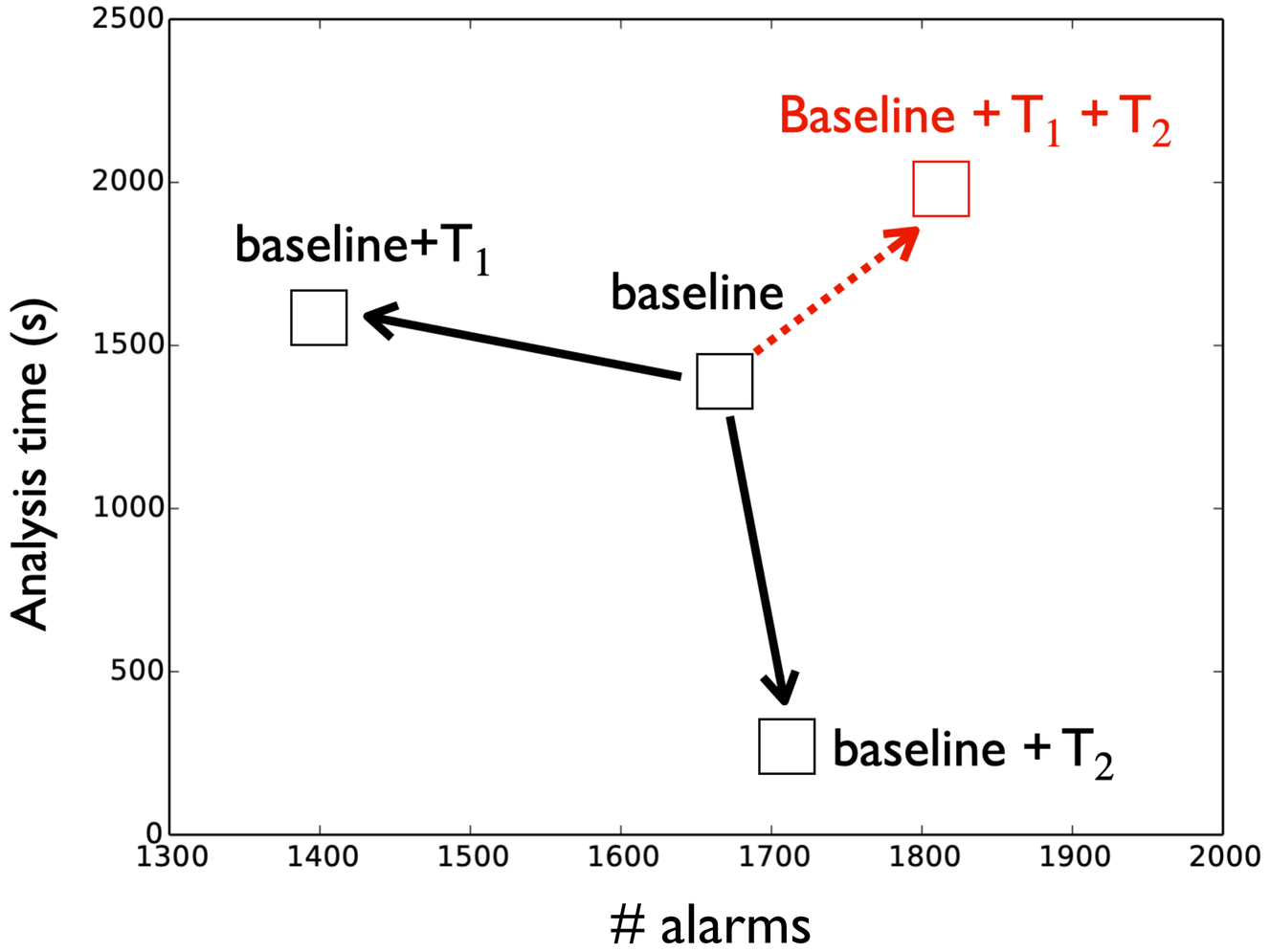
- Does a combination of individually effective techniques achieve effective performance?



Research Question

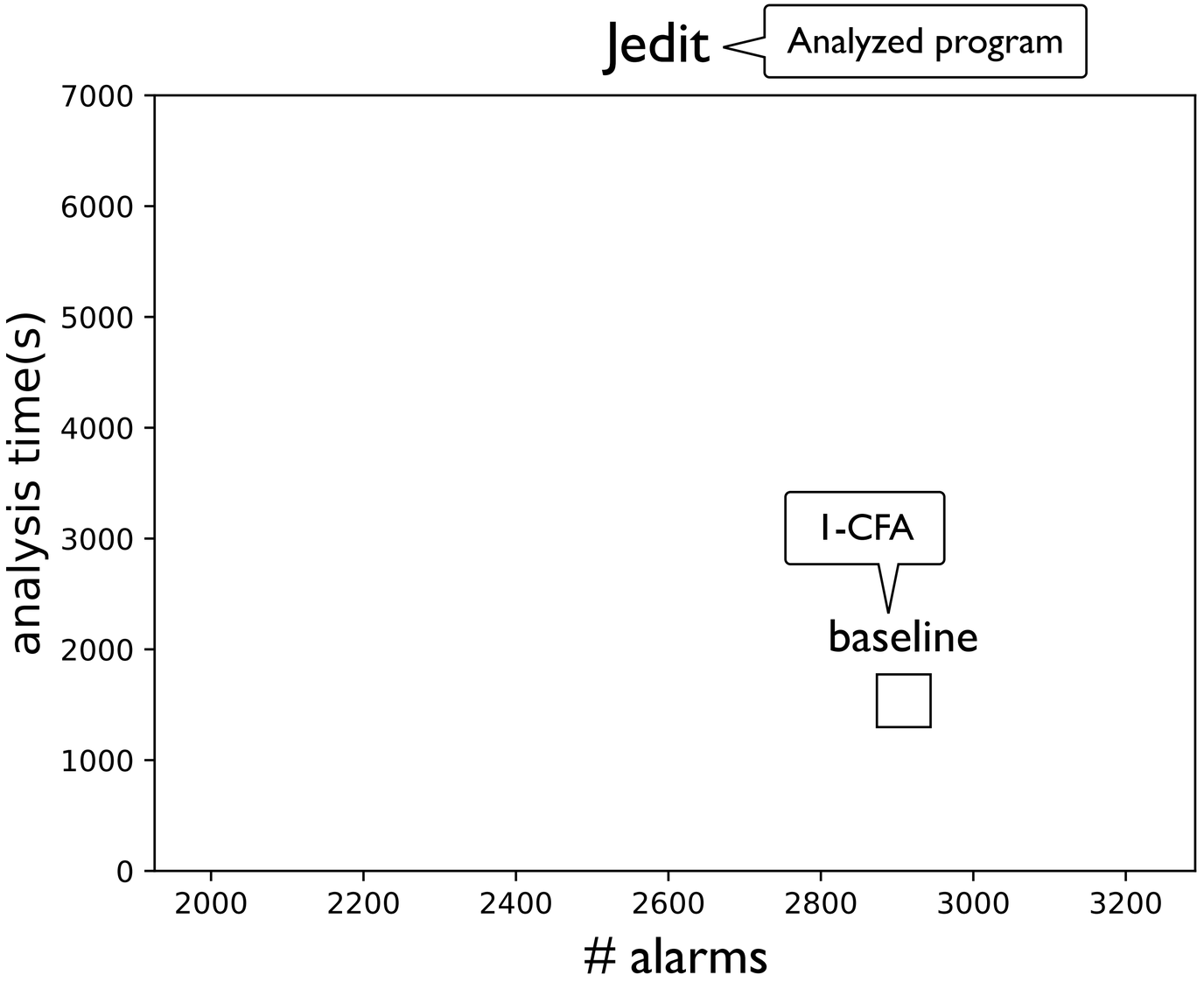
- Does a combination of individually effective techniques achieve effective performance?

