

Construction of Verifier Combinations Based on Off-the-Shelf Verifier

Dirk Beyer, Sudeep Kanav, and **Cedric Richter**

04.04.2022

Software Verification

```
int main(){  
  
    unsigned int n = __VERIFIER_nondet_uint();  
    unsigned int x=n, y=0;  
  
    while(x>0){  
        x--;  
        y++;  
    }  
  
    __VERIFIER_assert(y==n);  
}
```

Verification Task

Software Verification

`int main(){`
Program

```
unsigned int n = __VERIFIER_nondet_uint();
unsigned int x=n, y=0;

while(x>0){
    x--;
    y++;
}
```

```
__VERIFIER_assert(y==n);
}
```

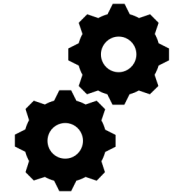
Software Verification

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    }  
    Specification  
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Software Verification

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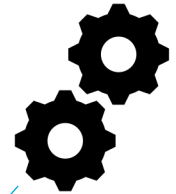
Verifier



Software Verification

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int main(){  
  
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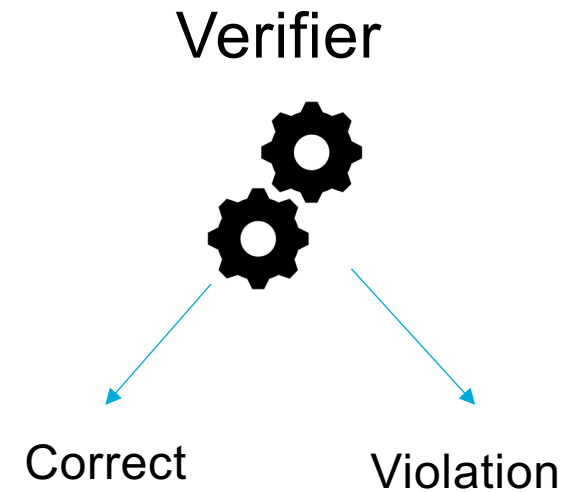
Verifier



Correct

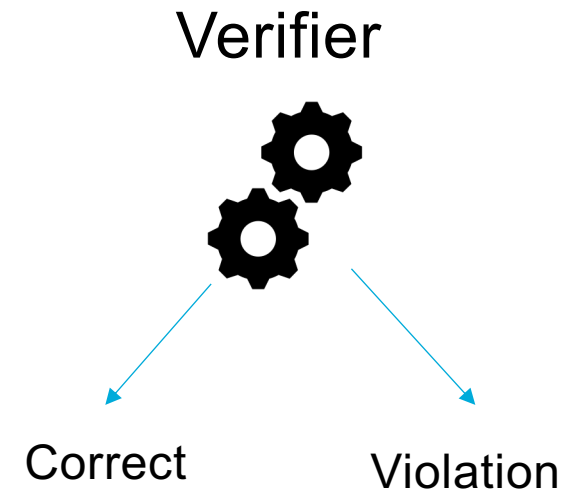
Software Verification

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Realistic Setting

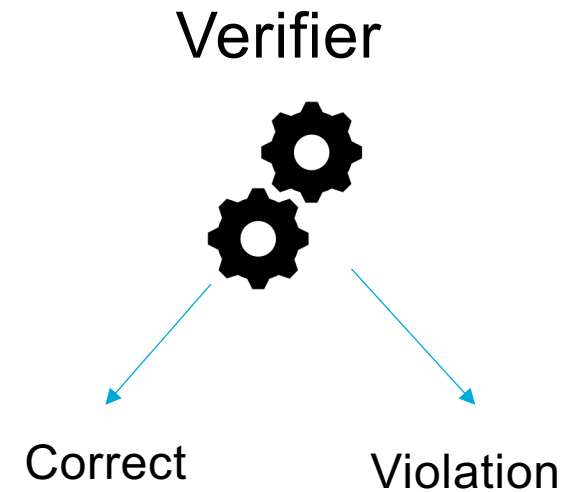
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Realistic Setting

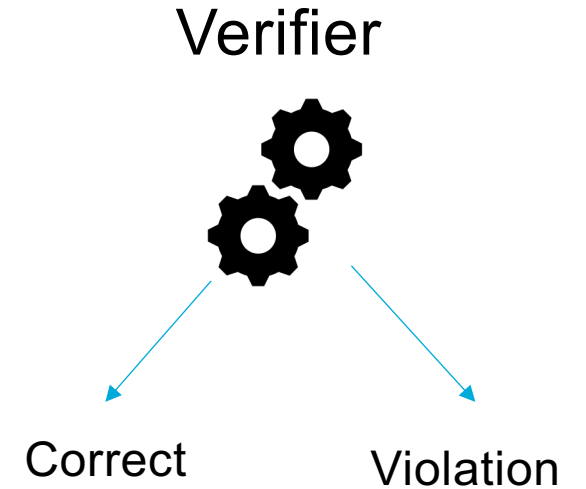
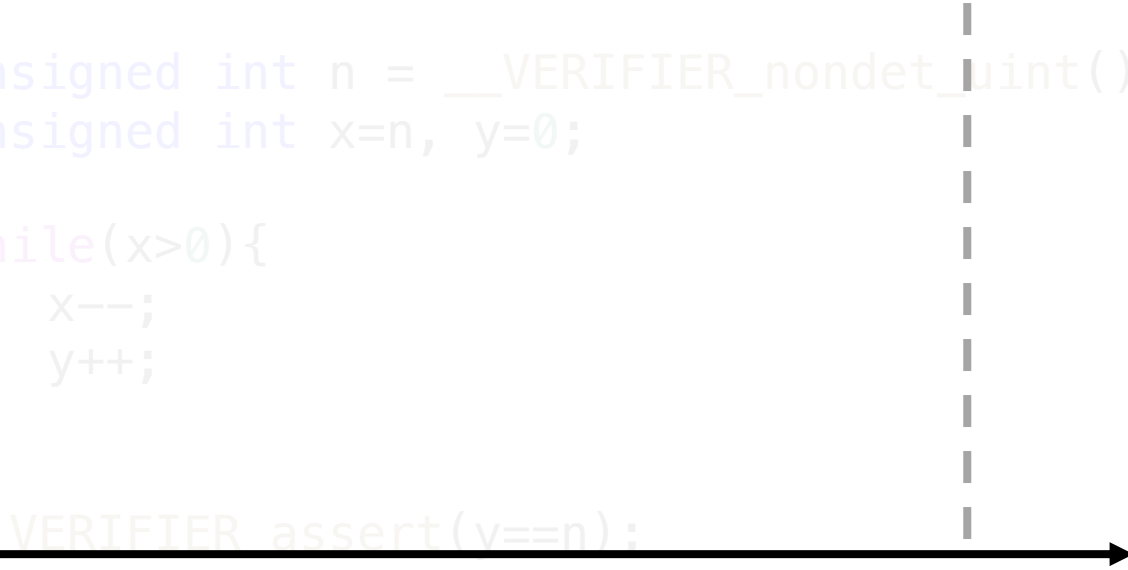
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    }  
  
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Time →

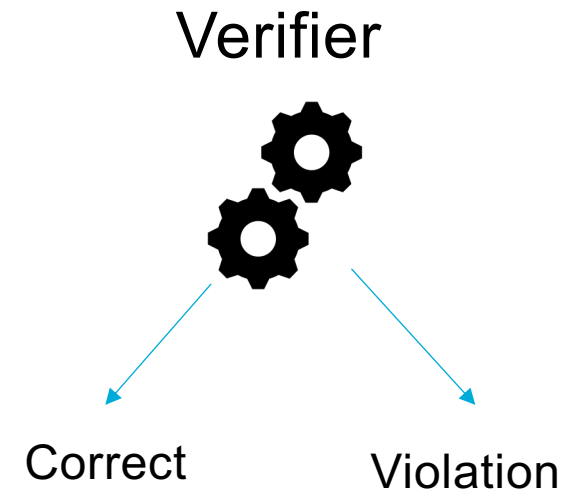
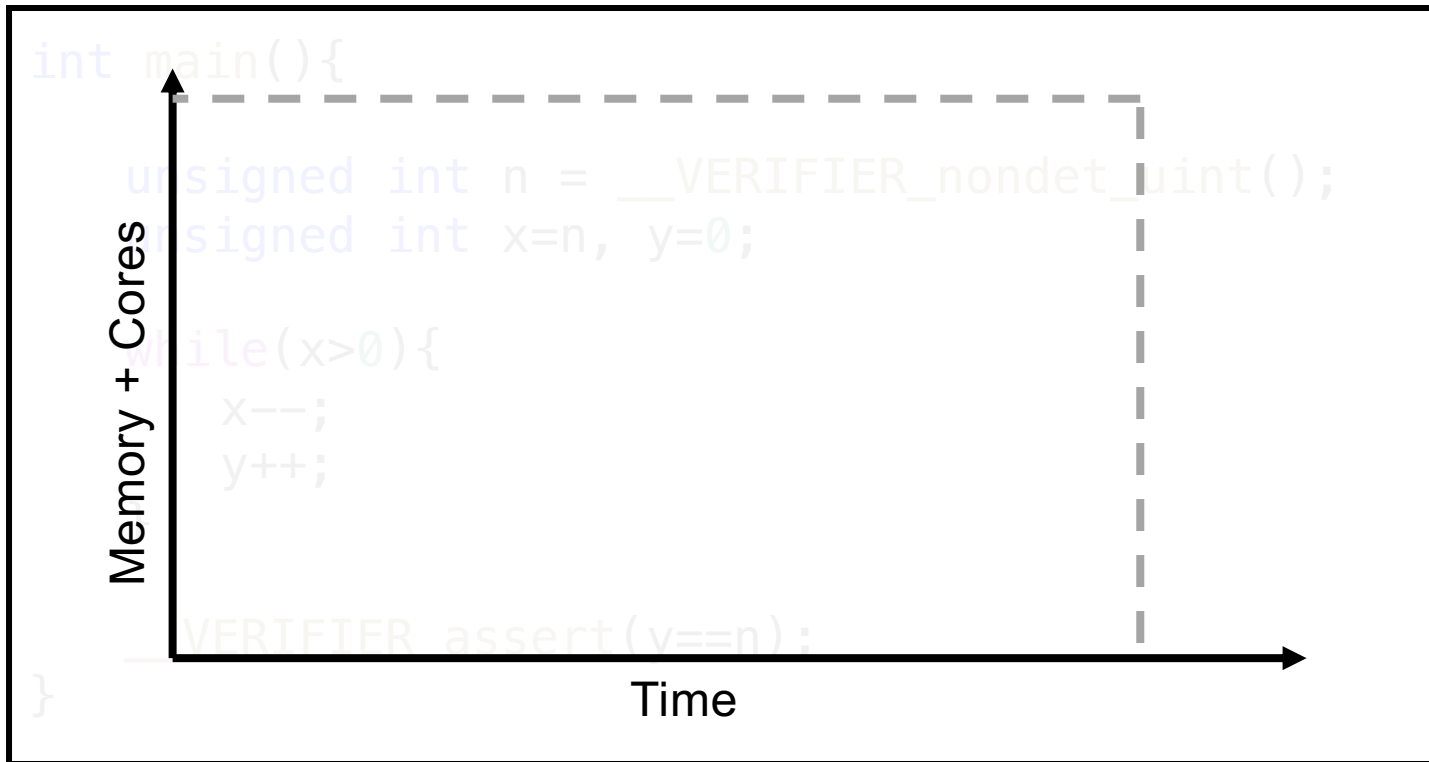


