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SEFM’19
Oslo, Norway

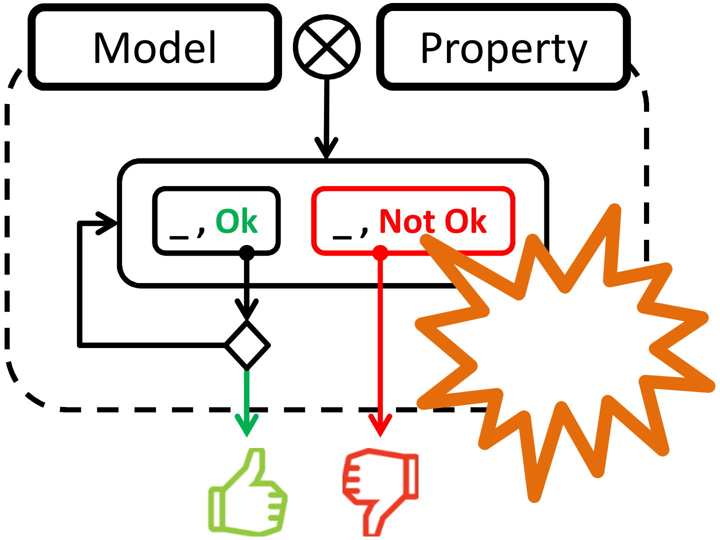
Partially Bounded Context-Aware Verification

LE ROUX Luka & TEODOROV Ciprian

Lab-STICC, ENSTA Bretagne, Brest, France

Introduction

Model-Checking

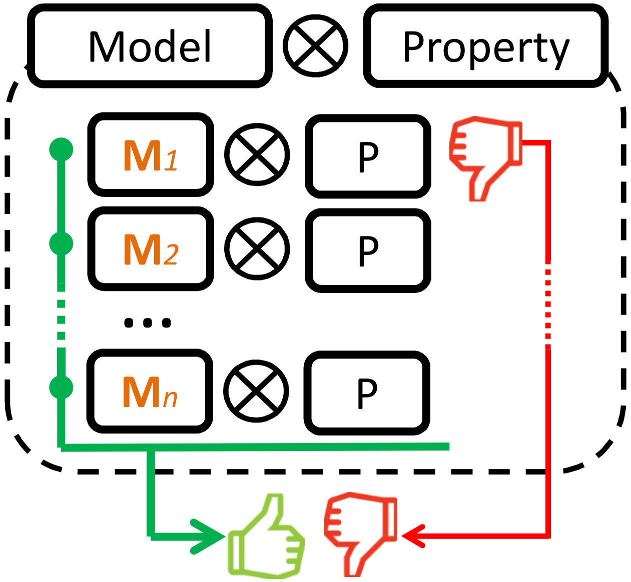


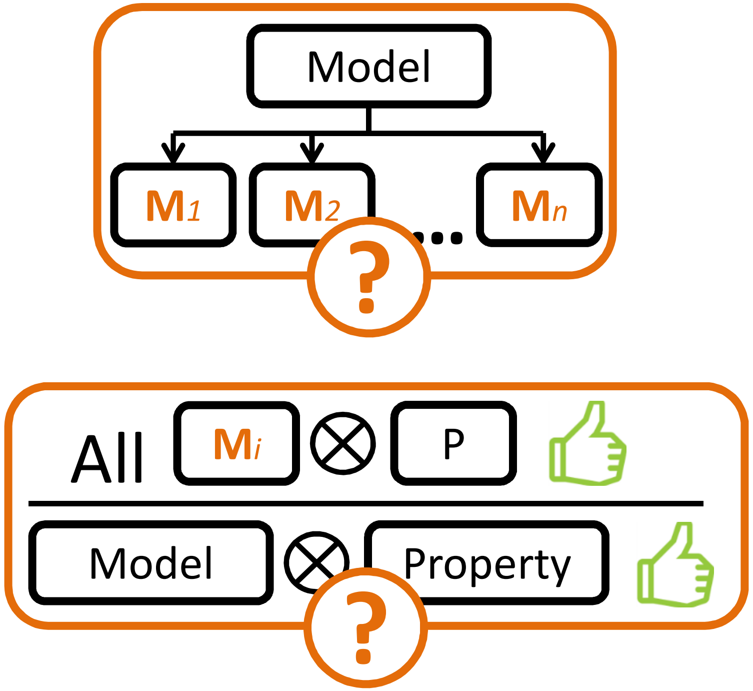
Exhaustive and automatic formal method
[ClarkeEmerson82, QueillleSifakis82]

