# Software Product Lines with Unbounded Parametric Real-Time Constraints

## FOSD Meeting (Grasellenbach, March 14, 2017)


**Lars Luthmann**
Andreas Stephan
Johannes Bürdek
Malte Lochau



ES Real-Time Systems Lab
Prof. Dr. rer. nat. Andy Schürr
Dept. of Electrical Engineering and Information Technology
Dept. of Computer Science (adjunct Professor)

www.es.tu-darmstadt.de


IMoTEP 2 DFG

Integrated Model-based Testing
of Continuously Evolving
Software Product Lines

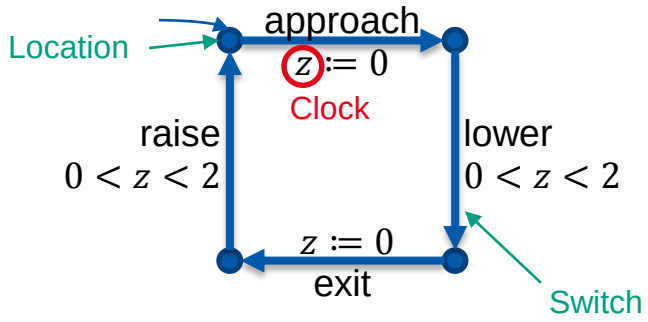
March 22, 2017

# Running Example

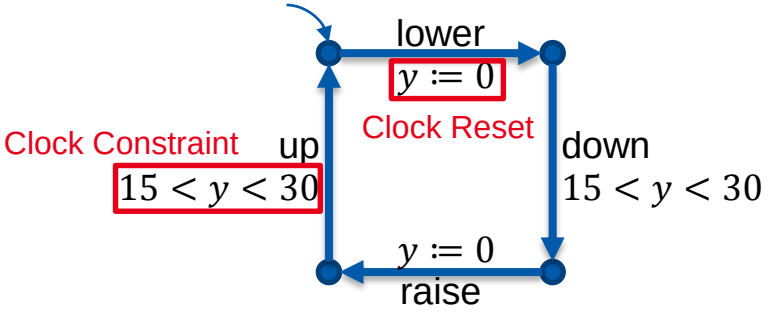
[Alur et al. (1993): Parametric Real-time Reasoning]