No



Experimental Results

- Combination of existing SOTA techniques achieve suboptimal performance



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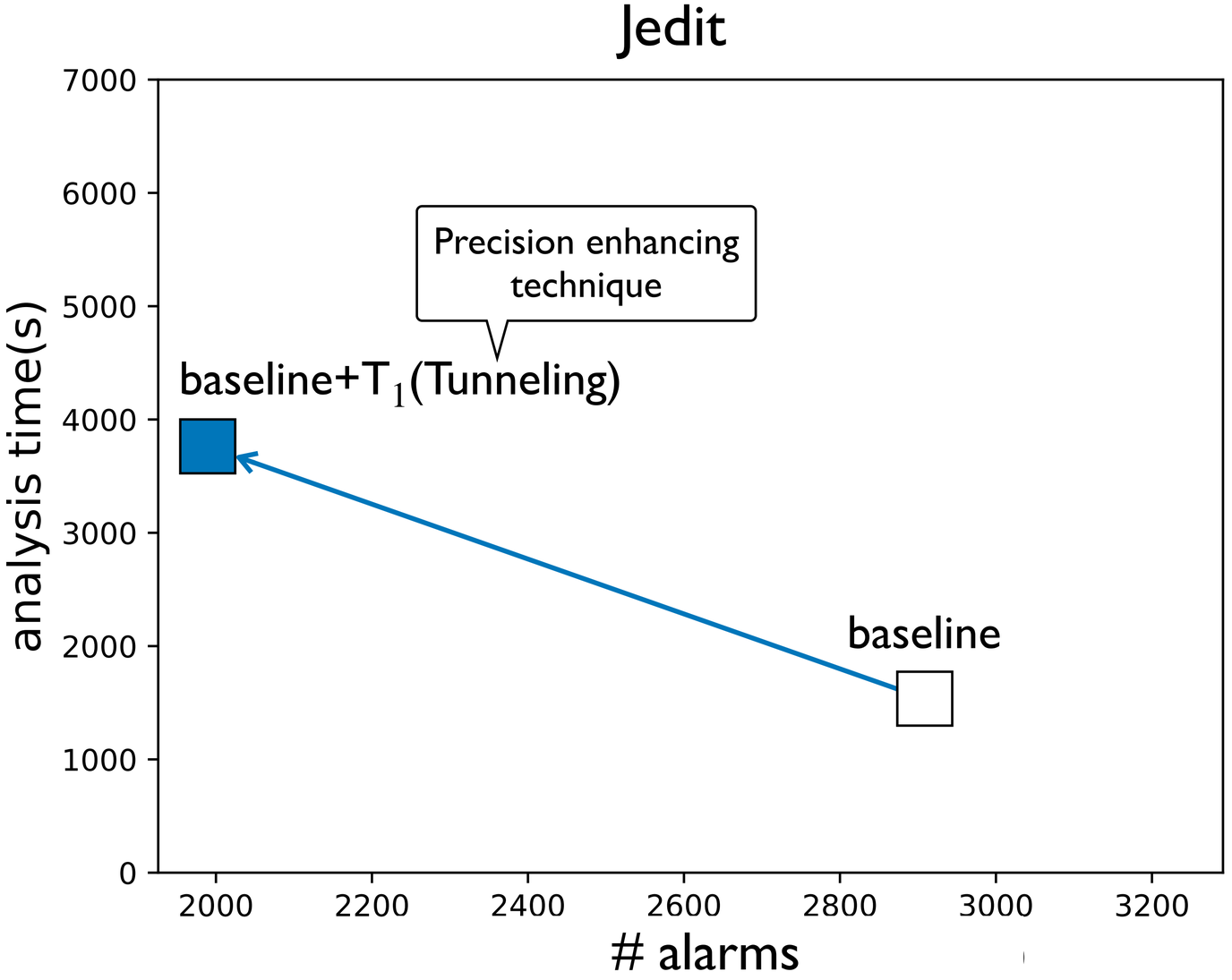

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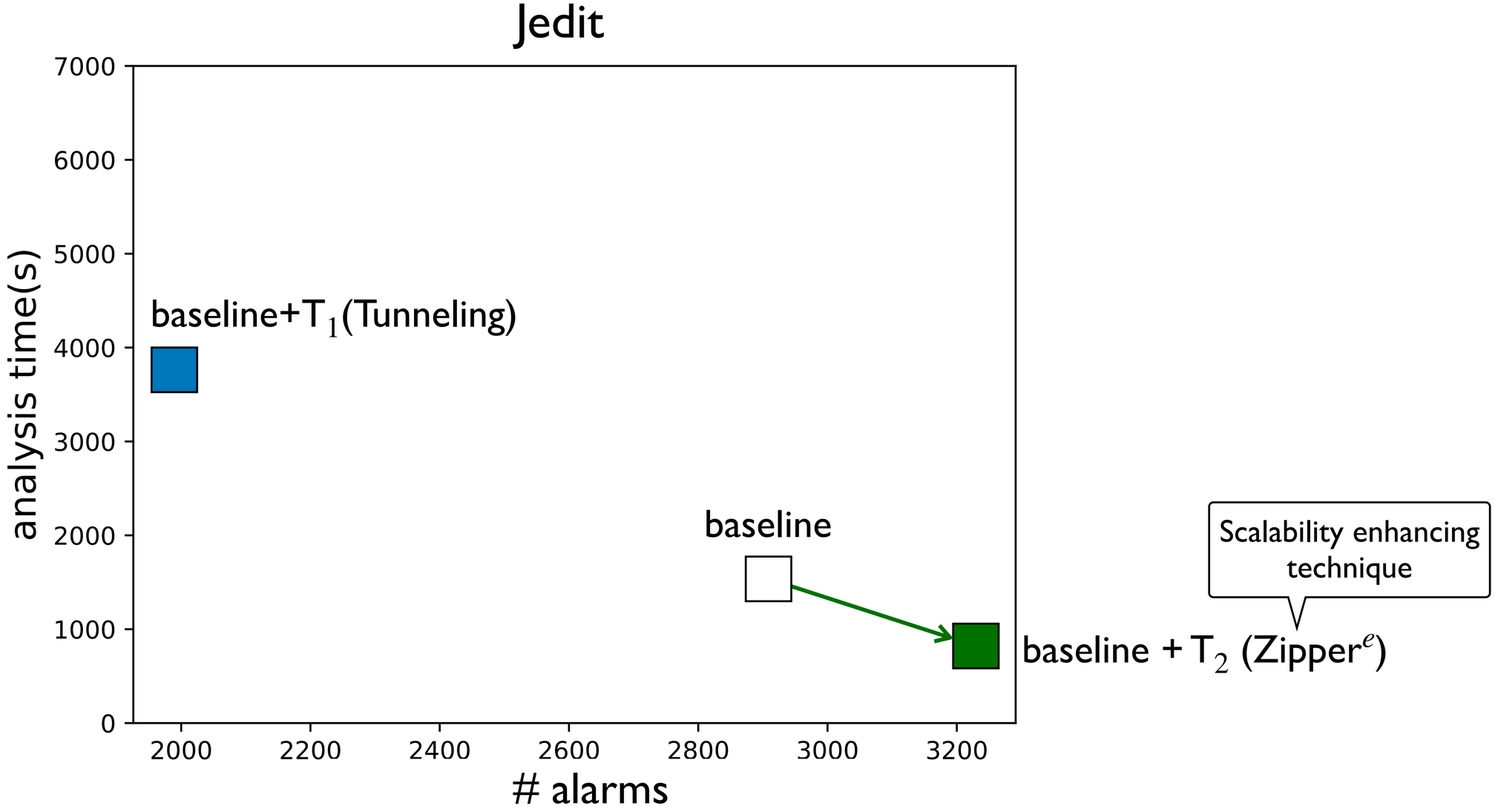