Realistic Setting

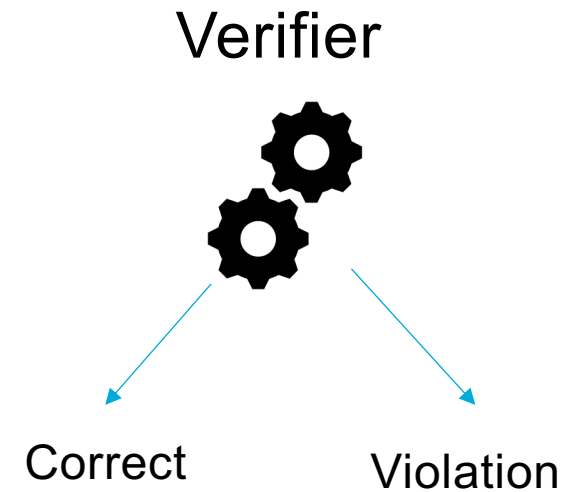
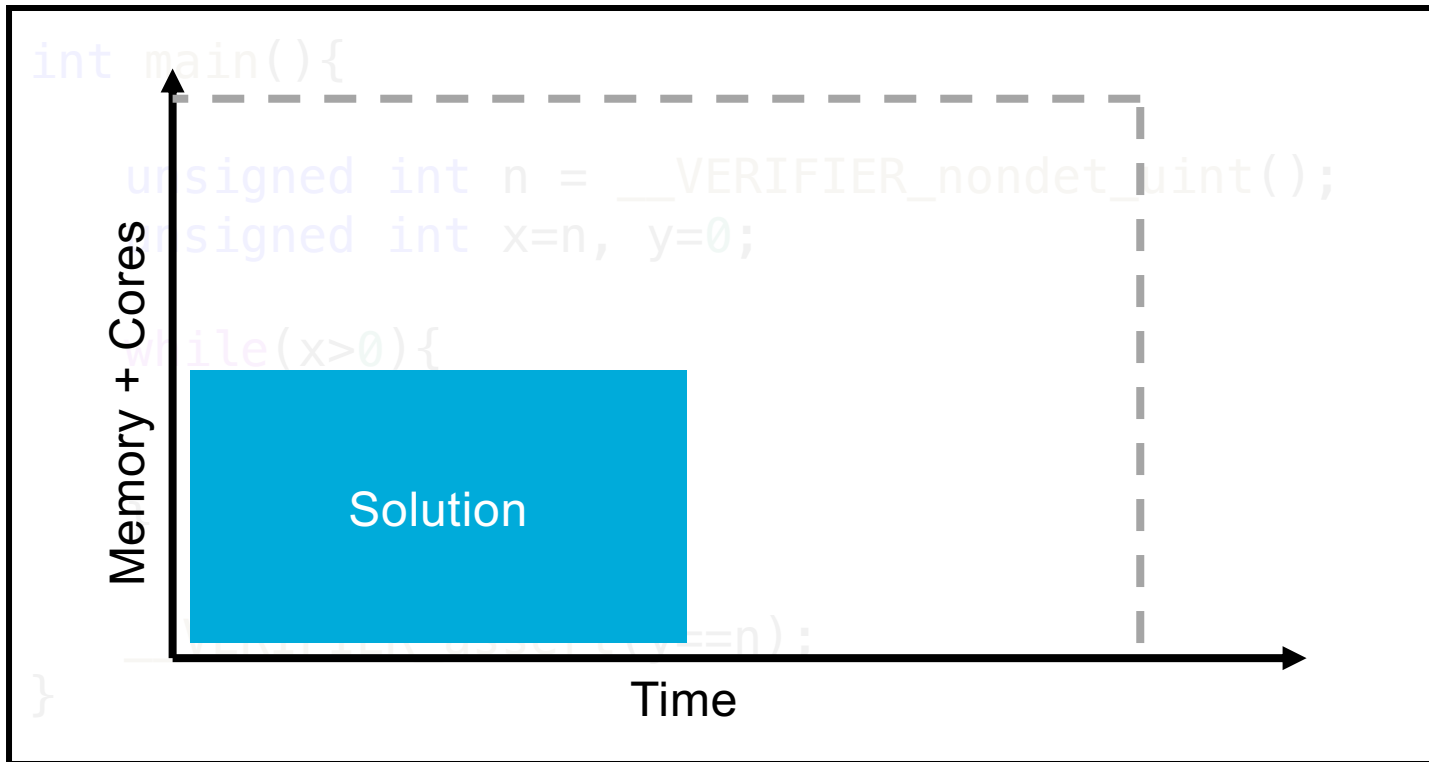
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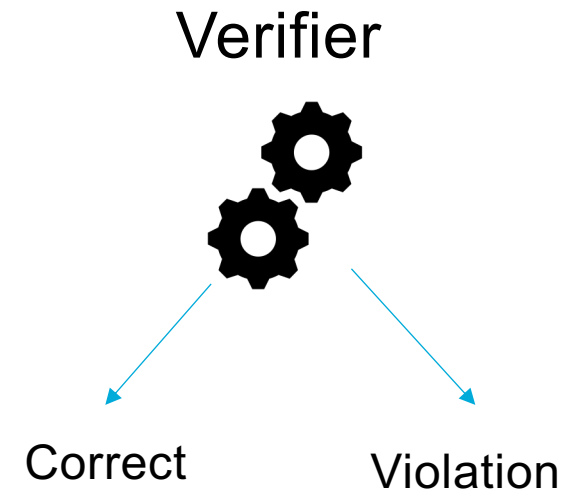
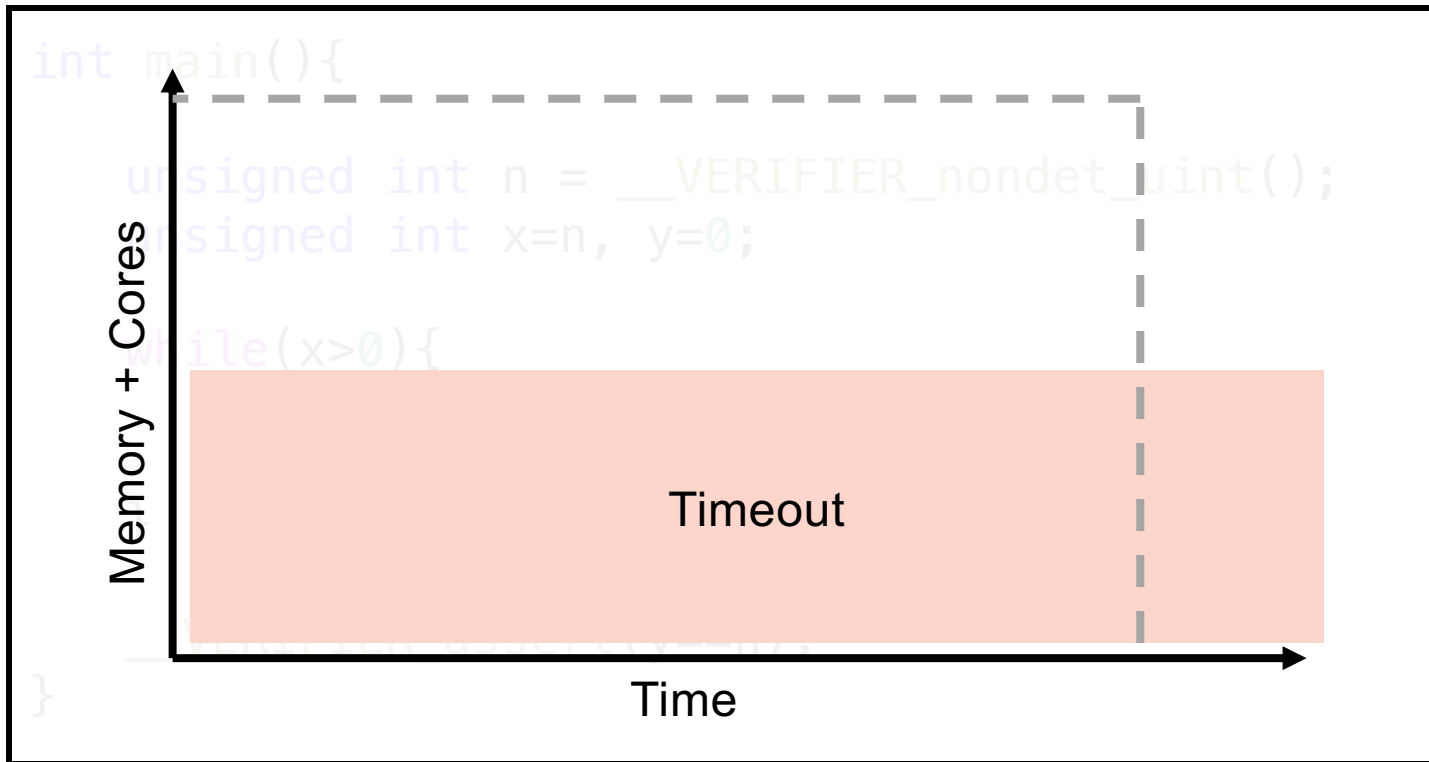
Realistic Setting



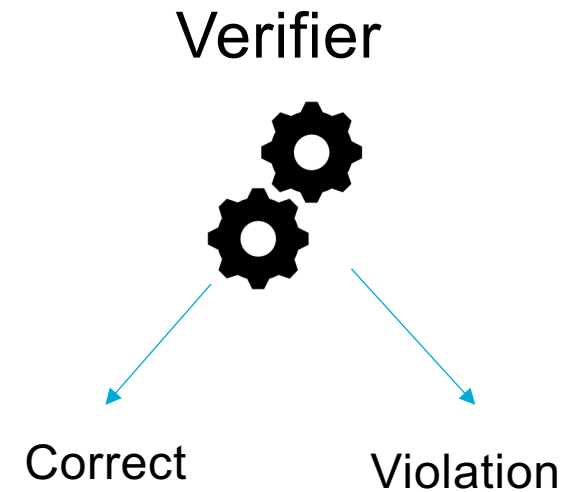
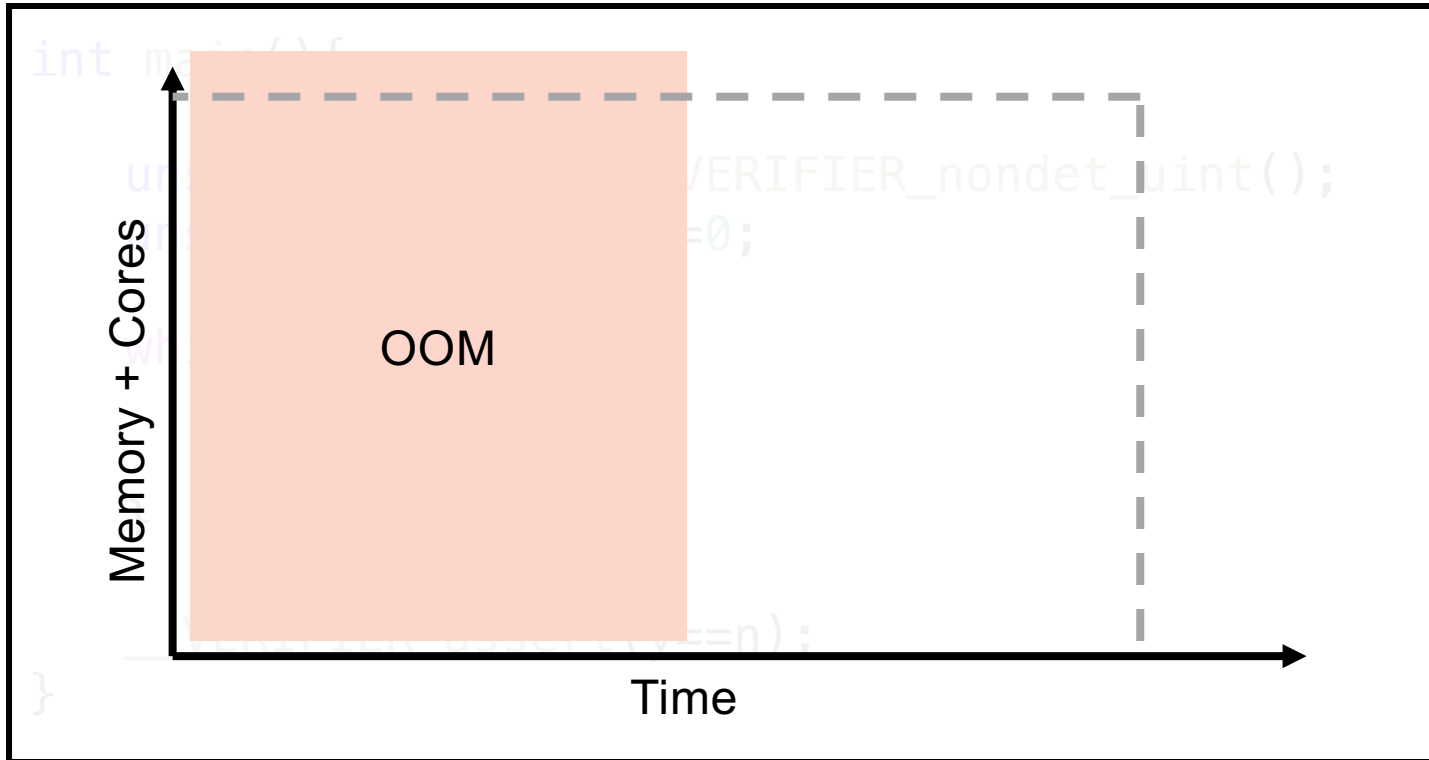
Realistic Setting