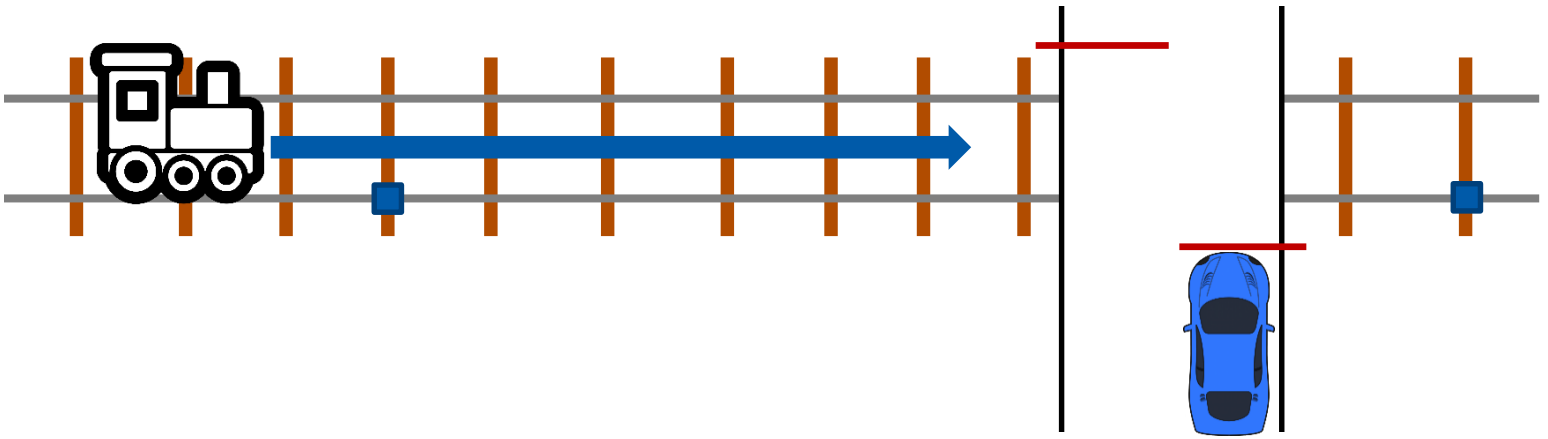
TECHNISCHE UNIVERSITÄT DARMSTADT

## Controller

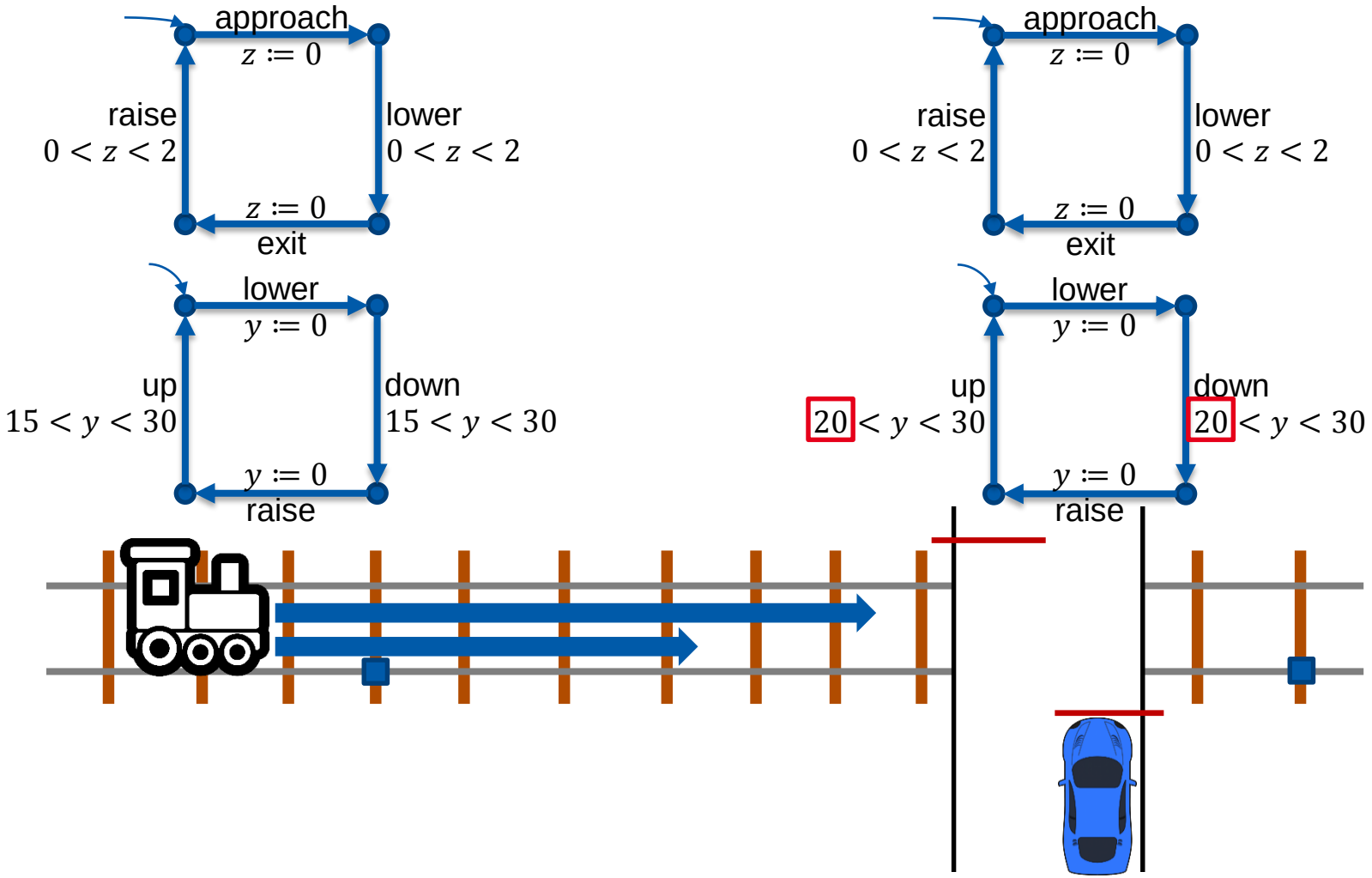



## Gate



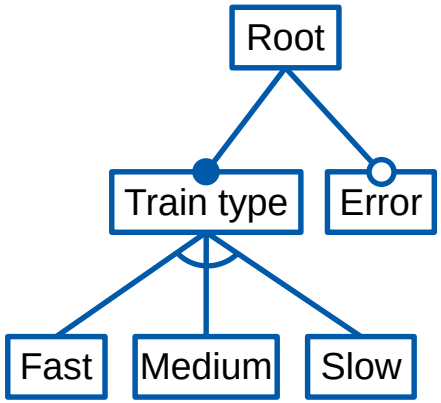



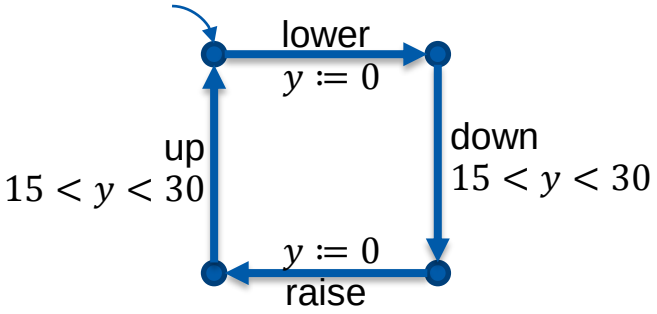
# Product Line of TA

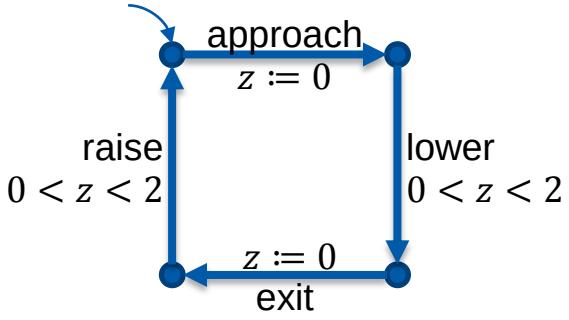


# Featured Timed Automata (FTA)

[Cordy et al. (2012): Behavioural Modelling and Verification of Real-Time Software Product Lines]



