The 6th Competition on Syntax-Guided Synthesis

Rajeev Alur, Dana Fisman, Saswat Padhi,
Andrew Reynolds, Rishabh Singh and Abhishek Udupa

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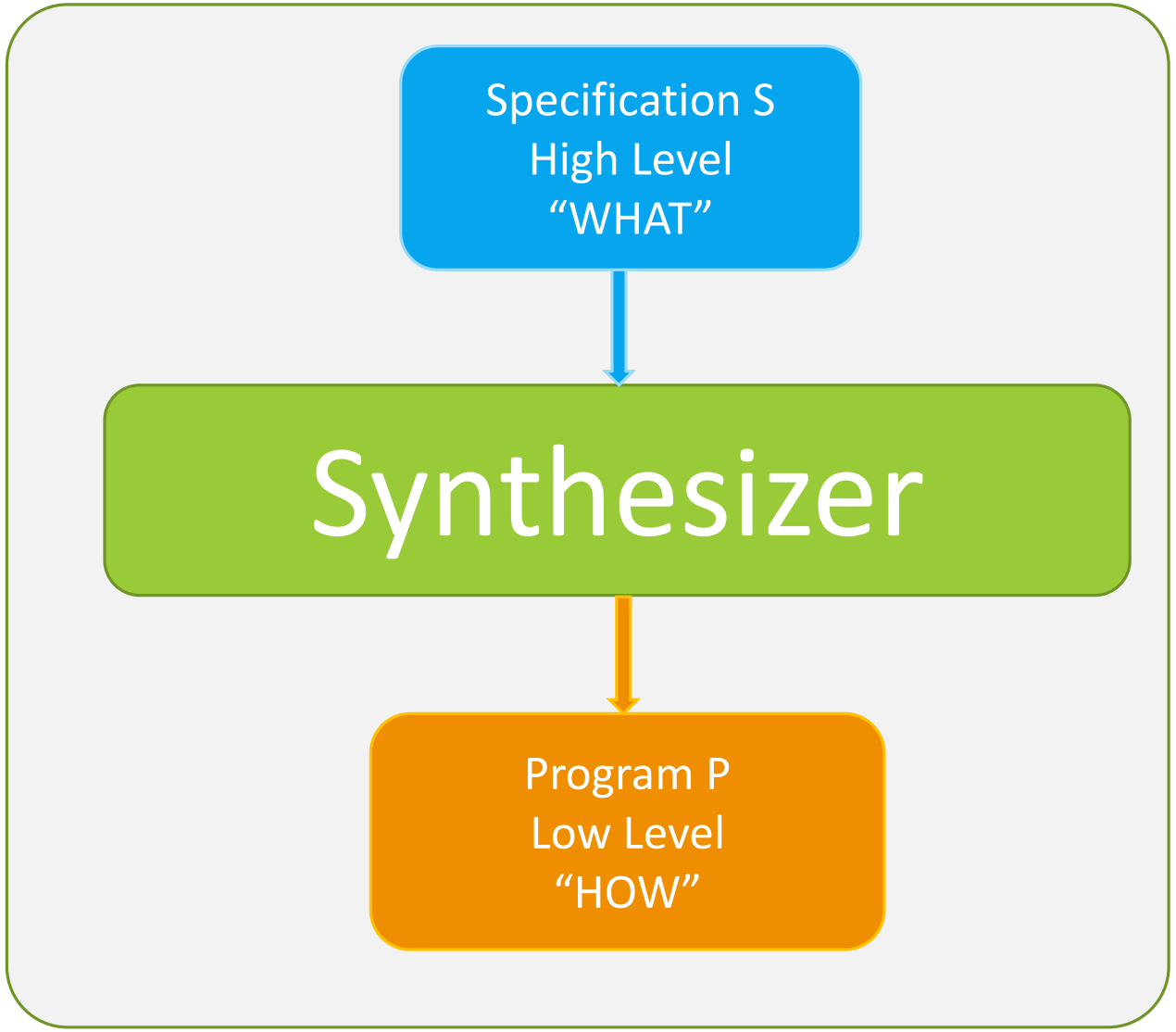
Idea and Definition in a Nutshell

