2025

14th Confluence Competition

Raúl Gutiérrez **Aart Middeldorp** Naoki Nishida
Teppei Saito René Thiemann

https://project-coco.uibk.ac.at/2025

Outline

Acknowledgements

- CoCo 2025 tool authors

Acknowledgements

- CoCo 2025 tool authors
- IWC 2025 chairs

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- IWC 2025 chairs
- CoCo 2025 panel
  - Thiago Felicissimo
  - Cynthia Kop
  - Geoff Sutcliffe

Outline

2012	TRS	CPF
ACP	✓	
CSI	✓	✓
Saigawa	✓	
CeTA		✓

2013	TRS	CPF
ACP	✓	
CSI	✓	✓
Saigawa	✓	
CeTA		✓

2014	TRS	CPF	CTRS
ACP	✓	✓	
CSI	✓	✓	
Saigawa	✓		
CeTA		✓	
CoLL	✓		
ConCon		✓	✓
CO3			✓

2015	TRS	CPF	CTRS	HRS	GCR	NRS
ACP	✓	✓				
CSI	✓	✓				
CeTA		✓				
CoLL-Saigawa	✓					
ConCon		✓	✓			
CO3			✓			
CoScart			✓			
ACPH				✓		
CSIˆho				✓		
AGCP					✓	
NoCo						✓

2016	TRS	CPF-TRS	CTRS	HRS	GCR	NRS	UN	CPF-CTRS
ACP	✓	✓						
CSI	✓	✓					✓	
CeTA		✓						✓
CoLL-Saigawa	✓							
ConCon			✓					✓
CO3			✓					
CoScart			✓					
ACPH				✓				
CSIˆho				✓				
AGCP					✓			
Nrbox						✓		
FORT					✓		✓	

2017	TRS	CPF-TRS	CTRS	HRS	GCR	NFP	UNR	CPF-CTRS	UNC
ACP	✓	✓							
CSI	✓	✓				✓	✓		✓
CeTA		✓						✓	
CoLL-Saigawa	✓								
ConCon			✓					✓	
CO3			✓						
ACPH				✓					
CSIˆho				✓					
AGCP					✓				
FORT					✓	✓	✓		✓
SOL				✓					

2018	TRS	CPF-TRS	CTRS	HRS	GCR	NFP	UNR	CPF-CTRS	UNC
ACP	✓	✓	✓						✓
CSI	✓	✓				✓	✓		✓
CeTA		✓						✓	
CoLL-Saigawa	✓								
ConCon			✓					✓	
CO3			✓						
CSIˆho				✓					
AGCP					✓				
FORT					✓	✓	✓		✓
SOL				✓					

2019	TRS	CPF-TRS	CTRS	HRS	GCR	NFP	UNR	CPF-CTRS	UNC	COM	INF	SRS
ACP	✓	✓	✓						✓	✓		✓
CSI	✓	✓				✓	✓		✓			✓
CoLL										✓		
CeTA		✓						✓				
CoLL-Saigawa	✓											✓
ConCon			✓					✓			✓	
CO3			✓								✓	
infChecker											✓	
maedmax											✓	
CSIˆho				✓								
AGCP					✓							
Moca											✓	
FORT					✓	✓	✓		✓	✓		
noko-leipzig												✓
nonreach											✓	

2020	TRS	CPF-TRS	CTRS	HRS	GCR	NFP	UNR	CPF-CTRS	UNC	COM	INF	SRS
ACP	✓	✓	✓						✓	✓		✓
CSI	✓	✓				✓	✓		✓			✓
CoLL										✓		
CeTA		✓						✓				
CoLL-Saigawa	✓											✓
ConCon			✓					✓			✓	
CO3			✓								✓	
infChecker											✓	
CSIˆho				✓								
AGCP					✓							
Moca											✓	
FORT-h					✓	✓	✓		✓	✓		
SOL				✓								
nonreach											✓	

2021	TRS	CPF-TRS	CTRS		GCR	NFP	UNR		UNC	COM	INF	SRS
ACP	✓	✓	✓						✓	✓		✓
CSI	✓	✓				✓	✓		✓			✓
CoLL										✓		
CeTA		✓										
CoLL-Saigawa	✓											✓
CO3			✓								✓	
infChecker											✓	
FORTify	✓				✓		✓		✓	✓		
CONFident	✓		✓									✓
AGCP					✓							
NaTT											✓	
FORT-h					✓	✓	✓		✓	✓		

2022	TRS	CPF-TRS	CTRS		GCR	NFP	UNR	CSR	UNC	COM	INF	SRS
ACP	✓	✓	✓						✓	✓		✓
CSI	✓	✓				✓	✓		✓			✓
CoLL										✓		
CeTA		✓										
Hakusan	✓											✓
Toma											✓	
CO3			✓								✓	
infChecker											✓	
FORTify		✓			✓	✓	✓		✓	✓		
CONFident	✓		✓					✓				✓
AGCP					✓							
NaTT											✓	
FORT-h		✓			✓	✓	✓		✓	✓		

2023	TRS		CTRS		GCR	NFP	UNR	CSR	UNC	COM	INF	SRS
ACP	✓		✓				✓		✓	✓		✓
CSI	✓					✓	✓		✓			✓
CoLL										✓		
CeTA	✓									✓	✓	✓
Hakusan	✓											✓
Toma											✓	
CO3			✓								✓	
infChecker											✓	
FORTify	✓				✓	✓	✓		✓	✓		
CONFident	✓		✓					✓				✓
AGCP					✓							
NaTT											✓	
FORT-h	✓				✓	✓	✓		✓	✓		
ConfCSR								✓				
nonreach											✓	

2024	TRS	LCTRS	CTRS		GCR	NFP	UNR	CSR	UNC	COM	INF	SRS
ACP	✓		✓				✓		✓	✓		✓
CSI	✓					✓	✓		✓			✓
CeTA	✓									✓	✓	✓
Hakusan	✓											✓
Moca											✓	
CO3			✓								✓	
infChecker											✓	
FORTify	✓				✓	✓	✓		✓	✓		
CONFident	✓		✓					✓				✓
AGCP					✓							
NaTT											✓	
FORT-h	✓				✓	✓	✓		✓	✓		
CRaris		✓										
crest		✓										

- CoCo is powered by StarExec 

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- exciting to watch

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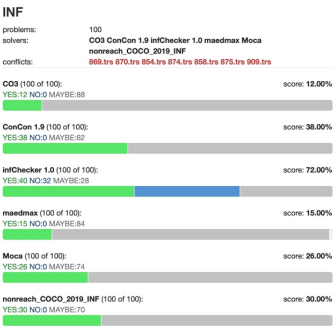
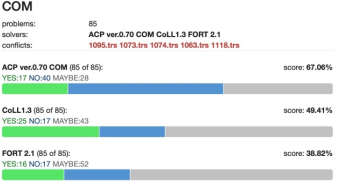
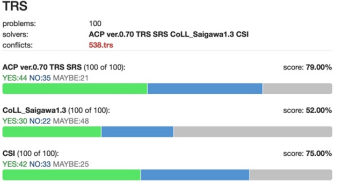
- exciting to watch, partly due to real–time yes/no conflicts