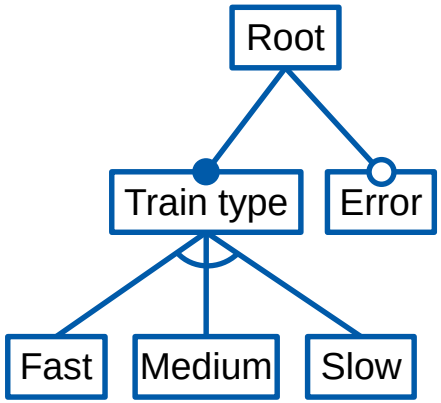



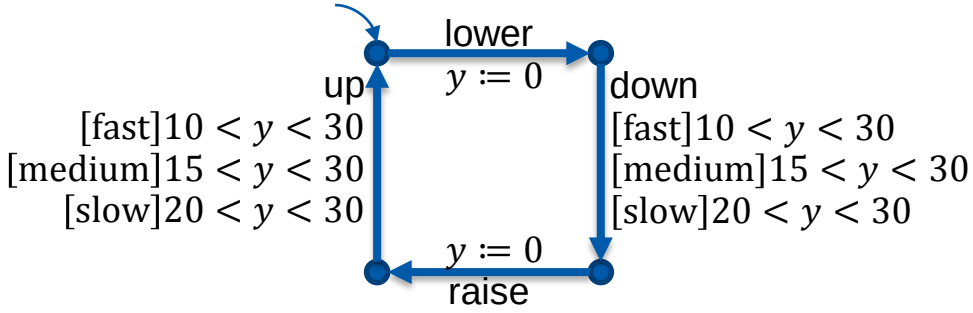




- Presence conditions for clock constraints and switches

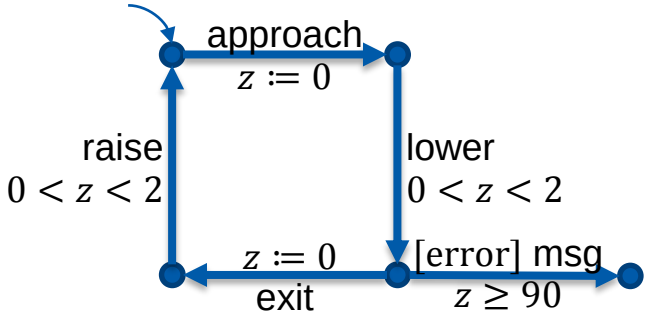
# Featured Timed Automata (FTA)

[Cordy et al. (2012): Behavioural Modelling and Verification of Real-Time Software Product Lines]