Program Synthesis



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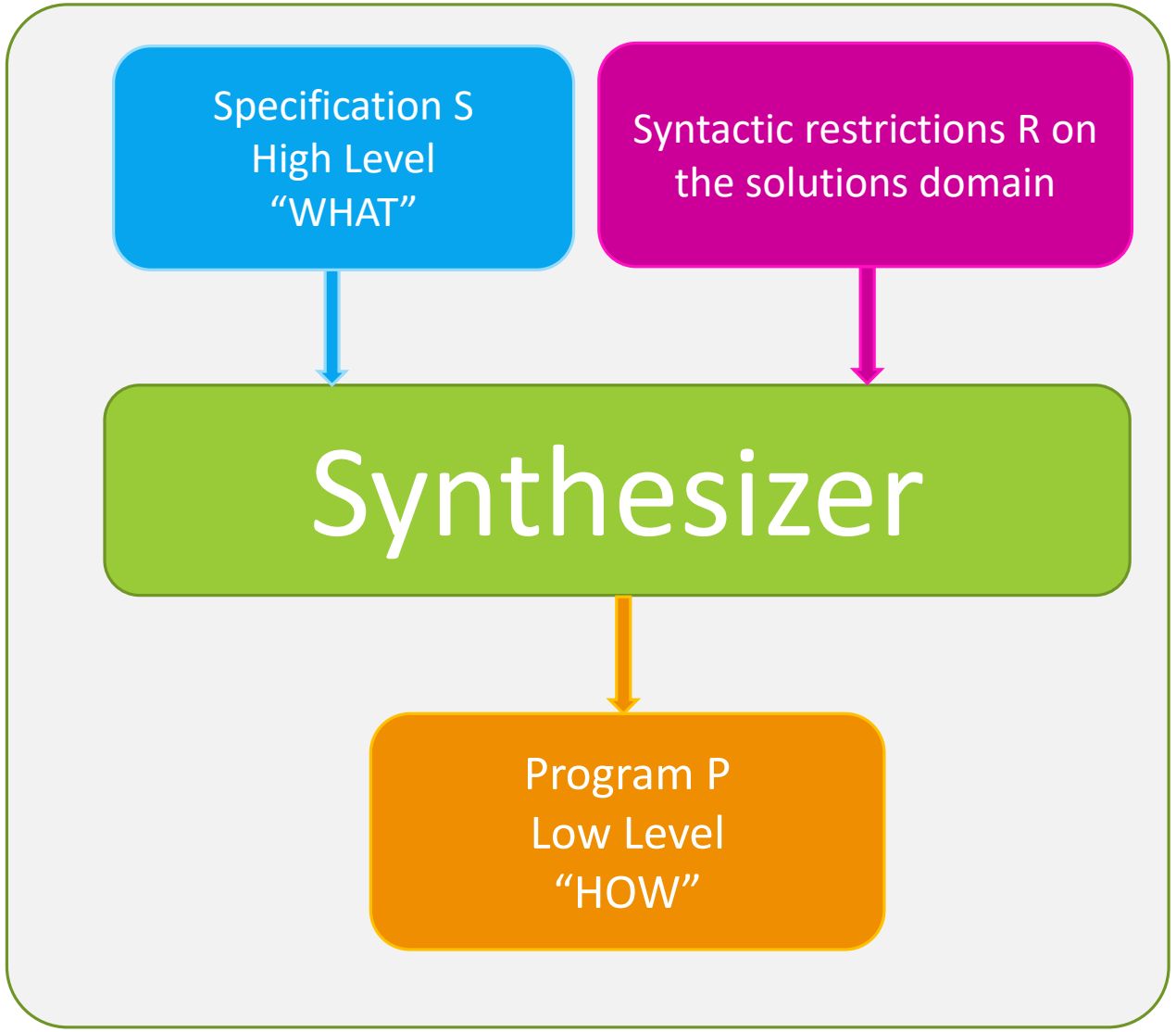
Recent Trends in Synthesis



