Categorical Automata Learning Framework

calf-project.org

Gerco van Heerdt **Matteo Sammartino** Alexandra Silva

LiVe @ ETAPS 2017

UCL ENGINEERING
Change the world

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Our team

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Radboud University

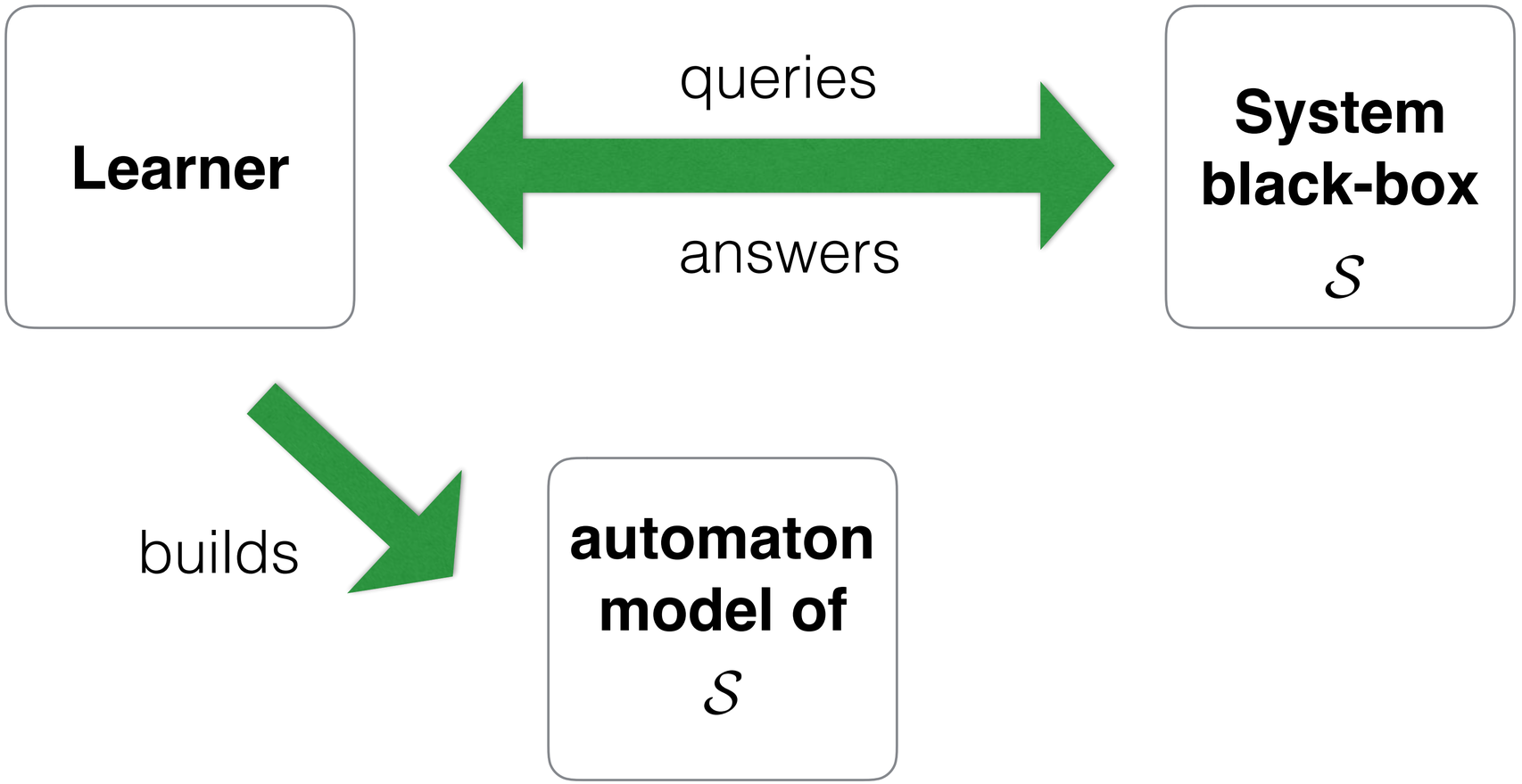
Maverick Chardet
ENS Lyon

Collaborators:

Bartek Klin
Warsaw University

Michal Szynwelski
Warsaw University

Automata learning



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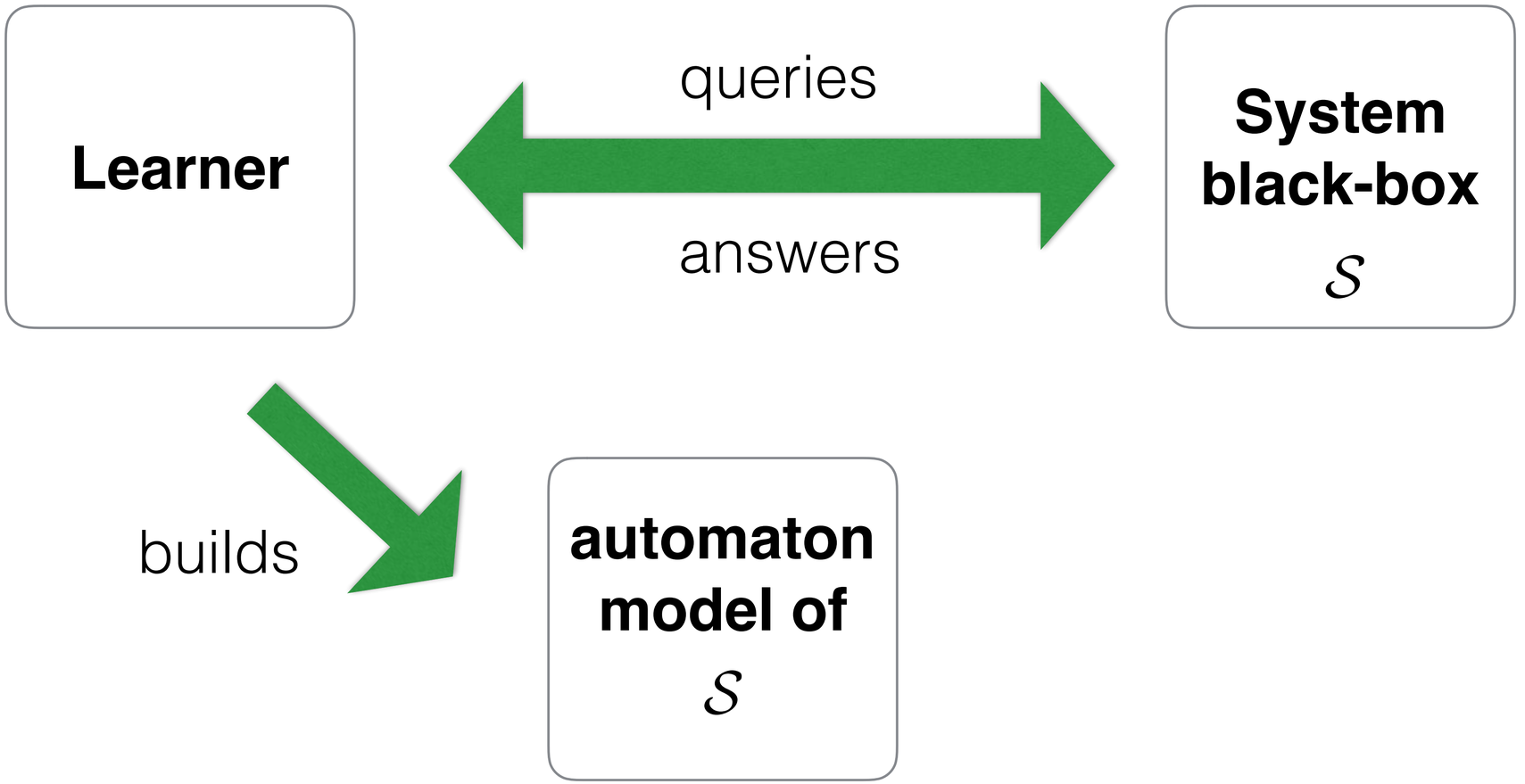

No formal specification available? **Learn it!**

L* algorithm (D.Angluin ’87)

Finite alphabet of system’s actions A

set of system behaviors is a **regular language** $\mathcal{L} \subseteq A^\star$

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Learner

Teacher

$\mathcal{L}$

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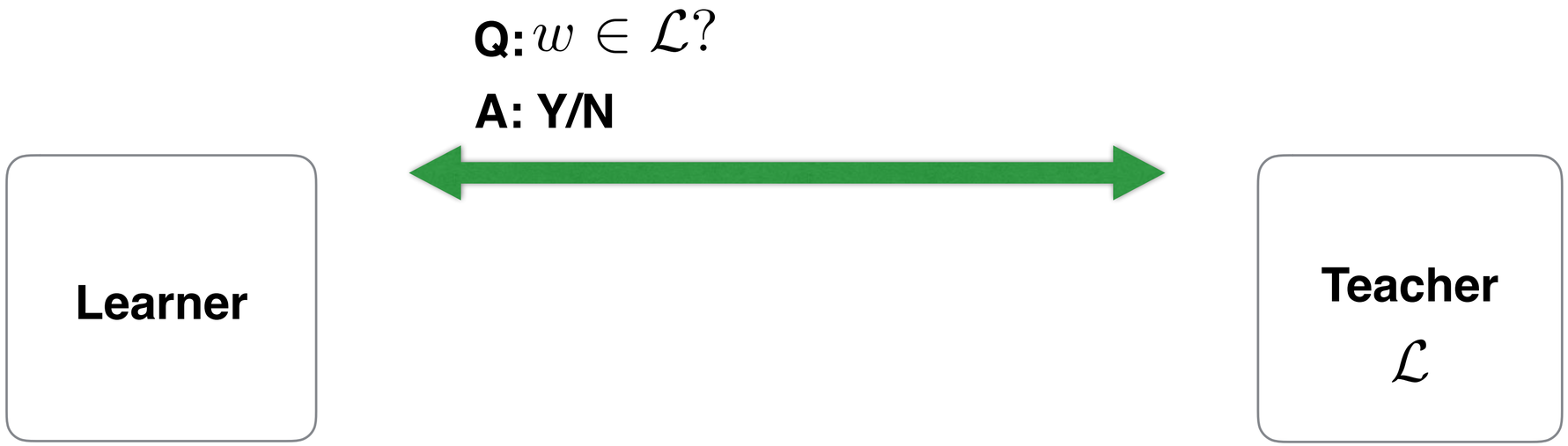