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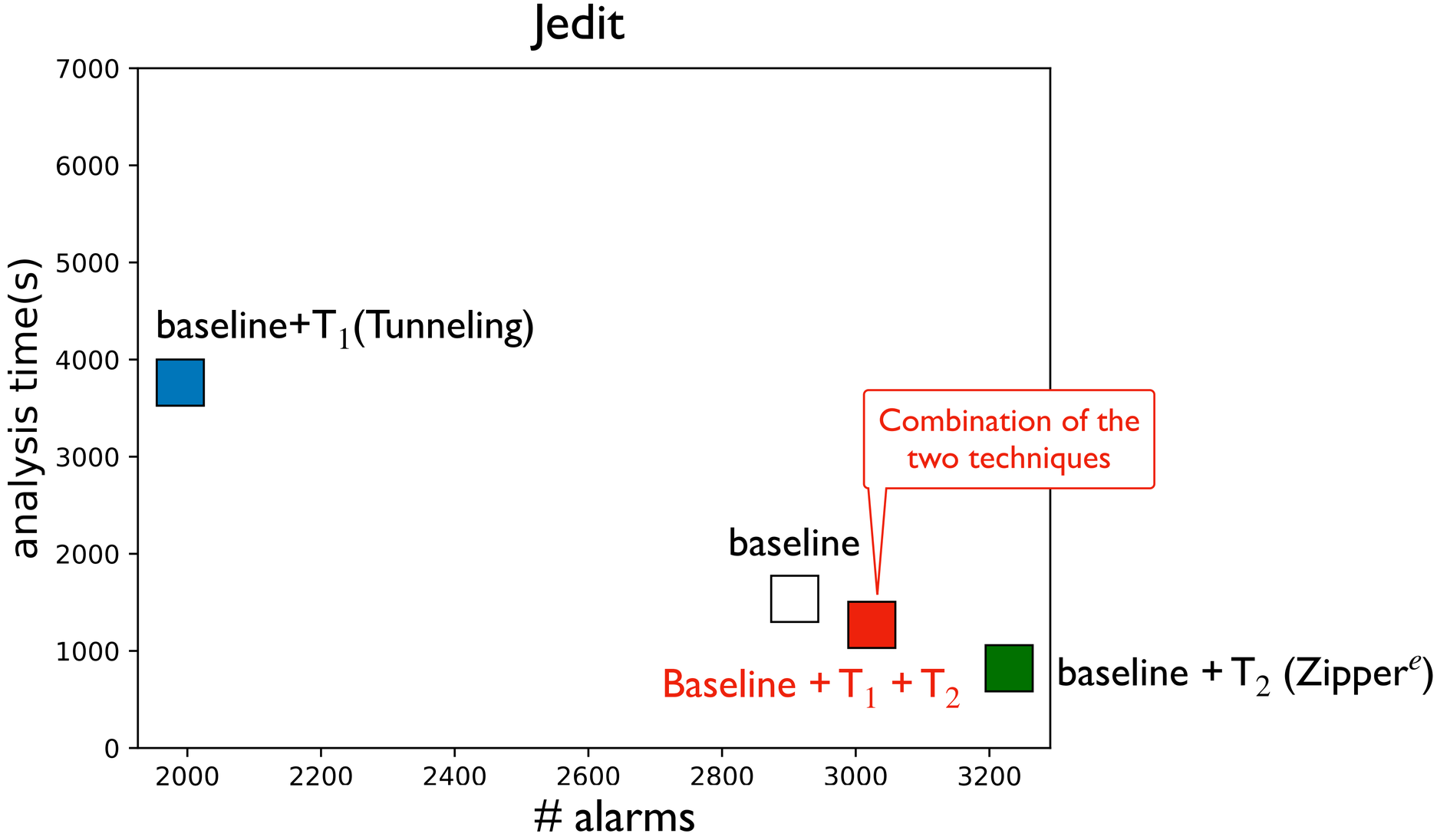