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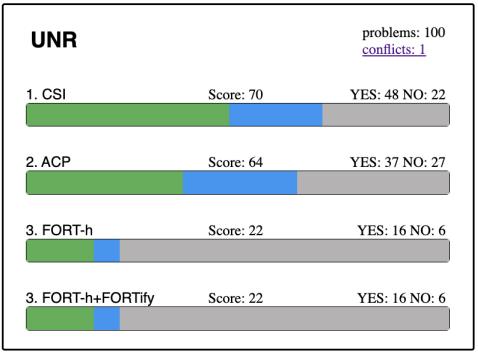
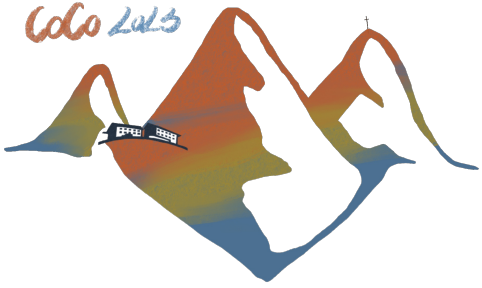
- exciting to watch, partly due to real–time yes/no conflicts

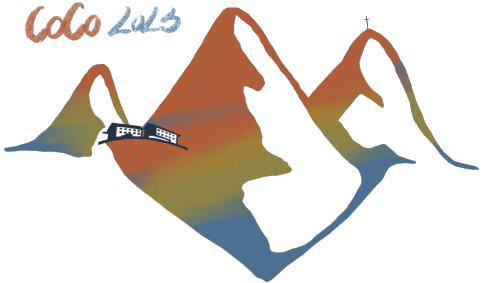


final slide CoCo 2024 presentation

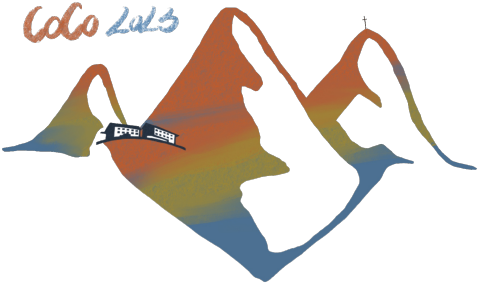
- CoCo 2025 during IWC 2025 ?
- new T−shirt ?
- revive previous categories ?
  - HRS 
  - NRS 

Outline

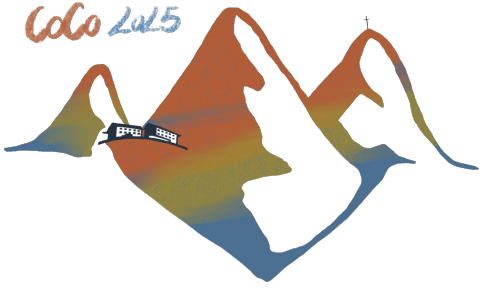

CoCo 2025



T–shirt 20 €



T–shirt 20 €



https://ari-cops.uibk.ac.at/liveview/2025.html

2024	TRS	LCTRS	CTRS		GCR	NFP	UNR	CSR	UNC	COM	INF	SRS
ACP	✓		✓				✓		✓	✓		✓
CSI	✓					✓	✓		✓			✓
CeTA	✓									✓	✓	✓
Hakusan	✓											✓
Moca											✓	
CO3			✓								✓	
infChecker											✓	
FORTify	✓				✓	✓	✓		✓	✓		
CONFident	✓		✓					✓				✓
AGCP					✓							
NaTT											✓	
FORT-h	✓				✓	✓	✓		✓	✓		
CRaris		✓										
crest		✓										

2025	TRS	LCTRS	CTRS					CSR			INF	
ACP	✓		✓									
CSI	✓											
Grackle-CSI	✓											
CeTA	✓										✓	
Hakusan	✓											
Natto											✓	
CO3			✓								✓	
infChecker											✓	
FORTify	✓											
CONFident	✓		✓					✓				
AProVE	✓											
SOL								✓				
FORT-h	✓											
CRaris		✓										
crest		✓										

Outline

Categories

TRS	confluence of first-order term rewrite systems
CTRS	confluence of first-order conditional term rewrite systems
HRS	confluence of higher-order rewrite systems
GCR	ground-confluence of many-sorted first-order rewrite systems
LCTRS	confluence of logically constrained term rewrite systems
NFP	normal form property of first-order rewrite systems
UNR	unique normal forms wrt reduction of first-order rewrite systems
UNC	unique normal forms wrt conversion of first-order rewrite systems
COM	commutation of first-order rewrite systems
INF	infeasibility
SRS	confluence of string rewrite systems
CSR	confluence of context-sensitive rewriting

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TRS	confluence of first-order term rewrite systems
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  - at most two problems per category per tool

Secret Problems

8 secret problems submitted to CoCo 2024

Secret Problems

5 secret problems submitted to CoCo 2025:

- 1 by Jonas Schöpf LCTRS

$$\mathsf{f}(x,y) \to x+y \quad [x > 0] \qquad \mathsf{f}(x,y) \to \mathsf{d}(x,y) \quad [x = 2 \cdot y \wedge y > 0]$$
$$\mathsf{f}(x,y) \to \mathsf{f}(y,x) \quad [x \leqslant 0] \qquad \mathsf{d}(x,y) \to y+x$$

Secret Problems

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$$\mathsf{f}(x,y) \to \mathsf{f}(y,x) \quad [x \leqslant 0] \qquad \mathsf{d}(x,y) \to y+x$$

- 1 by Thiago Felicissimo TRS

$$\infty \to \mathsf{S}(\infty) \qquad \mathsf{Eq}(X,X,X) \to \top$$
$$\mathsf{Eq}(\mathsf{S}(X),X,\mathsf{S}(Z)) \to \mathsf{Eq}(\mathsf{S}(X),X,Z) \qquad \mathsf{Eq}(\mathsf{S}(V),0,V) \to \bot$$

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$$\mathsf{f}(x,y) \to \mathsf{f}(y,x) \quad [x \leqslant 0] \qquad \mathsf{d}(x,y) \to y+x$$

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- 1 by Jan-Christoph Kassing TRS

- 1 by Naoki Nishida LCTRS

- 1 by Raúl Gutiérrez CSR (CSTRS)

Competition Rules

- Scoring
  - 100 random problems per category, using seed digits provided by panel members
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Problem Selection

Example: ARI–COPS queries for LCTRS category

1. `1621 or 1623`

2. `limit:98,509 1..1619 lctrs well-formed`

Problem Selection

Example: ARI–COPS queries for LCTRS category

1. `1621 or 1623`
   returns 2 secret problems
2. `limit:98,509 1..1619 lctrs well-formed`

- secret problems have numbers 1620 ... 1624

Problem Selection

Example: ARI−COPS queries for LCTRS category

1. `1621 or 1623`
   returns 2 secret problems
2. `limit:98,509 1..1619 lctrs well-formed`

- secret problems have numbers `1620 ... 1624`
- seed digits of panel members

Problem Selection

Example: ARI−COPS queries for LCTRS category

1. `1621 or 1623`
   returns 2 secret problems
2. `limit:98,509 1..1619 lctrs well-formed`

- secret problems have numbers 1620 ... 1624
- seed digits of panel members
- 1619 problems in ARI−COPS database

Problem Selection

Example: ARI−COPS queries for LCTRS category

1. `1621 or 1623`
   returns 2 secret problems
2. `limit:98,509 1..1619 lctrs well-formed`
   returns 98 problems

- secret problems have numbers 1620 ... 1624
- seed digits of panel members
- 1619 problems in ARI−COPS database