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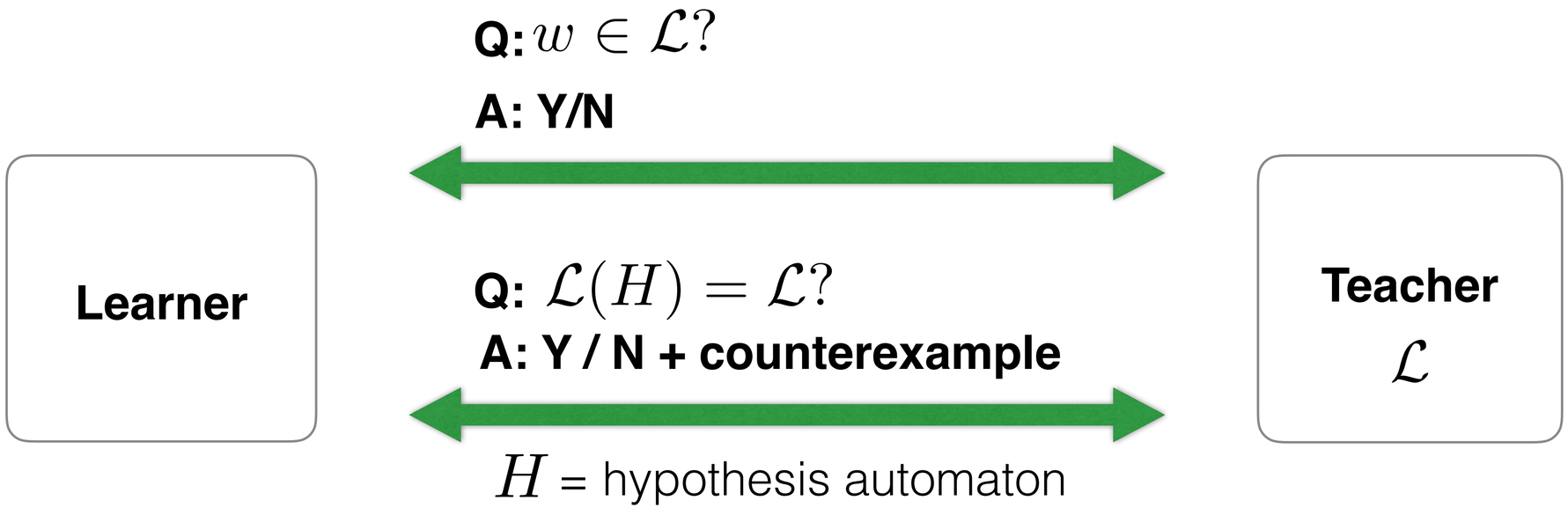