- Major algorithmic breakthroughs
  [ClarkeEmersonSifakis09]
  - *Symbolic approach (OBDDs)*
  - *Partial order reduction*
  - *Bounded Model Checking*
  - *Abstraction Refinement Loop* (CEGAR)
- When scalability issues persist
  - Refine the specifications
  - Narrow the modeling scope
  - **Split the analysis**

Introduction

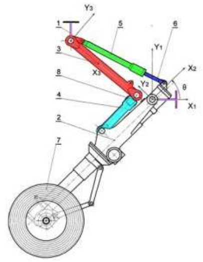
Splitting the analysis

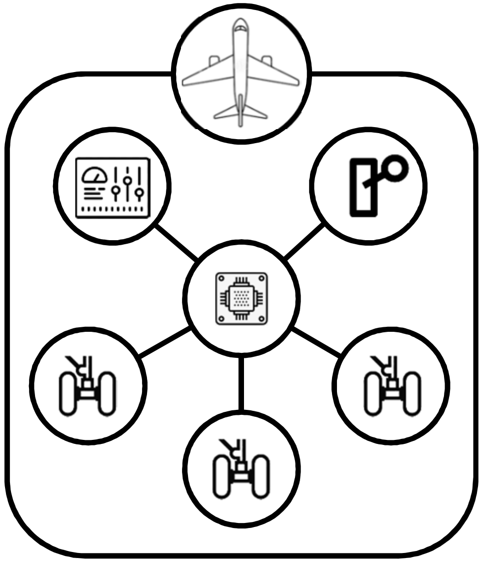




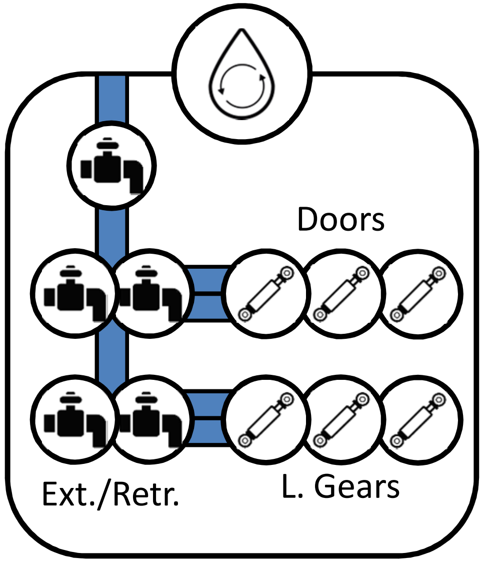
Case Study

Landing Gear System [F. Boniol, V. Wiels, ABZ’2014]