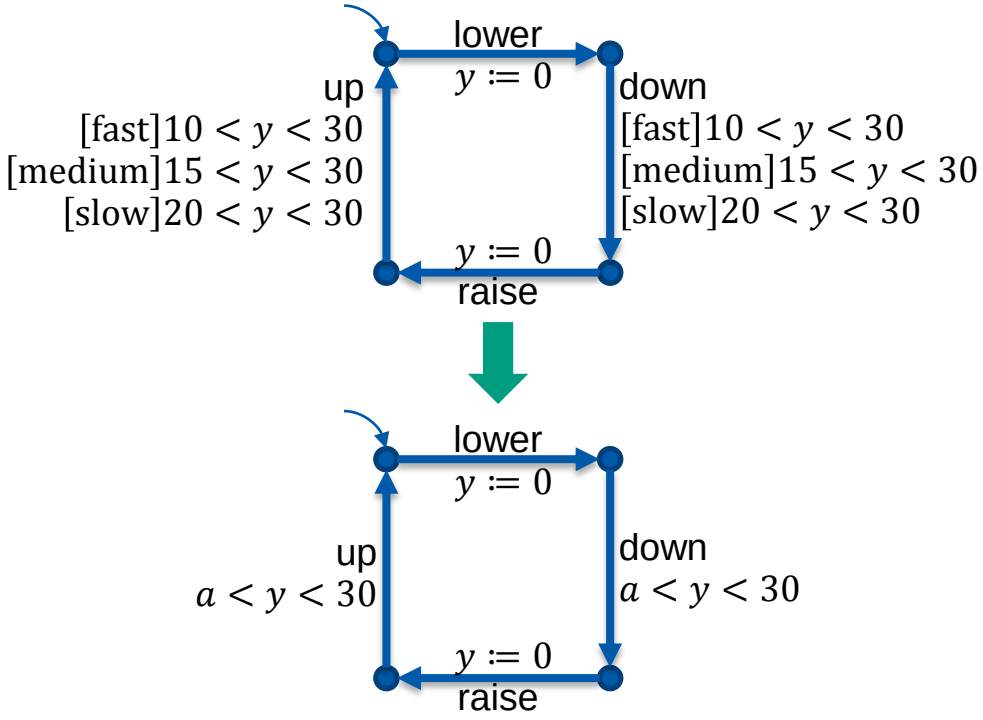



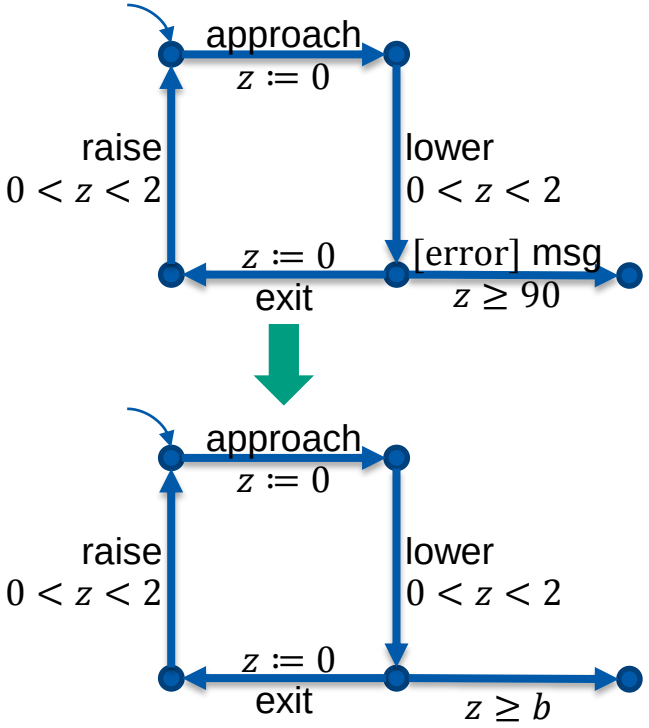

- Presence conditions for clock constraints and switches



# Parametric Timed Automata (PTA)

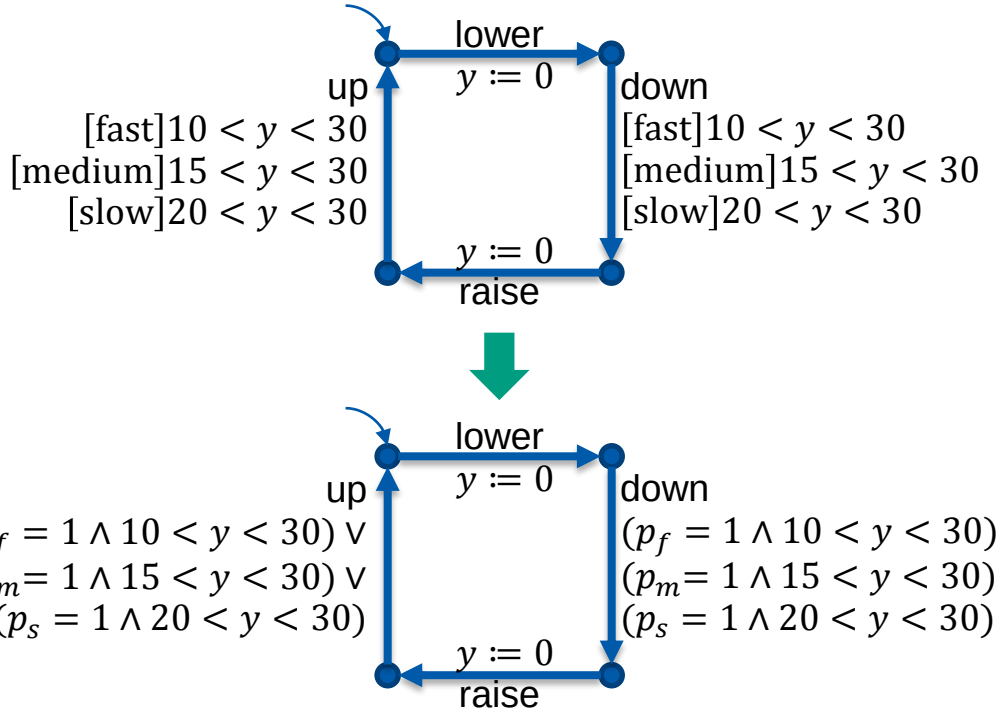
[Alur et al. (1993): Parametric Real-time Reasoning]

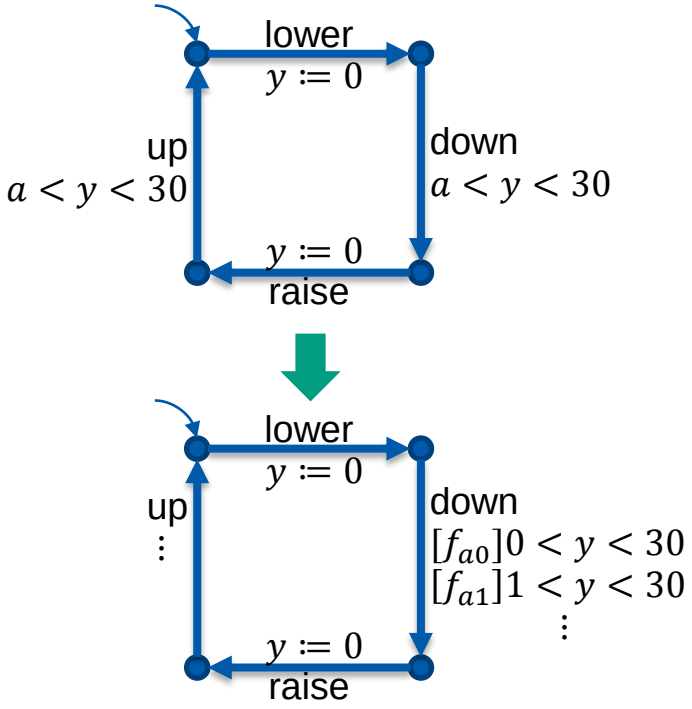



- Unbounded numeric parameters instead of Boolean features
- Results in (potentially) infinite number of configurations