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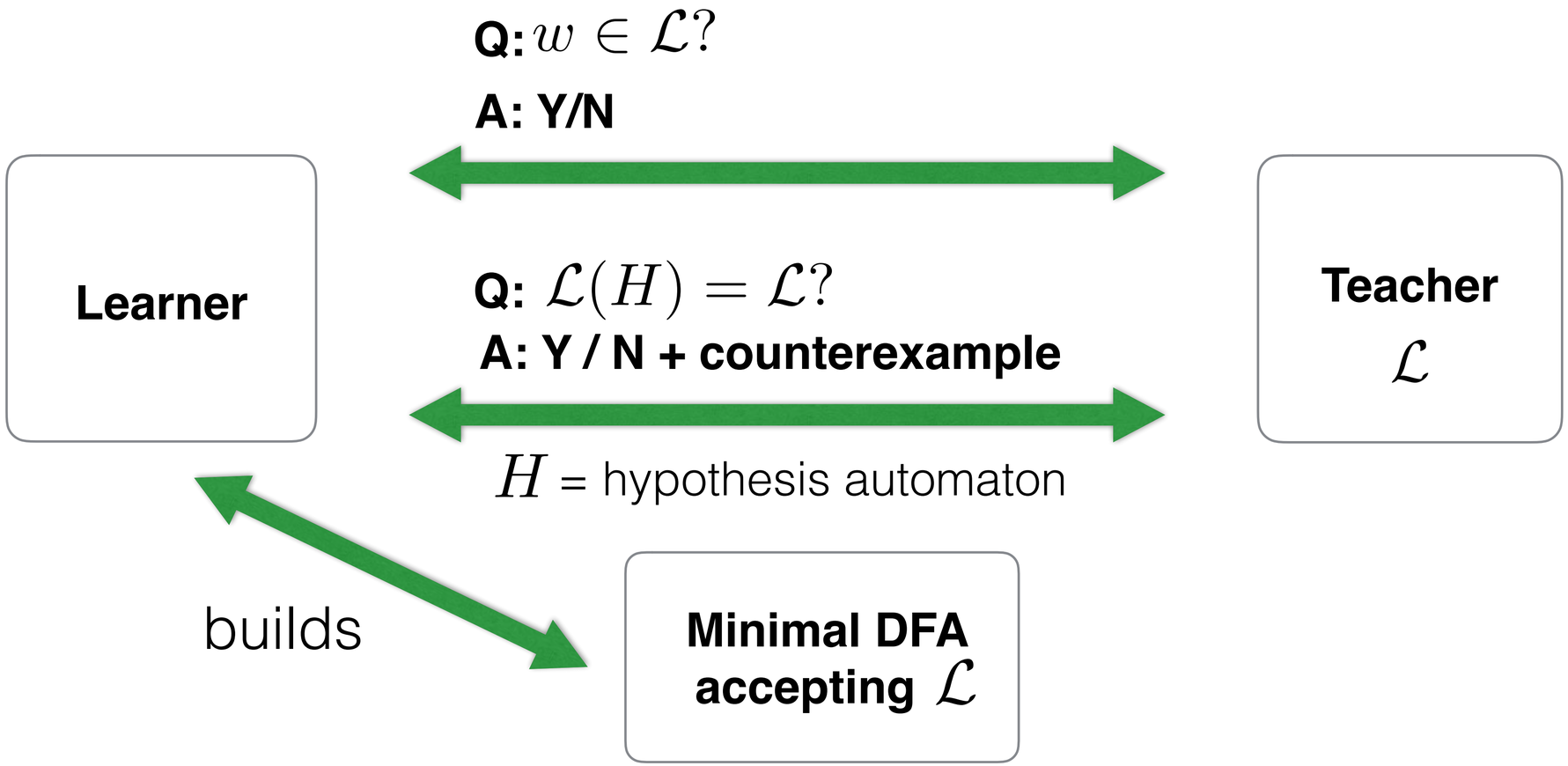


