Controller Synthesis and its Magical Futures

Anna Lukina

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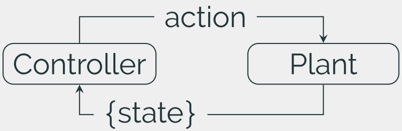
@ Synthesis of Models and Systems Seminar

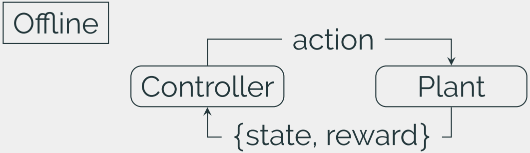
IST AUSTRIA
Institute of Science and Technology

Simons Institute for the Theory of Computing

Controller Design



Controller Design via Deep RL



Goal: maximize expected rewards

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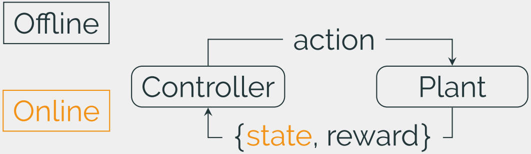

Goal: maximize expected rewards

What if the agent has never seen this state offline?

Key Contributions

Current research focus: reliable design of learned systems via combination of formal methods and machine learning

(FMCAD-20) Formal Methods with a Touch of Magic. Alizadeh Alamdari, Avni, Henzinger, **Lukina**.

(ECAI-20) Outside the Box: Abstraction-Based Monitoring of Neural Networks. Henzinger, **Lukina**, Schilling.

(ATVA-17) Attacking the V: on the Resiliency of Adaptive-Horizon MPC. Smolka, Tiwari, Esterle, **Lukina**, Yang, Grosu.

(TACAS-17) ARES: Adaptive Receding-Horizon Synthesis of Optimal Plans. **Lukina**, Esterle, Hirsch, Bartocci, Yang, Tiwari, Smolka, Grosu.

A Touch of Magic 🪄

Formal Methods with a Touch of Magic [FMCAD 2020]

Reactive Synthesis

Given a specification φ, finds a controller that ensures the plant satisfies φ

Deep RL

Optimizes performance

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Given a specification φ, finds a controller that ensures the plant satisfies φ

No performance guarantee

Deep RL

Optimizes performance

No correctness guarantee

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A model

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Follow advice as closely as possible

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Optimizes performance

Neural networks are large and uninterpretable

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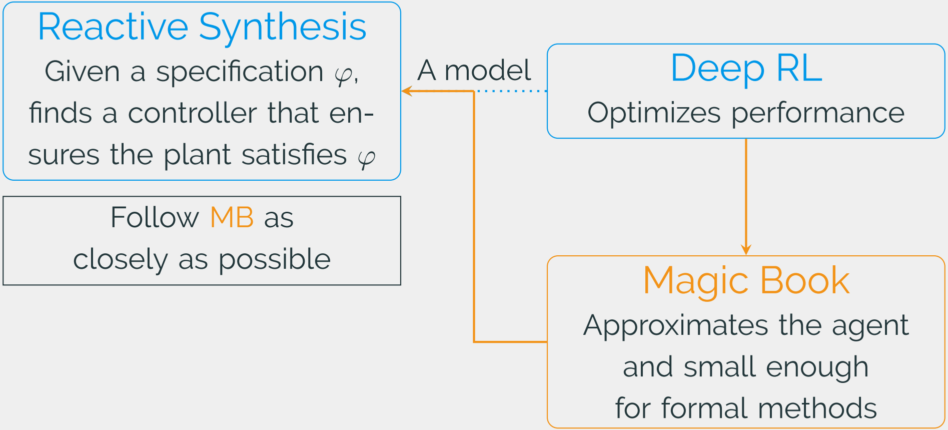

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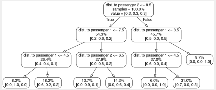
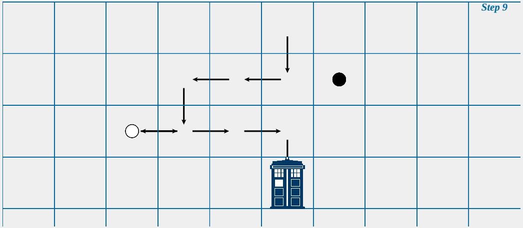


Magic Book

Approximates the agent and small enough for formal methods

Verification of the Magic Book [FMCAD 2020]