Realistic Setting

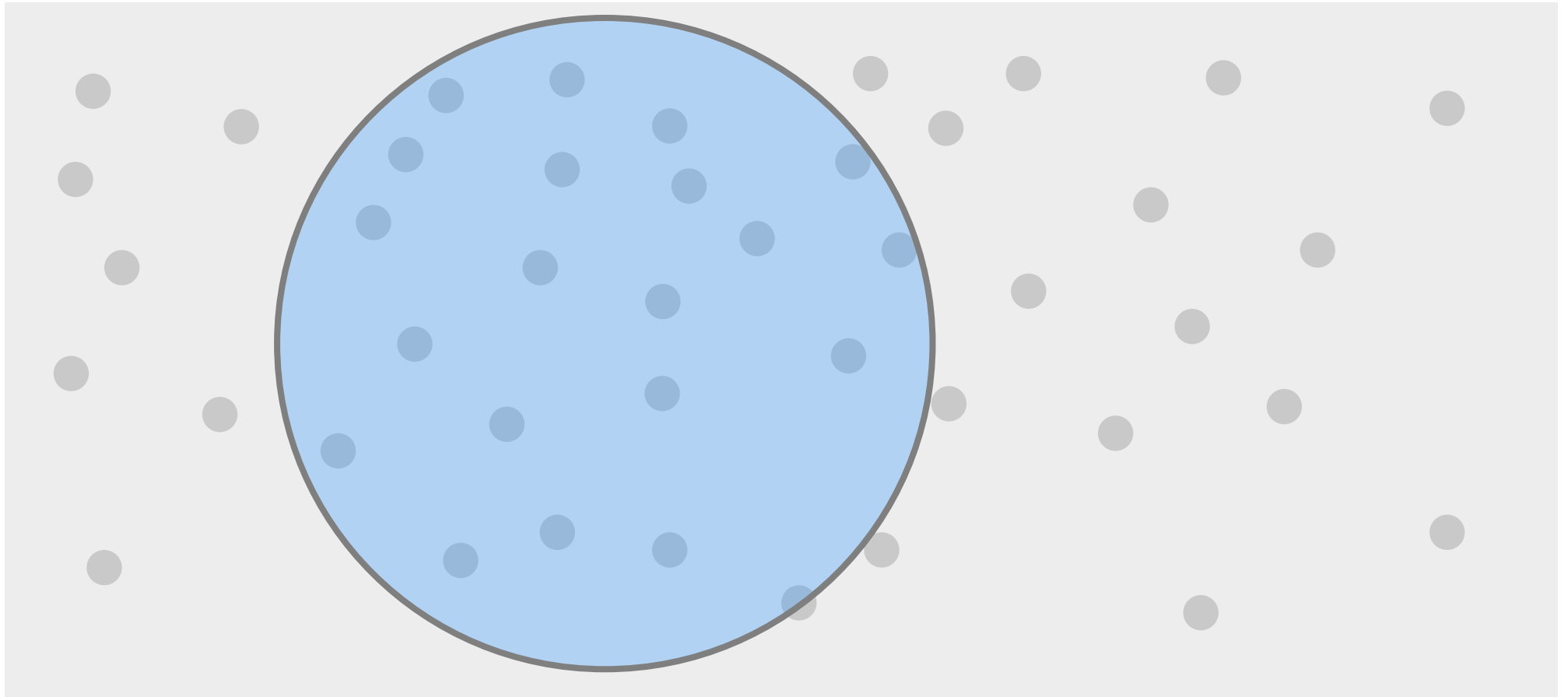


Realistic Setting



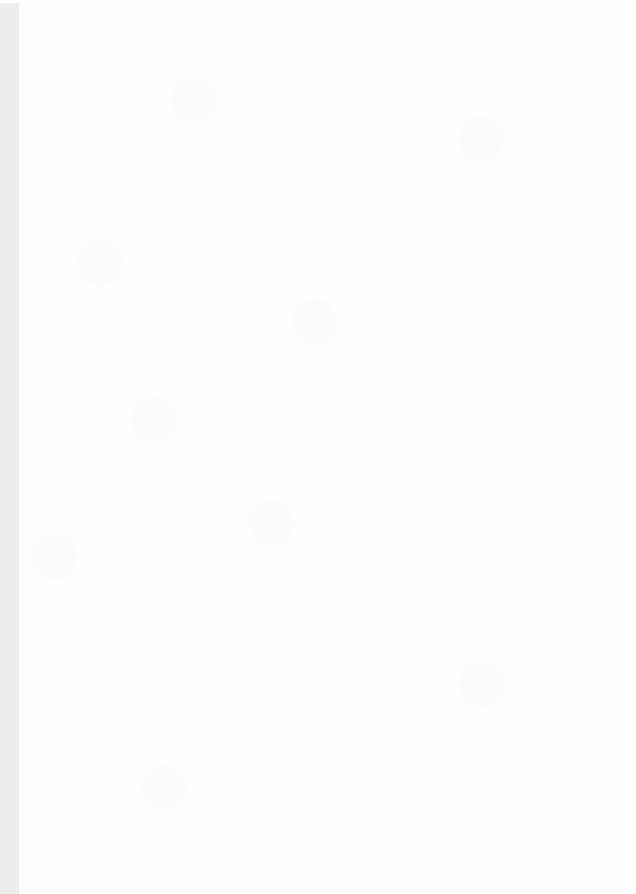
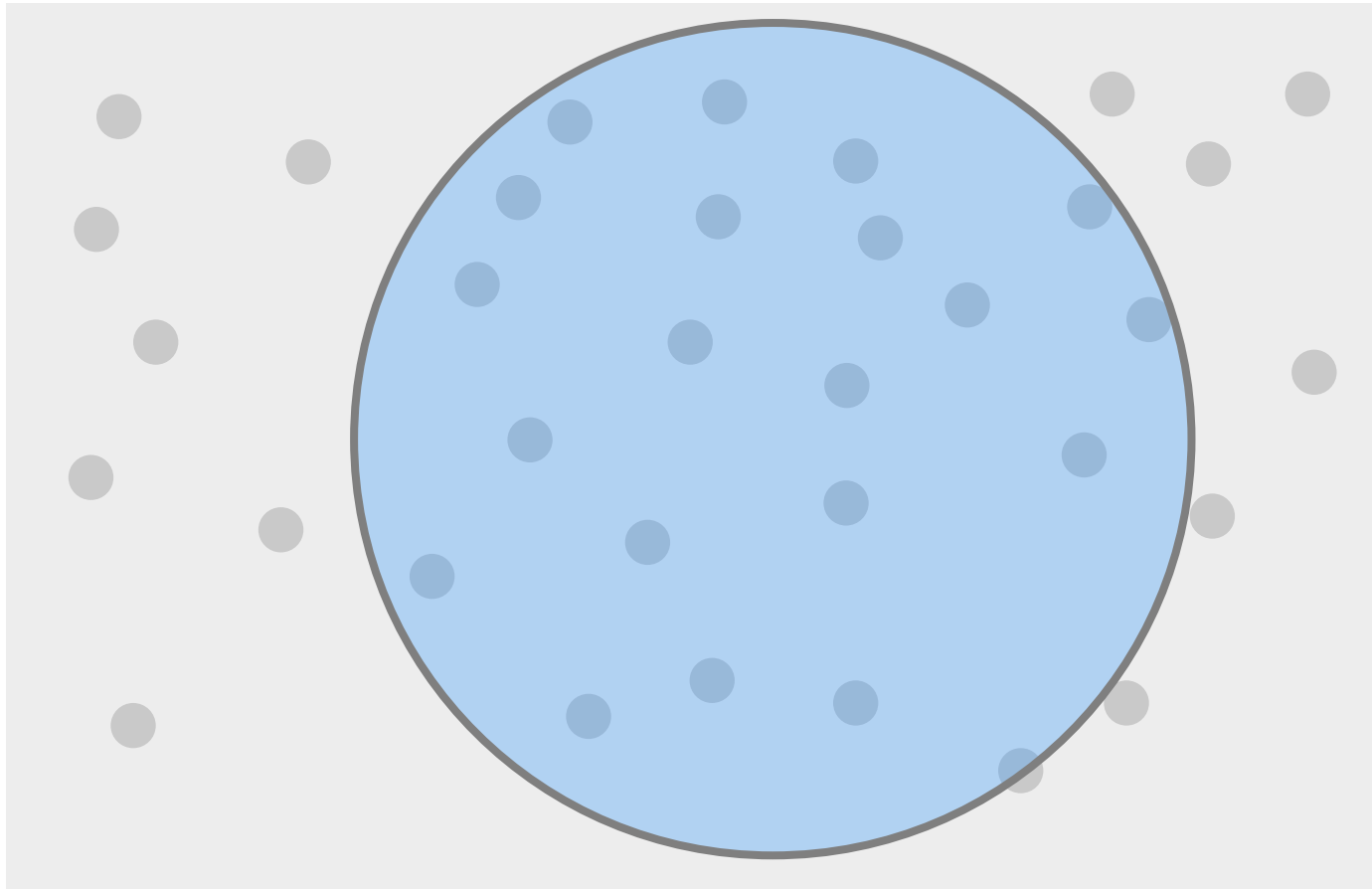


Limits of a **single** verifier



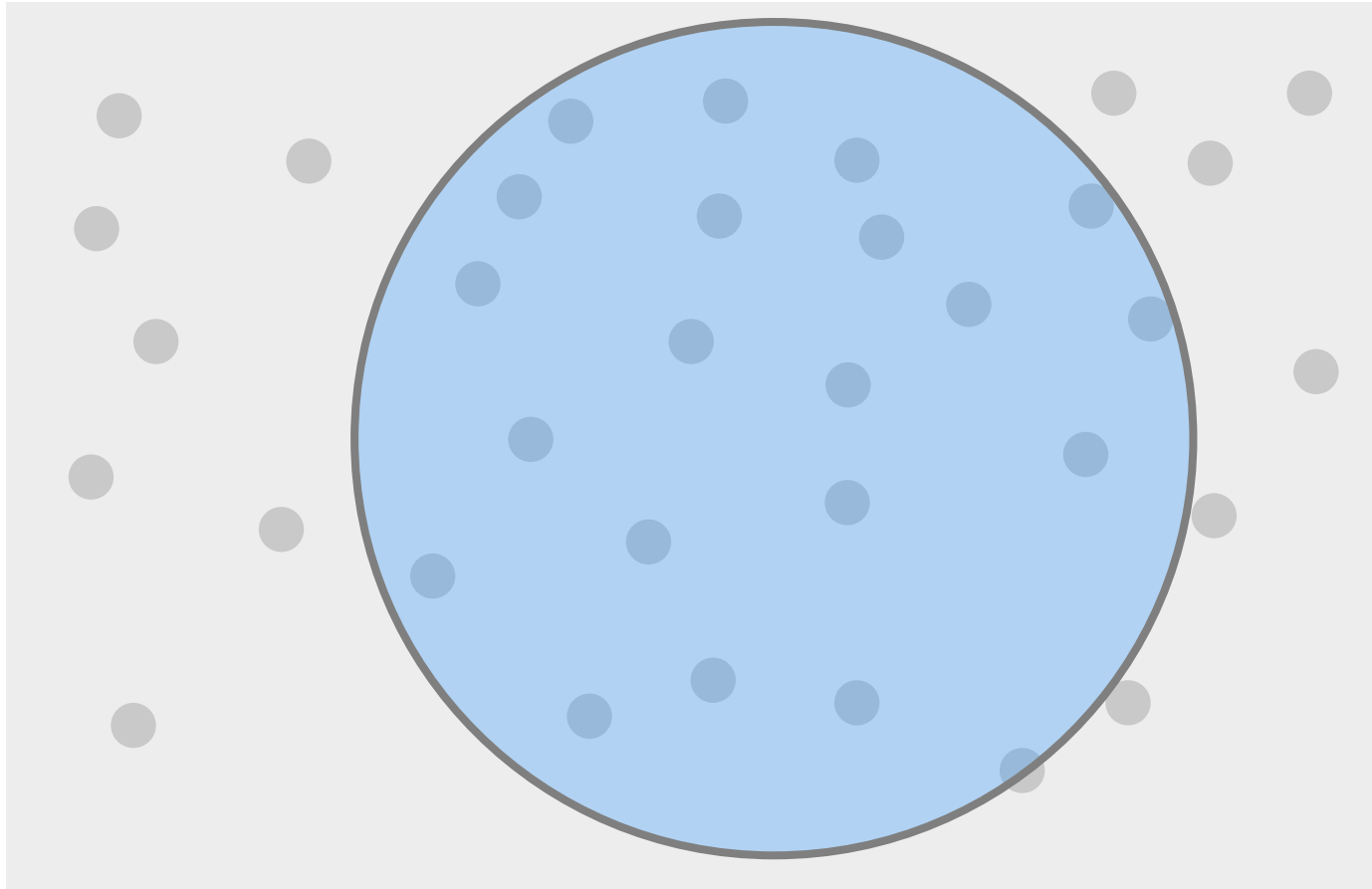
● Verification Task

Limits of a **single** verifier



● Verification Task

Limits of a **single** verifier



CPAchecker

UAutomizer

ESBMC

Symbiotic

CBMC

Divine

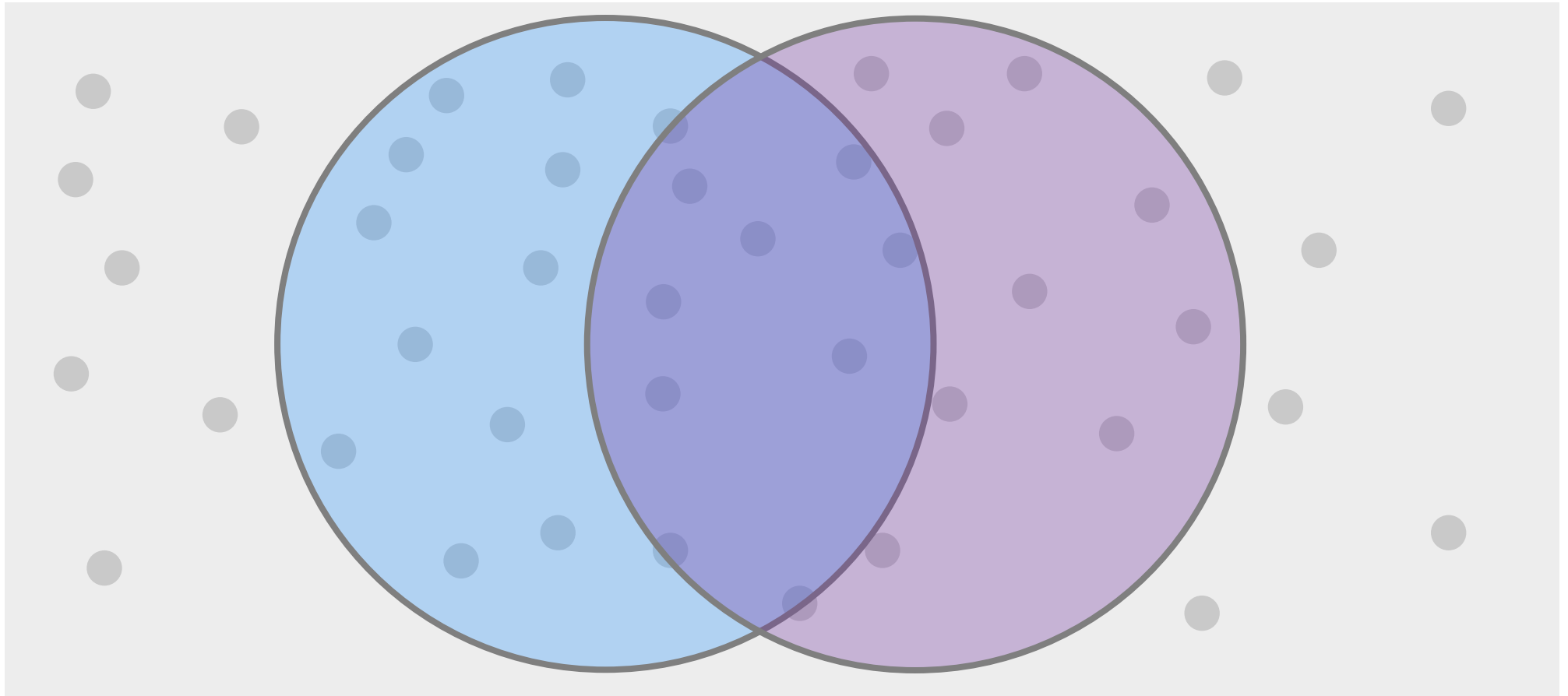
Goblint

UTaipan

⋮

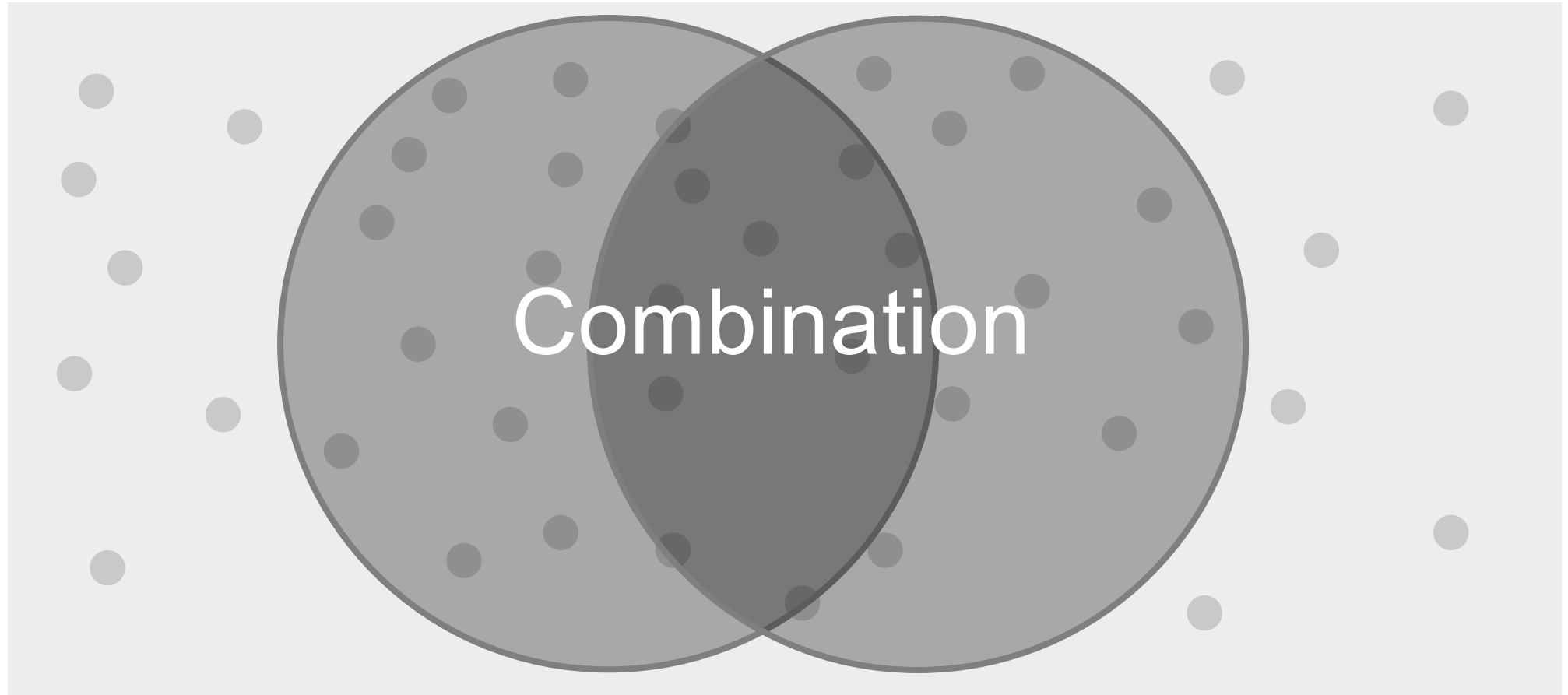
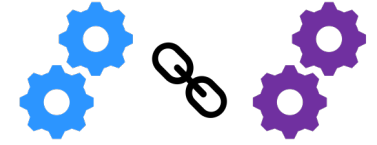
● Verification Task