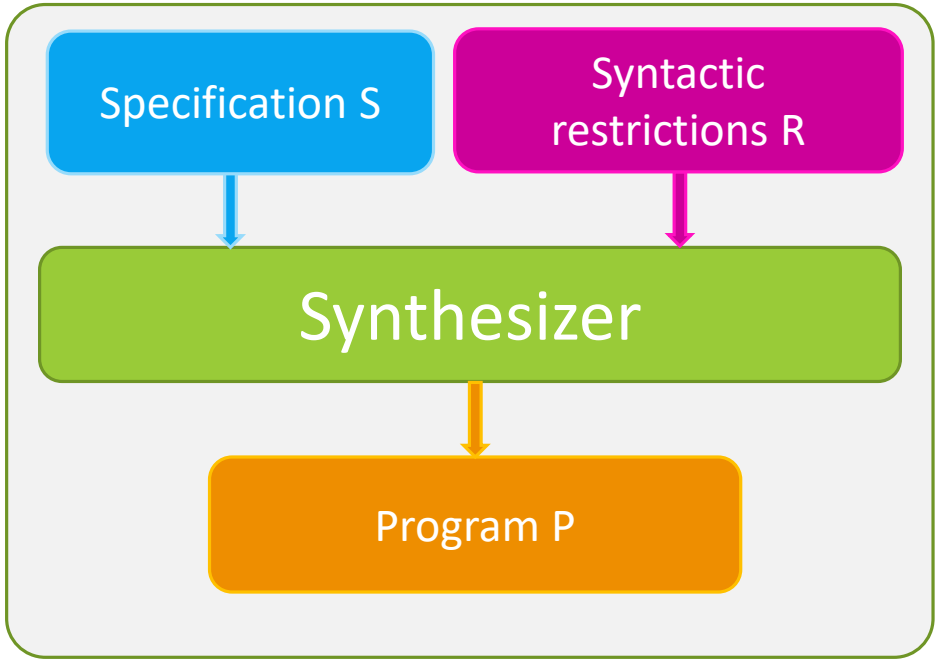
Syntax Guided Synthesis - Idea

Motivation:

- Tractability
- Combines:

  human expert insights with

  computers exhaustiveness & efficiency
- Benefit progress SAT & SMT Solvers



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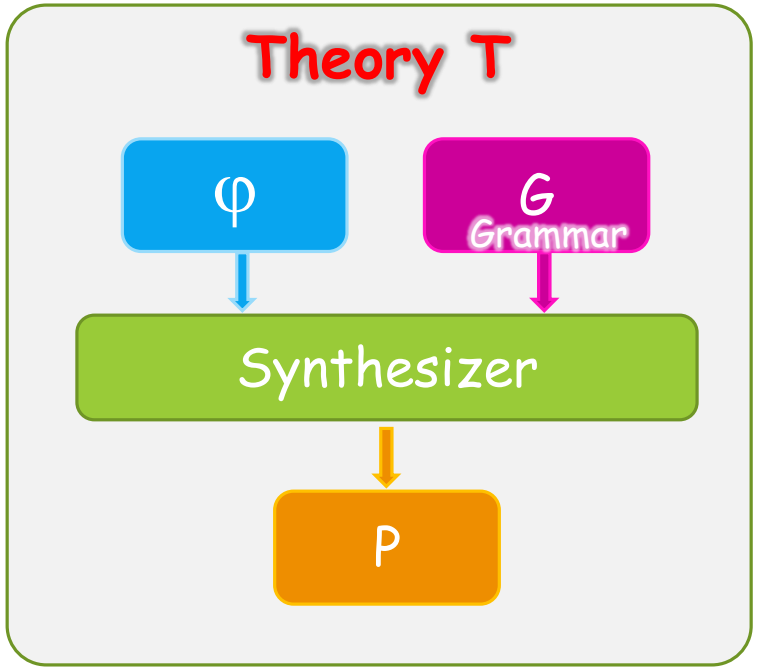
Syntax-Guided Synthesis (SyGuS) Problem