Counterexample

- Combining individually ideal techniques does not result in ideal performance

```
0:  id(v, i){
1:    if (i > 0){
2:      return id(v, i-1);}
3:    return v;}
4:
5:  main(){
6:    i = input();
7:    v1 = id(1, i);
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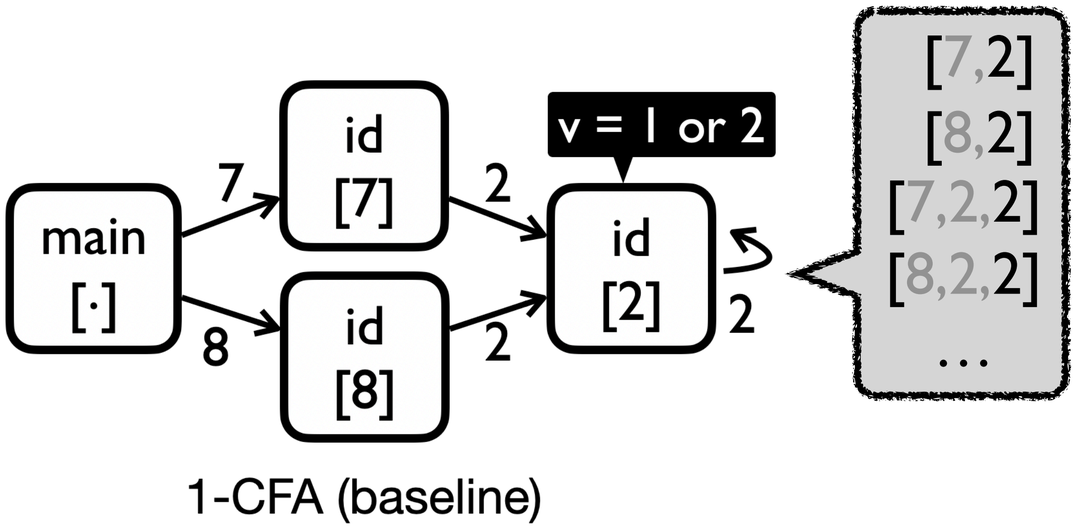
Example program



1-CFA (baseline)

Counterexample

- Selective ctx sensitivity improves scalability by selectively analyzing methods coarsely

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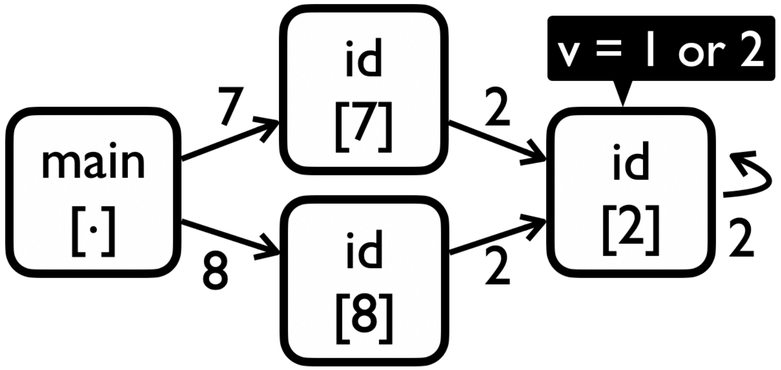

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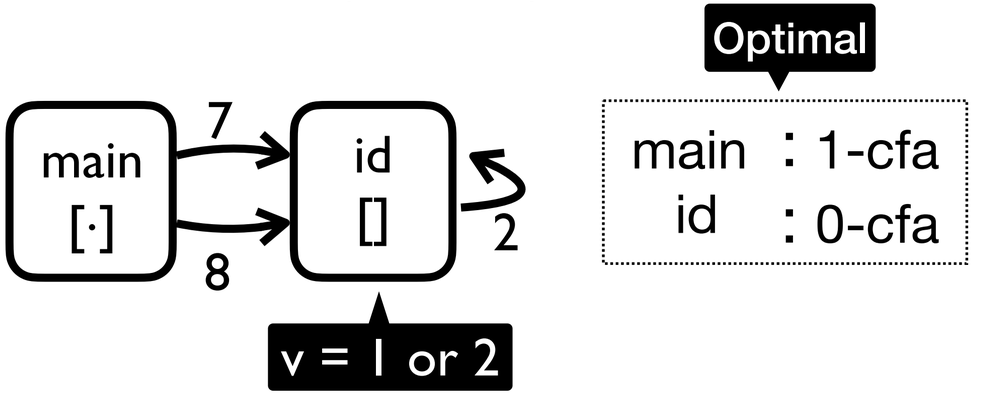

1-CFA with Selective Ctx Sensitivity

Counterexample

- Context tunneling improves precision by keeping key context elements

```
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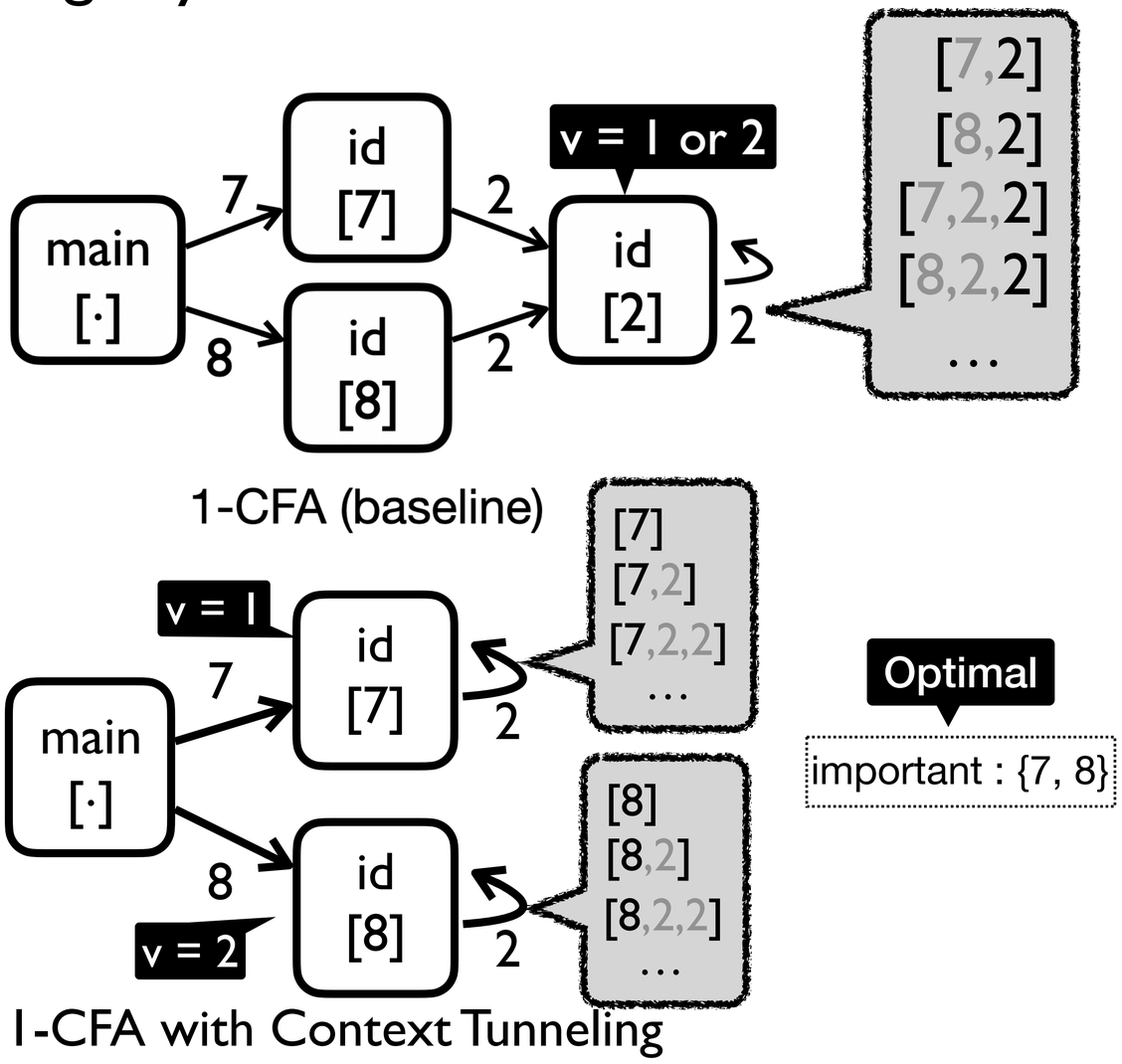

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- Does combining individually ideal techniques also result in ideal performance?