Limits of a **single** verifier



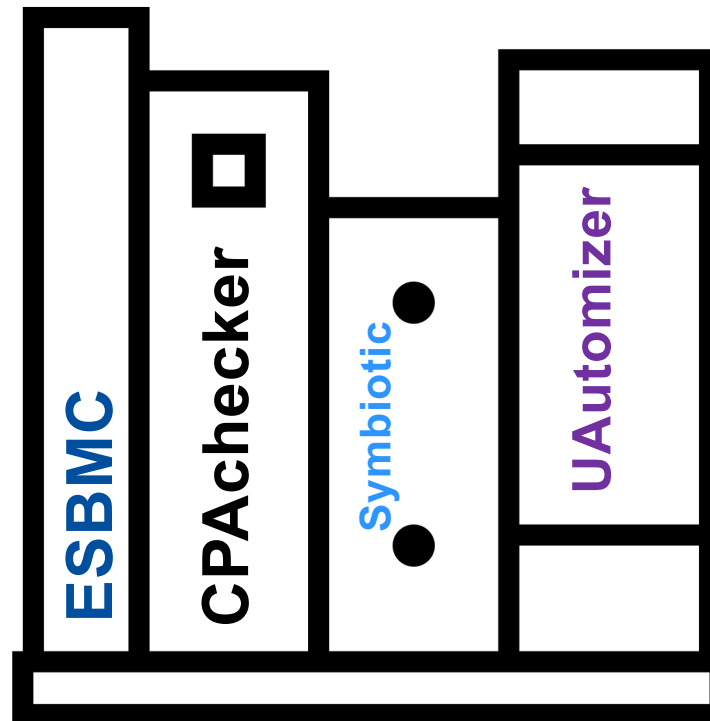
● Verification Task

Can we improve a single verifier **by combination**?



● Verification Task

Off-the-shelf construction of combinations



Verifier Selection

CPAchecker [7]

ESBMC [30]

Symbiotic [21]

UAutomizer [31]

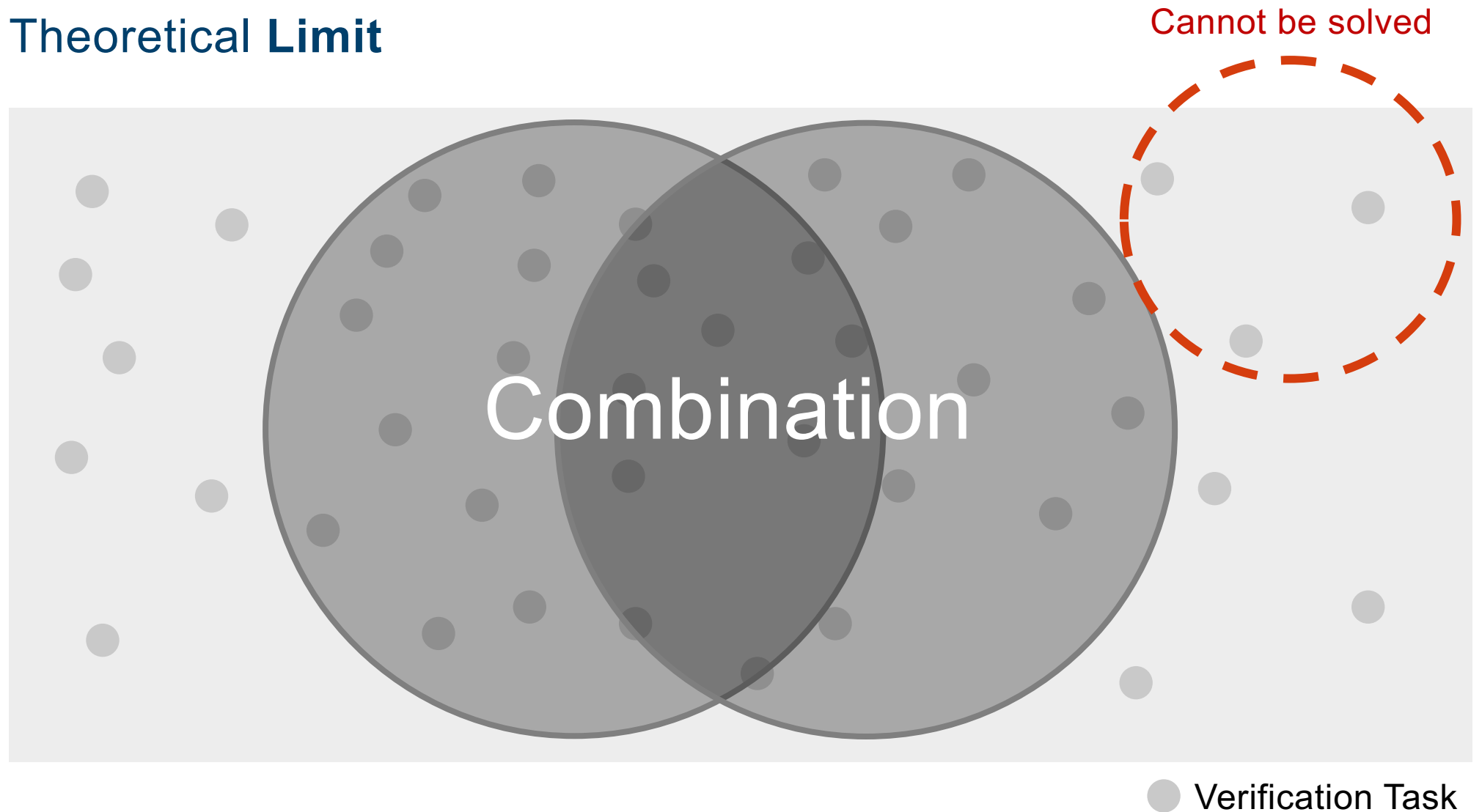
CBMC [40]

Divine [41]

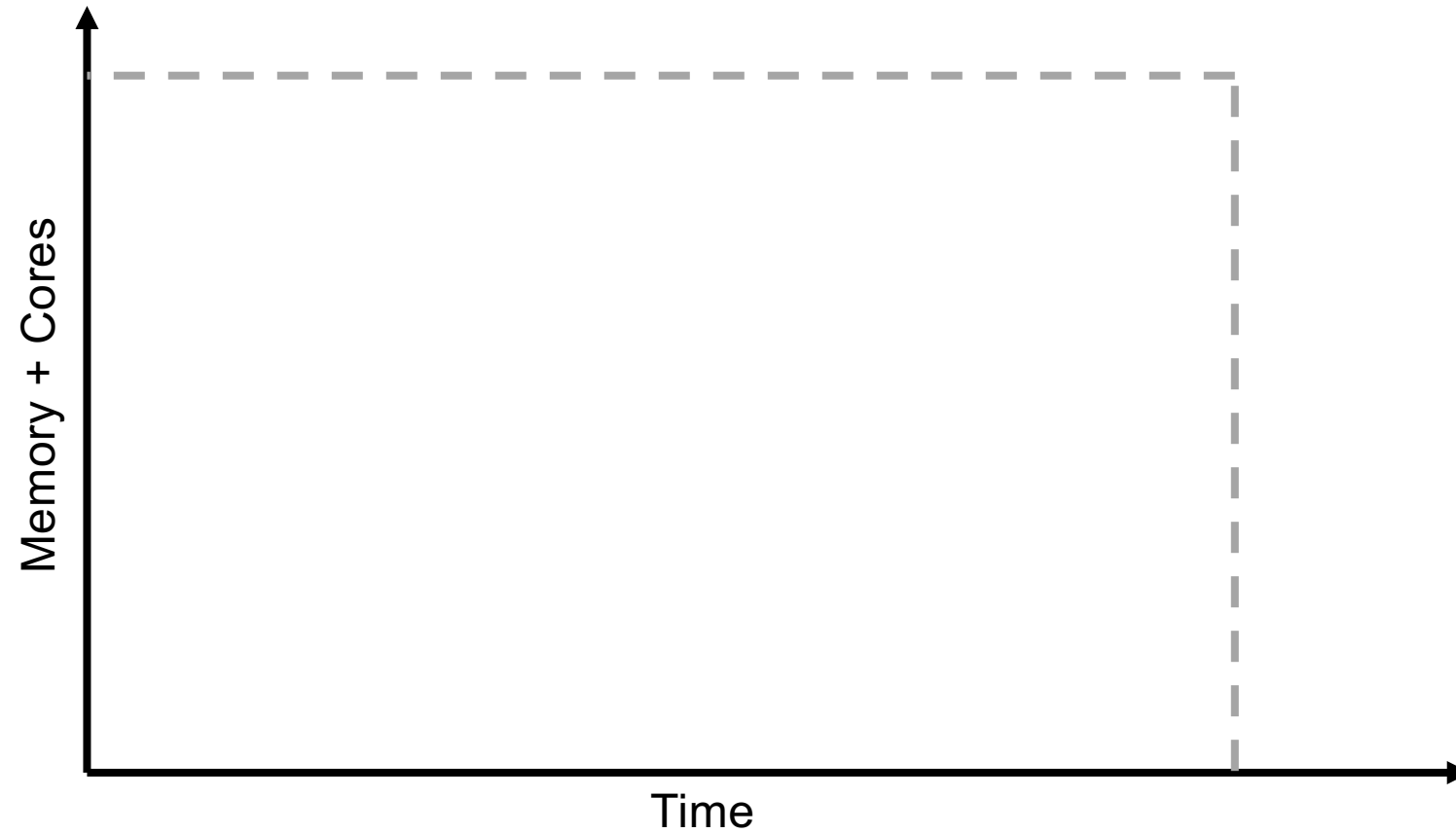
Goblint [50]

UTaipan [28]

