**Highlights 2022**
of Logic, Games and Automata
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# Scalable Anytime Algorithms for Learning Fragments of Linear Temporal Logic (SCARLET)

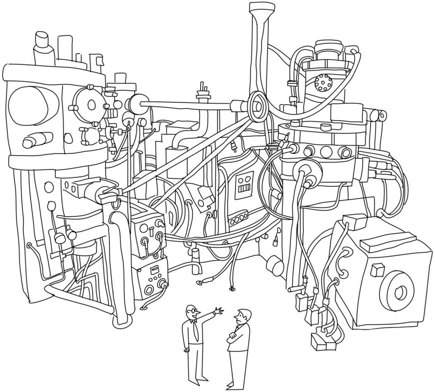

**Ritam Raha** Rajarshi Roy Nathanaël Fijalkow Daniel Neider

Universiteit Antwerpen
LaBRI
MAX PLANCK INSTITUTE FOR SOFTWARE SYSTEMS



Appeared at TACAS'22

# Explainable AI



*Well, it looks too complicated*

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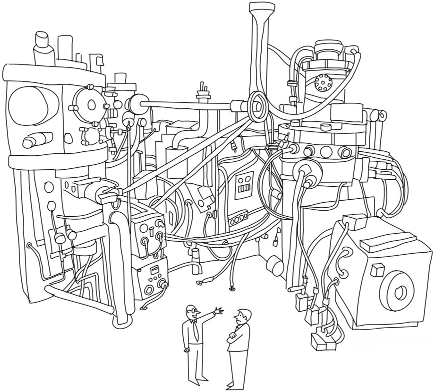

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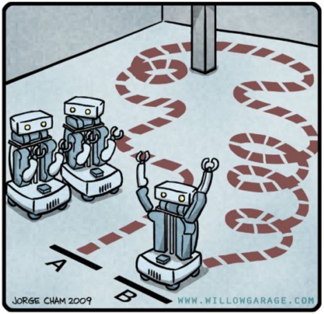
**Goal:** Learn simple (human interpretable) models by observing complex systems

# Robot Motion-Planning

R.O.B.O.T. Comics

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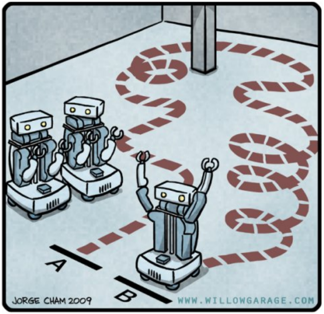


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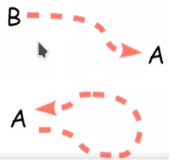
*Positive*


*Negative*



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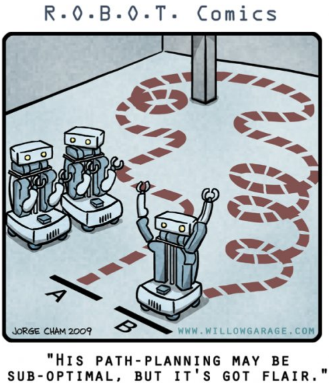


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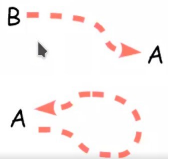


$A \wedge$ Finally $B$

# LTL as a descriptive model

**Linear Temporal Logic**
Eg. *Globally, Finally, Next*

**Syntax:**

$$\varphi ::= p \in \Sigma \mid \neg p \mid \varphi_1 \vee \varphi_2 \mid \varphi_1 \wedge \varphi_2 \mid \mathbf{X}\varphi \mid \mathbf{F}\varphi \mid \mathbf{G}\varphi \mid \varphi_1 \mathbf{U} \varphi_2$$

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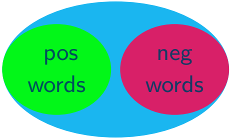
The fragment: <u>LTL(F, X, G, ∧, ∨)</u>

# The learning problem

Sample $\mathcal{S}$




LTL Learning on Finite Words

**Input:** A set of positive words $P$ & negative words $N$

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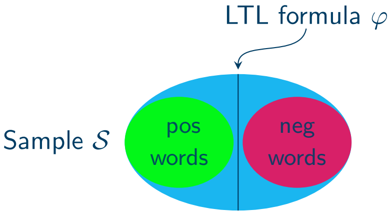


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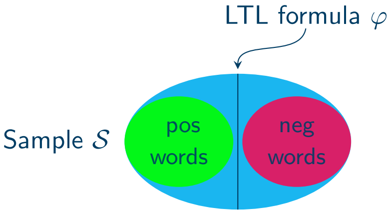


**LTL Learning on Finite Words**

**Input:** A set of positive words $P$ & negative words $N$

**Question:** Find a minimal LTL formula $\varphi$ such that, $\forall w \in P, w \models \varphi$ and $\forall w \in N, w \not\models \varphi$?