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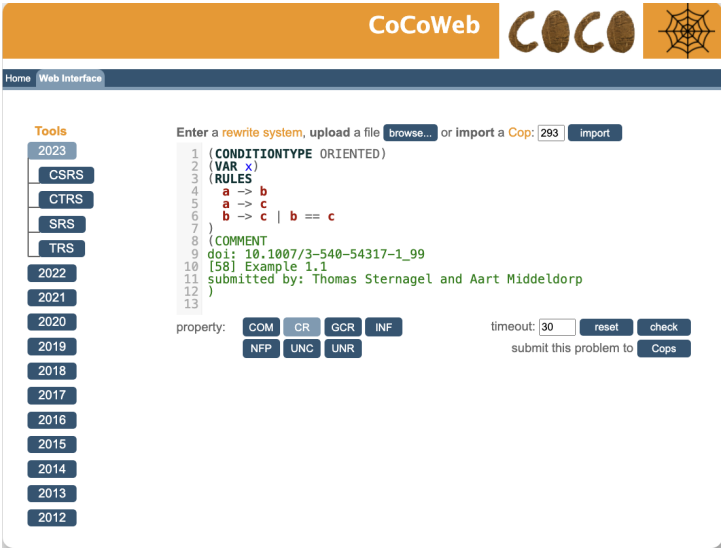
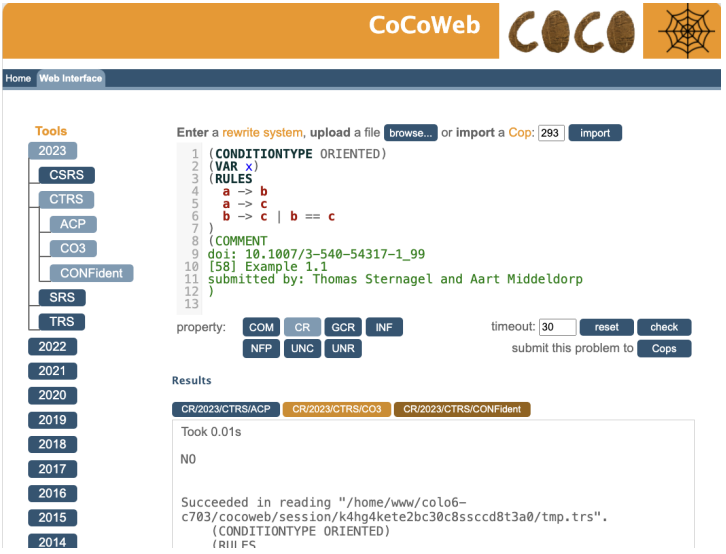

CoCoWeb
Home
Web Interface
Tools
2023
CSRS
CTRS
SRS
TRS
2022
2021
2020
2019
2018
2017
2016
2015
2014
2013
2012
Enter a rewrite system, upload a file browse... or import a Cop: 293 import
1 (CONDITIONTYPE ORIENTED)
2 (VAR x)
3 (RULES
4 a -> b
5 a -> c
6 b -> c | b == c
7)
8 (COMMENT
9 doi: 10.1007/3-540-54317-1_99
10 [58] Example 1.1
11 submitted by: Thomas Sternagel and Aart Middeldorp
12)
13
property: COM CR GCR INF NFP UNC UNR
timeout: 30 reset check
submit this problem to Cops


CoCoWeb
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CONFident
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2019
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2014
Enter a rewrite system, upload a file browse... or import a Cop: 293 import
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8 (COMMENT
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11 submitted by: Thomas Sternagel and Aart Middeldorp
12)
13
property: COM CR GCR INF NFP UNC UNR
timeout: 30 reset check
submit this problem to Cops
Results
CR/2023/CTRS/ACP
CR/2023/CTRS/CO3
CR/2023/CTRS/CONFident
Took 0.01s
NO
Succeeded in reading "/home/www/colo6-c703/cocoweb/session/k4hg4kete2bc30c8ssccd8t3a0/tmp.trs".
(CONDITIONTYPE ORIENTED)
(RULES

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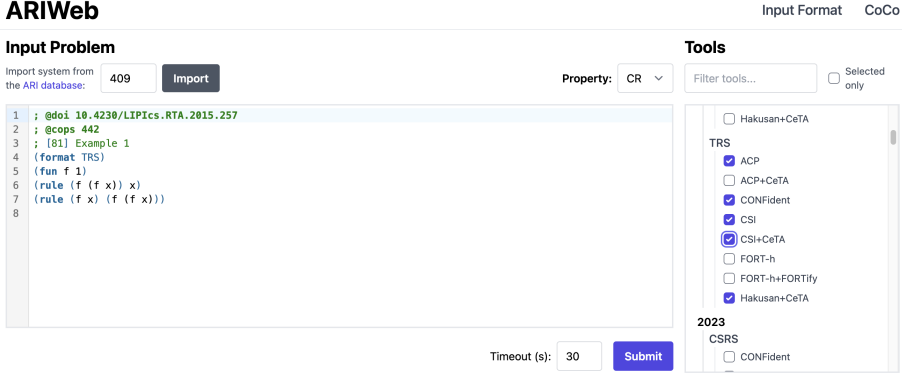
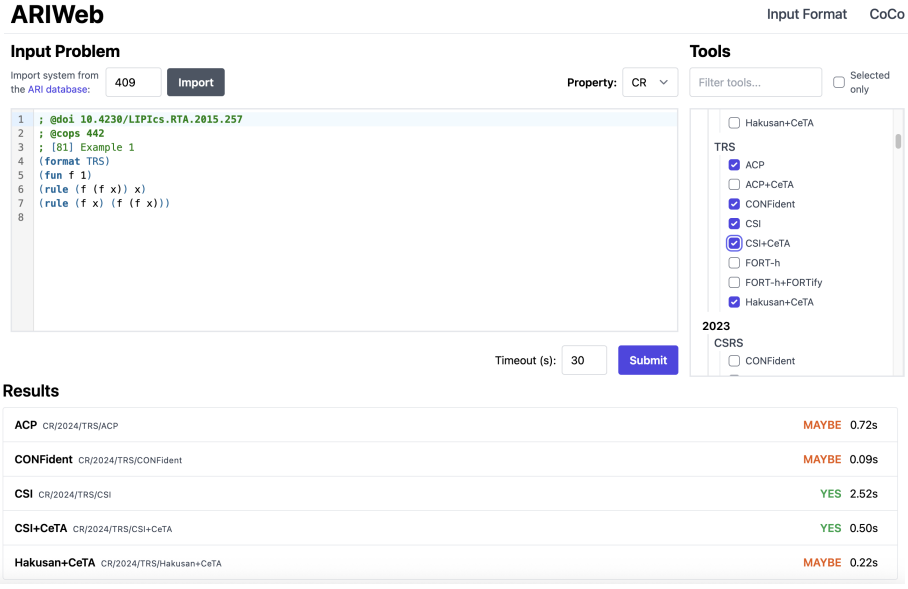

ARIWeb
Input Format
CoCo
Input Problem
Import system from the ARI database:
409
Import
Property:
CR
Tools
Filter tools...
Selected only
; @doi 10.4230/LIPIcs.RTA.2015.257
; @cops 442
; [81] Example 1
(format TRS)
(fun f 1)
(rule (f (f x)) x)
(rule (f x) (f (f x)))
Hakusan+CeTA
TRS
ACP
ACP+CeTA
CONFident
CSI
CSI+CeTA
FORT-h
FORT-h+FORTify
Hakusan+CeTA
2023
CSRS
CONFident
Timeout (s):
30
Submit