A zoo of automata

Probabilistic

Weighted

Alternating

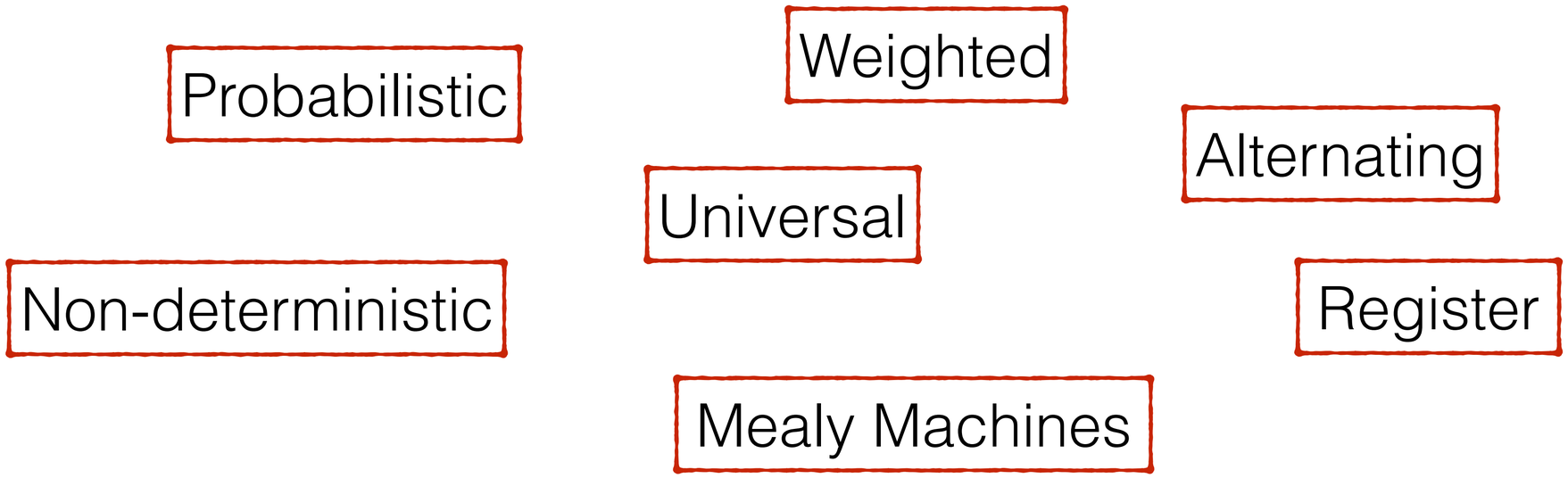
Universal

Non-deterministic

Register

Mealy Machines

A zoo of automata



Algorithms **Correctness proofs**

involved and hard to check

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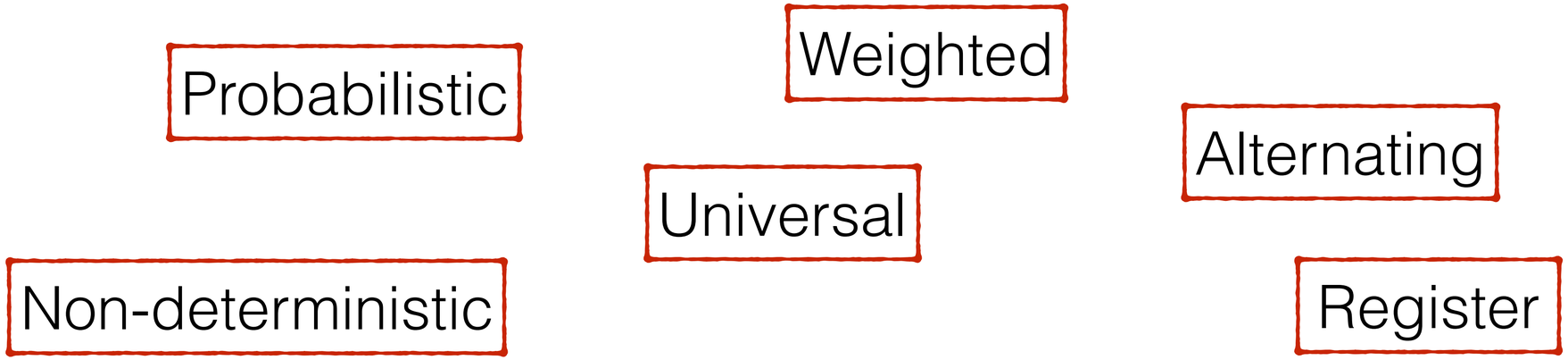

Category theory comes to the rescue!

Algorithms **Correctness proofs**

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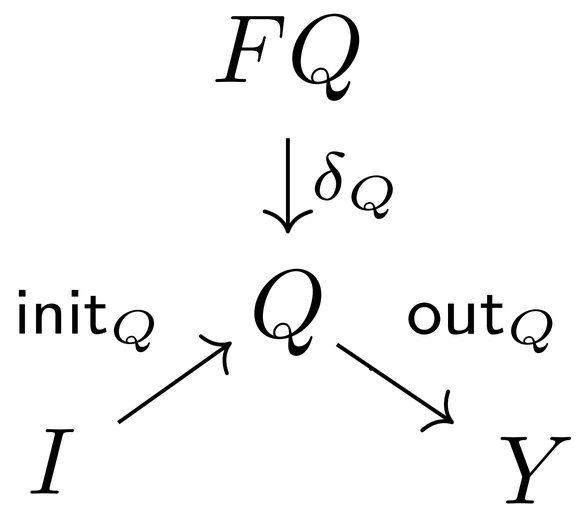
Abstract automata

Category $\mathbf{C}$ = universe of state-spaces

Endofunctor $F\colon \mathbf{C} \to \mathbf{C}$ = automaton type



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Category $\mathbf{C}$ = universe of state-spaces

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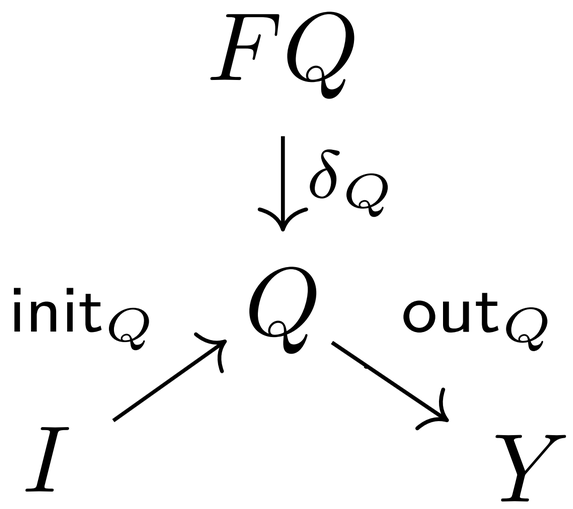
DFAs