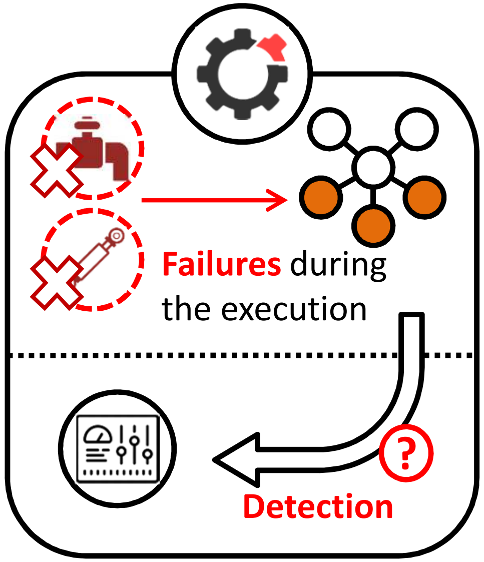


Overview



Hydraulic Parts

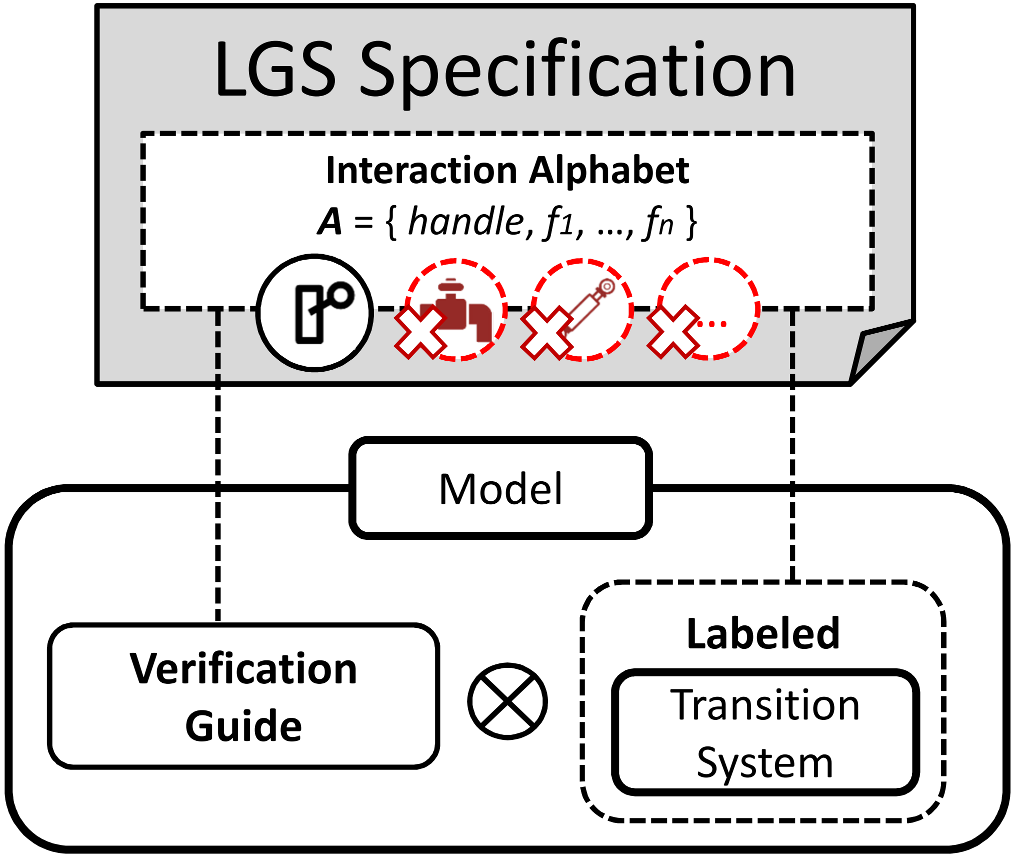
(Extension / Retraction)



Failures Injection

& Requirements

Context-Aware Verification [STTT'17]