# State-of-the-Art

**Theorem (Fijalkow & Lagarde '21)**

*The learning problem for the fragments of LTL: LTL(X, $\wedge$), LTL(F, $\wedge$) and LTL(F, X, $\wedge$, $\vee$) is NP-complete.*

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**Overview**

- For all LTL formulas of size $k$, check if separating.
- Increase $k$ and repeat.

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- Extract LTL patterns of increasing complexity from sample
  (Technique used: Dynamic Programming)

- Generate their Boolean combinations to find the (minimal) formula by solving **Boolean Set Cover** problem
  (Technique used: Greedy approximation or Decision Tree)

# Finding LTL patterns

**Sample $S$**

| **Positive Words** | **Negative Words** |
| --- | --- |
| pqqp | qqqq |
| qqpp | ppqp |

**Idea:**

**Candidate:**

**Formula:**

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**Formula:** $X(q \wedge Fp)$

# Directed LTL

LTL patterns that arise from the following grammar:

$$\varphi :\, = X^n p \quad | \quad FX^n p \quad | \quad X^n(p \wedge \varphi) \quad | \quad FX^n(p \wedge \varphi),$$

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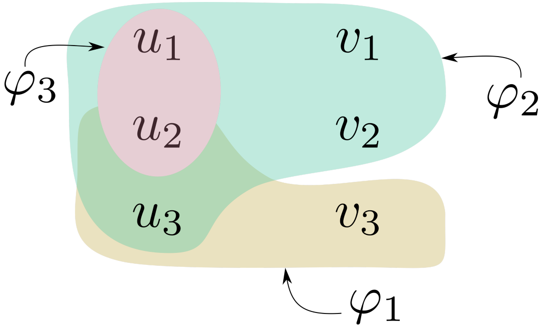

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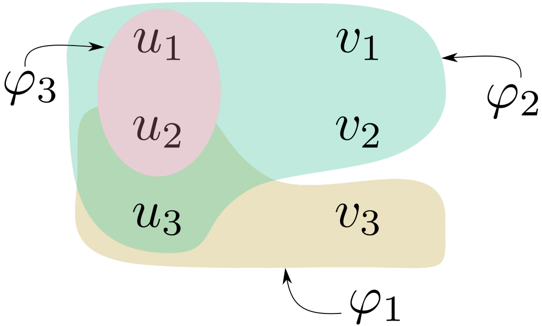


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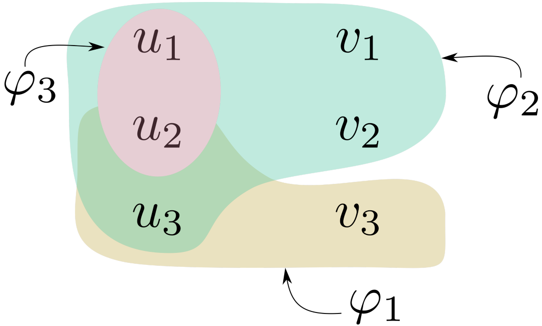


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**Sol:** $(\varphi_1 \wedge \varphi_2) \vee \varphi_3$

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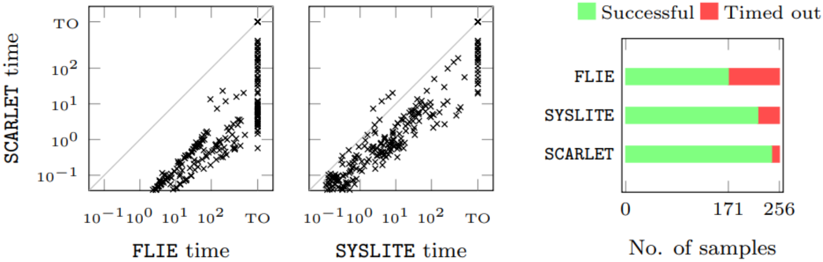
# SCARLET



TO
$10^2$
$10^1$
$10^0$
$10^{-1}$
SCARLET time
$10^{-1}$ $10^0$ $10^1$ $10^2$ TO
FLIE time
$10^{-1}$ $10^0$ $10^1$ $10^2$ TO
SYSLITE time
Successful
Timed out
FLIE
SYSLITE
SCARLET
0
171
256
No. of samples

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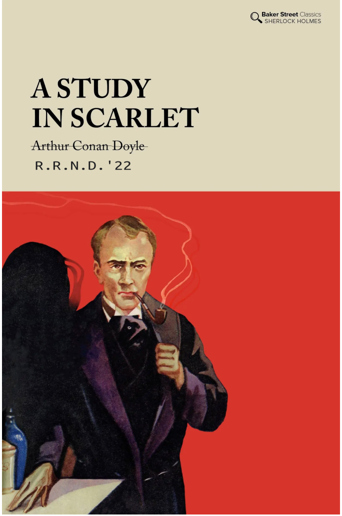
- Capture more expressive power: learn formulas with U-operator
- Towards real-valued traces: learn formulas in STL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*Thank you!*