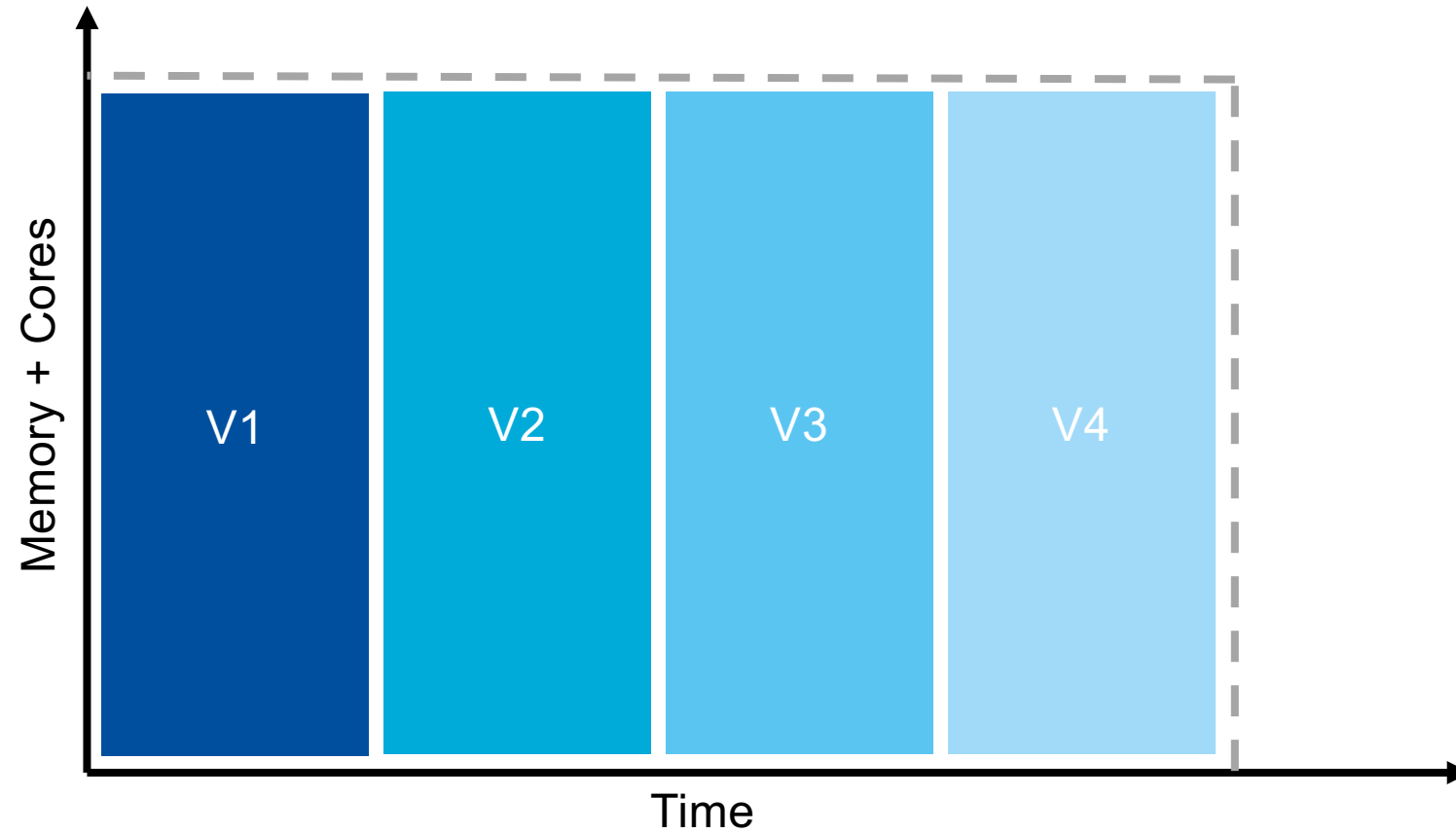
Theoretical Limit



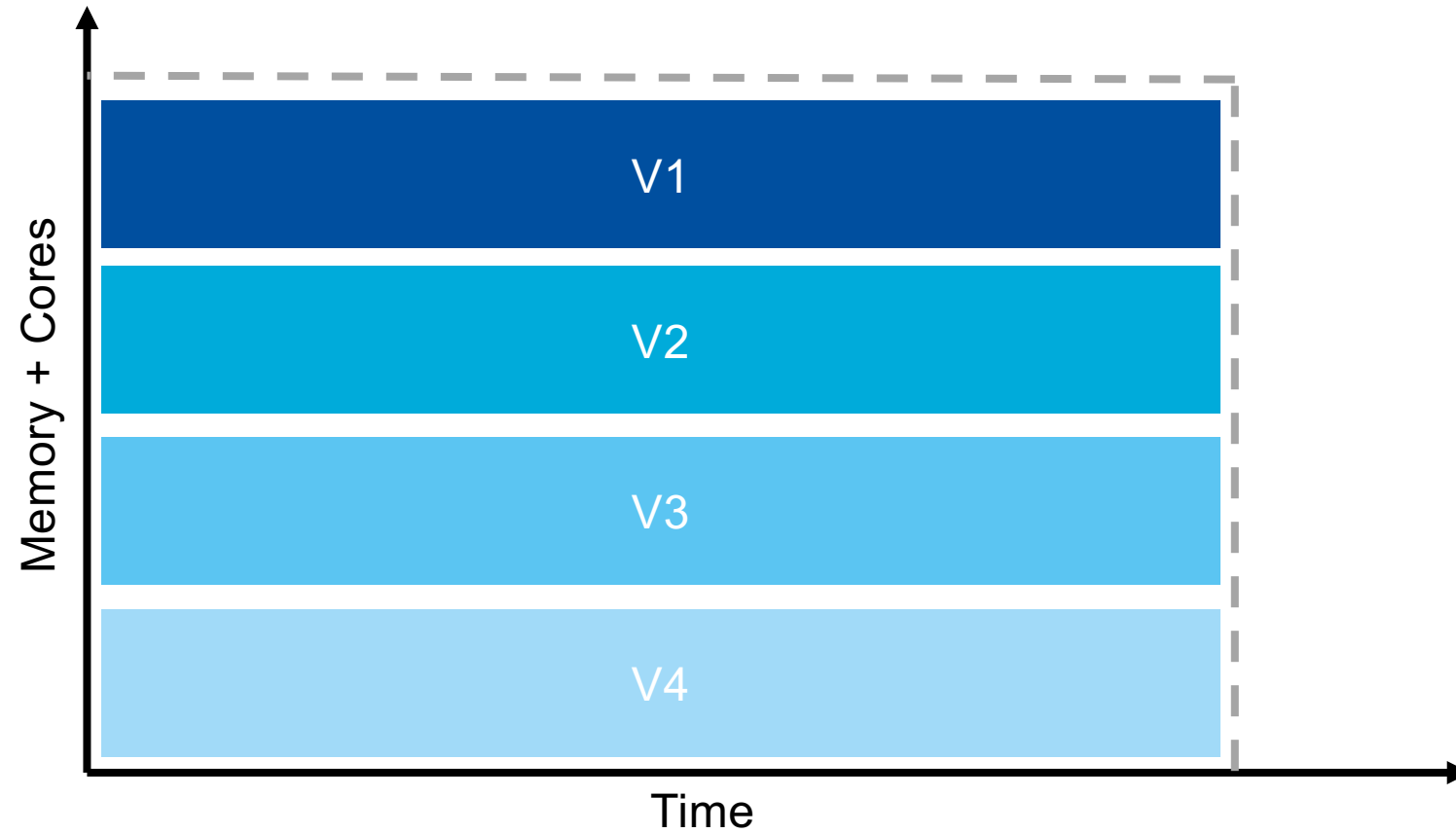
Black-box combinations



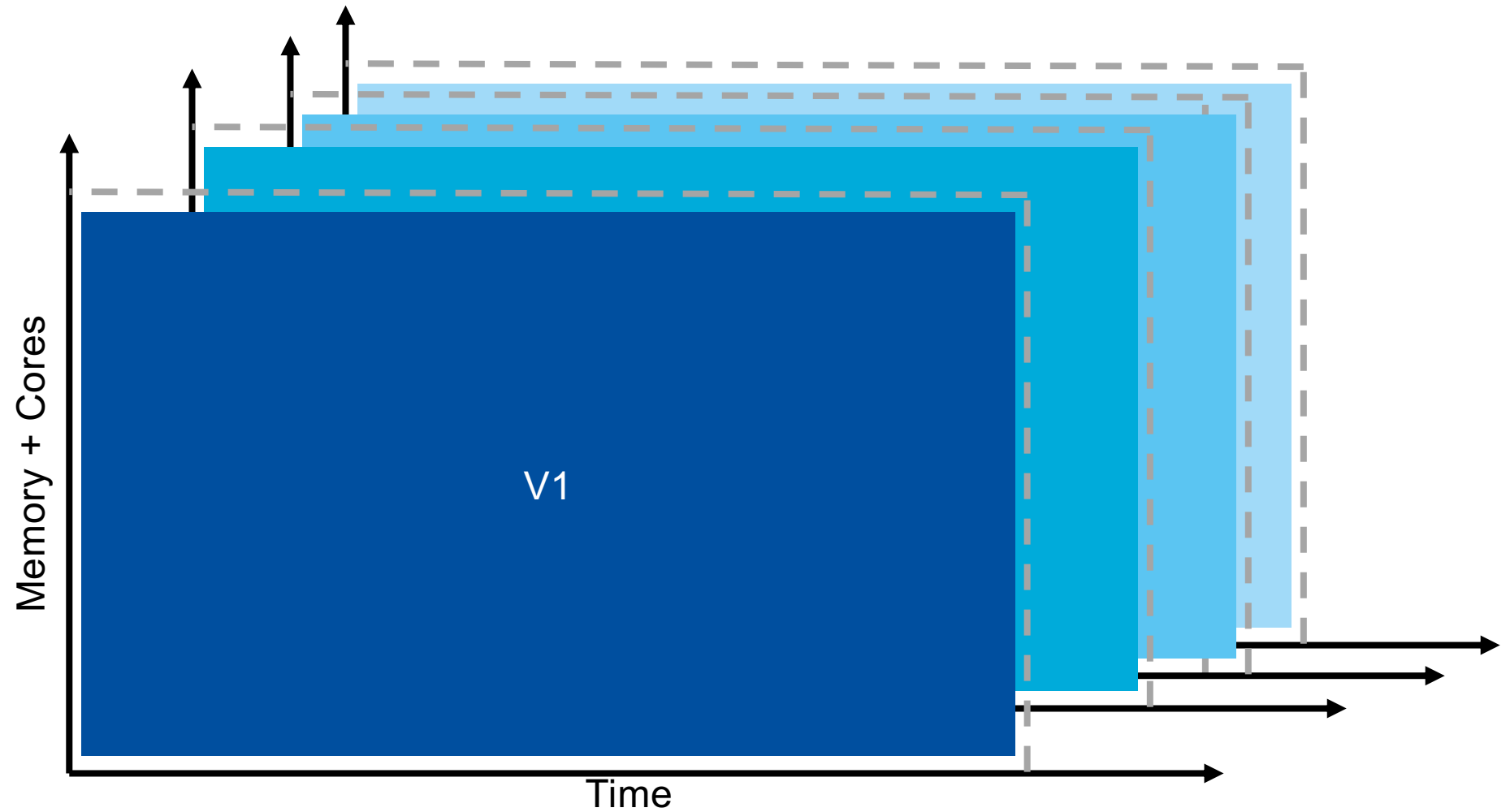
Sequential portfolios



Parallel portfolios

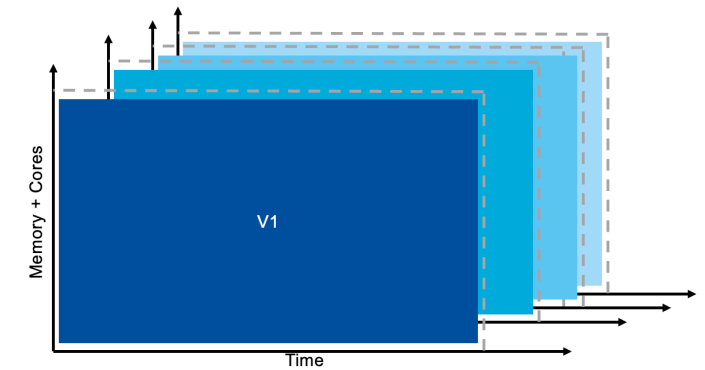
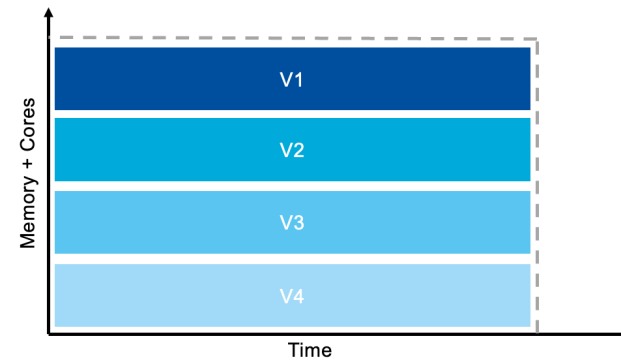
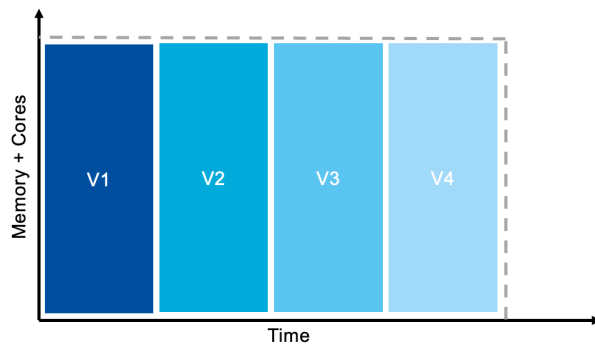


Algorithm selection

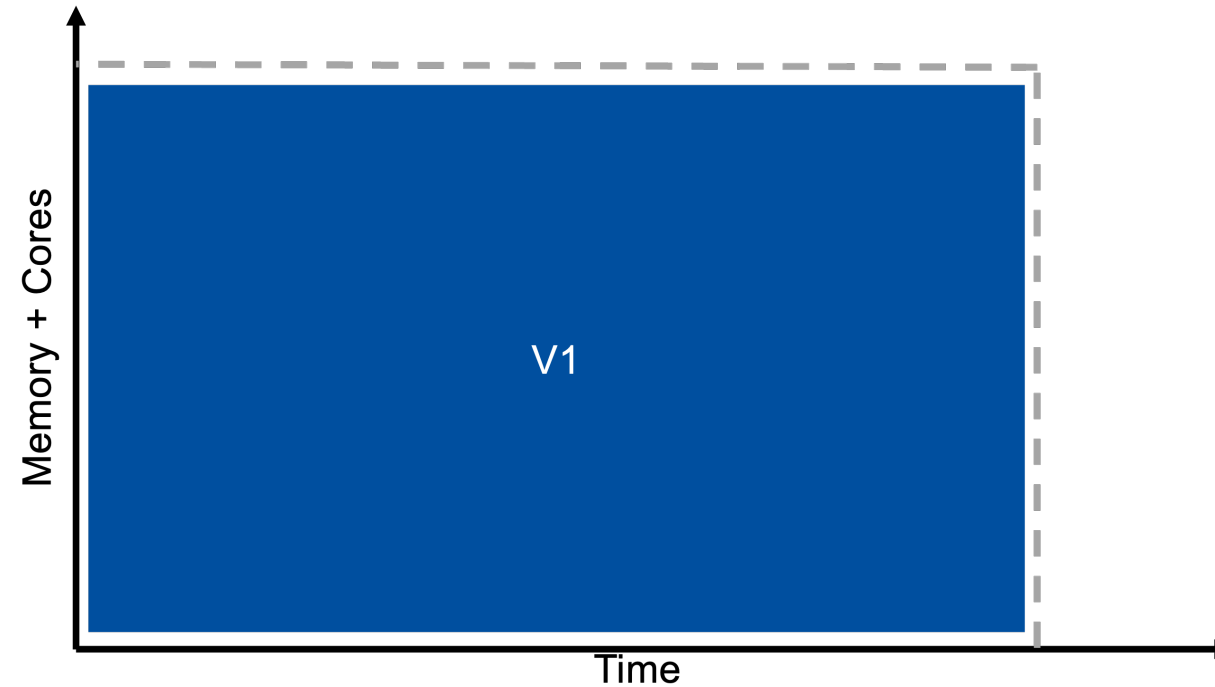


Evaluation

Integrated into **CoVeriTeam**



Can we improve a single verifier **by combination**?