$\mathbf{C} = \mathbf{Set}$

$F = (-) \times A$



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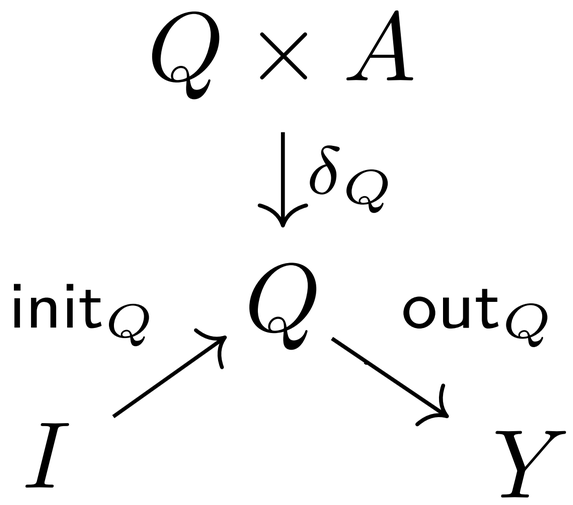

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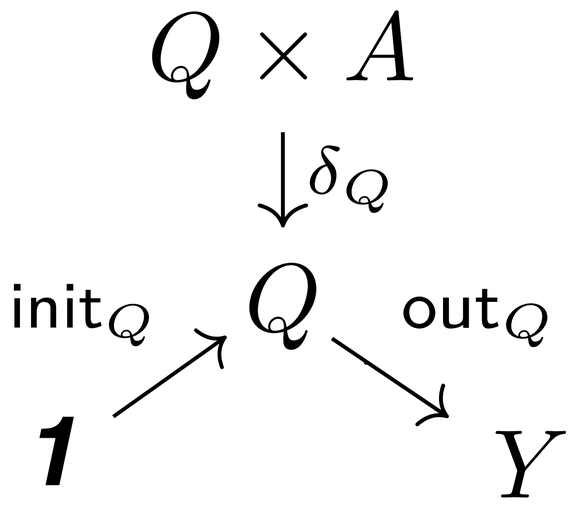

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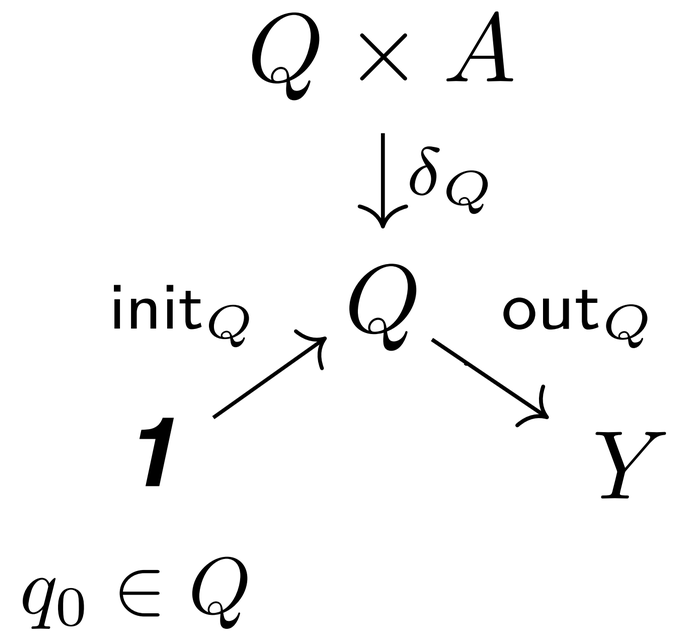

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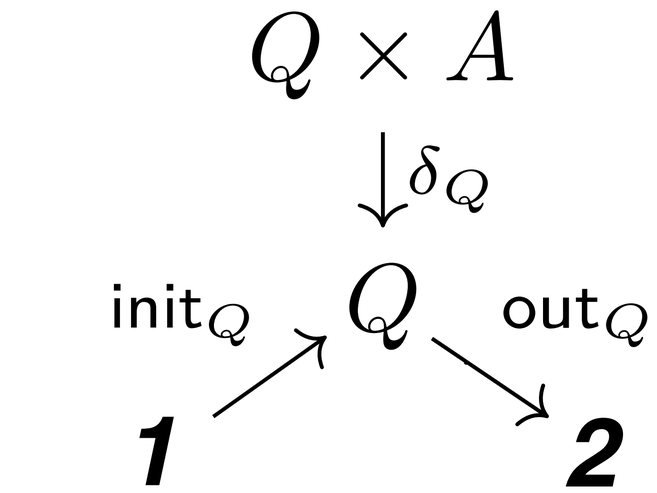