ARIWeb
Input Format
CoCo
Input Problem
Import system from the ARI database:
409
Import
Property:
CR
Filter tools...
Selected only
; @doi 10.4230/LIPIcs.RTA.2015.257
; @cops 442
; [81] Example 1
(format TRS)
(fun f 1)
(rule (f (f x)) x)
(rule (f x) (f (f x)))
Hakusan+CeTA
TRS
ACP
ACP+CeTA
CONFident
CSI
CSI+CeTA
FORT-h
FORT-h+FORTify
Hakusan+CeTA
2023
CSRS
CONFident
Timeout (s):
30
Submit
Results
ACP CR/2024/TRS/ACP MAYBE 0.72s
CONFident CR/2024/TRS/CONFident MAYBE 0.09s
CSI CR/2024/TRS/CSI YES 2.52s
CSI+CeTA CR/2024/TRS/CSI+CeTA YES 0.50s
Hakusan+CeTA CR/2024/TRS/Hakusan+CeTA MAYBE 0.22s

ARI-COPS Database

> ARI COPS CoCo results

search

1605 problems matched (download) **view:** problems | results **order:** asc | desc **download:** all data

« back next »

1.ari

```
; @author Takahito Aoto
; @author Junichi Yoshida
; @author Yoshihito Toyama
; @doi 10.1007/BFb0027006
; @cops 1
; [1] Example 6
(format TRS)
(fun F 2)
(fun f 2)
(fun g 1)
(fun h 1)
(rule (f x y) x)
(rule (f x y) (f x (g y)))
(rule (g x) (h x))
(rule (F (g x) x) (F x (g x)))
(rule (F (h x) x) (F x (h x)))
```

YES: well-formed trs CR

NO: ctrs cstrs csctrs mstrs ictrs 2trs infeasibility ground left-linear right-ground srs

2.ari

```
; @author Takahito Aoto
; @author Junichi Yoshida
; @author Yoshihito Toyama
; @doi 10.3217/jucs-003-11-1134
; @cops 2
; [2] Example 1
(format TRS)
(fun F 2)
```

ARI-COPS Database

> ARI COPS CoCo results

search

1605 problems matched (download) **view:** problems | results **order:** asc | desc **download:** all data

« back next »

1.ari

```
; @author Takahito Aoto
; @author Junichi Yoshida
; @author Yoshihito Toyama
; @doi 10.1007/BFb0027006
; @cops 1
; [1] Example 6
(format TRS)
(fun F 2)
(fun f 2)
(fun g 1)
(fun h 1)
(rule (f x y) x)
(rule (f x y) (f x (g y)))
(rule (g x) (h x))
(rule (F (g x) x) (F x (g x)))
(rule (F (h x) x) (F x (h x)))
```

YES: well-formed trs CR

NO: ctrs cstrs csctrs mstrs ictrs 2trs infeasibility ground left-linear right-ground srs

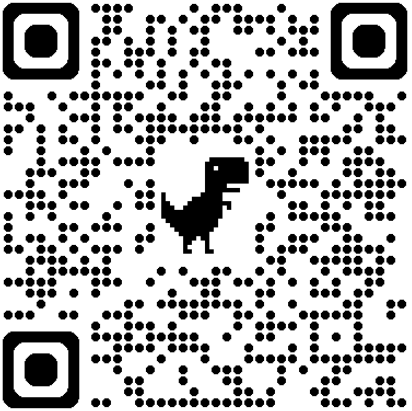
2.ari

```
; @author Takahito Aoto
; @author Junichi Yoshida
; @author Yoshihito Toyama
; @doi 10.3217/jucs-003-11-1134
; @cops 2
; [2] Example 1
(format TRS)
(fun F 2)
```

confluence problems database (ARI−COPS) consists of 1619 problems

CoCo 2025 Live View

https://ari-cops.uibk.ac.at/liveview/2025.html



2024 Results

TRS category

2024 Results

TRS category

- previous winners: ACP 2012 2013 2014 2015 2019
  CSI 2015 2016 2017 2018 2020 2021 2022 2023

2024 Results

TRS category

- previous winners: ACP 2012 2013 2014 2015 2019
  CSI 2015 2016 2017 2018 2020 2021 2022 2023
- 2025 participants: ACP ACP + CeTA AProVE CONFident CSI CSI + CeTA FORT-h
  FORT-h + FORTify Grackle-CSI Hakusan Hakusan + CeTA

2024 Results

TRS category

- previous winners: ACP 2012 2013 2014 2015 2019
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  FORT-h + FORTify Grackle-CSI Hakusan Hakusan + CeTA

14th International Workshop on Confluence

Jan-Christoph Kassing and Tobias Sokolowski

02.09.2025

AProVE25: Confluence Analysis in a Termination Tool

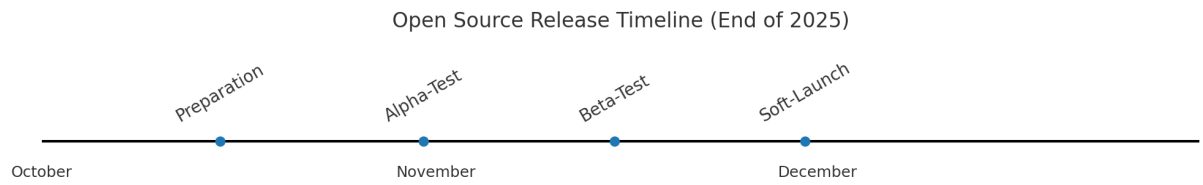
UnRAVeL Research Training Group – Uncertainty and Randomness in Algorithms, Verification, and Logic

RWTH AACHEN UNIVERSITY

AProVE

- **AProVE (Automated Program Verification Environment)**:
  - Automated Termination, Complexity, and Safety Prover for Java, C, **Term Rewriting**, Integer Programs, etc.
  - **Confluence Analysis**:
    - Orthogonality Check
    - Strong Confluence Check
    - Modularity Results:
      - Disjoint Union
      - Constructor Sharing
      - Compositable
    - Newman Lemma Check (WCR + **Termination**)
    - Disproving Confluence by Searching for Counterexamples
- **Open Source Release: End of This Year**

Open Source Release



Target License: **LGPL (Lesser General Public License)**

- You can **use, modify, and redistribute** LGPL software (for free or commercially).
- If you **modify the LGPL-covered code itself**, you must release those modifications under the LGPL.
- If you **just use the library** (e.g., link to it in your own code), your own program does *not* have to be LGPL/GPL.

- **Future Ideas:**
  - Probabilistic Rewriting and Confluence
    - Newman Lemma for Probabilistic Rewriting? (Hard Open Problem, [Faggian 2022])
  - Probabilistic Rewriting and Reachability / Infeasibility (Current Research)
    - **Given**: Terms s, t and probability p.
    - **Question**: Does there exist a substitution σ such that $s\sigma \to t\sigma$ with at least / at most probability p?

universität innsbruck

CSI 1.2.7

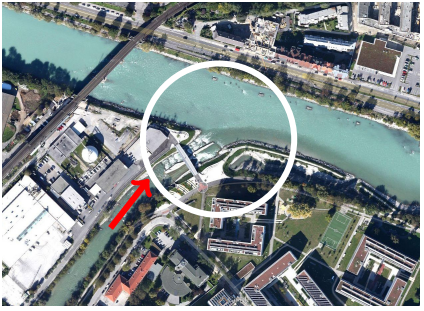
Fabian Mitterwallner Aart Middeldorp

University of Innsbruck

[Google Maps]

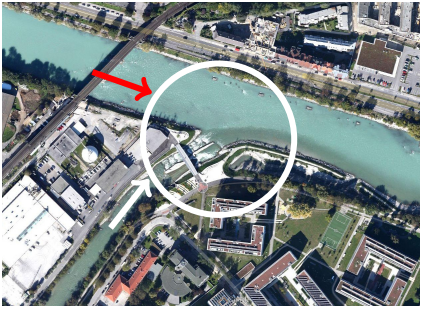
[Google Maps]