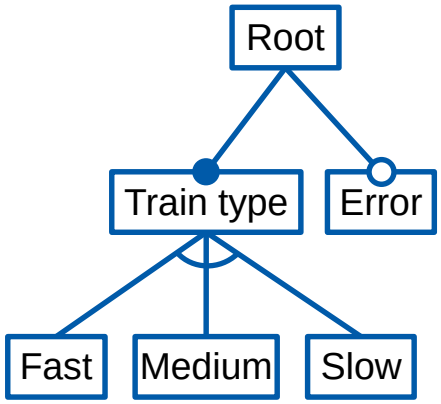
# Mutual encoding of FTA and PTA

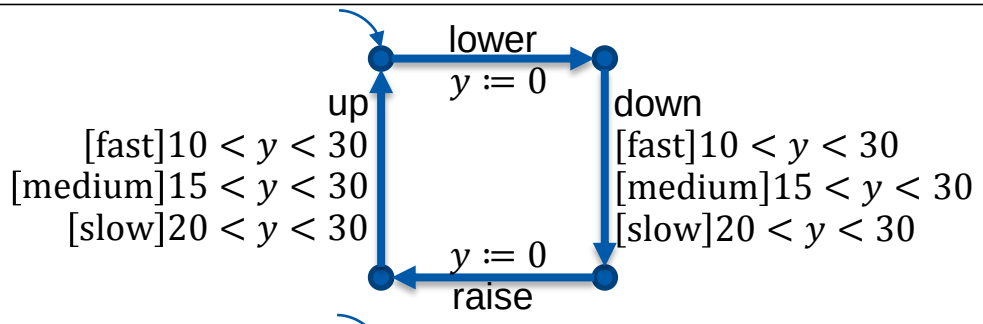


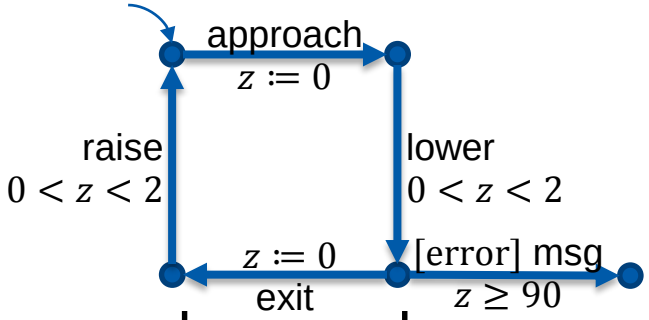



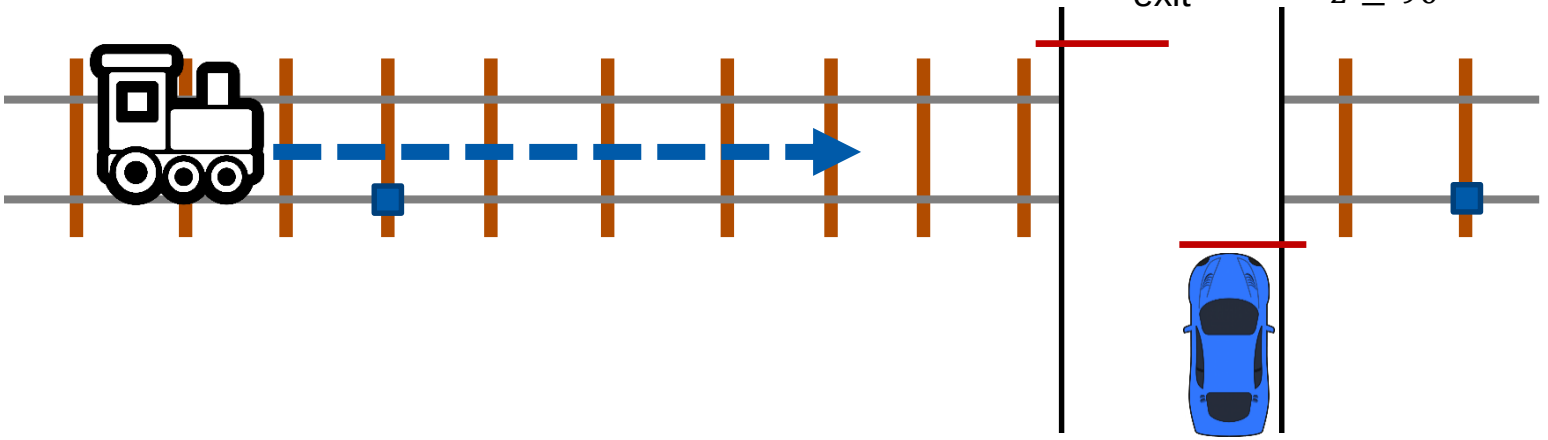

- FTA → PTA: one parameter for each feature
- (Bounded) PTA → FTA: one feature for each parameter valuation
- Restriction: Unbounded parameter domains cannot be mapped