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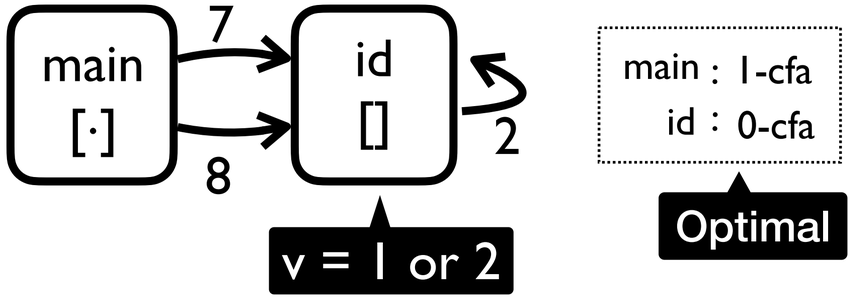

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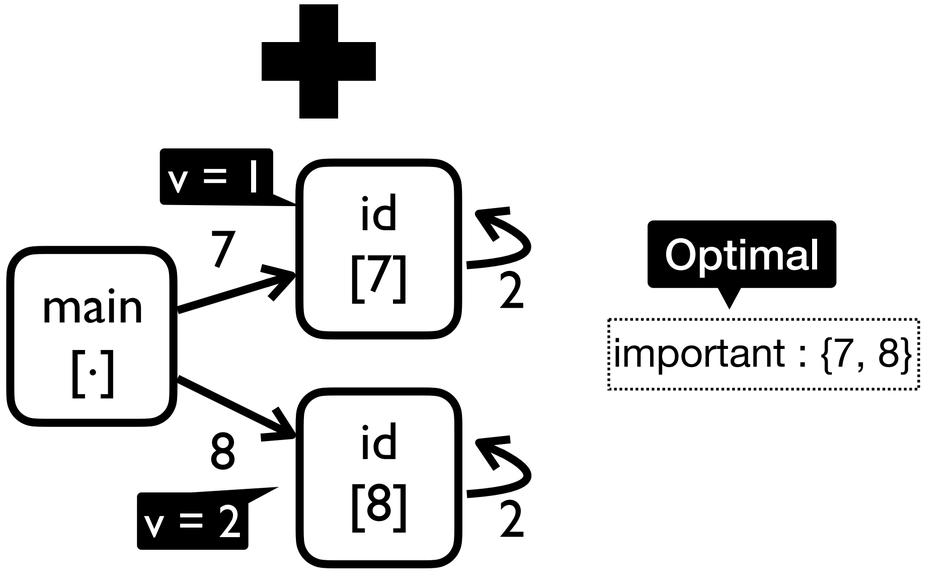