C



[Google Maps]

CS



[Google Maps]

CSI

[Google Maps]

CSI 1.2.7

- open source
- convenient web interface
- `http://cl-informatik.uibk.ac.at/software/csi/`
- CSI won NFP, SRS, TRS, UNC, UNR categories in 2024

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CoCo 2025 Categories

TRS (also in combination with CeTA)

- open source
- convenient web interface
- `http://cl-informatik.uibk.ac.at/software/csi/`
- CSI won NFP, SRS, TRS, UNC, UNR categories in 2024

CoCo 2025 Categories

TRS (also in combination with CeTA)

No New Features in 2025

- CSI uses ARI $\rightarrow$ COPS conversion tool

Grackle CSI

Liao Zhang, Qinxiang Cao

University of Innsbruck, Austria
Shanghai Jiao Tong University, China

September 2, 2025

Grackle CSI

- CSI
  - Confluence analysis tool developed by the University of Innsbruck
  - Employ a complicated strategy document to combine many confluence analysis techniques
- Grackle:
  - General parameter optimization tool for automated theorem proving
- Grackle CSI:
  - CSI but not the competition strategy used in CoCo 2024
  - Strategies invented by Grackle

v0.12

Fuyuki Kawano **Hiroka Hondo**
Nao Hirokawa **Kiraku Shintani**

JAIST

Confluence Proof by Rule Removal

$$\mathcal{R} = \left\{ \begin{array}{rcl} \mathsf{s}(\mathsf{p}(x)) & \xrightarrow{\mathbf{1}} & \mathsf{p}(\mathsf{s}(x)) \\ \mathsf{p}(\mathsf{s}(x)) & \xrightarrow{\mathbf{2}} & x \\ \infty & \xrightarrow{\mathbf{3}} & \mathsf{s}(\infty) \end{array} \right\}$$

Confluence Proof by Rule Removal

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1 $\mathsf{CR}(\mathcal{R}) \iff \mathsf{CR}(\{\mathbf{3}\})$ by critical pair system

Confluence Proof by Rule Removal

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Confluence Proof by Rule Removal

$$\mathcal{R} = \left\{ \begin{array}{rcl} \mathsf{s}(\mathsf{p}(x)) & \overset{\mathbf{1}}{\to} & \mathsf{p}(\mathsf{s}(x)) \\ \mathsf{p}(\mathsf{s}(x)) & \overset{\mathbf{2}}{\to} & x \\ \infty & \overset{\mathbf{3}}{\to} & \mathsf{s}(\infty) \end{array} \right\}$$

1. $\mathsf{CR}(\mathcal{R}) \iff \mathsf{CR}(\{\mathbf{3}\})$ by critical pair system
2. $\mathsf{CR}(\{\mathbf{3}\}) \iff \mathsf{CR}(\varnothing)$ by rule labeling

Confluence Proof by Rule Removal

$$\mathcal{R} = \left\{ \begin{array}{rcl} \mathsf{s}(\mathsf{p}(x)) & \xrightarrow{\mathbf{1}} & \mathsf{p}(\mathsf{s}(x)) \\ \mathsf{p}(\mathsf{s}(x)) & \xrightarrow{\mathbf{2}} & x \\ \infty & \xrightarrow{\mathbf{3}} & \mathsf{s}(\infty) \end{array} \right\}$$

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1. $\mathsf{CR}(\mathcal{R}) \iff \mathsf{CR}(\{\mathbf{3}\})$ by critical pair system
2. $\mathsf{CR}(\{\mathbf{3}\}) \iff \mathsf{CR}(\varnothing)$ by rule labeling
3. $\mathsf{CR}(\varnothing)$ is trivial

Non-Confluence Proof by Tree Automata Completion

$$\mathcal{F} = \left\{ \begin{array}{r} \mathsf{h} \\ \mathsf{f}, \mathsf{g} \\ \mathsf{a}, \mathsf{b} \end{array} \right\} \quad \mathcal{R} = \left\{ \begin{array}{r} \mathsf{h}(\mathsf{g}, \mathsf{a}, \mathsf{a}) \to \mathsf{h}(\mathsf{f}, \mathsf{a}, \mathsf{a}) \\ \mathsf{h}(x, \mathsf{b}, y) \to \mathsf{h}(x, y, y) \\ \mathsf{a} \to \mathsf{b} \end{array} \right\} \quad \mathcal{A} = \left\{ \begin{array}{r} \mathsf{h}(0, 1, 1) \to 2 \\ \mathsf{g} \to 0 \\ \mathsf{b} \to 1 \end{array} \right\}$$

Non-Confluence Proof by Tree Automata Completion

$$\mathcal{F} = \left\{ \begin{array}{c} \mathsf{h} \\ \mathsf{f}, \mathsf{g} \\ \mathsf{a}, \mathsf{b} \end{array} \right\} \quad \mathcal{R} = \left\{ \begin{array}{c} \mathsf{h}(\mathsf{g}, \mathsf{a}, \mathsf{a}) \to \mathsf{h}(\mathsf{f}, \mathsf{a}, \mathsf{a}) \\ \mathsf{h}(x, \mathsf{b}, y) \to \mathsf{h}(x, y, y) \\ \mathsf{a} \to \mathsf{b} \end{array} \right\} \quad \mathcal{A} = \left\{ \begin{array}{r} \mathsf{h}(0, 1, 1) \to 2 \\ \mathsf{g} \to 0 \\ \mathsf{b} \to 1 \end{array} \right\}$$

1 compatibility shows closedness of $L(\mathcal{A})$ under rewriting

$$\forall (q_1, q_2) \in \{0, 1\}^2.\ \mathsf{h}(q_1, \mathsf{b}, q_2) \to_{\mathcal{A}}^* 2 \implies \mathsf{h}(q_1, q_2, q_2) \to_{\mathcal{A}}^* 2$$

Non-Confluence Proof by Tree Automata Completion

$$\mathcal{F} = \left\{ \begin{array}{c} \mathsf{h} \\ \mathsf{f}, \mathsf{g} \\ \mathsf{a}, \mathsf{b} \end{array} \right\} \quad \mathcal{R} = \left\{ \begin{array}{c} \mathsf{h}(\mathsf{g}, \mathsf{a}, \mathsf{a}) \to \mathsf{h}(\mathsf{f}, \mathsf{a}, \mathsf{a}) \\ \mathsf{h}(x, \mathsf{b}, y) \to \mathsf{h}(x, y, y) \\ \mathsf{a} \to \mathsf{b} \end{array} \right\} \quad \mathcal{A} = \left\{ \begin{array}{r} \mathsf{h}(0, 1, 1) \to 2 \\ \mathsf{g} \to 0 \\ \mathsf{b} \to 1 \end{array} \right\}$$

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$$\forall (q_1, q_2) \in \{0, 1\}^2.\ \mathsf{h}(q_1, \mathsf{b}, q_2) \to_{\mathcal{A}}^* 2 \implies \mathsf{h}(q_1, q_2, q_2) \to_{\mathcal{A}}^* 2$$

2 persistency eases compatibility check

$$\left\{ \begin{array}{lll} \{q_1 \mapsto 0, q_2 \mapsto 0\} & \{q_1 \mapsto 0, q_2 \mapsto 1\} & \{q_1 \mapsto 0, q_2 \mapsto 2\} \\ \{q_1 \mapsto 1, q_2 \mapsto 0\} & \{q_1 \mapsto 1, q_2 \mapsto 1\} & \{q_1 \mapsto 1, q_2 \mapsto 2\} \\ \{q_1 \mapsto 2, q_2 \mapsto 0\} & \{q_1 \mapsto 2, q_2 \mapsto 1\} & \{q_1 \mapsto 2, q_2 \mapsto 2\} \end{array} \right\}$$