# Unbounded Real-Time Constraints

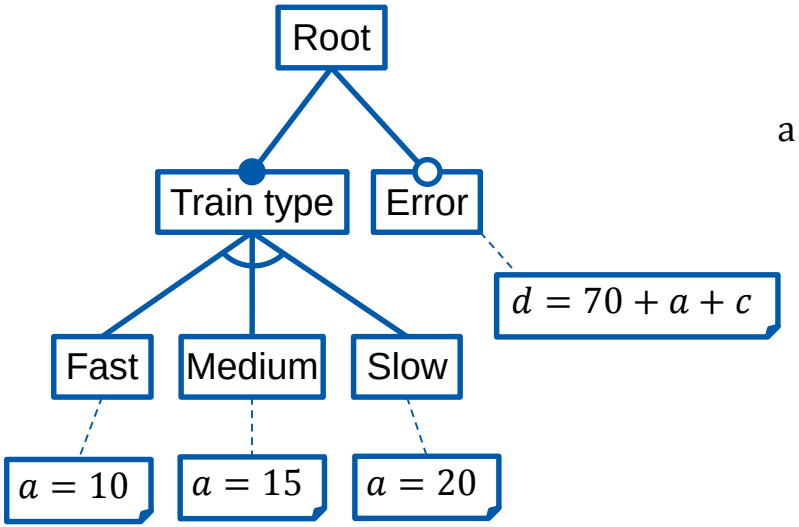


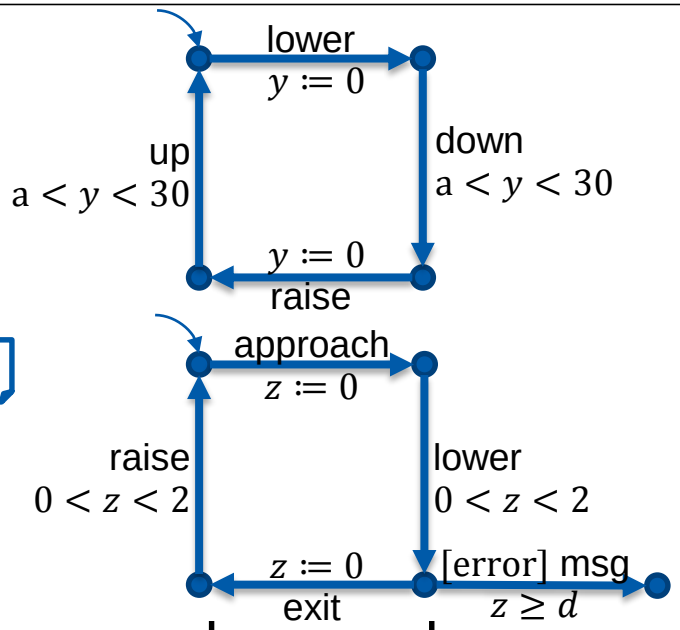



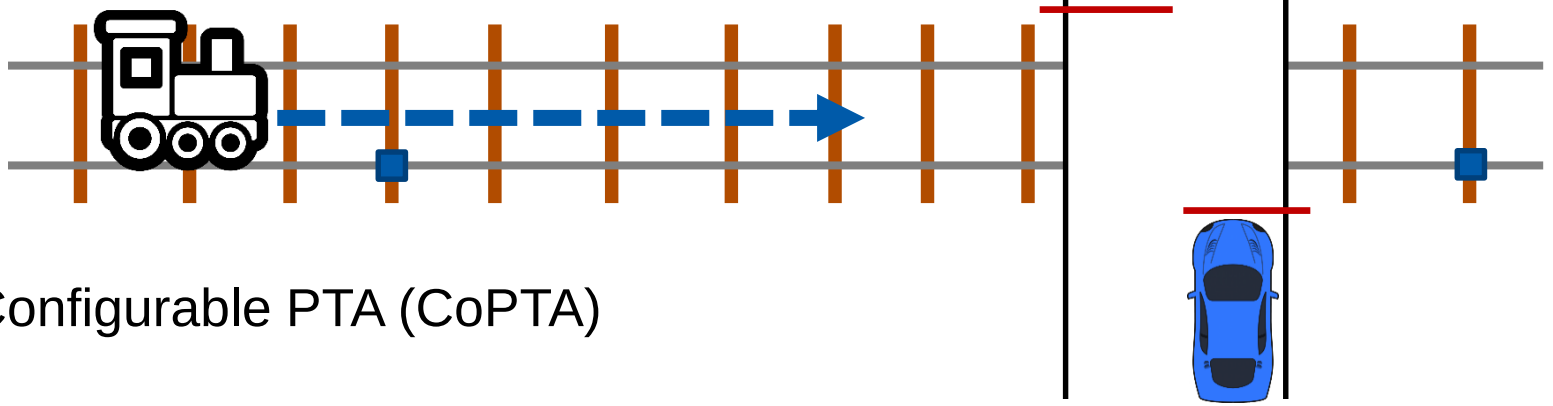



# Unbounded Real-Time Constraints



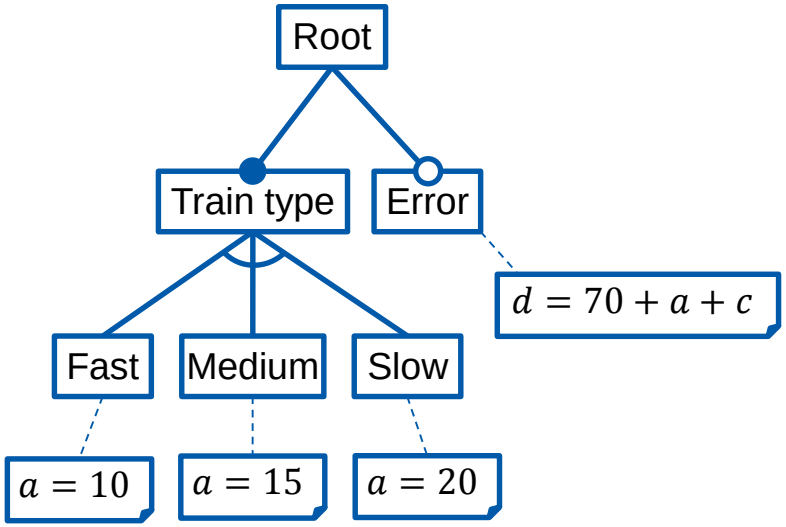



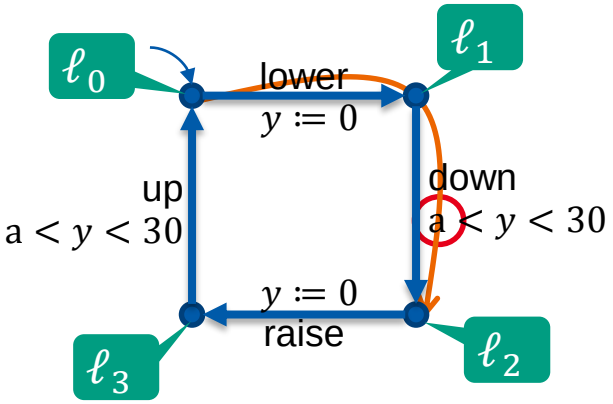



⇒ Configurable PTA (CoPTA)