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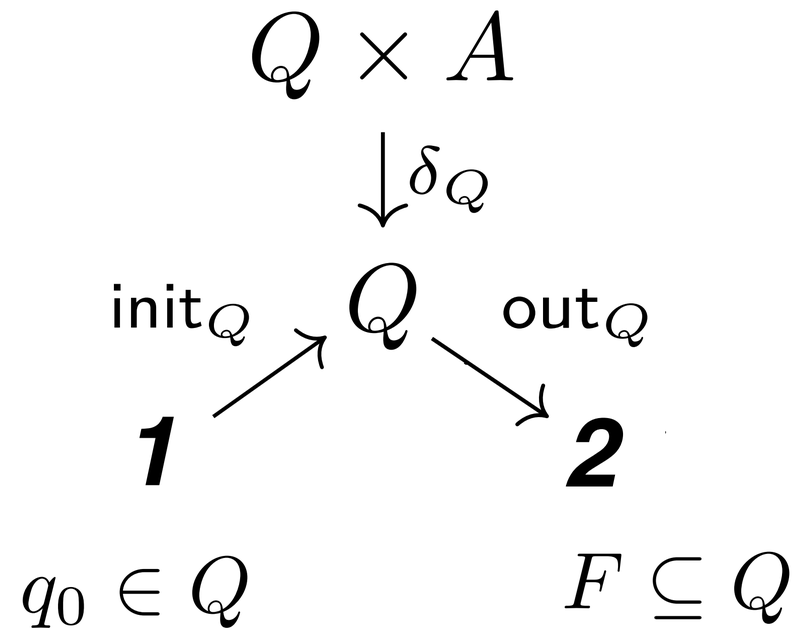


Abstract learning

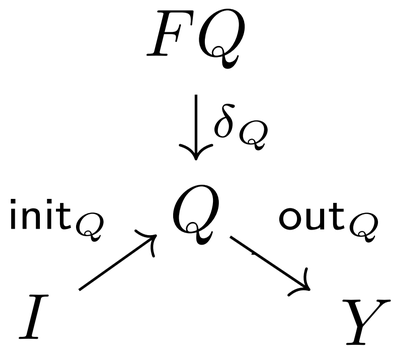
Abstract observation data structure

Abstract learning

Abstract observation data structure

approximates

Target minimal automaton



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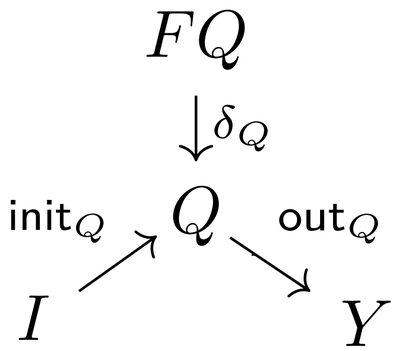
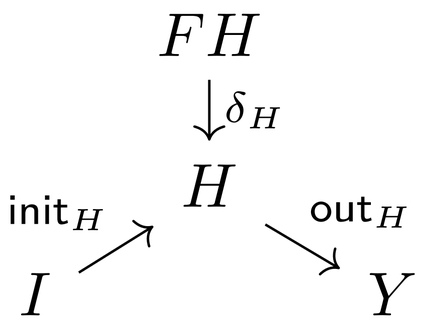


abstract closedness and consistency

Hypothesis automaton



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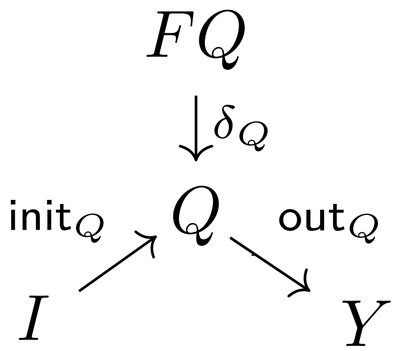

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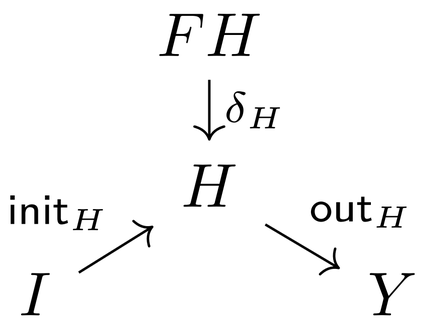

General correctness theorem

Guidelines for implementation

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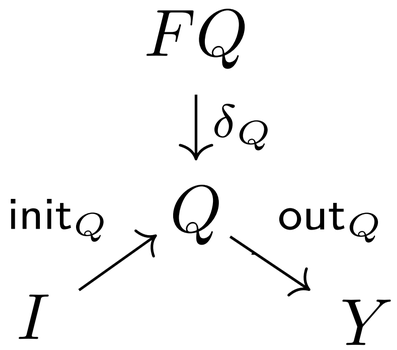

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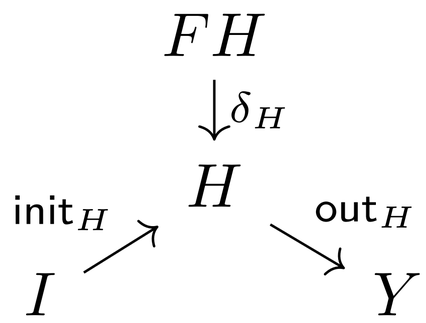