Single Verifier

Single Verifier

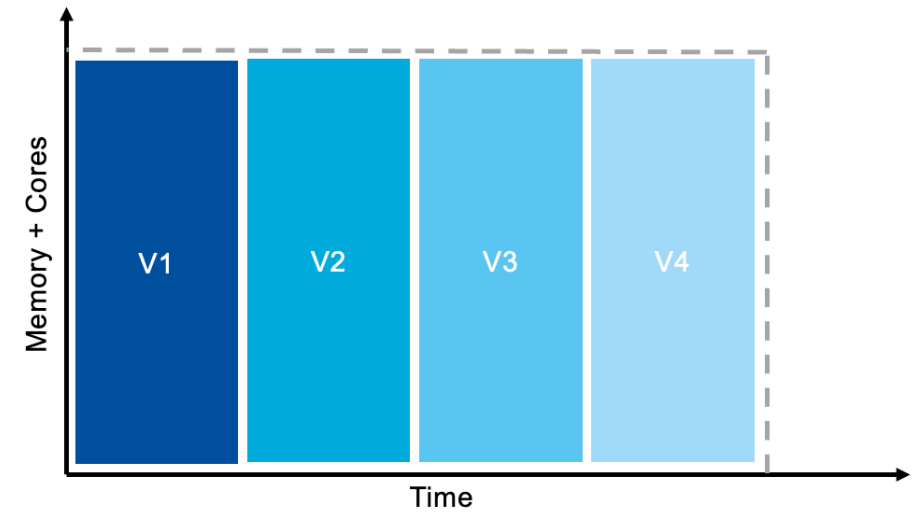
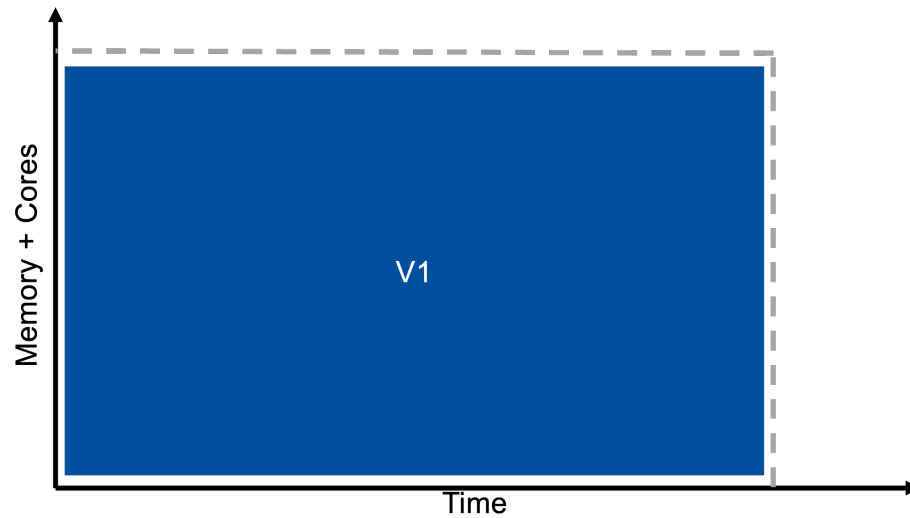
Verifier	<i>CPACHECKER</i>	<i>ESBMC</i>	<i>SYMBIOTIC</i>	<i>UAUTOMIZER</i>	<i>CBMC</i>	<i>DIVINE</i>	<i>GOBLINT</i>	<i>UTAIPAN</i>
Score	9 040	6 623	4 878	7 146	4 663	3 679	2 770	5 338
Correct results	5 652	4 481	3 001	4 358	3 484	2 922	1 385	3 725
Correct proofs	3 516	2 958	1 909	2 836	1 499	1 605	1 385	2 365
Correct alarms	2 136	1 523	1 092	1 522	1 985	1 317	0	1 360
Wrong results	8	29	2	2	19	41	0	24
Wrong proofs	0	22	0	1	1	12	0	23
Wrong alarms	8	7	2	1	18	29	0	1

*Verifiers are taken from SVComp 2021

Single Verifier

Verifier	CPACHECKER	ESBMC	SYMBIOTIC	UAUTOMIZER	CBMC	DIVINE	GOBLINT	UTAIPAN
Score	9 040	6 623	4 878	7 146	4 663	3 679	2 770	5 338
Correct results	5 652	4 481	3 001	4 358	3 484	2 922	1 385	3 725
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Wrong results	8	29	2	2	19	41	0	24
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Wrong alarms	8	7	2	1	18	29	0	1

Can we improve a single verifier **by sequential portfolios**?



Sequential Portfolio

Verifier	CPACHECKER	Sequential Portfolio of			
		2	3	4	8
Score	9 040	9 198	9 519	9 522	8 349
Correct results	5 652	6 058	6 239	6 275	6 084
Correct proofs	3 516	3 780	3 920	3 903	3 721
Correct alarms	2 136	2 278	2 319	2 372	2 363
Wrong results	8	26	26	27	61
Wrong proofs	0	14	14	14	30
Wrong alarms	8	12	12	13	31

A portfolio of **two** already improves the performance

Verifier	CPACHECKER		Sequential Portfolio of		
		2	3	4	8
Score	9 040	9 198	9 519	9 522	8 349
Correct results	5 652	6 058	6 239	6 275	6 084
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Wrong results	8	26	26	27	61
Wrong proofs	0	14	14	14	30
Wrong alarms	8	12	12	13	31

CPAchecker [7]

ESBMC [30]

More verifiers lead to further improvements

Verifier	CPACHECKER	2	3	Sequential Portfolio of 4	8
Score	9 040	9 198	9 519	9 522	8 349
Correct results	5 652	6 058	6 239	6 275	6 084
Correct proofs	3 516	3 780	3 920	3 903	3 721
Correct alarms	2 136	2 278	2 319	2 372	2 363
Wrong results	8	26	26	27	61
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CPAchecker [7]

ESBMC [30]

Symbiotic [21]

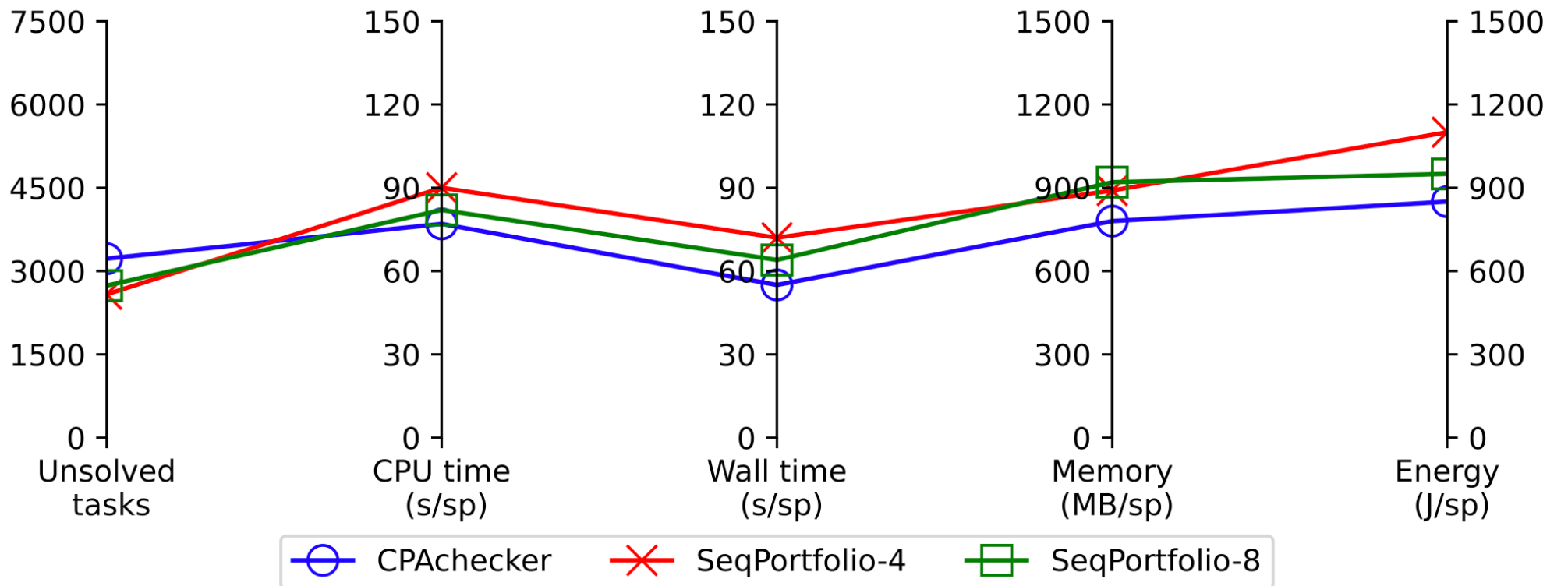
UAutomizer [31]

Limited by time

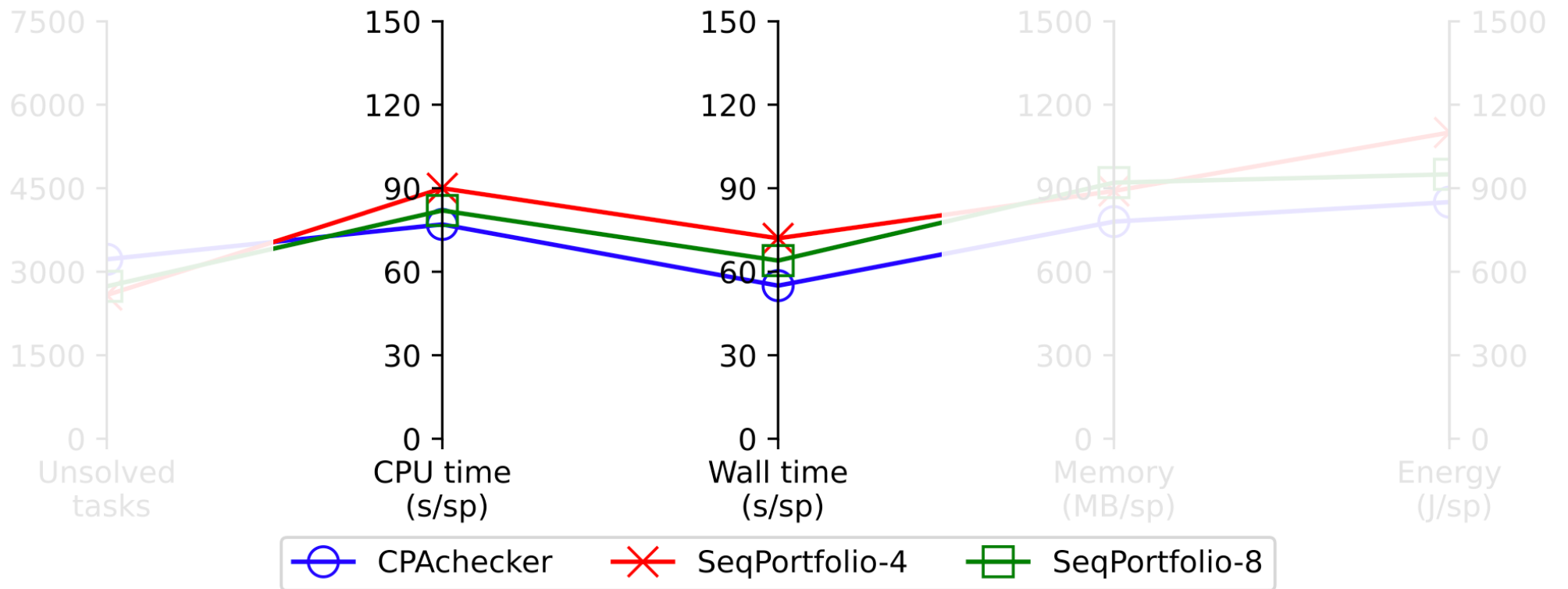
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CPAchecker [7] ESBMC [30] Symbiotic [21] UAutomizer [31]
CBMC [40] Divine [41] Goblint [50] UTaipan [28]

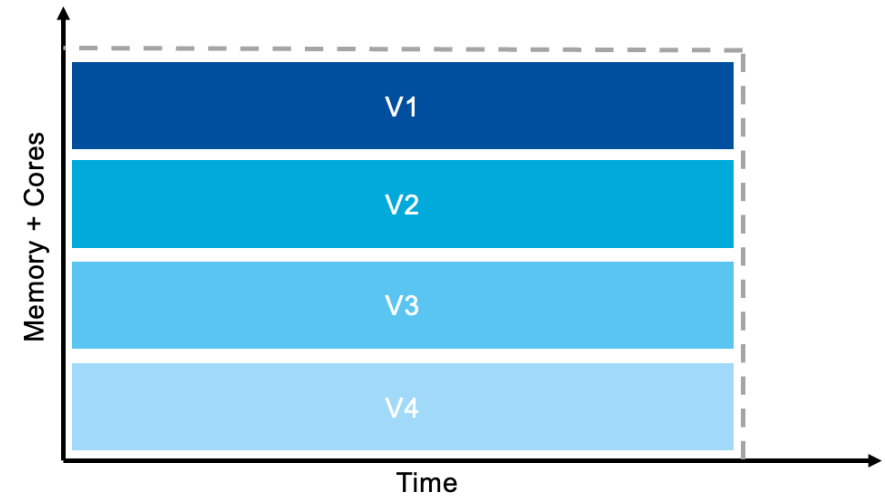
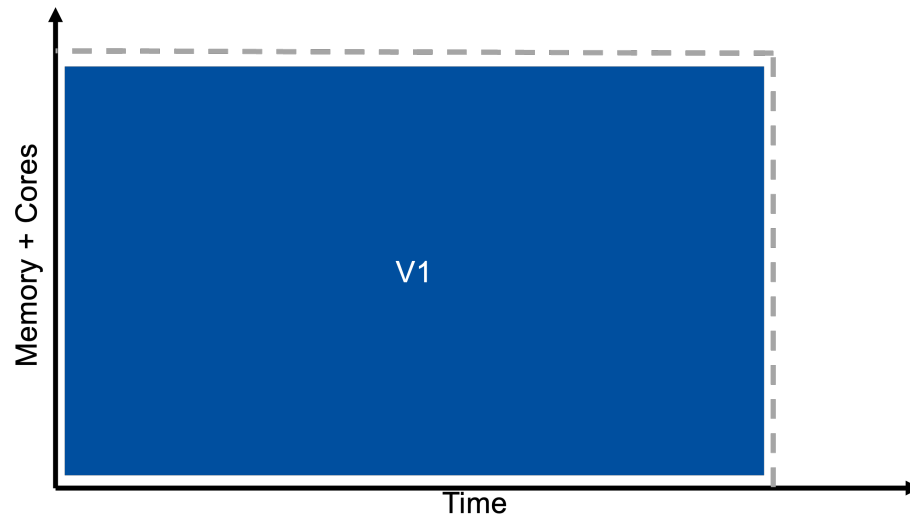
Sequential Portfolios come at a **negligible cost**



Sequential Portfolios come at a **negligible cost**



Can we improve a single verifier by **parallel portfolios**?