- Fix a background theory T: fixes types and operations
- Function to be synthesized: name f along with its type
  - General case: multiple functions to be synthesized
- Inputs to SyGuS problem:
  - Specification φ

    Typed formula using symbols in T + symbol f
  - Context-free grammar G

    Characterizing the set of allowed expressions [[G]] (in theory T)
- Computational problem:

  Find expression e in [[G]] such that φ[f/e] is valid (in theory T)



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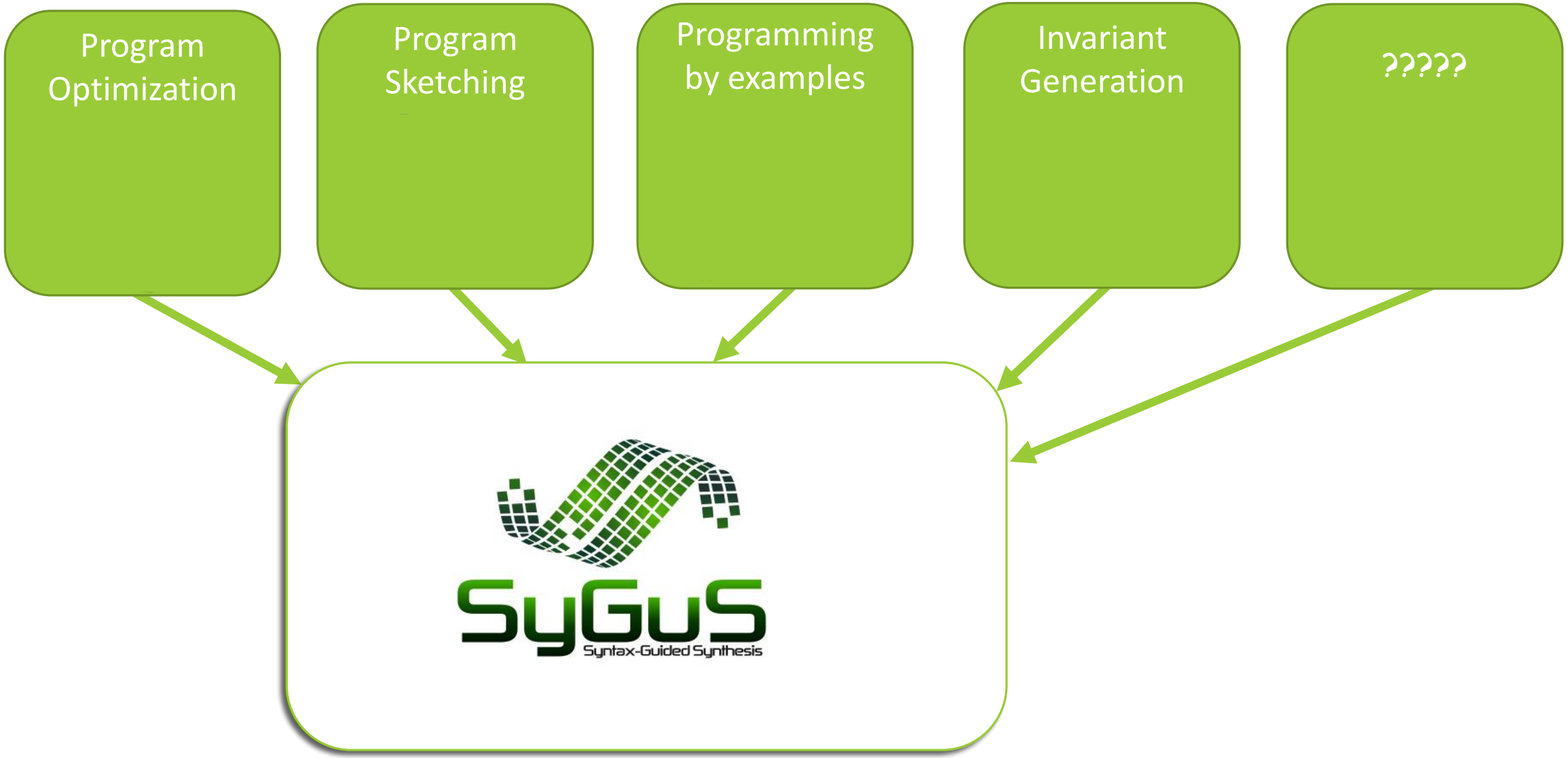
SyGuS – The Vision