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CALF: Categorical Automata Learning Framework (arXiv:1704.05676)

Gerco van Heerdt, Matteo Sammartino, Alexandra Silva

Other automata & optimizations

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Change base category

Set	**DFAs**
Nom	**Nominal automata**
Vect	**Weighted automata**

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Side-effects (via monads)

Powerset	**NFAs**
Powerset with intersection	**Universal automata**
Double powerset	**Alternating automata**
Maybe monad	**Partial automata**

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Observation tables

Discrimination trees

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Learning Nominal Automata (POPL ’17)

Joshua Moerman, Matteo Sammartino, Alexandra Silva, Bartek Klin, Michal Szynwelski

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Discrimination trees

Learning Automata with Side-effects (arXiv:1704.08055)

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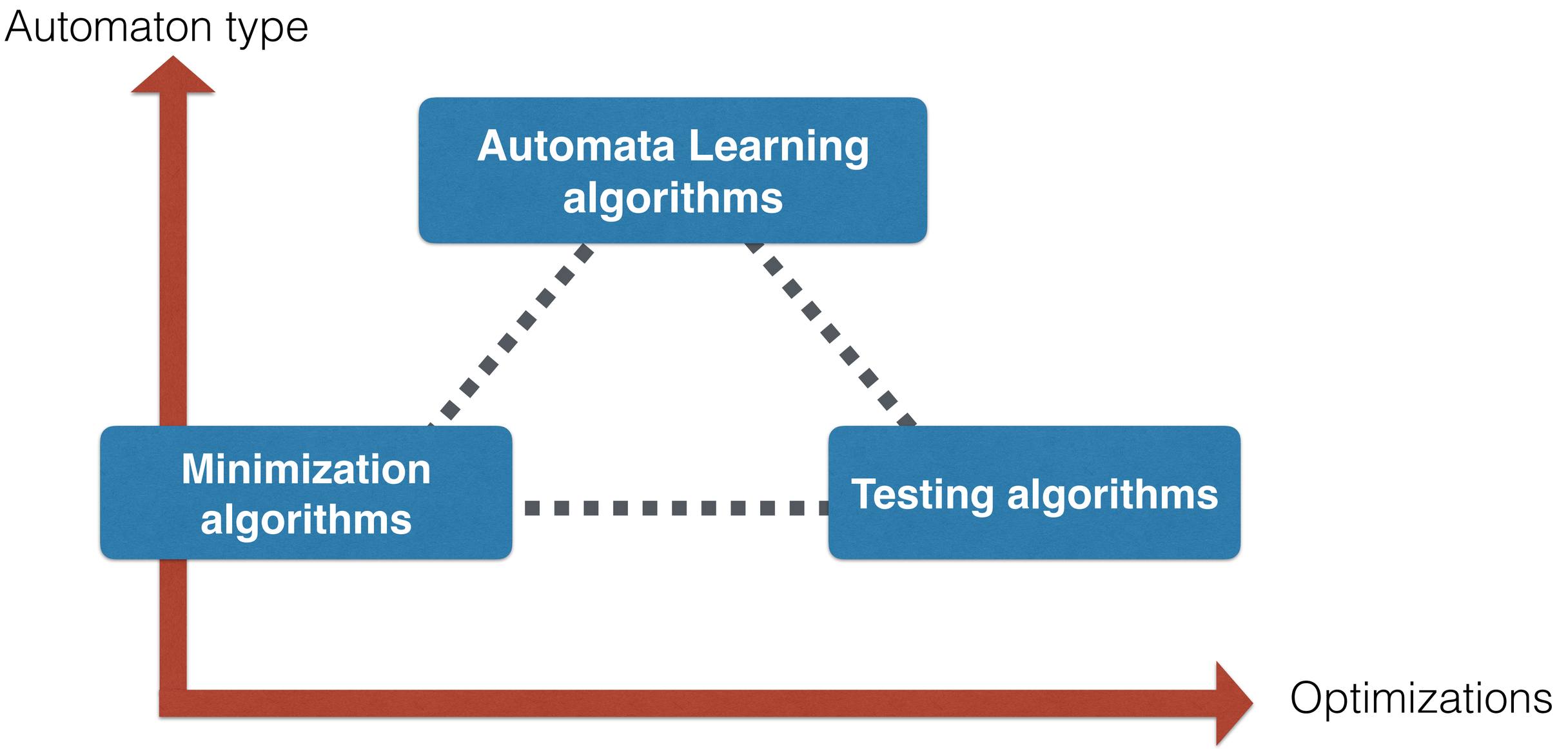
Connections with other algorithms



Ongoing and future work

- **Library & tool** to learn control + data-flow models (as **nominal automata**)
- Applications:
  - Specification mining
  - Network verification, with amazon
  - Verification of cryptographic protocols
  - Ransomware detection