Model Checking LTL over the finite horizon

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Linear-temporal logic over finite horizon (LTLf)

[Baier and McIlraith; 2006][De Giacomo and Vardi; IJCAI 2013]

- Specification language
  - Temporal logic over discrete time

- Syntax
  - Boolean variables and operators
  - Temporal operators: Always, Eventually, Next, Until …

Example: Always (Request → (Grant ∨ Next Grant))

- "Every request is granted within the two steps"

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Request	T	F	T	F	T	T
Grant	T	F	F	T	F	T

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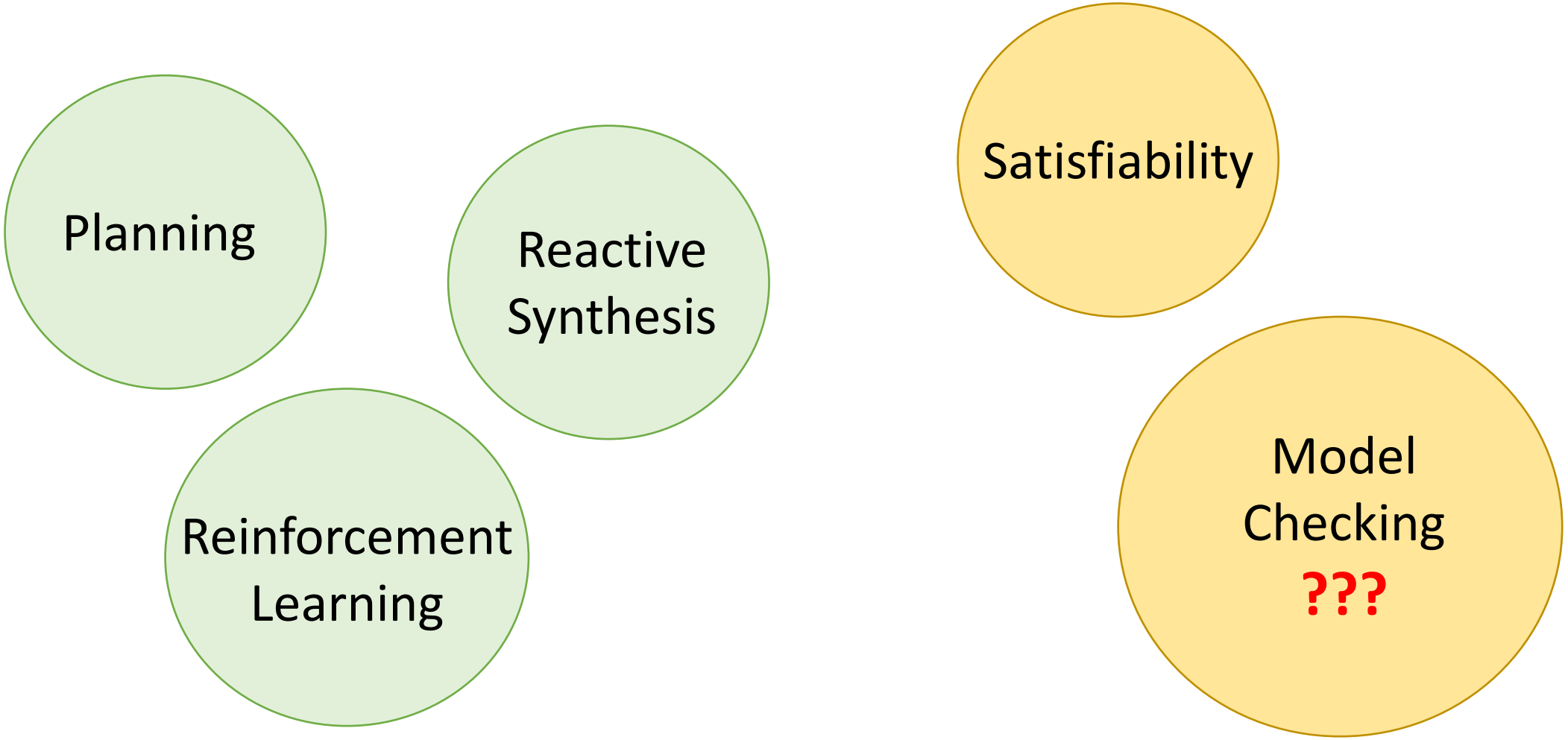
Prior works on LTLf



LTL vs. LTLf

LTLf is at most as hard as LTL, if not easier

	LTL	LTLf
Deterministic automata	(DPA) 2 Exponential	(DFA) 2 Exponential
Satisfiability	PSPACE-complete	PSPACE-complete
Synthesis	2EXPTIME-complete	2EXPTIME-complete

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Model Checking	**PSPACE-complete**	**EXPSPACE-complete**

LTL model checking

[Vardi and Woolper; LICS 1986]

Model M satisfies LTL specification ψ if

Every execution of model satisfies ψ

$$M \subseteq \psi \quad \text{iff} \quad M \cap \underbrace{\neg\psi}_{\text{Counterexamples}} = \emptyset$$

LTL model checking is PSPACE-complete

The issue with LTLf model checking

Model M satisfies LTLf specification ψ if

Every execution of model satisfies ψ

Executions are of Infinite-length

Defined over finite-length executions

Non-terminating models are without terminating states

- Model checking of LTL is on non-terminating models
- Generated by most LTLf reactive synthesis algorithms/tool

LTLf model checking

Model M satisfies LTLf specification ψ if

Every execution of model **has a prefix** that satisfies ψ

$$M \subseteq \underbrace{\exists \text{ prefix, prefix satisfies } \psi}_{\text{Words of infinite-length}}$$

$$(M \cap \underbrace{\forall \text{ prefix, prefix satisfies } \neg\, \psi}_{\text{Counterexamples}}) = \emptyset$$

Complexity

Given LTLf formula ψ, generate counterexample automata

- Accepts infinite word if all prefixes satisfy $\neg\psi$

- Deterministic form is double exponential in ψ (upper bound)

- Non-deterministic form is also double exponential in ψ (lower bound)
  - Universal quantification on prefixes
  - LTLf can identify Last of a finite execution
  - Intuition: (For every prefix, Last a) $\equiv$ (Globally a) in LTL

Theorem.
For non-terminating models, LTLf model checking is EXPSPACE-hard

In a nutshell
Model Checking LTL over the Finite Horizon

- Among the first to study model checking of LTLf specifications

- For non-terminating models, LTLf model checking is EXPSPACE-hard
- For terminating models, LTLf model checking is PSPACE-hard

- Efficient and scalable algorithms for LTLf model checking
- Busted the myth that LTLf is easier than LTL: Examine implications