More verifiers can lead to more than 700 additional tasks solved

Verifier	CPACHECKER	2	3	4	8
Score	9 040	8 969	9 459	8 952	7 547
Correct results	5 652	6 101	6 363	6 001	5 367
Correct proofs	3 516	3 780	3 992	3 639	3 236
Correct alarms	2 136	2 321	2 371	2 362	2 131
Wrong results	8	36	35	28	42
Wrong proofs	0	21	21	15	24
Wrong alarms	8	15	14	13	18

CPAchecker [7]

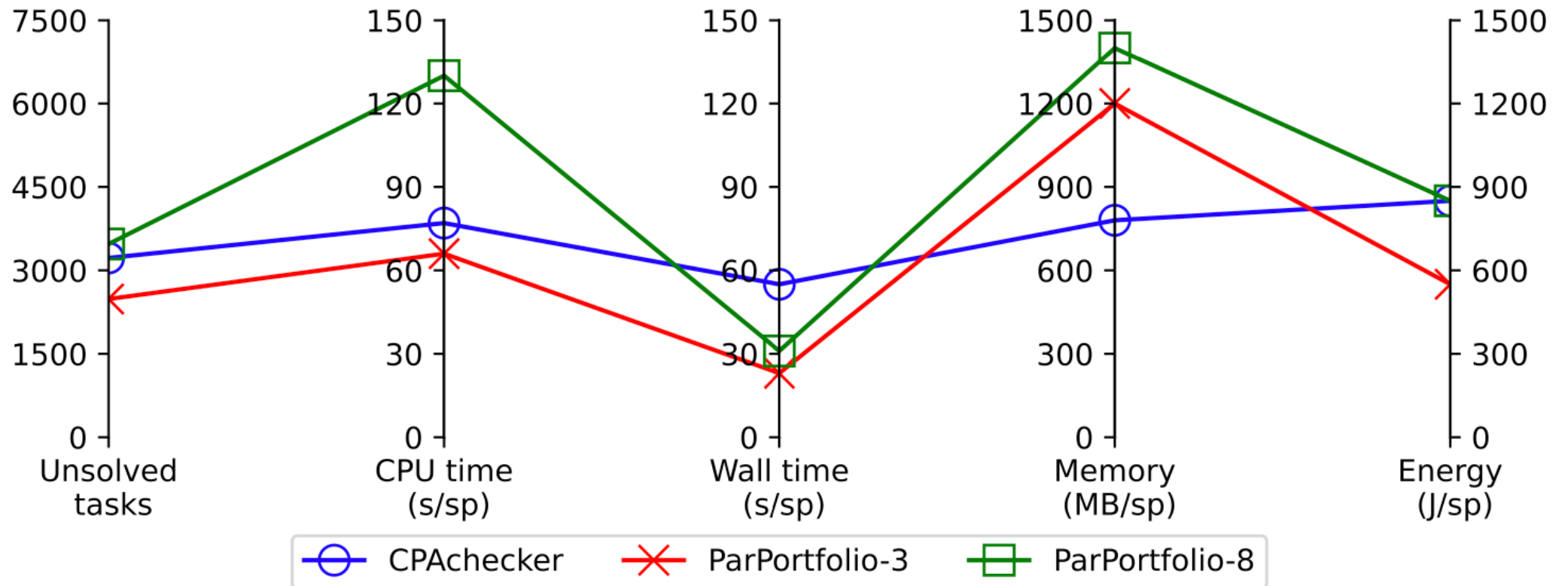
ESBMC [30]

Symbiotic [21]

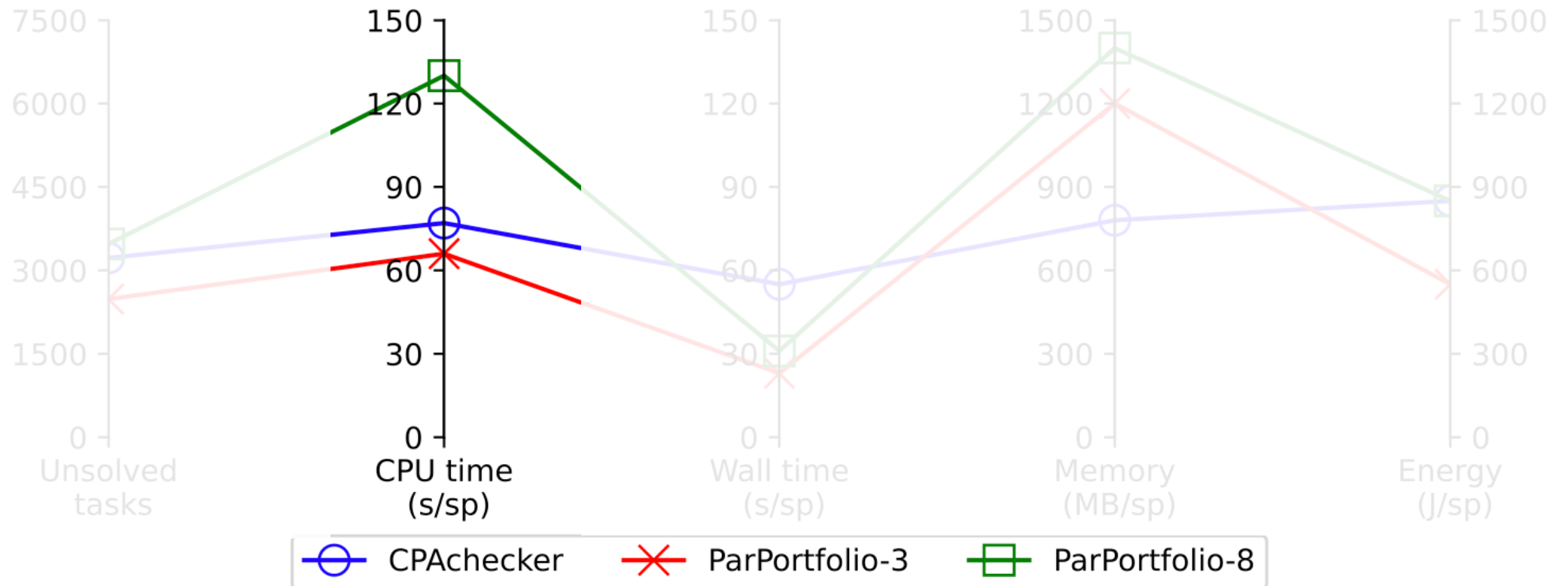
Limited by memory and cores

Verifier	CPACHECKER	2	3	Portfolio of 4	8
Score	9 040	8 969	9 459	8 952	7 547
Correct results	5 652	6 101	6 363	6 001	5 367
Correct proofs	3 516	3 780	3 992	3 639	3 236
Correct alarms	2 136	2 321	2 371	2 362	2 131
Wrong results	8	36	35	28	42
Wrong proofs	0	21	21	15	24
Wrong alarms	8	15	14	13	18

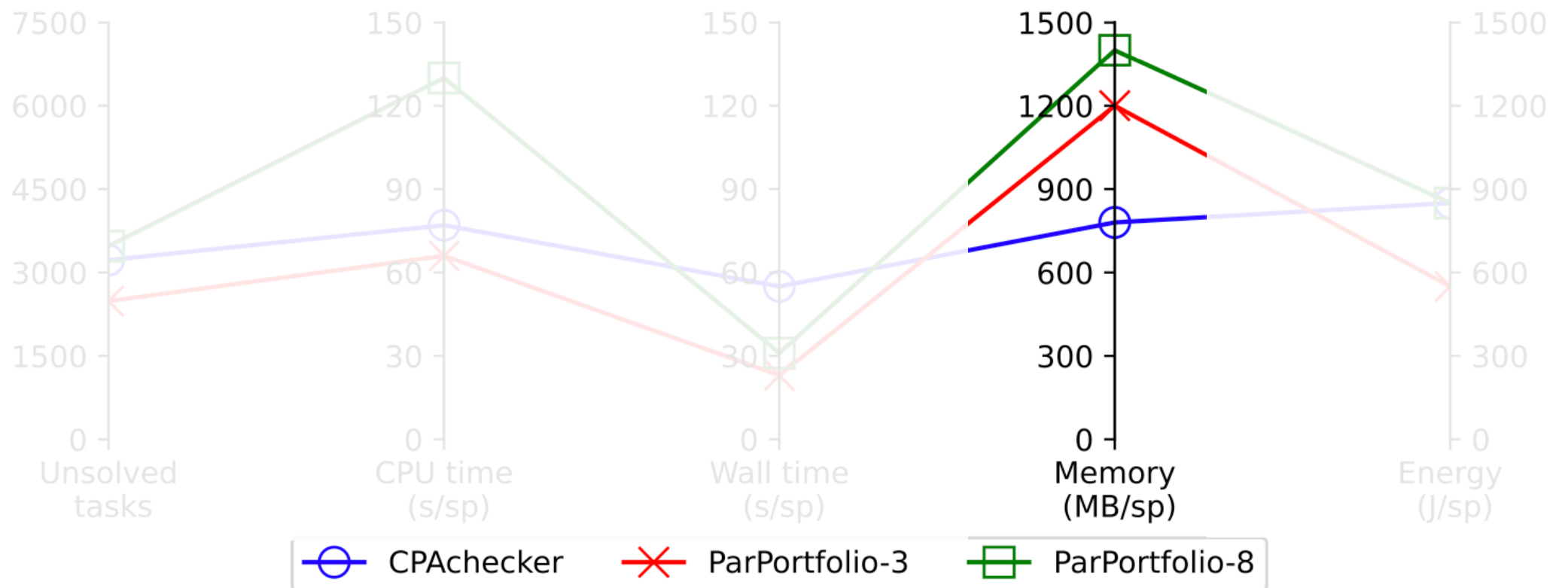
Parallel portfolios come at a **negligible cost**



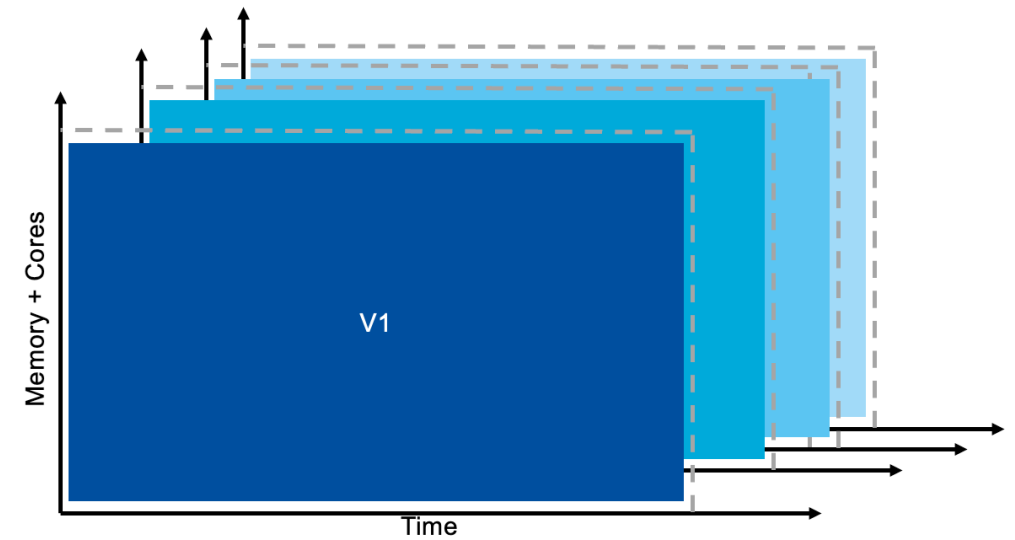
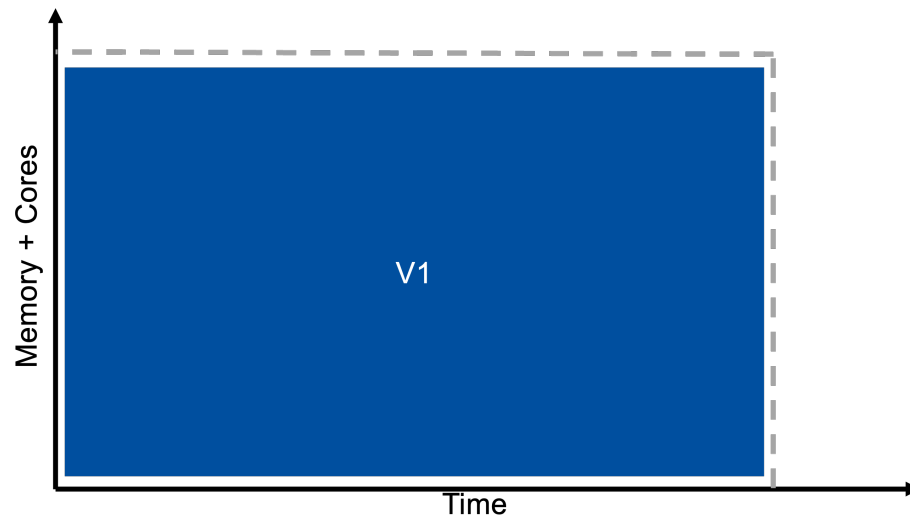
Parallel portfolios come at a **negligible cost**



Parallel portfolios come at a **negligible cost**



Can we improve a single verifier **by algorithm selection**?



More verifiers lead to better performance

Verifier	CPACHECKER	2	3	4	8
Score	9 040	9 226	9 689	9 816	9 886
Correct results	5 652	5 904	6 086	6 125	6 214
Correct proofs	3 516	3 658	3 843	3 867	3 896
Correct alarms	2 136	2 246	2 243	2 258	2 318
Wrong results	8	15	11	8	11
Wrong proofs	0	6	4	3	3
Wrong alarms	8	9	7	5	8

CPAchecker [7] ESBMC [30] Symbiotic [21] UAutomizer [31]

CBMC [40] Divine [41] Goblint [50] UTaipan [28]