# Test-Case Generation

[Bürdek et al. (2015): Facilitating Reuse in Multi-goal Test-Suite Generation for Software Product Lines]
[André (2009): IMITATOR: A Tool for Synthesizing Constraints on Timing Bounds of Timed Automata]

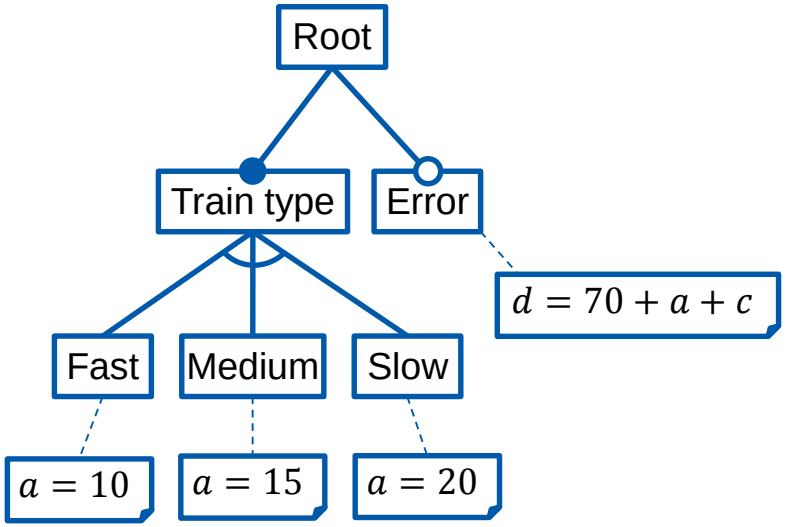


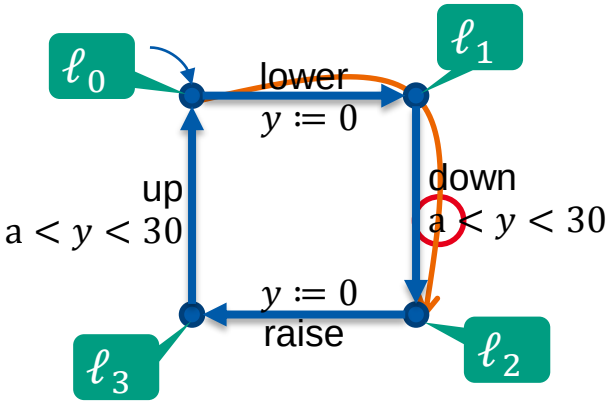




- Test case for $\ell_2$: $\ell_0 \xrightarrow{(7,lower)} \ell_1 \xrightarrow{(12,down)} \ell_2$
- May be reused for $\ell_1$ [Bürdek et al., 2015]
- May be reused for configurations with feature *fast* [Bürdek et al., 2015]
- Implementation based on Imitator [André, 2009]

# Test-Case Generation

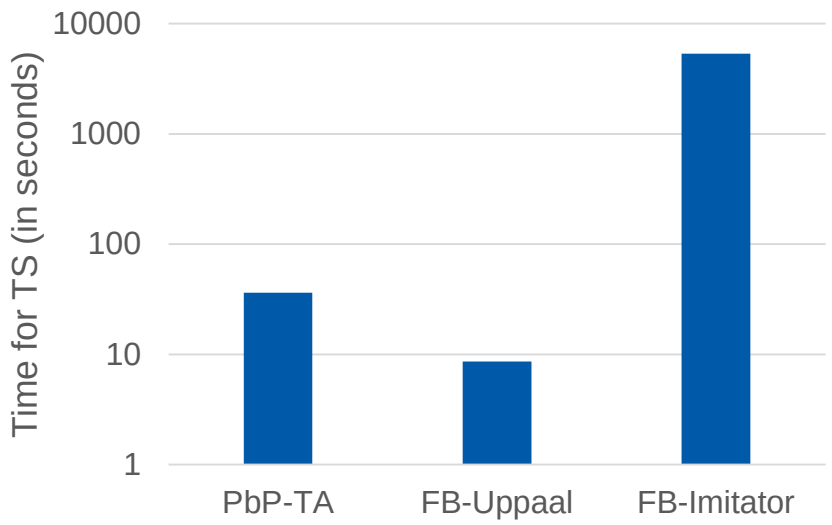
[Bürdek et al. (2015): Facilitating Reuse in Multi-goal Test-Suite Generation for Software Product Lines]
[André (2009): IMITATOR: A Tool for Synthesizing Constraints on Timing Bounds of Timed Automata]

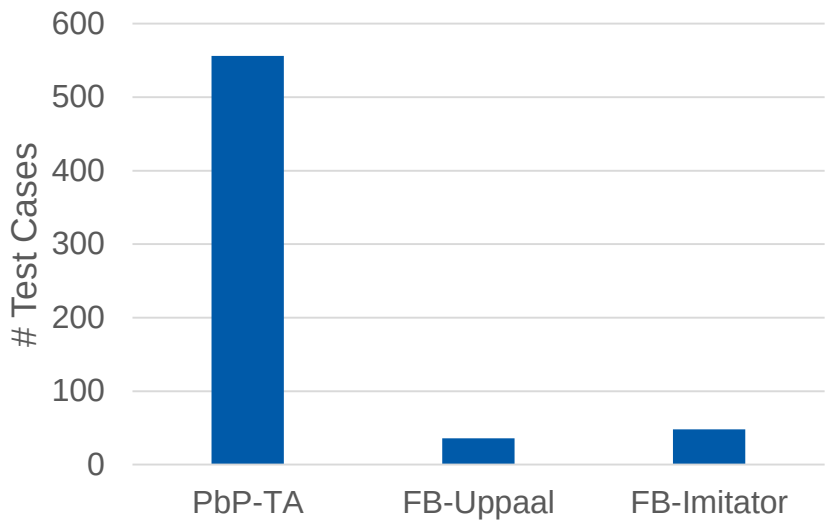



# HeliC++PTA

# Evaluation (Gear Control)




- Can we reduce computational effort and the test suite size?