Non-Confluence Proof by Tree Automata Completion

$$\mathcal{F} = \left\{ \begin{array}{r} \mathsf{h} : A \times B \times B \to C \\ \mathsf{f}, \mathsf{g} : A \\ \mathsf{a}, \mathsf{b} : B \end{array} \right\} \quad \mathcal{R} = \left\{ \begin{array}{c} \mathsf{h}(\mathsf{g}, \mathsf{a}, \mathsf{a}) \to \mathsf{h}(\mathsf{f}, \mathsf{a}, \mathsf{a}) \\ \mathsf{h}(x, \mathsf{b}, y) \to \mathsf{h}(x, y, y) \\ \mathsf{a} \to \mathsf{b} \end{array} \right\} \quad \mathcal{A} = \left\{ \begin{array}{r} \mathsf{h}(0, 1, 1) \to 2 \\ \mathsf{g} \to 0 \\ \mathsf{b} \to 1 \end{array} \right\}$$

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$$\forall (q_1, q_2) \in \cancel{\{0,1\}^2}\ \underset{\{0\}\times\{1\}}{\cdot}\ \mathsf{h}(q_1, \mathsf{b}, q_2) \to^*_{\mathcal{A}} 2 \implies \mathsf{h}(q_1, q_2, q_2) \to^*_{\mathcal{A}} 2$$

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2024 Results

SRS category

2024 Results

- previous winner: CSI 2019 2020 2021 2022 2023

2024 Results

- previous winner: CSI 2019 2020 2021 2022 2023
- noko-leipzig produced most NO answers in 2019

2024 Results

INF category

2024 Results

INF category

- previous winner: infChecker 2019 2020 2021 2022 2023

2024 Results

INF category

- previous winner: infChecker 2019 2020 2021 2022 2023
- 2025 participants: CO3 infChecker Natto+CeTA

2024 Results

INF category

- previous winner: infChecker 2019 2020 2021 2022 2023
- 2025 participants: CO3 infChecker Natto+CeTA

CO3 (Ver. 2.6)

a **CO**nverter for proving **CO**nfluence of **CO**nditional TRSs

Naoki Nishida Misaki Kojima
Nagoya University, Japan

Overview

CO3 proves confluence of 3-DCTRSs or infeasibility of conditions by using

- very simple termination/confluence criteria for TRSs,
- the improved sequential unraveling $\mathbb{U}_{conf}$ [Gmeiner et al, 13],
- narrowing trees [Nishida & Maeda, 18], and
- reduction of confluence of join or semi-equational CTRSs to that of oriented ones

Infeasibility and Confluence Criterion

- Condition c is infeasible w.r.t. DCTRS $\mathcal{R}$ if $\mathbb{U}_{conf}(\mathcal{R})$ is right-linear and a narrowing tree for c defines $\emptyset$ [Maeda et al, 19]
- Syntactically deterministic 3-CTRSs $\mathcal{R}$ is confluent if either
  - $\mathcal{R}$ is weakly left-linear and $\mathbb{U}_{conf}(\mathcal{R})$ is confluent [Gmeiner et al, 13]
    or
  - $\mathbb{U}_{conf}(\mathcal{R})$ is terminating and right-linear
    and $\forall \langle s, t\rangle \Leftarrow c \in CP(\mathcal{R})$, $(c = \epsilon \wedge s = t) \vee$ "c is infeasible" [Maeda et al, 19]

- Improved a processor for the subterm criterion [Ver. 2.6]

VRAIN Valencian Research Institute for Artificial Intelligence

infChecker **at CoCo 2025**

Raúl Gutiérrez[1] Salvador Lucas[1]

LEIPZIG, 2025

[1] Valencian Research Institute for Artificial Intelligence
Universitat Politècnica de València
Spain

UPV

Description

- infChecker is a tool for checking **(in)feasibility of goals** $\mathcal{G} = \{F_i\}_{i=1}^{m}$, where $F_i = (s_{ij} \bowtie_{ij} t_{ij})_{i=1}^{n_i}$.
- $\bowtie_{ij}$ represents **predicates** on terms defined by provability of goals $s \bowtie_{ij} t$ with respect to a *first-order theories* $\mathrm{Th}_{\bowtie_{ij}}$.
- $\bowtie_{ij}$ can be one of the following predicates:
  - One (CS-)rewriting step (`->`, `\->`).
  - Zero or more (CS-)rewriting steps (`->*`, `\->*`).
  - One or more (CS-)rewriting steps (`->+`, `\->+`).
  - Subterm (`|>=`) and strict subterm (`|>`).
  - (CS-)Joinability (`->*<-`, `\->*<-/`).
  - One (CS-)convertibility step (`<->`, `<-/\->`).
  - Zero or more (CS-)convertibility steps (`<->*`, `<-/\->*`).
- This year, our participation involves utilizing the same tool employed in the previous year.

An Example

- Given the TRS $\mathcal{R} = \{a \to c(b), b \to c(b)\}$, infChecker can prove the nonloopingness of a as the infeasibility of

$$(\{\overline{\mathcal{R}}, Th_{\trianglerighteq}\}, \{\neg(x,y)(a \to x, x \to^* y, y \trianglerighteq a)\})$$

by obtaining the following structure over $\mathbb{N} \cup \{-1\}$:

$$\begin{array}{rr} a^{\mathcal{A}} = -1 & b^{\mathcal{A}} = 1 \\ c^{\mathcal{A}}(x) = x & x \to^{\mathcal{A}} y \Leftrightarrow x \leq 1 \wedge y \geq 1 \\ x\ (\to^*)^{\mathcal{A}}\ y \Leftrightarrow x \leq y & x \trianglerighteq^{\mathcal{A}} y \Leftrightarrow x \leq y \end{array}$$

Implementation and Bibliography

- It is written in Haskell and implements the **Feasibility Framework**. The tool is available here:

  `http://zenon.dsic.upv.es/infChecker/`

- Bibliography:

GL25 R. Gutiérrez and S. Lucas. Proving and disproving feasibility with infChecker. In Proc. of the 14th International Workshop on Confluence, IWC'25, to appear, 2025.

GL20 R. Gutiérez and S. Lucas. Automatically Proving and Disproving Feasibility Conditions. In Proc. of IJCAR'2020, LNCS 12167:416–435. Springer, 2020.

Luc24 S. Lucas. Local confluence of conditional and generalized term rewriting systems. Journal of Logical and Algebraic Methods in Programming, 136, paper 100926, pages 1-23, 2024.

LG18 S. Lucas and R. Gutiérrez. Use of Logical Models for Proving Infeasibility in Term Rewriting. Information Processing Letters, 136:90-95, 2018.

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2024 Results

CTRS category

2024 Results

CTRS category

- previous winners: CO3 2014 ConCon 2015 2016 2017 2018 2020 ACP 2019 CONFident 2021 2022 2023

2024 Results

CTRS category

- previous winners: CO3 2014 ConCon 2015 2016 2017 2018 2020 ACP 2019 CONFident 2021 2022 2023
- 2025 participants: ACP CO3 CONFident

2024 Results

CTRS category

- previous winners: CO3 2014 ConCon 2015 2016 2017 2018 2020 ACP 2019 CONFident 2021 2022 2023
- 2025 participants: ACP CO3 CONFident

ACP (Automated Confluence Prover)

Takahito Aoto

- ACP entered to ~~COM~~/CTRS/~~SRS~~/TRS/~~UNR~~/~~UNC~~
- ACP+CeTA entered to ~~COM~~/~~SRS~~/TRS
- Written in Standard ML of New Jersey (SML/NJ)
- Version: 0.10 (2009) $\cdots$ 0.75 (2024)
- Implementing multiple direct methods and divide-and-conquer methods
- Our latest effort is to incorporate UNR proving and certificates generation for COM.

