

Data structures for Partially Ordered Sets

Preparatory work for the master thesis

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1. **Introduction** Subject and motivations
2. **Definitions** Poset and antichains
3. **Existing implementation**
4. **Objective** Requirements and overview

Subject

- ▶ Implement data structures to represent partially ordered sets
- ▶ Main focus on antichain-based algorithms in automata theory

Motivations

- ▶ There exists new algorithms that uses antichains, for known practical and theoretical problems:
 - ▶ Model checking [3]
 - ▶ Synthesis problem [4]
 - ▶ Language universality [2]
- ▶ There is a need for an efficient implementation of antichains

Partial order

A partial order \preceq on a set S is a binary relation $\preceq \subseteq S \times S$ that is reflexive, transitive and antisymmetric.

Partially ordered set (or poset)

A partially ordered set is a pair $\langle S, \preceq \rangle$ where S is a set, and \preceq a partial order on S .

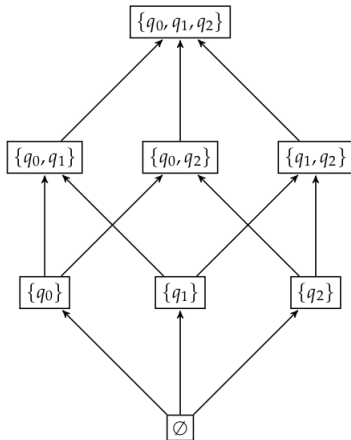
Antichains

An antichain α is a set of incomparable elements of poset $\langle S, \preceq \rangle$ w.r.t. to \preceq .

Interesting operations

- ▶ **Lower closure** of an antichain α on S , denoted $\downarrow\alpha$, is the set of all elements of S that are smaller or equal to an element of α
- ▶ **Appartenance** $s \in \downarrow\alpha_1$
- ▶ **Inclusion** $\downarrow\alpha_1 \subseteq \downarrow\alpha_2$
- ▶ **Union** $\downarrow\alpha_1 \cup \downarrow\alpha_2 = \downarrow[\alpha_1 \cup \alpha_2]$
- ▶ **Intersection** $\downarrow\alpha_1 \cap \downarrow\alpha_2$

Example



- ▶ Poset is $\langle 2^Q, \subseteq \rangle$, where $Q = \{q_0, q_1, q_2\}$
- ▶ $\alpha = \{\{q_0, q_2\}, \{q_1, q_2\}\}$ is an antichain
- ▶ Can retrieve all subset of cardinality 1 using the closure on the antichain:
 $\downarrow \alpha$
- ▶ $\downarrow \alpha = \{\{q_0\}, \{q_1\}, \{q_2\}, \{q_0, q_2\}, \{q_1, q_2\}\}$

Do implementation already exists ?

Yes, 2 for antichains:

1. **AaPAL**[1]: Antichains implementation in *C*
 - ▶ More of an API: user must implement comparison and intersection
2. Antichains for the Dedekind number problem [5]
 - ▶ Bitarray representation (a bit is a subset)
 - ▶ Can only be applied to natural numbers

Requirements

- ▶ Owl library: an automata library
- ▶ But symbolic antichain-based algorithm are missing (including antichain data structures)
- ▶ Implementation in Java 10

What to do ?

- ▶ Provide an API and implement it against 0^w1
- ▶ Provide some implementation for antichains depending on the universe of the sets
- ▶ Define the algorithms to test our antichains implementation against
- ▶ Study the performance of those implementations

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Thank you!

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