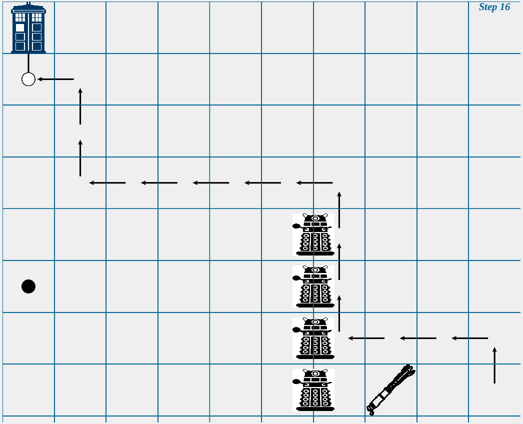
φ : "the taxi never enters a loop in which no passenger is collected"



A state at time i: $\{x_0^i, y_0^i, \ldots, x_k^i, y_k^i\}$

Control Synthesis by the Magic Book [FMCAD 2020]

φ : "reach a gas station every t time steps"



Performance and Explainability [FMCAD 2020]

Num. of collected passengers	RF(5,6)	Wizard
Avg. performance	154	159
Max. performance	194	200
Synthesis avg. performance	96	–

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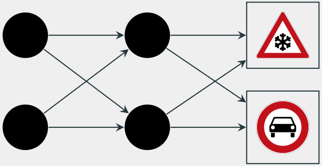
"Passenger 2 is collected first": $\bigwedge_{1 \leq i \leq \ell} (x_j^i = x_j^0 \wedge y_j^i = y_j^0) \; \forall \, j = 1, 3$

$$\neg (x_2^\ell = x_2^0 \wedge y_2^\ell = y_2^0)$$

Bound	Passenger 2	
	runtime	succ. ratio
6	0.25 s	85 %
7	0.30 s	87.2 %
8	0.36 s	89.9 %
9	0.47 s	82.2 %

Reaction to Novel Input Classes

neural network



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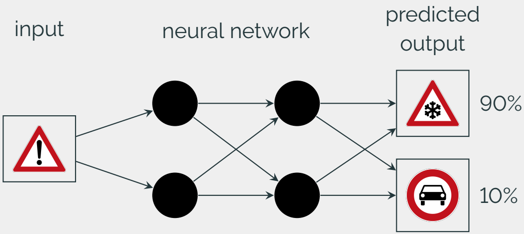
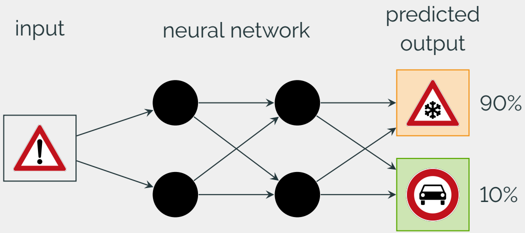


Must output "do not know"

Outside the Box

Abstraction-Based Monitoring of Neural Networks

[ECAI 2020]



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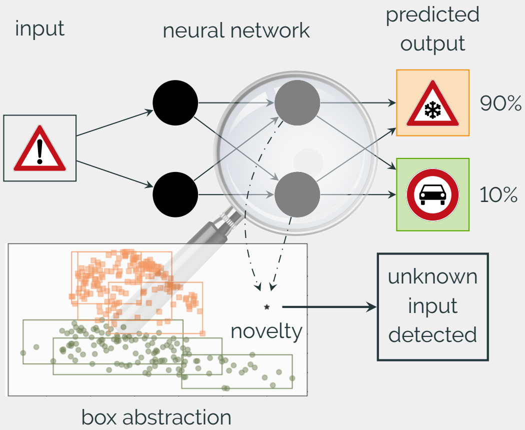

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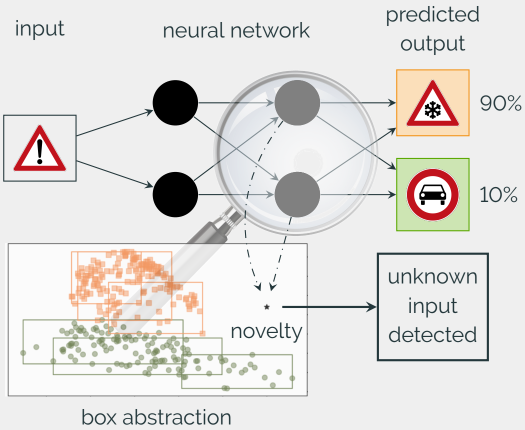