We couldn't make any efforts on ACP this year.

VRAIN Valencian Research Institute for Artificial Intelligence

CONFident **at CoCo 2025**

Raúl Gutiérrez[1] Salvador Lucas[1]

LEIPZIG, 2025

[1] Valencian Research Institute for Artificial Intelligence
Universitat Politècnica de València
Spain

UPV

Description

- CONFident is a tool for checking **(non-)confluence** of Generalized Term Rewriting Systems (GTRSs).
- A GTRS is a tuple $\mathcal{R} = (\Omega, \mu, H, R)$, where:
  - $\Omega = (\mathcal{F}, \Pi)$ is a signature with predicates.
  - $\mu \in M_{\mathcal{F}}$.
  - H is a set of auxiliary clauses (H is used to model the semantics of conditions).
  - R is a set of rewrite rules $\ell \to r \Leftarrow c$.
- This year, our participation involves utilizing the same tool employed in the previous year.
- In the bibliography, you can find new publications on some techniques that were unpublished last year.

An Example

- Consider the GTRS $\mathcal{R}$:

$$
\begin{array}{ll}
x \geq 0 & \mathit{odd}(x) \Leftrightarrow x \to^* s(0) \\
s(x) \geq s(y) \Leftrightarrow x \geq y & \mathit{zero}(x) \Leftrightarrow x \to^* 0 \\
\mathit{peven}(x) \Leftrightarrow x \to^* s(s(0)) & s(s(x)) \to x \Leftrightarrow x \geq s(0)
\end{array}
$$

- CONFident can prove the confluence of $\mathcal{R}$.

Implementation and Bibliography

- It is written in Haskell and implements the **Confluence Framework**. The tool is available here:

  `http://zenon.dsic.upv.es/confident/`

- Bibliography:

GL24 R. Gutiérez and S. Lucas. Proving Confluence in the Confluence Framework with CONFident. Fundamenta Informaticae 192, Issue 2: LOPSTR 2022, 2024.

GL25 R. Gutiérrez and S. Lucas. Proving and disproving feasibility with infChecker. In Proc. of the 14th International Workshop on Confluence, IWC'25, to appear, 2025.

GLV23 R. Gutiérez, S. Lucas and M. Vítores. Proving Confluence in the Confluence Framework with CONFident. CoRR abs/2306.16330, 2023.

Luc25 S. Lucas. Confluence of Almost Parallel-Closed Generalized Term Rewriting Systems. In Proc. of 30th International Conference on Automated Deduction, CADE-30, to appear, 2025.

UPV

2024 Results

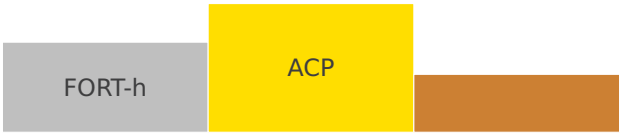
GCR category

2024 Results

GCR category

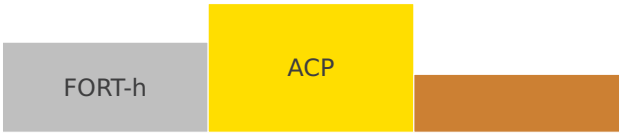
- previous winner: AGCP 2015 2016 2017 2018 2019 2020 2021 2022 2023

2024 Results



COM category

2024 Results



COM category

- previous winners: FORT 2019 ACP 2020 2023 CoLL 2021 2022

2024 Results

UNC category

2024 Results

UNC category

- previous winners: CSI 2017 ACP 2018 2019 2020 2021 2022 2023

2024 Results

UNR category

- ACP was disqualified

2024 Results

UNR category

- ACP was disqualified
- previous winners: CSI 2017 2018 2019 2020 2021 2022 ACP 2023

2024 Results

NFP category

2024 Results

- previous winner: CSI 2017 2018 2019 2020 2021 2022 2023

2024 Results

CSR category

2024 Results

CSR category

- previous winner: CONFident 2022 2023

2024 Results

CSR category

- previous winner: CONFident 2022 2023
- 2025 participants: CONFident SOL

2024 Results

CSR category

- previous winner: CONFident 2022 2023
- 2025 participants: CONFident SOL

SOL 2025 (Makoto Hamana, Shotaro Karasaki)

- ▷ SOL: Haskell-based tool for analysing confluence and termination of higher-order rewriting [H. JFP19][H., Abe, Kikuchi SCP20]
- ▷ New: Rewriting with Term Evaluation and Refinement System (TERS) [Muroya, H. FLOPS'24]
- ▷ New: Simulate context-sensitive rewriting by TES
- ▷ New: CS-Confluence based on criterion [Lucus'20]

– If $\mathcal{R}$ is left-linear, empty CS-CP, LHRV then CS-CR

– If $\mathcal{R}$ is CS-SN and all CS-CPs are CS-joinable, LHRV then CS-CR

- ▷ LHRV: active variables in lhs are not non-actuive in l nor r

$$\mathrm{Var}^{\mu}(l) \cap (\mathrm{Var}^{\mu'}(l) \cup \mathrm{Var}^{\mu'}(r))$$

- ▷ CS-SN by SN of normal TRS

2024 Results

certification category

2024 Results

certification category

- previous winner: CeTA 2023
- 2025 participants: CeTA FORTify

2024 Results

certification category

- previous winner: CeTA 2023
- 2025 participants: CeTA FORTify

CeTA 3.6

- CeTA: certifier of various properties
- verified in Isabelle/HOL in IsaFoR library
- mostly developed by Computational Logic Group in Innsbruck
- several confluence techniques supported, see a complete list at:

  `http://cl-informatik.uibk.ac.at/software/ceta/`

- usage in CoCo: certify proofs and disproofs of
  - confluence
  - commutation (not this year)
  - infeasibility
- usage in ARI-database: certify YES/NO for CR/COM/INF-tags

New techniques in CeTA 3.6 in comparison to 2024

- new term ordering: core matrix interpretations
  - original matrix ordering for SRSs, developed by Hofbauer and Waldmann
  - generalized to TRSs
  - usage: discrimination pair, co-rewrite pair, reduction pair, reduction order
  - details on ordering: see WST talk
- feasibility proofs via explicit rewrite sequences of (C)TRSs
  - unfortunately no certificate generating tool yet
- explicit swap for non-commutation proofs
  - improves application of non-symmetric techniques
- on its way: Okui's confluence criterion
  - soundness of criterion has been formally proven in IsaFoR
  - missing: verified computation of simultaneous critical pairs