LGS Specification

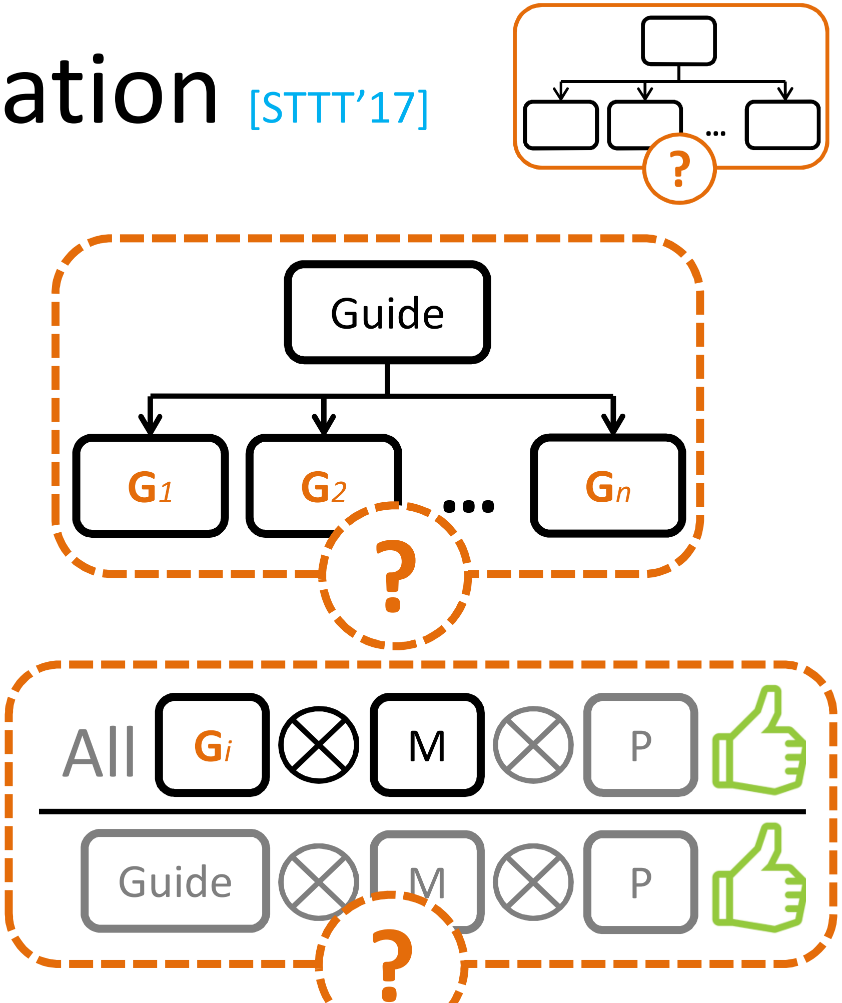
Interaction Alphabet

$\boldsymbol{A} = \{ \textit{handle}, f_1, \ldots, f_n \}$

…

Model

Verification Guide ⊗ **Labeled** Transition System



…

?

Guide

G_1 G_2 … G_n

?

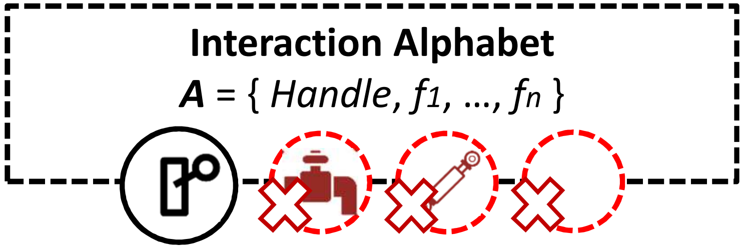
All G_i ⊗ M ⊗ P ✓

Guide ⊗ M ⊗ P ✓

?

xGDL

Operators



Interaction Alphabet

A = { *Handle*, f_1, …, f_n }

a	Interaction
⊥	Empty term
C_1 **;** C_2	Sequence
C_1 □ C_2	Alternative
C **?**	Optional

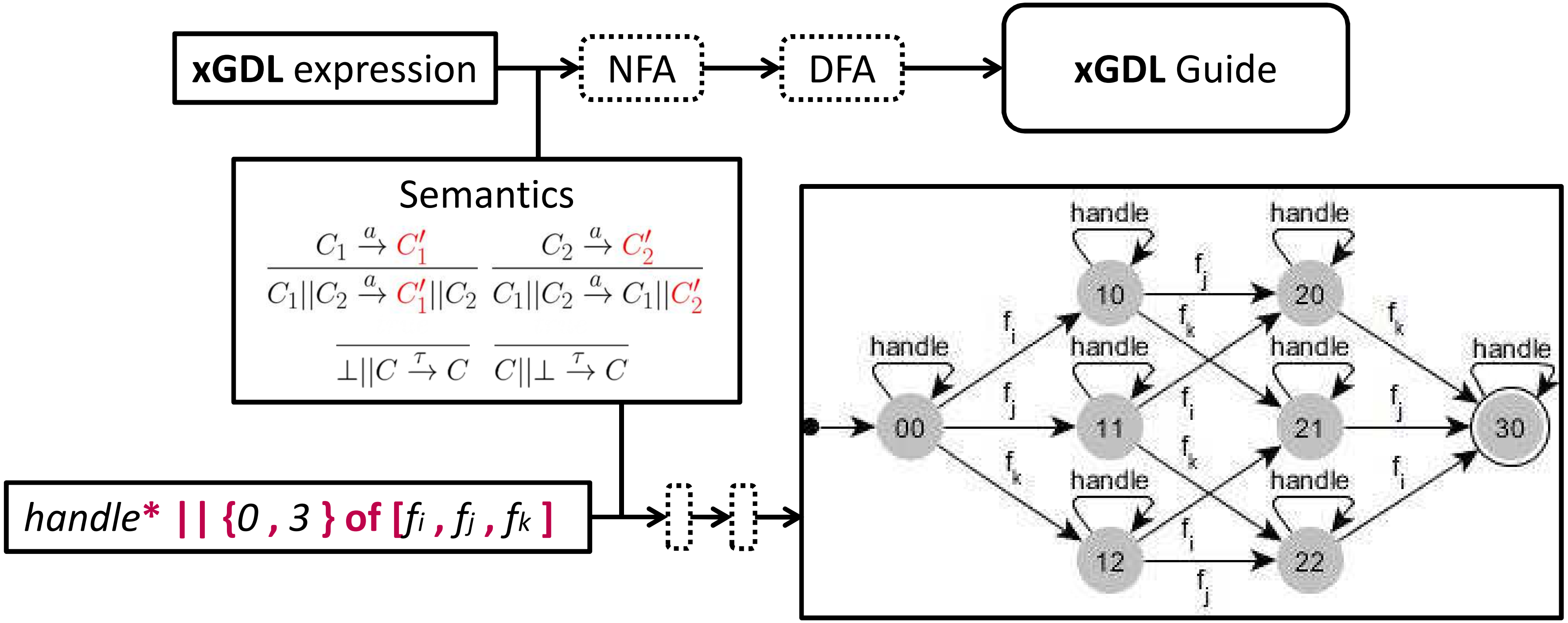
C *****	Repetition (*0+*)
C **+**	Repetition (*1+*)
C **{*i, j*}**	Repetition (*bounded*)
C_1 **||** C_2	Parallel interleaving
{*i, j*} of [C_1**,** C_2**,** …**,** C_n**]**	Permutations

