LTL$_f$ Synthesis with Fairness and Stability Assumptions

Shufang Zhu, [1] Giuseppe De Giacomo, [2] Geguang Pu [1] and Moshe Y. Vardi [3]

[1] Each China Normal University, [2] Sapienza Università di Roma, [3] Rice University

shufangzhu.szhu@gmail.com, degiacomo@diag.uniroma1.it, ggpu@sei.ecnu.edu.cn, vardi@cs.rice.edu

Linear Temporal Logic over Finite Traces

$$\phi ::= a \mid \neg\phi \mid \phi_1 \wedge \phi_2 \mid X\phi \mid \phi_1 U \phi_2$$

LTL$_f$: same syntax as Linear Temporal Logic, but interpreted over finite traces [DV13].

LTL$_f$ Synthesis under Assumptions

A game of two players, the *environment* and the *agent*, contrasting each other:

- **Given:** LTL$_f$ formula ϕ over environment variables $\mathcal{X}$ and agent variables $\mathcal{Y}$, LTL formula ψ over $\mathcal{X}$ as the environment assumption;
- **Obtain:** A strategy $g : (2^{\mathcal{X}})^+ \rightarrow 2^{\mathcal{Y}}$ which tells how the agent reacts in terms of the environment behaviors.

ϕ describes the desired goal when the environment behaviors satisfy the assumption ψ.

Planning for LTL$_f$ goals can be considered as a form of LTL$_f$ synthesis under assumptions, where the assumptions are the dynamics of the environment encoded in the planning domain [ADMR19].

LTL$_f$ Synthesis with Fairness and Stability Assumptions

LTL$_f$ synthesis under assumptions can be reduced to standard LTL synthesis, which remains a challenging problem [Finkbeiner2016]. How about environment assumptions with particular interests?

We propose a **reduction to two-player DFA games** to capture two different basic, but quite significant, forms of assumptions:

- a basic form of **fairness GF**α (always eventually α),
- a basic form of **stability FG**α (eventually always α),

where in both cases boolean formula α is over environment variables $\mathcal{X}$.

Highlighted Contributions

Each LTL$_f$ goal ϕ can be translated to a Deterministic Finite Automaton (DFA) that accepts exactly the traces satisfying ϕ.

Key Idea: Conduct specific two-player DFA games to interpret the synthesis problems.

- express the LTL$_f$ goal using the corresponding DFA as the game arena,
- express the assumption as part of the game winning condition.

Agent wins the game if specific winning condition is satisfied.

Reduction to Two-player DFA Games

LTL$_f$ synthesis under **fairness assumption** $GF\alpha$, the *agent* wins the game if one of the following conditions holds:

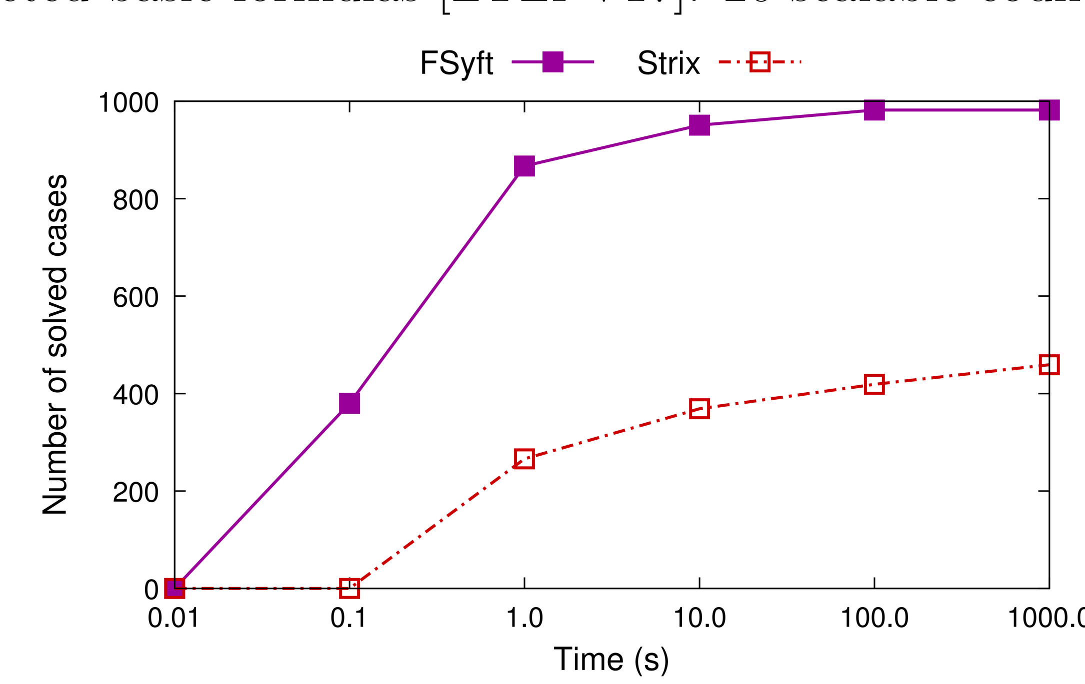
- Stability: the trace over $\mathcal{X} \cup \mathcal{Y}$ does not satisfy the fairness assumption $GF\alpha$,
- Reachability: an accepting state is reached.