1. Computationally cheap

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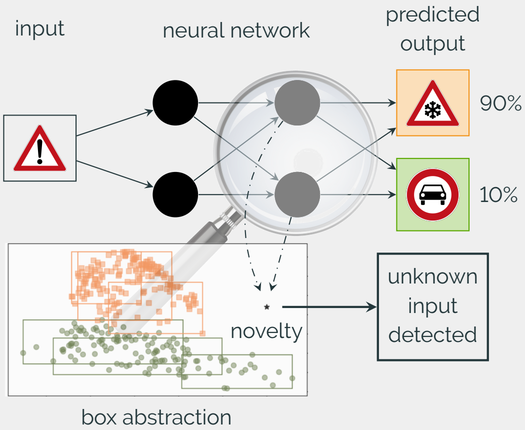

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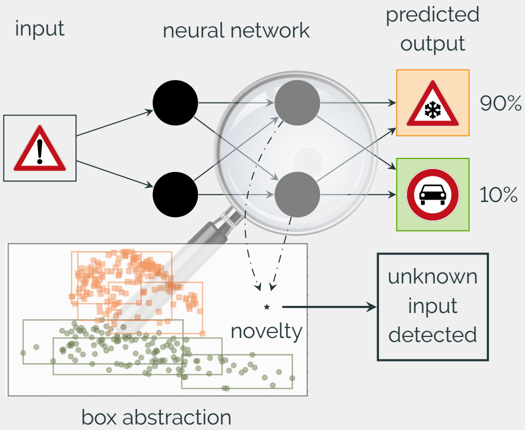

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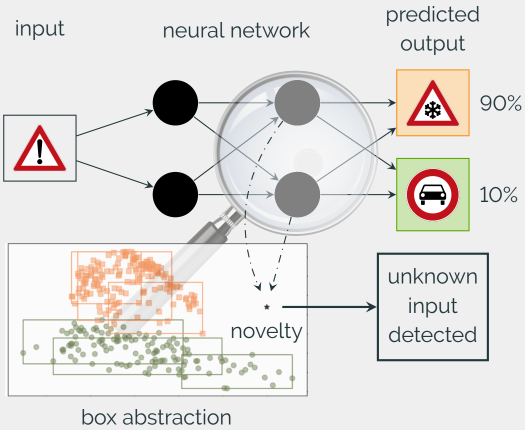

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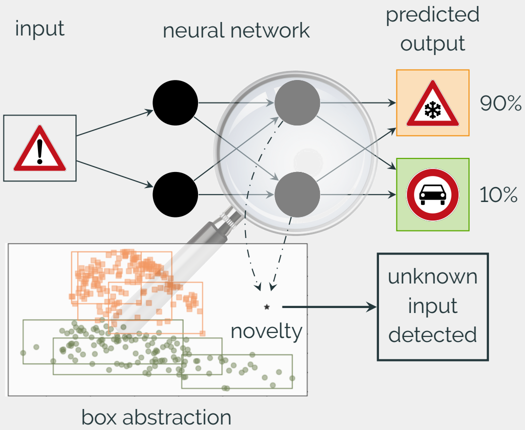

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3. Data and model independent
4. Easy to integrate
5. Flexible to user configuration

Neural Networks in Dynamic Environments

Real-time object detection with neural networks[1]:

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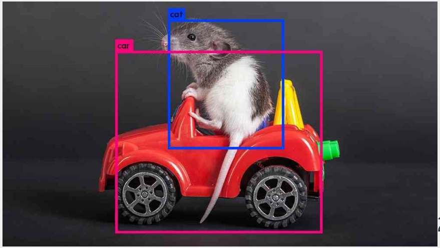

[2]

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[2] https://rpubs.com/dgolicher/yolo

Open Problems

Verification ⟳ Learning

- Scalability:
  - Dimensionality of the input for controllers.
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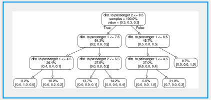

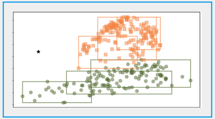

- How to make model checkers generate good-for-learning counterexamples?
- How to use statistical model checking for learned controllers?