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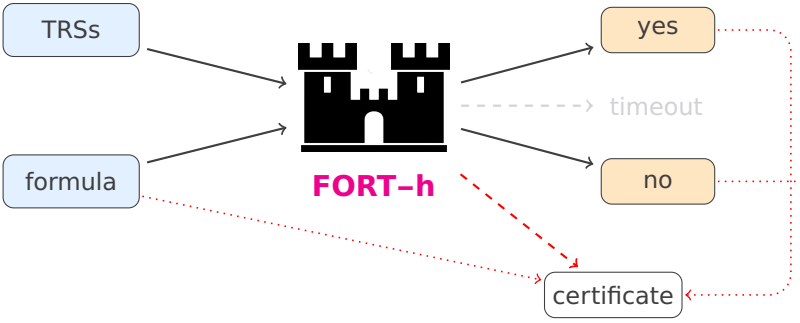
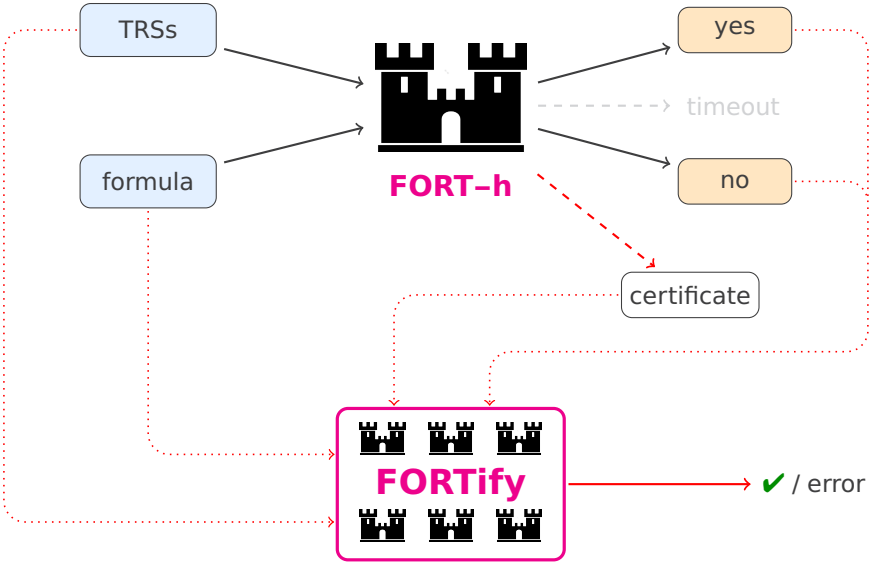
FORTify 2.1

Fabian Mitterwallner Aart Middeldorp

University of Innsbruck


TRSs
formula
FORT–h
yes
timeout
no
certificate


TRSs
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FORTify
✔ / error

- code generated from formalization of decision procedure in Isabelle/HOL
- `https://fortissimo.uibk.ac.at/fort(ify)/`

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CoCo 2025 Category

TRS (with FORT−h)

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CoCo 2025 Category

TRS (with FORT–h)

Literature

Aart Middeldorp, Alexander Lochmann and Fabian Mitterwallner

First-Order Theory of Rewriting for Linear Variable–Separated Rewrite Systems: Automation, Formalization, Certification

Journal of Automated Reasoning 67(2), 2023

doi: 10.1007/s10817-023-09661-7

2024 Results

reliability category

2024 Results

- previous winner: FORT-h 2023
- 2025 participants: ACP CSI FORT-h Hakusan Natto

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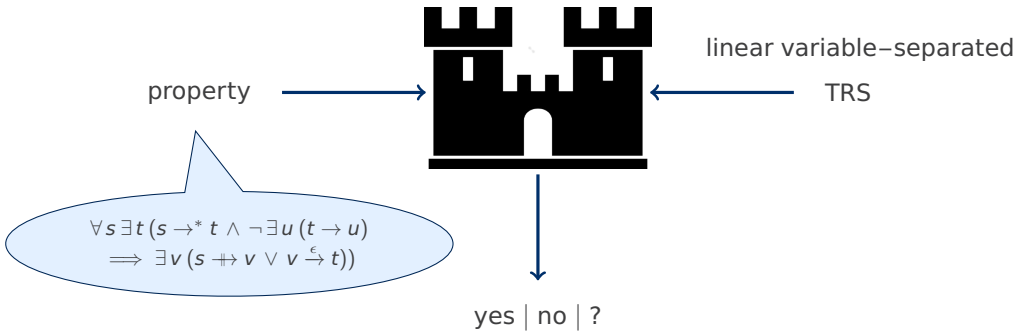
FORT–h 2.1

Fabian Mitterwallner Aart Middeldorp

University of Innsbruck

FORT–h



property is arbitrary formula in first–order theory of rewriting

- convenient web interface
- `https://fortissimo.uibk.ac.at/fort(ify)/`

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CoCo 2025 Categories

TRS

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Natto

Teppei Saito

JAIST

CoCo 2025

Natto — Infeasibility Tool

prototype infeasibility tool for a paper by Kim et al. (2025)

implements a subset of ordering-based methods of NaTT for INF

generates CPF3 proofs which can be verified by CeTA

should demonstrate progress of CeTA team :)

2024 Results

LCTRS category

2024 Results

LCTRS category

- 2025 participants: CRaris crest

CRaris (Ver. 1.1)

a **CR** checker for LCTRSs in **ARI** style

Naoki Nishida Misaki Kojima
Nagoya University, Japan

Overview

CRaris, which is a part of Crisys2, proves confluence of LCTRSs written in ARI style

- Crisys2 is a rewriting-induction tool for LCTRSs

Supported SMT-LIB Theories

`Core`, `Ints`, `FixedSizeBitVecotrs`

Implemented Confluence Criteria

- weak orthogonality (left-linearity + triviality of CPs) [Kop and Nishida, 2013]
- termination + triviality of CPs [Schöpf and Middeldorp, 2023]

Implemented DP Processors for Termination

- SCC processor
- singleton self-looping removal processor for BV-LCTRSs [Matsumi et al, 2023]

- Added a disproof criterion by means of logical-variable CPs $\langle x, y \rangle$ $[\varphi]$ [Ver. 1.1]

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supported by FWF project I 5943-N

crest 1.0

Jonas Schöpf Aart Middeldorp

University of Innsbruck

crest

- Constrained REwriting Software Tool

crest

- Constrained REwriting Software Tool
- confluence and termination analysis of logically constrained rewrite systems

crest

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- crest accepts input problems in (more liberal) ARI format

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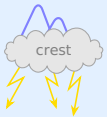

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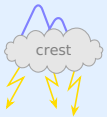

new in 2025

- merging constrained rewrite rules — TACAS 2025

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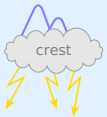

new in 2025

- merging constrained rewrite rules — TACAS 2025
- redundant rules — IWC 2025

crest

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- crest accepts input problems in (more liberal) ARI format
- crest uses Z3 as SMT solver

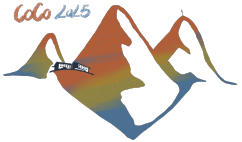
new in 2025

- merging constrained rewrite rules — TACAS 2025
- redundant rules — IWC 2025
- splitting constrained critical pairs — TACAS 2025

and the 2025 winners are . . .

https://ari-cops.uibk.ac.at/liveview/2025.html

Outline



the steering committee of the

14th Confluence Competition

awarded

TOOL by *authors*

the

First Place in the ? category

Leipzig, 2 September 2025

Awards

- top three tools in each category (excluding tool + certifier)

Awards

- top three tools in each category (excluding tool + certifier)
- certifiers based on total number of certified answers

CERTIFICATION

Awards

- top three tools in each category (excluding tool + certifier)
- certifiers based on total number of certified answers — CERTIFICATION
- top three tools that produce most certifiable answers — RELIABILITY

Awards

- top three tools in each category (excluding tool + certifier)
- certifiers based on total number of certified answers — CERTIFICATION
- top three tools that produce most certifiable answers — RELIABILITY

no Award Ceremony: certificates will be sent by email

Outline

Outlook

- CoCo 2026 during IWC 2026 ?

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- T–shirt ?

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