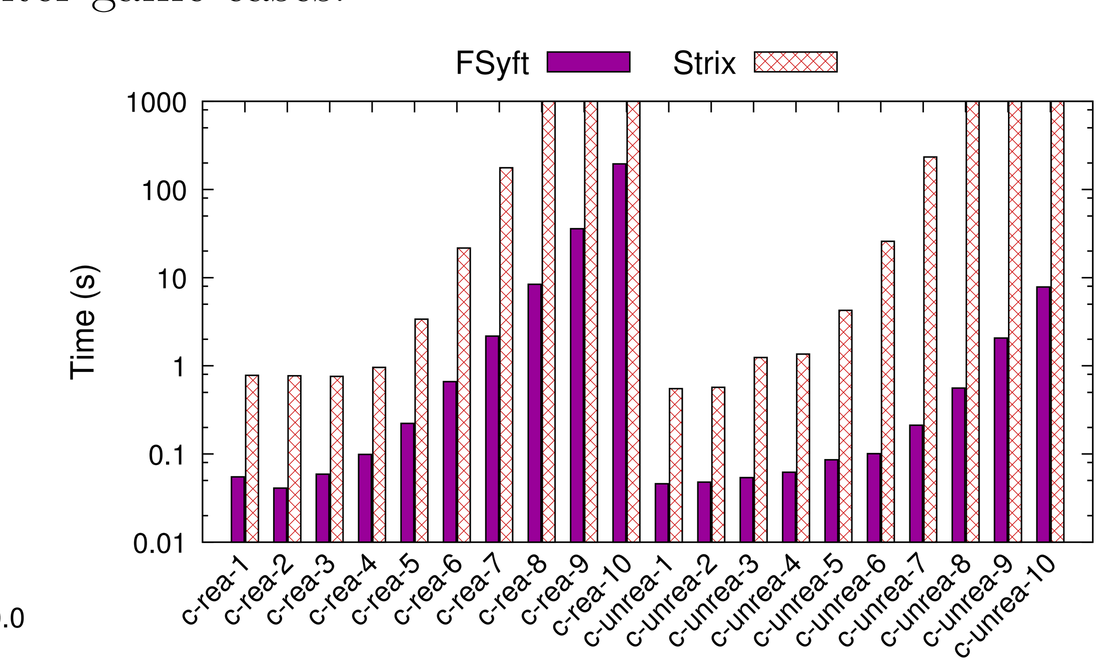
LTL$_f$ synthesis under **stability assumption** $FG\alpha$, the *agent* wins the game if one of the following conditions holds:

- Recurrence: the trace over $\mathcal{X} \cup \mathcal{Y}$ does not satisfy the stability assumption $FG\alpha$,
- Reachability: an accepting state is reached.

Experiments

Comparison between our tool *FSyft* and LTL synthesis tool Strix for solving the problem of LTL$_f$ synthesis under fairness assumptions. 1000 randomly conjuncted cases, generated by taking conjunctions over randomly selected basic formulas [ZTLPV17]. 20 scalable counter game cases.





For more experimental results, please see our paper in the proceedings.

Future Work

Targeting more general LTL assumptions. A possible approach is transforming only the assumption into a parity automaton, taking product with the DFA and then playing parity/reachability game on it.