- 66 locations
- 22 Variants
- No unbounded parametric variability

# Conclusion

TECHNISCHE UNIVERSITÄT DARMSTADT

- Family-based approach with FTA:
  - Smaller test suite
  - Faster test-suite generation
- Family-based parametric approach with CoPTA:
  - Slower test-suite generation
  - Potentially unlimited amount of variants
- Generate CoPTA models from source code


[https://commons.wikimedia.org/wiki/File:Future_plate_blue.svg]

# Decidability Properties for PTA

[André (2008): What's decidable about parametric timed automata?]

TECHNISCHE UNIVERSITÄT DARMSTADT

- $\mathcal{P}$-emptiness: Is a property satisfiable with a given parameter valuation?
- $\mathcal{P}$-universality: Is a property satisfiable for all parameter valuations?
- $\mathcal{P}$-finiteness: Is the set which satisfies a given property finite?

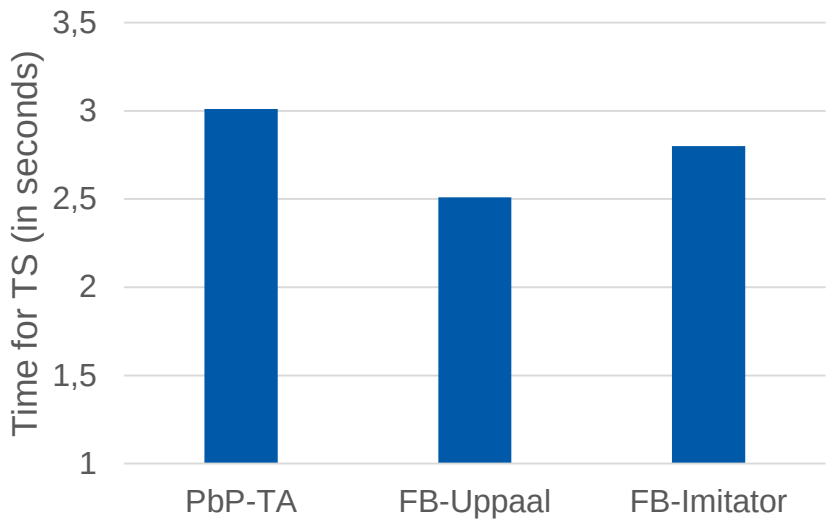
# Decidability Results for PTA

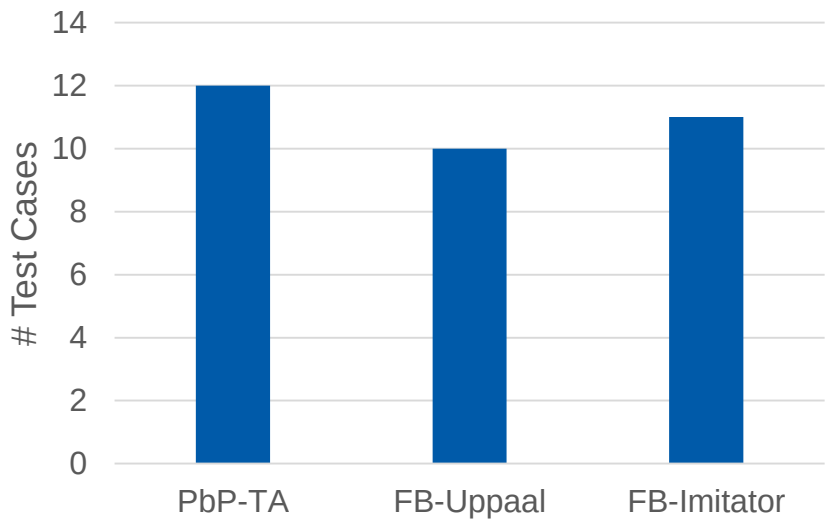
[André (2008): What's decidable about parametric timed automata?]

TECHNISCHE UNIVERSITÄT DARMSTADT

| Time Domain | Parameter Domain | P-Clocks | NP-Clocks | Params | Decidable? |
|---|---|---|---|---|---|
| $\mathbb{N}_0$ | $\mathbb{N}_0$ | 3 | 0 | 1 | No |
| $\mathbb{R}_+$ | $\mathbb{N}_0$ | 2 | any | 1 | Yes |
| $\mathbb{R}_+$ | $\mathbb{N}_0$ | 3 | 0 | 1 | No |
| $\mathbb{R}_+$ | $\mathbb{N}_0$ (bounded) | any | any | any | Yes |
| $\mathbb{R}_+$ | $\mathbb{Q}_+$ | 1 | 0 | any | Yes |
| $\mathbb{R}_+$ | $\mathbb{R}_+$ | 1 | 3 | 1 | No |

# Evaluation (Train-Gate-Controller)




- 12 locations
- 2 Variants
- No unbounded parametric variability