SyGuS-Comp 2019

The 6th competition on Syntax Guided Synthesis

Solvers

- **CVC4** - Andrew Reynolds (Univ. of Iowa), Haniel Barbosa (Univ. of Iowa), Andres Notzli (Stanford), Clark Barrett (Stanford) and Cesare Tinelli (Univ. of Iowa)
- **DryadSynth** - KangJing Huang (Purdue Univ.) , Xiaokang Qiu (Purdue Univ.) , Qi Tian (Nanjing University), and Yanjun Wang (Purdue Univ.)
- **LoopInvGen** - Saswat Padhi (UCLA) ,Todd Millstein (UCLA) and Rahul Sharma (MSR)
- **OASIS** - Sahil Bhatia (MSR), Saswat Padhi (UCLA), Nagarajan Natarajan (MSR) and Rahul Sharma (MSR)

Solver Strategies

CVC4:
- Counterexample-guided Quantifier Instantiation + Enumeration Strategies **[Reynolds et al CAV'15]**

CVC4-Fast, CVC4-Smart:
- "Fast and Smart Term Enumeration for Syntax-Guided Synthesis" **[Reynolds et al. CAV'19]**

CVC4-su:
- Pointwise-independent unification techniques **[Barbosa et al. FMCAD'19]**

DryadSynth:
- Concolic CEGIS + Unification + Decidable fragments for CLIA & INV

LoopInvGen:
- Data-driven invariant inference using automatic feature learning **[Padhi et al. PLDI'16]**

LoopInvGen-gplearn:
- LoopInvGen parallelized over multiple integer grammars **[Padhi et al. CAV'19]**

OASIS:
- Invariant inference over integers by solving ILPs (integer linear programs)

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Tracks

- **Conditional Linear Arithmetic (CLIA)**
  - No grammar restrictions, limited to logic of linear arithmetic
- **Programming-by-examples (PBE) Strings**
  - Limited to specifications in the form of I/O examples over strings
- **PBE Bit Vectors**
- **Invariant Synthesis (INV)**
  - Limited to invariant synthesis problems in linear integer arithmetic, no grammar restrictions
- **General**
  - Grammar restrictions, any SMT theory

Each track used a new input language, SyGuS IF version 2.0

- Consistent with SMT-LIB 2.6 standard for better compatibility with SMT solvers
- This year allowed solvers that accepted either version 1.0 or 2.0 format

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Tracks Participation

	General	CLIA	INV	PBE_BV	PBE_SLIA
CVC4	✓	✓			
CVC4-Fast	✓		✓	✓	✓
CVC4-Smart	✓		✓	✓	✓
CVC4-su			✓		
DryadSynth	✓	✓	✓		
LoopInvGen			✓		
LoopInvGen-gplearn			✓		
OASIS			✓		
Total	4	2	7	2	2