1-CFA with Context Tunneling

Counterexample

- Combining individually ideal techniques does not result in ideal performance

```
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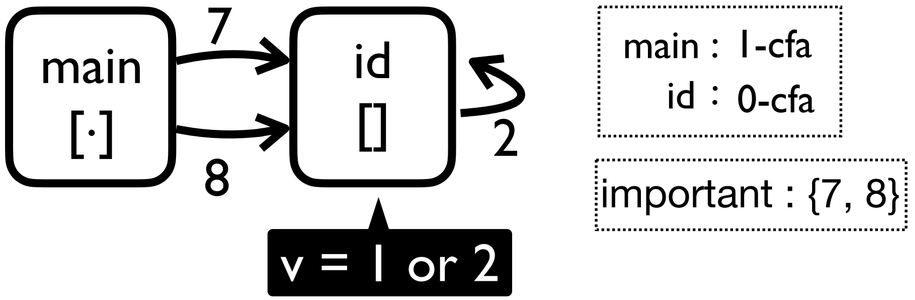
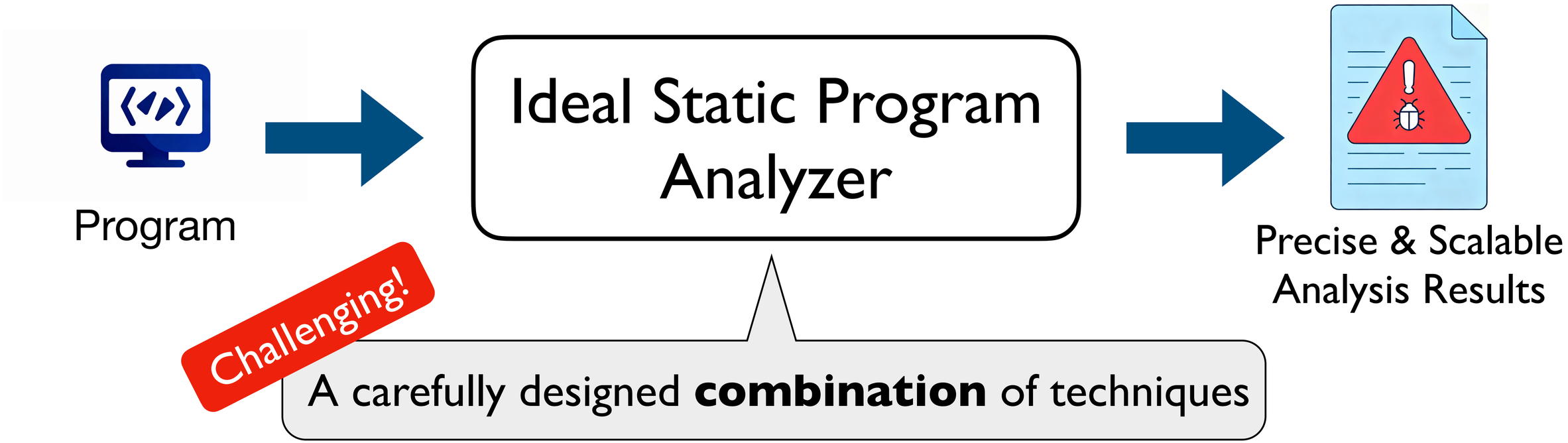


1-CFA with Selective + Tunneling

Problem

- Analysis techniques should be designed together with considering all their interactions



Our Solution

- We present a framework that safely reduces the burden of developing a combination of techniques

Enables sequential development

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- Suppose we design a pair of precision improving and scalability improving techniques

e.g., context tunneling

e.g., selective ctx sensitivity

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(1) Develop a precision improving technique without considering the other technique

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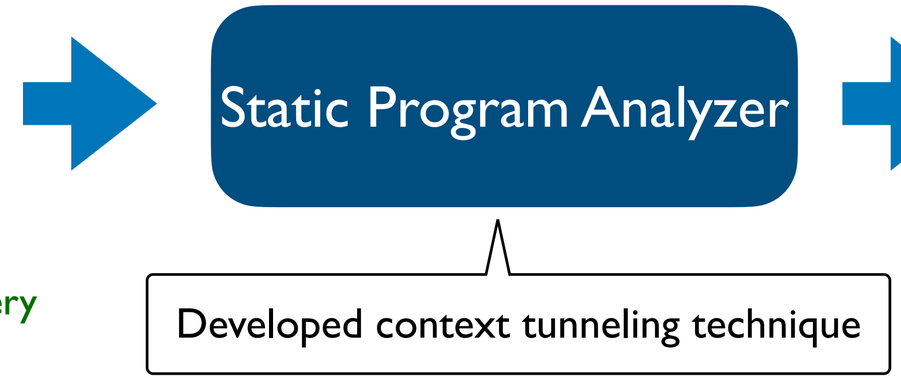