Examples

Pilot	handle *****	*« Handle the landing gears at will »*
Failures	**{**0, 3**} of [**f_1**,** f_2**,** …**,** f_{12}**]**	*« 0 to 3 unique failures among a set of 12 »*
Guide	Pilot **||** Failures	*« 0 to 3 unique failures, arbitrarily injected »*

xGDL

Compilation



xGDL expression → NFA → DFA → **xGDL** Guide

Semantics

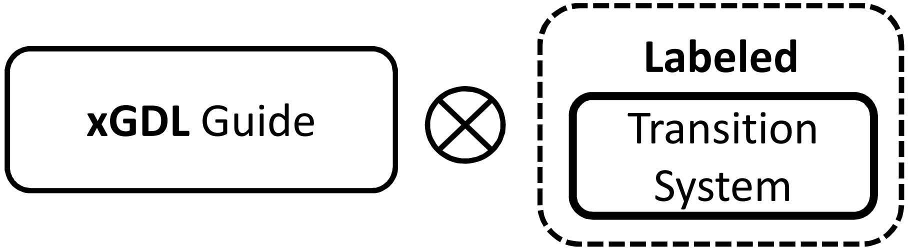
$$\frac{C_1 \xrightarrow{a} C_1'}{C_1||C_2 \xrightarrow{a} C_1'||C_2} \qquad \frac{C_2 \xrightarrow{a} C_2'}{C_1||C_2 \xrightarrow{a} C_1||C_2'}$$

$$\frac{}{\bot||C \xrightarrow{\tau} C} \qquad \frac{}{C||\bot \xrightarrow{\tau} C}$$

$handle^{*} \; || \; \{0 , 3\}$ **of** $[f_i , f_j , f_k]$

xGDL

Composition



xGDL Guide $\otimes$ **Labeled** Transition System

- Initial states $G_0 \times S_0$
- Synchronisation $a \neq \tau,\ (g, s) \xrightarrow{a} (g', s') \Leftrightarrow g \xrightarrow{a} g' \wedge s \xrightarrow{a} s'$
- Stuttering steps $(g, s) \xrightarrow{\tau} (g', s') \Leftrightarrow g = g' \wedge s \xrightarrow{\tau} s'$

Always possible to produce a *« neutral element »*

$$A = \{a_1, ..., a_n\}, G_{neutral} = (a_1 \square ... \square a_n)*$$

Initial Guide

Production & Soundness

LGS Requirements

[…] *Failures are irreversible*

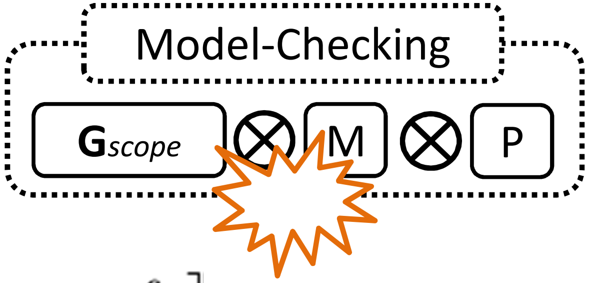
[…] *Four or more failures is outside the scope*

