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Learning Constraint Networks over Unknown Constraint Languages

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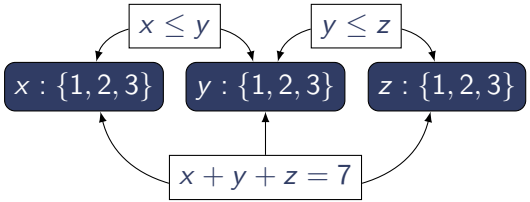
Background

A **constraint network**:

- a set of **variables** over a finite **domain**
- a set of **constraints**, i.e. relations between variables that must be satisfied in any **solution**



A **constraint language** is a set of relations over a domain.

- Language of a constraint network : set of all relations that appear in its constraints

Constraint Programming & Constraint Acquisition

Constraint programming is an **expressive**, **flexible**, **efficient** paradigm for solving problems.

Challenge | Designing a constraint network representing a given problem can be difficult.

- To overcome this, **constraint acquisition** learns a constraint network automatically.

Definition | Passive Constraint Acquisition

Instance: Set of examples, labelled as solutions and non-solutions.

Goal: Find a constraint network that correctly classifies the examples.

ConAcq.1 (Bessiere et al., 2006, 2017), ModelSeeker (Beldiceanu and Simonis, 2012), BayesAcq (Prestwich et al., 2021), Count-CP (Kumar et al., 2022)

Definition | Active Constraint Acquisition

Instance: An oracle that can answer queries about a *target* constraint network.

Goal: Find the target constraint network.

ConAcq.2 (Bessiere et al., 2006, 2017), QuAcq (Bessiere et al., 2013), G-QuAcq (Bessiere et al., 2014), DCA (Menguy et al., 2023)

Problem | All current approaches require some knowledge of the constraint language of the output network.

This problem is addressed in my article :

> **Learning Constraint Networks over Unknown Constraint Languages.** IJCAI 2023
> *Christian Bessiere, Clément Carbonnel, Areski Himeur*

Our contribution

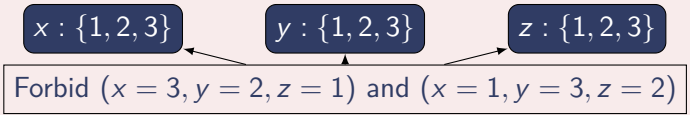
We develop a constraint acquisition method that
constructs a constraint language as part of the learning process.

In general, given a set of examples, a large number of constraint languages can be used.

Problem | Some languages are clearly unsatisfactory from a practical point of view

- Examples:
  - $(x = 1, y = 2, z = 3)$ is a solution.
  - $(x = 3, y = 2, z = 1)$ and $(x = 1, y = 3, z = 2)$ are non-solutions.
- A good network:

- A bad network:



Intuition | The best constraint language is the simplest.

First approximation: the **smallest** language in terms of arity and number of relations.

Problem | Language-Free Acq

Instance: Set of examples, labelled as solutions and non-solutions, two integers k and r.

Question: Is there a constraint network **over a language of size at most k and arity at most r** that correctly classifies the examples?

Language-Free Acq is NP-complete even for $(k, r) = (1, 1)$.

Method | Compute a constraint network with minimum (k, r) that correctly classifies the examples.

- **Strategy:** minimize $k + r^2$
- **Tie-breaking:** lower arity, more constraints, tighter constraints
- **Construct and solve a model for each** (k, r)**:**
  - Convert to an instance Weighted Partial Max-Sat
  - Compute the optimal network or prove that none exists
  - Output the first constraint network found

Experimental Results

Code and data

Code and data required for conducting the experiments are available at :
https://gite.lirmm.fr/coconut/language-free-acq

Experimental Results

Problem	Number of examples	(k, r)	Target Language	Target Network	Runtime (s)
Sudoku	100	$(1, 2)$	✓	✗	129.3
	200	$(1, 2)$	✓	✓	34.9
Schur's Lemma	50	$(1, 3)$	✓	✗	22.7
	200	$(1, 3)$	✓	−	0.8
	800	$(1, 3)$	✓	✓	1.8

Experimental Results

- Learn the **target language** and the **target network**:
  - Sudoku [200 examples]
  - Schur's Lemma [800 examples]
- Learn the **target language** and an **equivalent network**:
  - Jigsaw Sudoku [200-1400 examples depending on shape]
- Learn an **equivalent network** on another language:
  - Subgraph Isomorphism [800 examples]
  - Golomb Ruler (with 10 variables) [3200 examples]
- Neither learn the target language nor an equivalent network:
  - 8-Queens (coordinates model)

Recap

We proposed a novel constraint acquisition method that
does not require any knowledge on the constraint language of the target network.

Future Work

Defining a more sophisticated notions of “simplicity”.

Detecting topological information.

Constraint acquisition and neural networks.

Thank you for your time and attention.

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