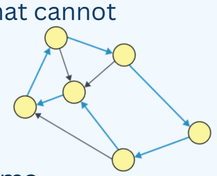
AllDifferent inside Circuit:

An Experimental Evaluation of Propagation strength and Explanation quality in Lazy Clause Generation

1. INTRODUCTION

Constraint Programming(CP)

- framework for solving combinatorial problems
- models problems using variables + constraints
- combines propgation & systematic search
- propagation removes values that cannot participate in any solution

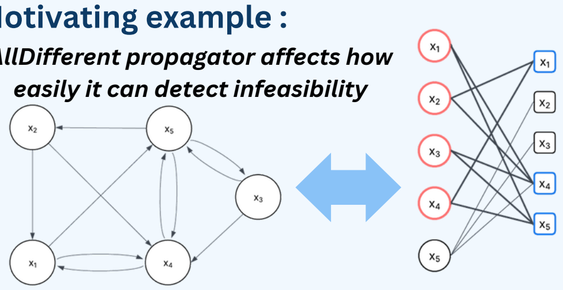


Circuit Constraint:

- ensures Hamiltonian cycle
- core to routing/TSP problems
- **uses *AllDifferent* constraint to ensure each node exactly one sucessor**

Motivating example :

AllDifferent propagator affects how easily it can detect infeasibility



- weak propagator (checks pairs) won't catch this → will ***branch*** first, discover conflict later
- strong propgator (global) catches ***infeasibility*** right away

However, strong propgation must also explain its pruning

- clause has to reference all four nodes
- clause is more specific → less reusable

Prior work has studied:

- AllDifferent in isolation
- Circuit with AllDifferent fixed
- *NEVER* how the 2 interact in LCG

Leads to Research Question:

Which AllDifferent propagator should Circuit use, inside LCG?

2. PROPAGATOR VARIANTS

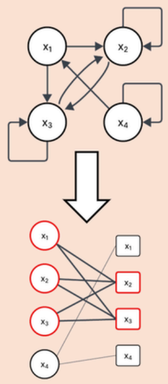
To answer this question: Implemented 4 propagator variants each strictly stronger than the last → Isolate each enhancement in isolation

V0 – Decomposition

AllDifferent (x_1, x_2, x_3, x_4)

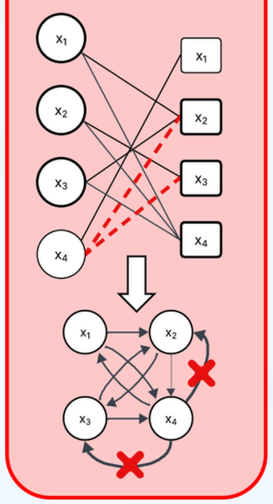
$x_1 \neq x_2$, $x_1 \neq x_3$, $x_2 \neq x_3$, $x_2 \neq x_4$, $x_3 \neq x_4$, $x_1 \neq x_4$

V1 – Conflict Only



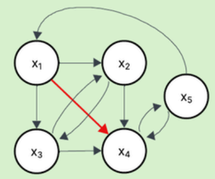
Global feasibility check

V2 – GAC

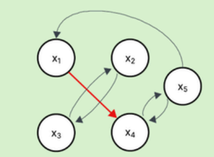


V3 – Hall-circuit Pruning[1]

Edge $x_1 \to x_4$ should be pruned:



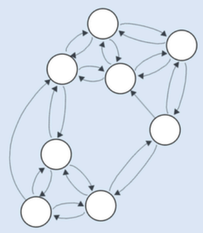
Otherwise -> Conflict:



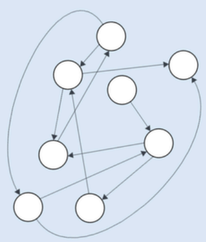
3. EXPERIMENTAL SETUP

BENCHMARKS:

Primary:
Structured synthetic graphs
Geographic k-nearest graphs[2]



Secondary:
Unstructured synthetic graphs
Erdős–Rényi Random graphs



Experiment 1.1 : Primary benchmark under fixed search

Goal: *Identify the strongest variant on structured geographic instances.*

Experiment 1.2 : Primary benchmark under VSIDS search

Goal: *Test whether structured-instance findings hold under VSIDS search*

Experiment 2 : Secondary benchmark under fixed search

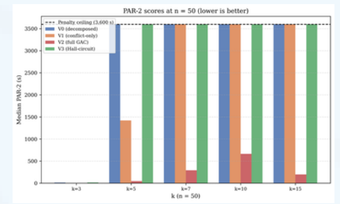
Goal: *Test whether structured-instance findings generalize to unstructured random graphs.*

4. RESULTS

Structured Instances:

V2 dominates

- *2 orders of magnitude faster than baseline*

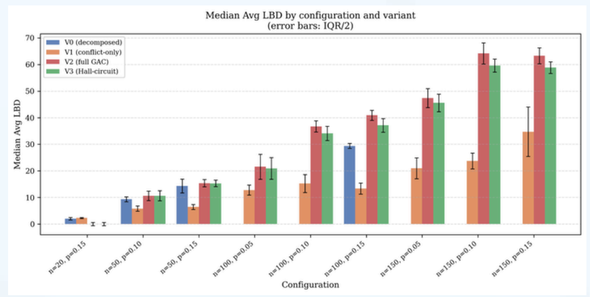


Lower Failures → strong propagation → branch reduction

V1 : Detects conflict late → unreliable

Unstructured Instances:

V2 : Same pruning BUT worse explanations



V2's advantage over V1 decreases due to worse ***explanation quality*** *(high AvgLBD)*

V3 : Strong on paper, but rarely fires

5. CONCLUSIONS & FUTURE WORK

Full GAC (V2) *is the* ***recommended choice*** *when embedding AllDifferent and Circuit in LCG*

Extensions:

- Test on larger real-word instances
- Explore different explanation schemes for V2
- Vary the subtour-prevention component (currently held fixed)

[1] Alessandro Bertagnon and Marco Gavanelli. Stronger integration of circuit and alld-ifferent propagators for the hamiltonian cycle problem. Technical report, 2024. URLhttps://ceur-ws.org/Vol-3883/paper2_RCRA7.pdf.
[2] Kathryn Glenn Francis and Peter J. Stuckey. Explaining circuit propagation. Constraints An Int. J., 19(1):1–29, 2014. doi: 10.1007/S10601-013-9148-0. URL https://doi.org/10.1007/s10601-013-9148-0.

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