$$
\begin{aligned}
G_{neutral} &= && (handle \Box f_1 \Box ... \Box f_n)* \\
&= && handle* \; || \; (f_1 \Box ... \Box f_n)* \\
G_{scope} &= && handle* \; || \; \{0, n\} of \left[f_1, ..., f_n\right] \quad (uniqueness) \\
G_{scope} &= && handle* \; || \; \{0, 3\} of \left[f_1, ..., f_n\right] \quad (at\ most\ 3)
\end{aligned}
$$

$$
\frac{\boxed{\mathbf{G}_{scope}} \otimes \boxed{\mathrm{M}} \otimes \boxed{\mathrm{P}} \quad \text{👍}}{\boxed{\mathrm{M}} \otimes \boxed{\mathrm{P}} \quad \text{👍}}
$$

Splitting the analysis

Illustration

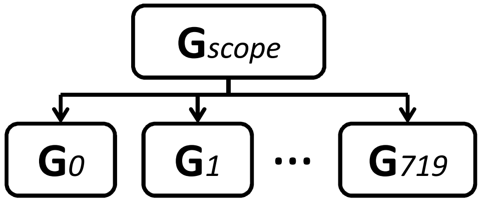


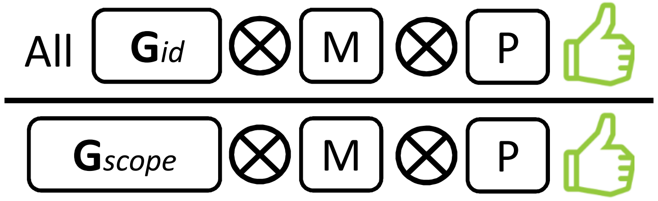
$$G_{scope} = handle* \quad || \quad \{0,3\}of\left[f_1, ..., f_n\right]$$

! *At most three failures may happen in one execution. There are 720 distinct subsets of three failures.*

$$G^3_{id} = handle* \quad || \quad \{0,3\}of\left[f_i, f_j, f_k\right]$$

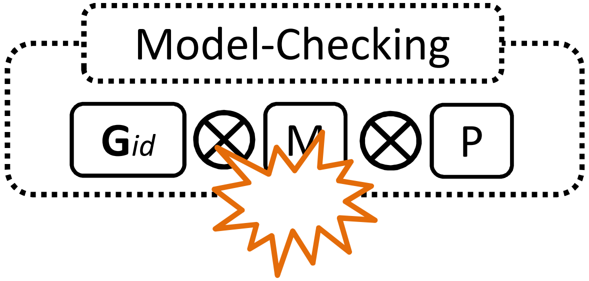
$$language(G_{scope}) \quad = \quad \cup_{id=0}^{719}\, language(G^3_{id})$$



