Transforming Robotic Plans with Timed Automata to Solve Temporal Platform Constraints

Tarik Viehmann, Till Hofmann, Gerhard Lakemeyer
Knowledge-Based Systems Group, RWTH Aachen University, Germany

Problem Statement

- Separate high-level concerns from low-level platform when reasoning in robotics
- Problem: hardware control may depend on the domain context
- Hiding platform details in interfaces becomes infeasible

$\rightarrow$ Plan transformation to include hardware-specific actions in plans generated by the reasoner

Approach

(1) Plan transformation that does not modify abstract plans, but rather extends them by adding platform actions.

(2) Operations of platform components are assumed to be disjoint from the domain of reasoning, modeled as **Timed Automaton (TA)**.

(3) Dependencies between platform and abstract plans modeled via temporal constraints (subset of **MTL**).

(4) Transformation encoded as reachability problem on TAs. Utilize existing model checking tools to solve.
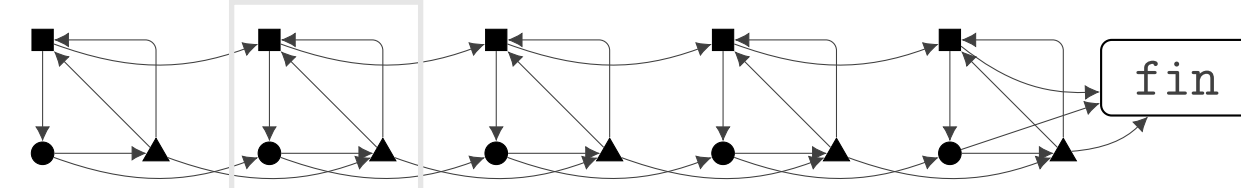
Transformation Procedure
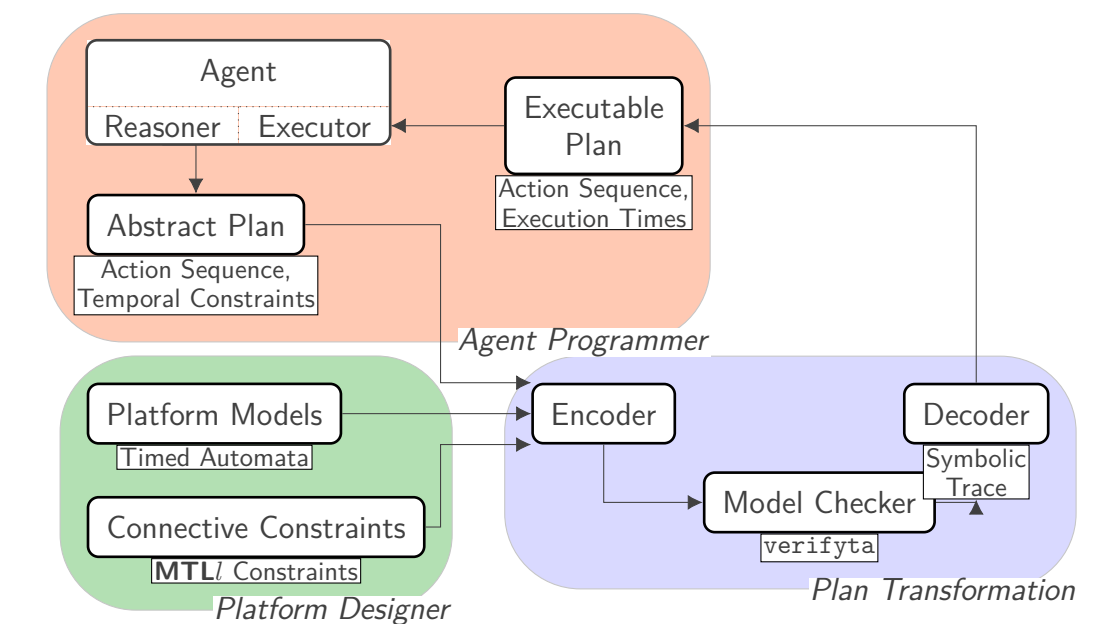
Encoding Idea

- Given: abstract plan (action sequence),
- Platform model (timed automaton),
- Constraints (MTL formulas)
- Construct a timed automaton $\mathcal{A}_{enc}$ with designated state `fin`:

  - `fin` is reachable $\Leftrightarrow$ executable plan can be found
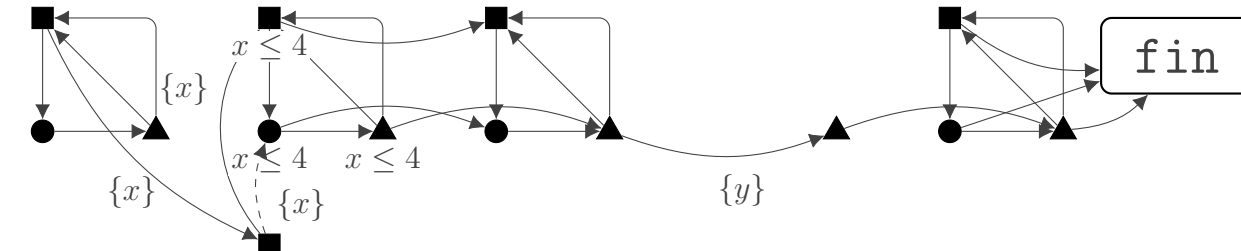 - Plan to final states $\rightarrow$ executable plan

- Encode high-level plan:
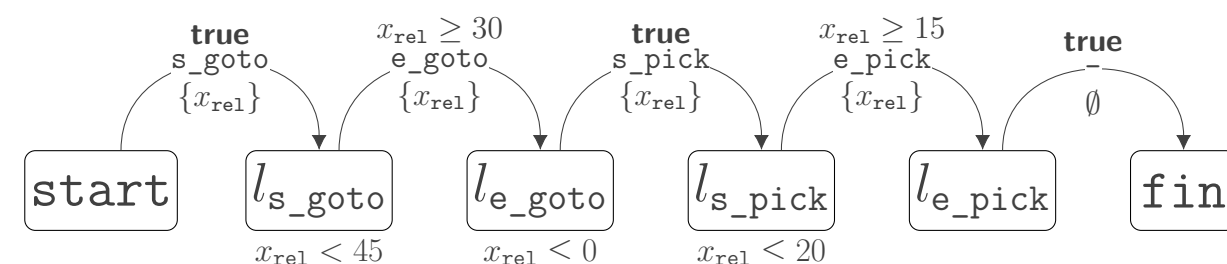
- Add platform automaton:

- Encode platform constraints:

Main Results

Plan length	Time (s)			# states		
	perc	perc calib	+ calib	perc	perc calib	+ calib
50	.6	.1	2.1	662	269	2574
100	2.0	.5	7.7	1325	527	5513
150	4.9	.1	15.5	1978	769	8297
300	19.2	2.9	53.1	3953	1538	16476

- Good scalability both with increasing platform and plan size on a product assembly domain (left table)
- Outperforms TFD on household domain (compared to simplified domain + transformation step)

Conclusion

- Integrate low-level requirements via a plan transformation
- High-level reasoning framework can be designed independently from the used platform, even if platform usage depends on the domain context.
- Express platform behavior utilizing a fragment of MTL and timed automata
- Translate plan transformation problem into a reachability query on timed automata
- Good performance, beneficial to speed up otherwise complex planning tasks