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Scoring System

- Solvers are rewarded:
  - **5 points** for each problem solved
  - **3 points** for each problem solved fastest
    - Grouped into buckets [0,1), [1, 3), [3, 10), …
  - **1 point** for each problem solved with the smallest solution
    - Also grouped into buckets [1,10), [10, 30), [30, 100), …

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New Benchmarks

- **General (160)**
  from “Solving Quantified Bit-Vectors Using Invertibility Conditions” **[Niemetz et al. CAV’18]**
  submitted by Mathias Preiner (Stanford)

- **General (160)**
  from “Towards Bit-Width Independent Proofs in SMT Solvers” **[Niemetz et al. CADE’19]**
  submitted by Yoni Zohar (Stanford)

- **INV (276)**
  from "Learning Loop Invariants for Program Verification" **[Si et al, NeurIPS'18]**
  submitted by Xujie Si (Penn)

- **INV (455)**
  from Lustre Invariant Synthesis
  submitted by Daniel Larraz (Univ. of Iowa)

- **PBE Strings (100)** and **General (16)**
  from “Accelerating Search-Based Program Synthesis using Learned Probabilistic Models” **[Lee et al. PLDI’18]**
  submitted by Woosuk Lee (Penn)

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SyGuS-Comp 2019

Results of Competition

CLIA Track (88)

Solver	Solved	Fastest	Smallest	Score
DryadSynth	**87**	**77**	37	**703**
CVC4	83	70	**57**	682

DryadSynth

PBE: Strings (210)

Solver	Solved	Fastest	Smallest	Score
CVC4-Fast	**204**	**203**	141	**1770**
CVC4-Smart	180	85	**151**	1306

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PBE: Bitvectors (753)

Solver	Solved	Fastest	Smallest	Score
CVC4-Fast	**751**	**751**	**530**	**6538**
CVC4-Smart	722	131	372	4375

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Inv Track (829)

Solver	Solved	Fastest	Smallest	Score
CVC4-su	**592**	423	264	**4493**
LoopInvGen	512	**442**	**364**	4250
LoopInvGen-gplearn	511	411	349	4137
CVC4-Fast	522	319	243	3810
CVC4-Smart	539	283	260	3804
OASIS	538	20	317	3067
DryadSynth	277	161	39	1907

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- ***Virtual best solver:*** *solves* ***650*** *benchmarks!*

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Inv Track (829)

Solved per category:

Solver	#	XC	Lustre	From2018
CVC4-su	**592**	**215**	**265**	112
LoopInvGen	512	186	209	**117**
LoopInvGen-gplearn	511	185	209	**117**
CVC4-Fast	522	**215**	194	113
CVC4-Smart	539	201	227	111
OASIS	538	204	217	**117**
DryadSynth	277	160	0*	**117**

* Due to unhandled input

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General Track (886)

Solver	Solved	Fastest	Smallest	Score
CVC4-Fast	670	**620**	**643**	**5853**
CVC4	**696**	474	568	5470
CVC4-Smart	649	360	523	4848
DryadSynth	143	121	93	1171

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CVC4	**696**	474	568	5470
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DryadSynth	143	121	93	1171

- ***Virtual best solver:*** *solves* ***719*** *benchmarks!*

Concluding Remarks

- **In this year's competition:**
  - New submitted benchmarks (1167 in total)
    - **Further use cases** for SyGuS
  - Continued Improved Performance in Solvers
    - **More solved instances:** PBE_BV 724 → 751 (753), PBE_Strings 160 → 204 (210)
    - **Orthogonality:** in particular in INV track

- **New extensions to the competition in the works:**
  - Specialized tracks per logic, unrealizability, weighted grammars

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Thanks!

- Co-organizers:
  - Rajeev Alur, Dana Fisman, Saswat Padhi, Rishabh Singh and Abhishek Udupa
- Participants and benchmark submitters
- StarExec team
  - Aaron Stump

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