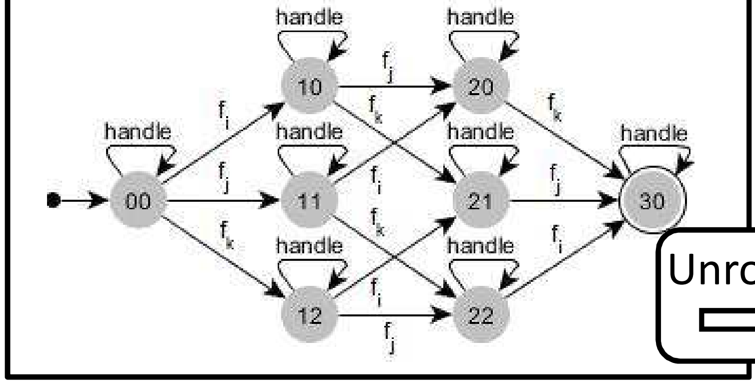


Partially Bounded

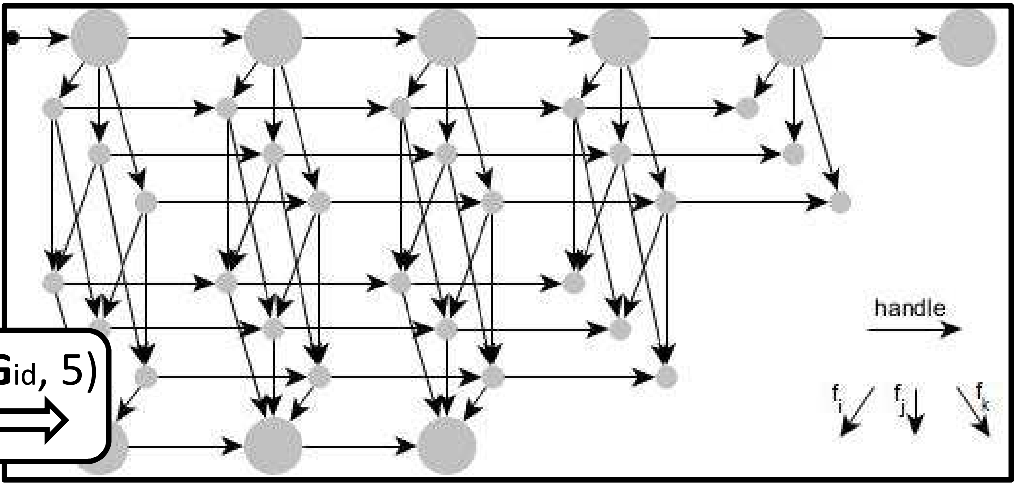
Unrolling the guide



$\mathbf{G}_{\mathrm{id}} = handle^{*}$ **|| {**0 **,** 3 **} of [**f_i **,** f_j **,** f_k **]**



Unroll($\mathbf{G}_{\mathrm{id}}$, 5) ⟹



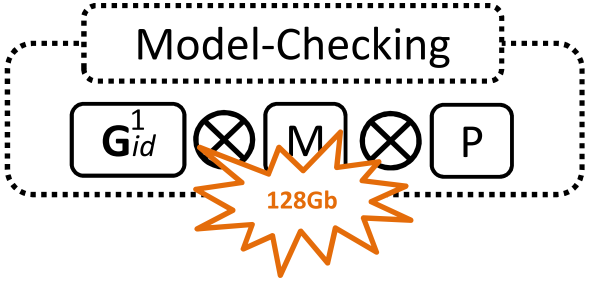
DAG specific algorithms from CaV literature

- Split: an automatic, recursive decomposition
- PastFree[ze]: reduces memory load

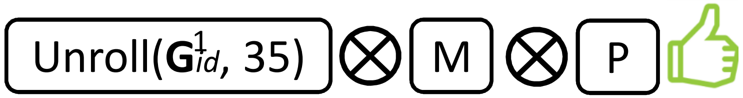
Soundness ?

Partially Bounded

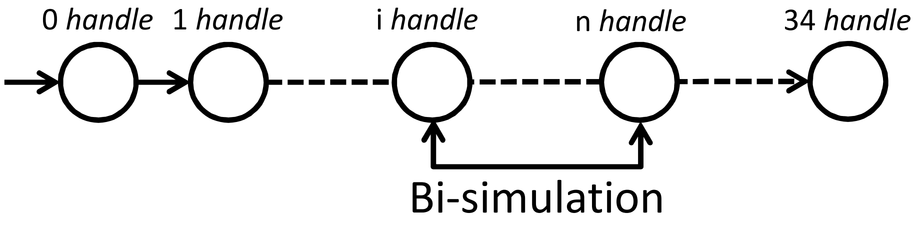
Soundness

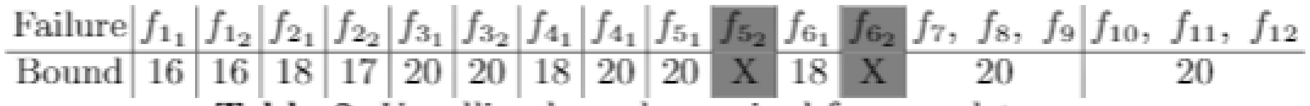


$$G^{1}_{id} = handle * \quad || \quad f_i$$



Resulting state space (indexed) :