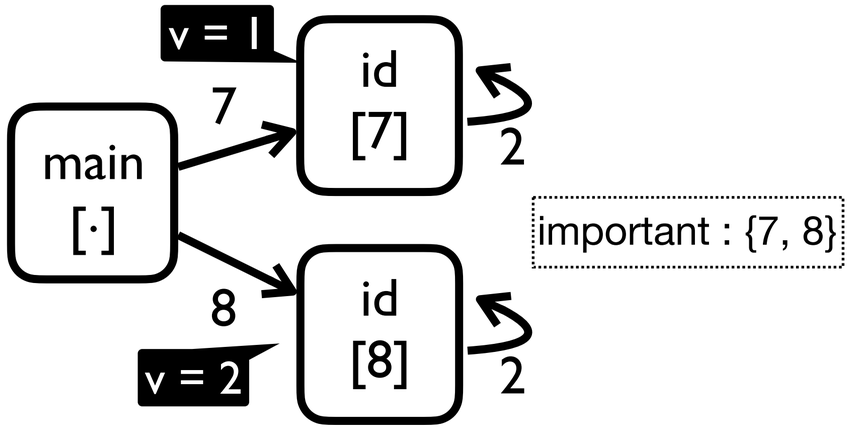

1-CFA with Tunneling

Our Solution

- We present a framework that safely reduces the burden of developing a combination of techniques
- Suppose we design a pair of precision improving and scalability improving techniques

e.g., context tunneling

e.g., selective ctx sensitivity

(1) Develop a precision improving technique without considering the other technique

(2) Develop a scalability improving technique based-on the previously developed precision improving technique

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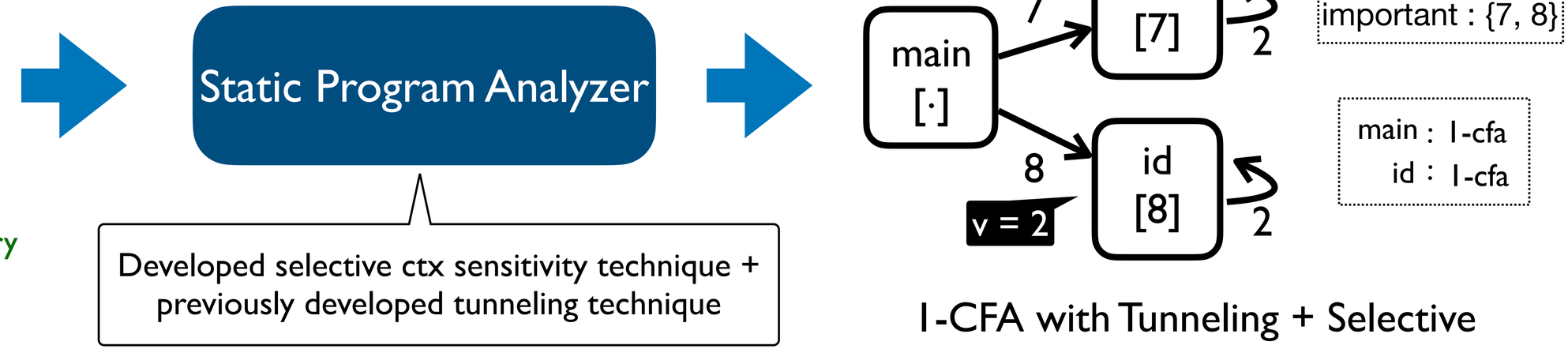


1-CFA with Tunneling + Selective

Our Solution

- We present a framework that safely reduces the burden of developing a combination of techniques
- Suppose we design a pair of precision improving and scalability improving techniques

e.g., context tunneling

e.g., selective ctx sensitivity

(1) Develop a precision improving technique without considering the other technique