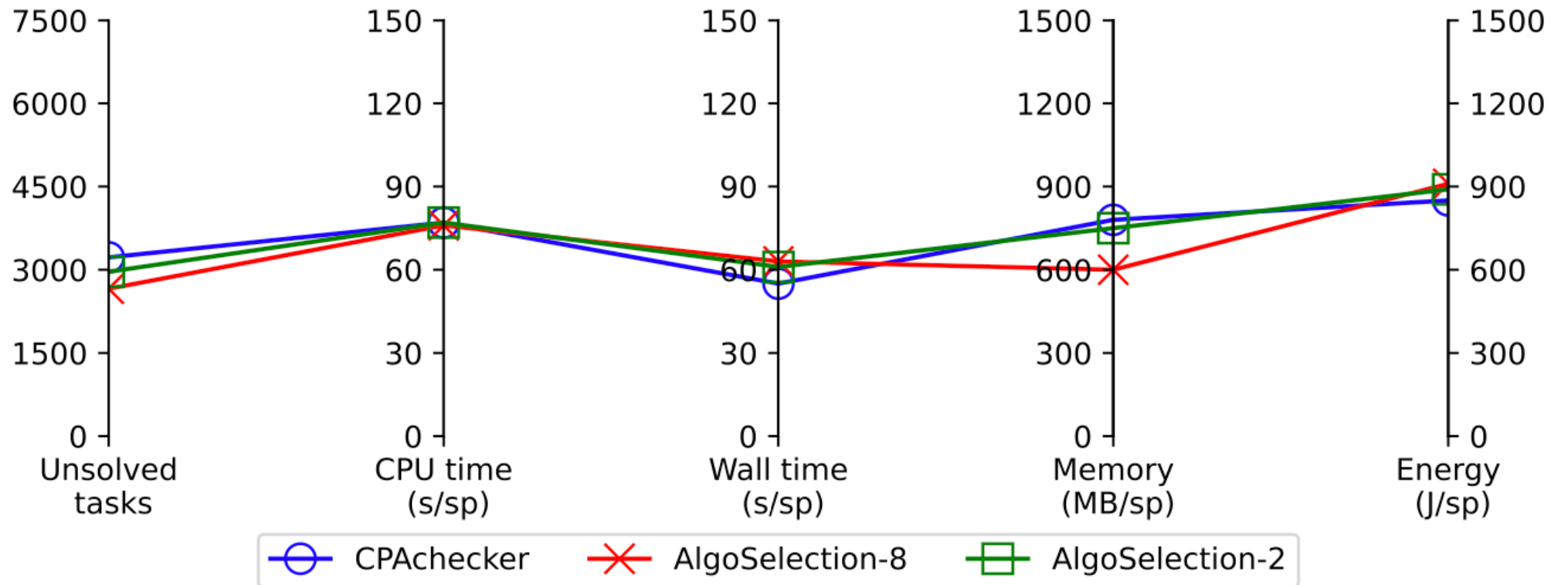
Clear trend

Verifier	CPACHECKER	Algorithm Selection of			
		2	3	4	8
Score	9 040	9 226	9 689	9 816	9 886
Correct results	5 652	5 904	6 086	6 125	6 214
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Wrong proofs	0	6	4	3	3
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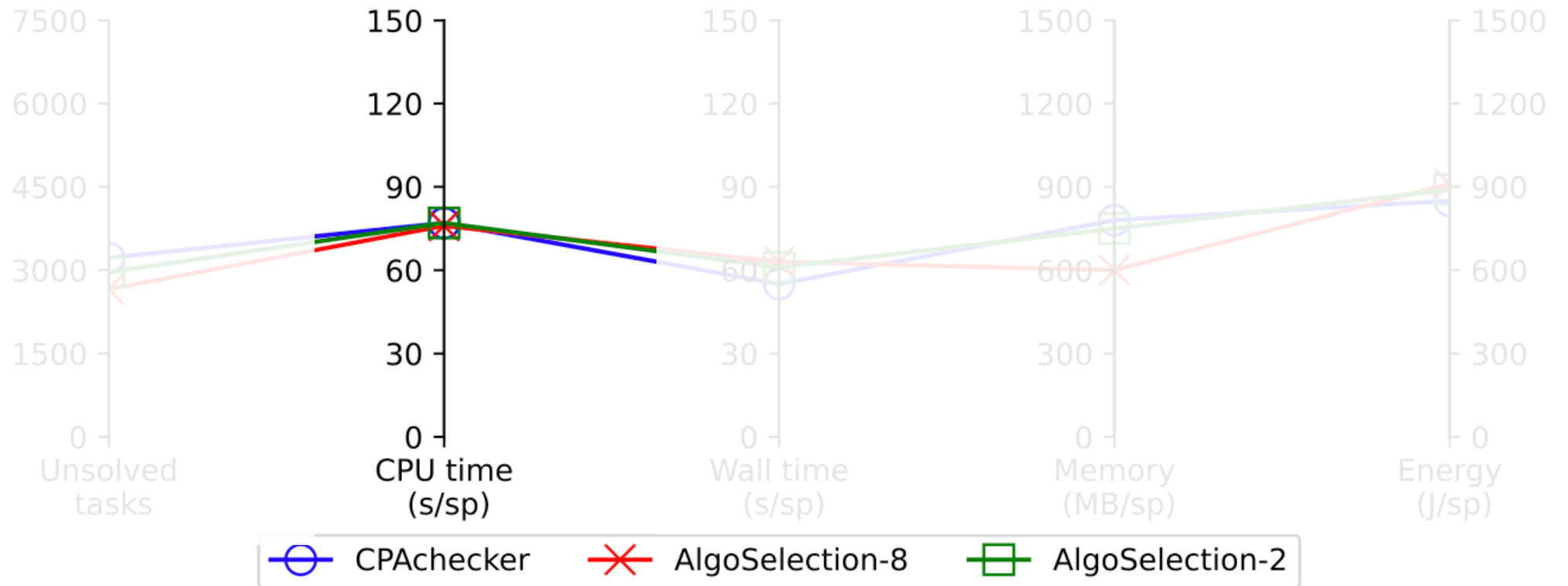
CPAchecker [7] ESBMC [30] Symbiotic [21] UAutomizer [31]

CBMC [40] Divine [41] Goblint [50] UTaipan [28]

Algorithm selection comes at a **negligible cost**

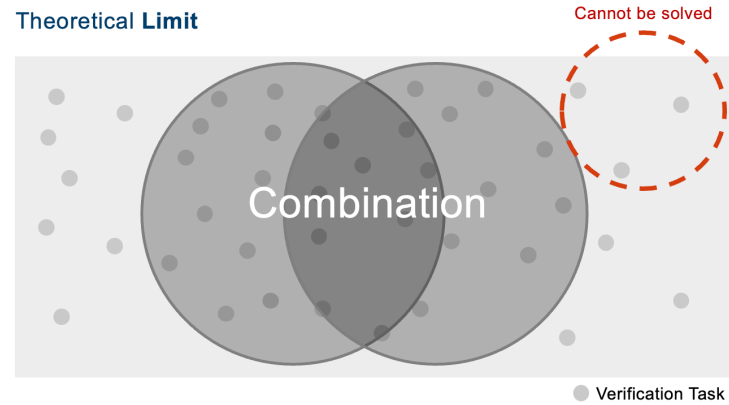


Algorithm selection comes at a **negligible cost**



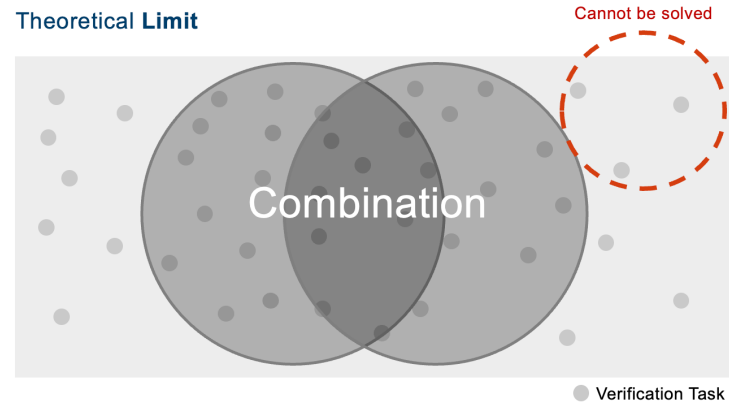
Future **Work**

Future Work

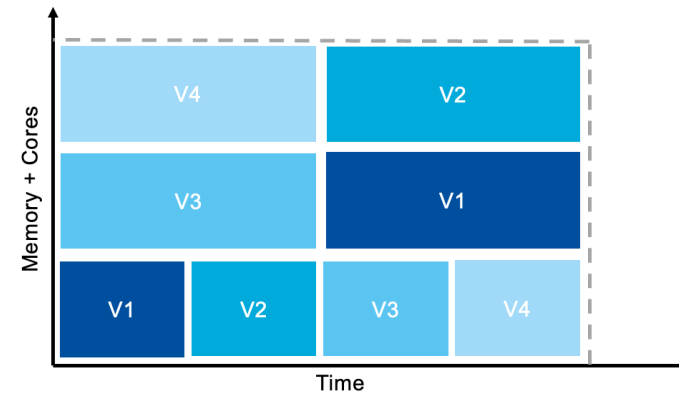


Theoretical Limit

Future Work

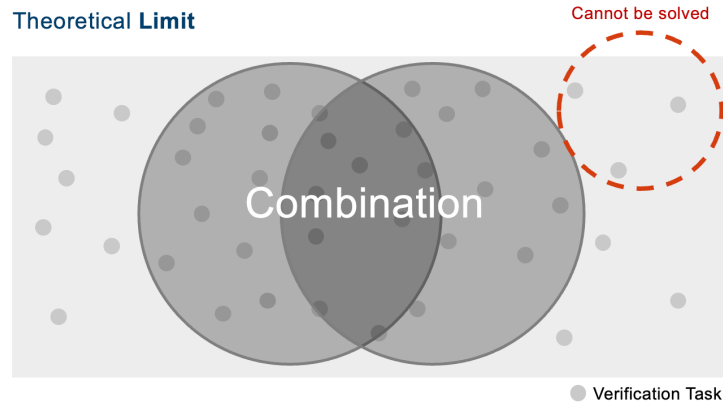


Theoretical Limit

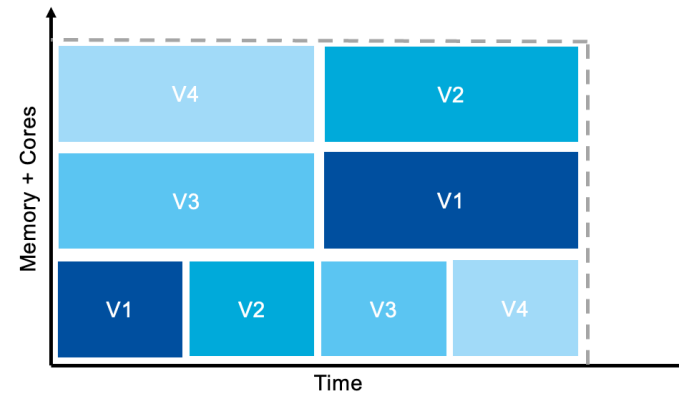


Hybrid approaches

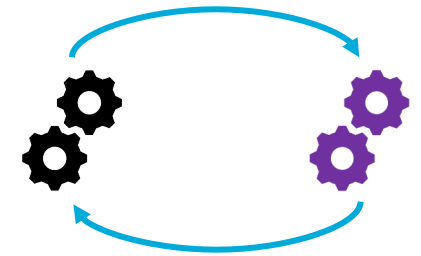
Future Work



Theoretical Limit



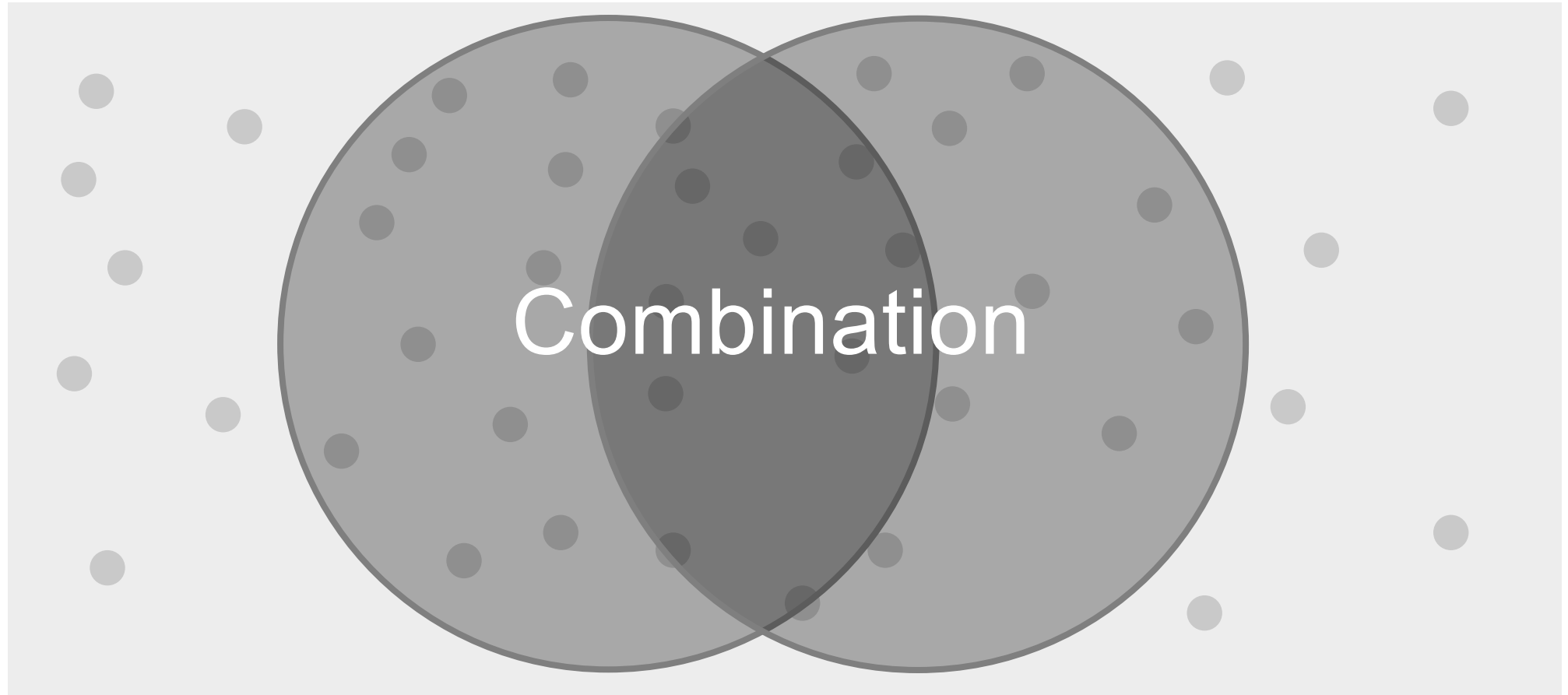
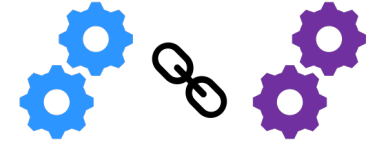
Hybrid approaches



Cooperation

Takeaway

We can improve a single verifier **by combination!**



● Verification Task

Takeaway

We

Learn more about CoVeriTeam!

TACAS Session

Wednesday,
at 15:30

CoVeriTeam: On-Demand Composition of Cooperative Verification Systems

Dirk Beyer  and Sudeep Kanav 

LMU Munich, Munich, Germany

Abstract. There is no silver bullet for software verification: Different techniques have different strengths. Thus, it is imperative to combine the strengths of verification tools via combinations and cooperation. CoVeriTeam is a language and tool for on-demand composition of cooperative approaches. It provides a systematic and modular way to combine existing tools (without changing them) in order to leverage their full potential. The idea of cooperative verification is that different tools help each other to achieve the goal of correctly solving verification tasks. The language is based on verification artifacts (programs, specifications, witnesses) as basic objects and verification actors (verifiers, validators, testers) as basic operations. We define composition operators that make it possible to easily describe new compositions. Verification artifacts are the interface between the different verification actors. CoVeriTeam consists of a language for composition of verification actors, and its interpreter.



● Verification Task