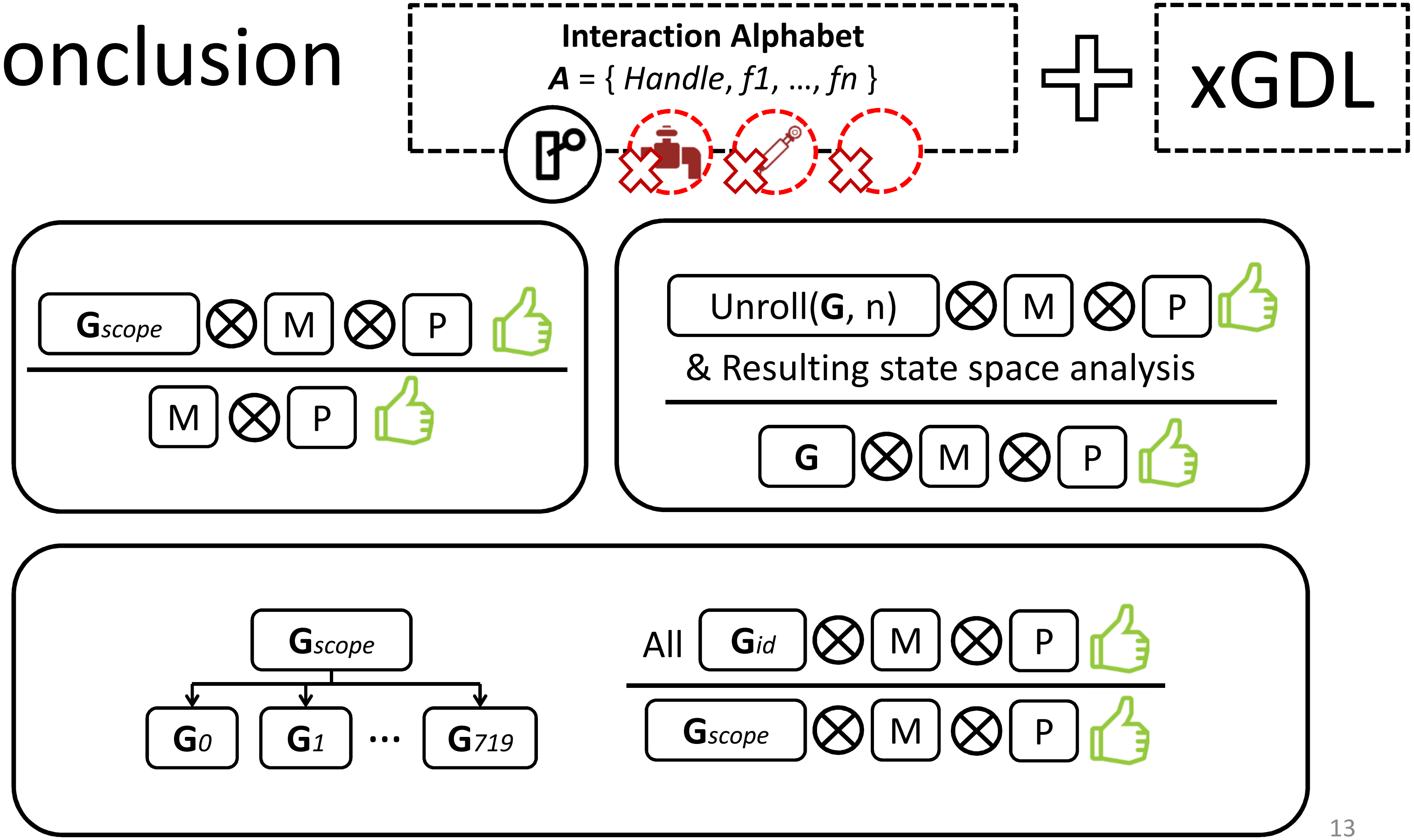




Failure	f_{1_1}	f_{1_2}	f_{2_1}	f_{2_2}	f_{3_1}	f_{3_2}	f_{4_1}	f_{4_1}	f_{5_1}	f_{5_2}	f_{6_1}	f_{6_2}	$f_7,\ f_8,\ f_9$	$f_{10},\ f_{11},\ f_{12}$
Bound	16	16	18	17	20	20	18	20	20	X	18	X	20	20

Table 2. Unrolling bounds required for completeness

Conclusion



Interaction Alphabet

A = { *Handle*, *f1*, …, *fn* }

+ xGDL

$$\frac{G_{scope} \otimes M \otimes P \ ✓}{M \otimes P \ ✓}$$

$$\frac{\text{Unroll}(\mathbf{G}, n) \otimes M \otimes P \ ✓ \quad \text{\& Resulting state space analysis}}{\mathbf{G} \otimes M \otimes P \ ✓}$$

G_{scope} → G_0, G_1 … G_{719}

$$\frac{\text{All } G_{id} \otimes M \otimes P \ ✓}{G_{scope} \otimes M \otimes P \ ✓}$$

Future Works

- PastFree[ze] with DFAs (cycles)
- Tooling / automation of the induced state clusters bi-simulation
- Usage in a collective and heterogeneous verification task

Tusen takk!

(thank you!)

Questions