(2) Develop a scalability improving technique based-on the previously developed precision improving technique

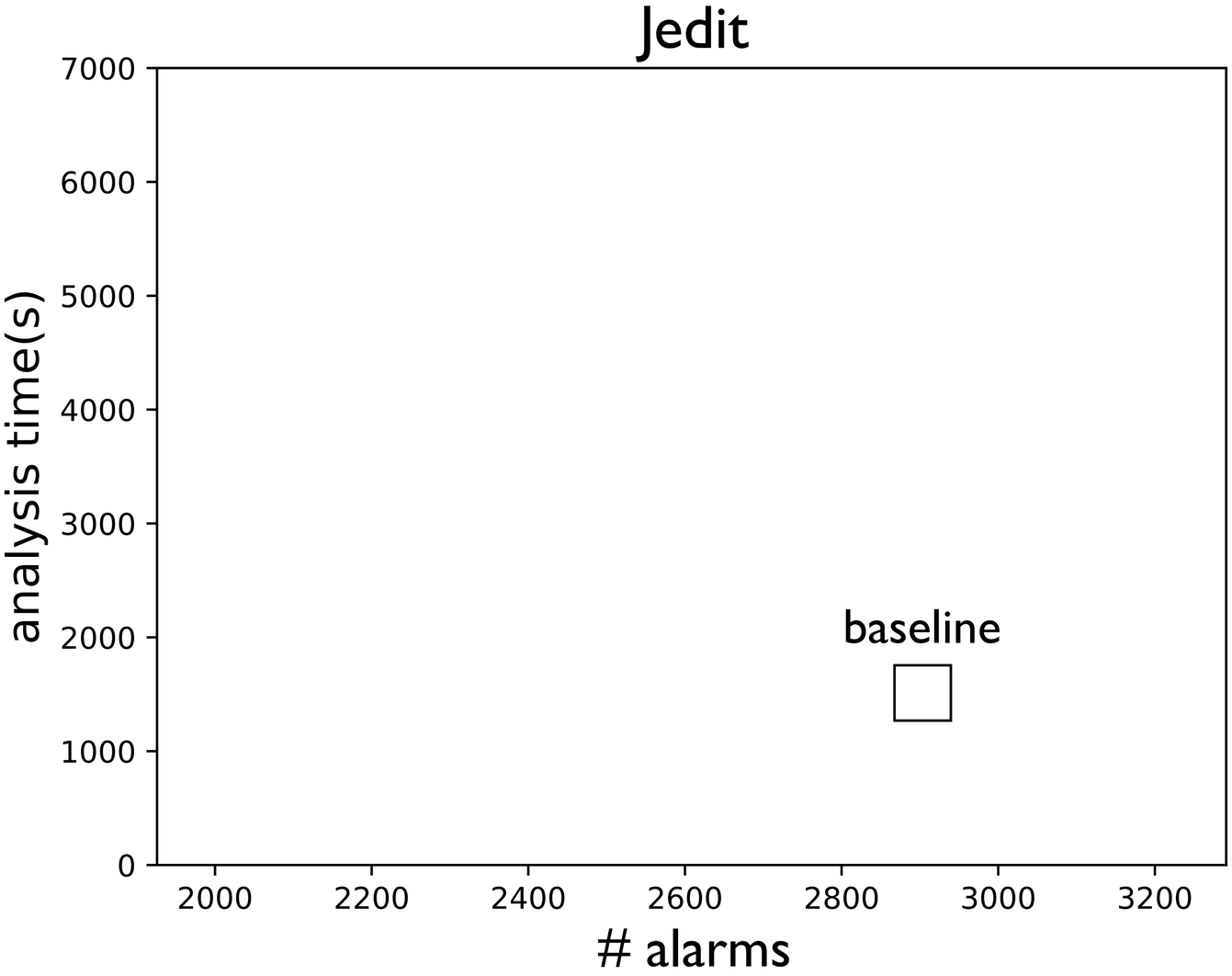
(3) Combine the two techniques

Theorem

Let T_1 be a tunneling technique which is ideal when used alone and T_2 be a selective context sensitivity technique which is ideal when used along with T_1, the the combination of the two techniques (T_1,T_2) is an ideal combination.

Experimental Results

- Following our framework enables developing an effective combination of the two techniques



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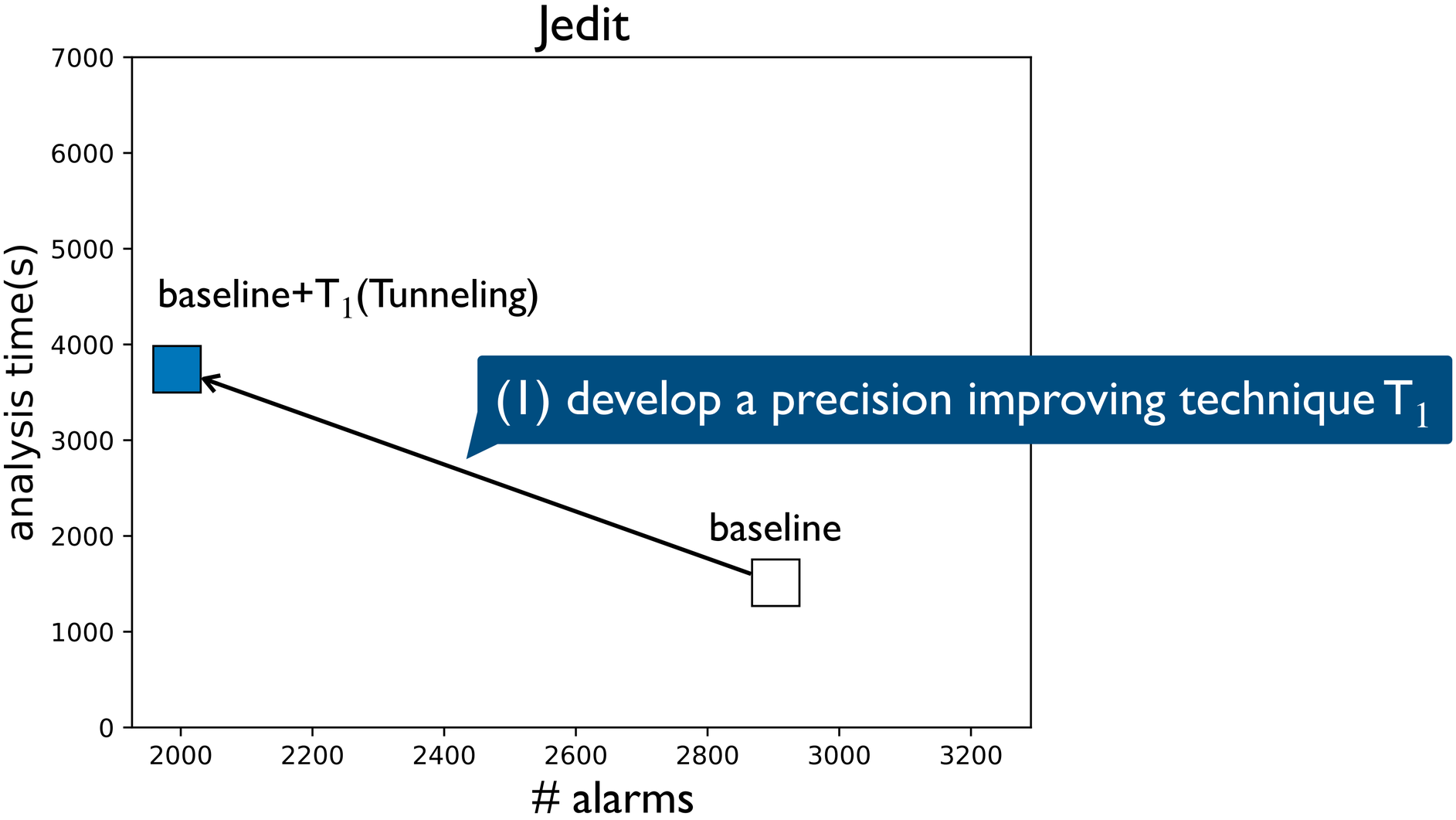

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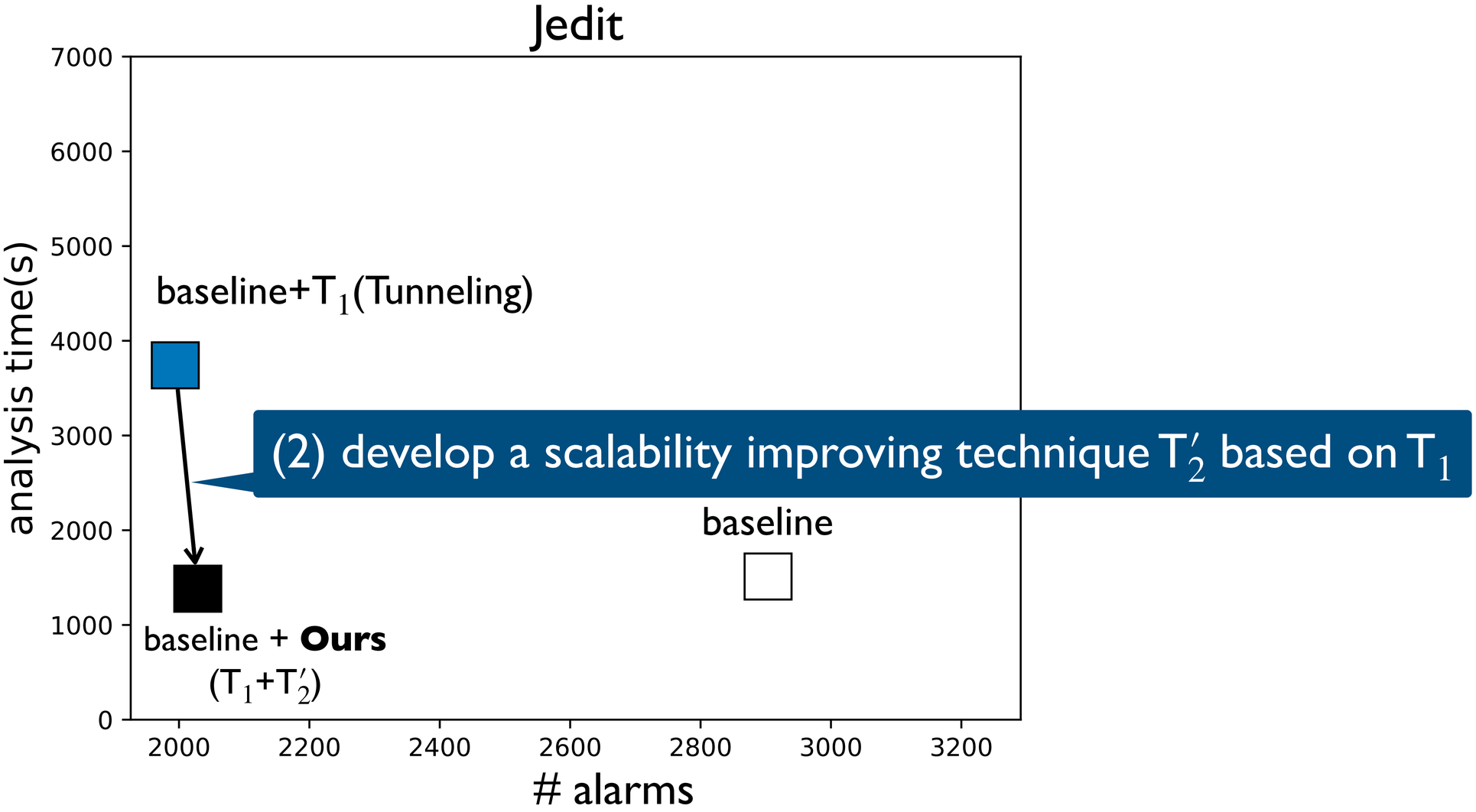

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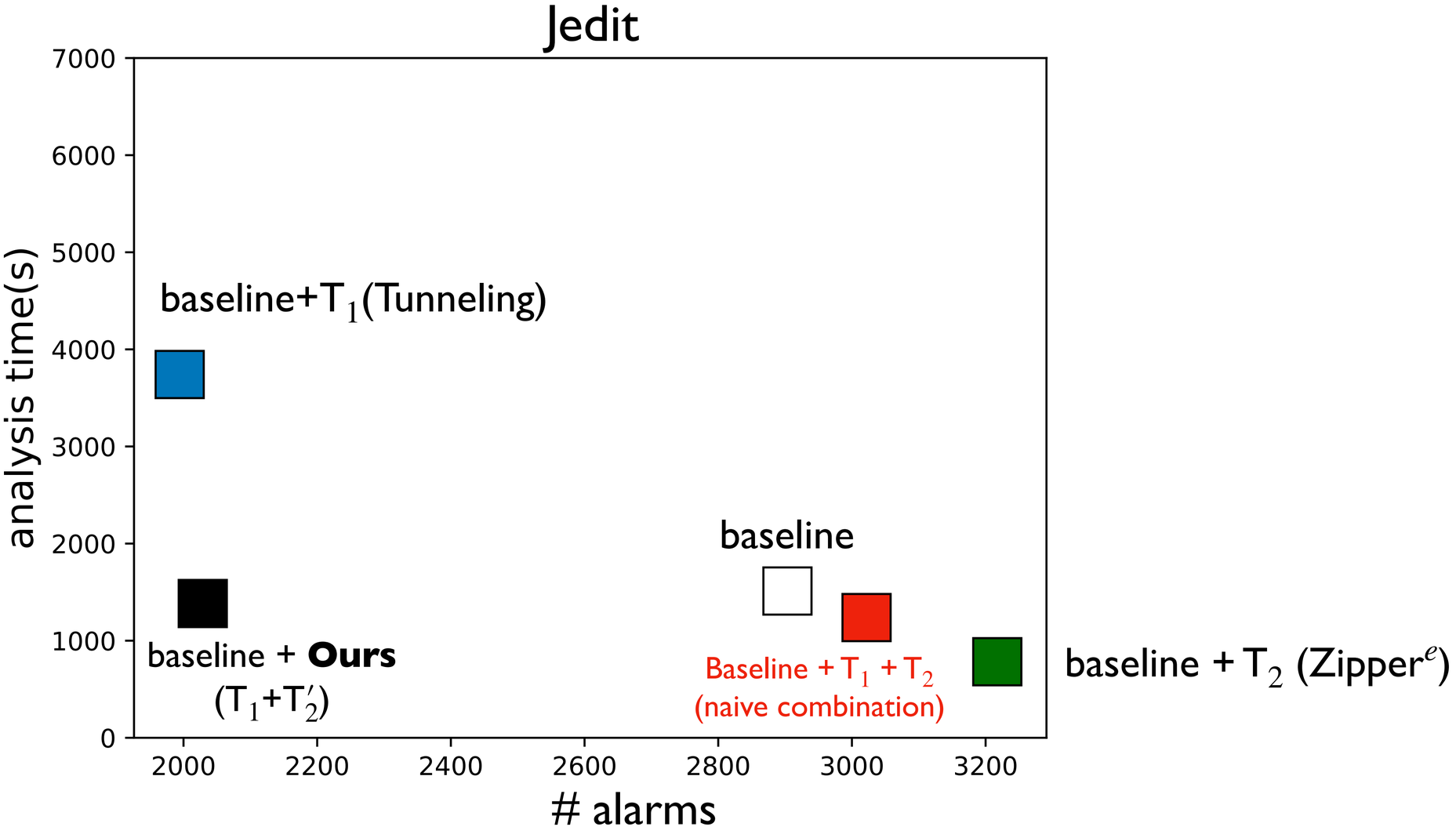

Conclusion

Independently developing analysis techniques will result in suboptimal analysis