

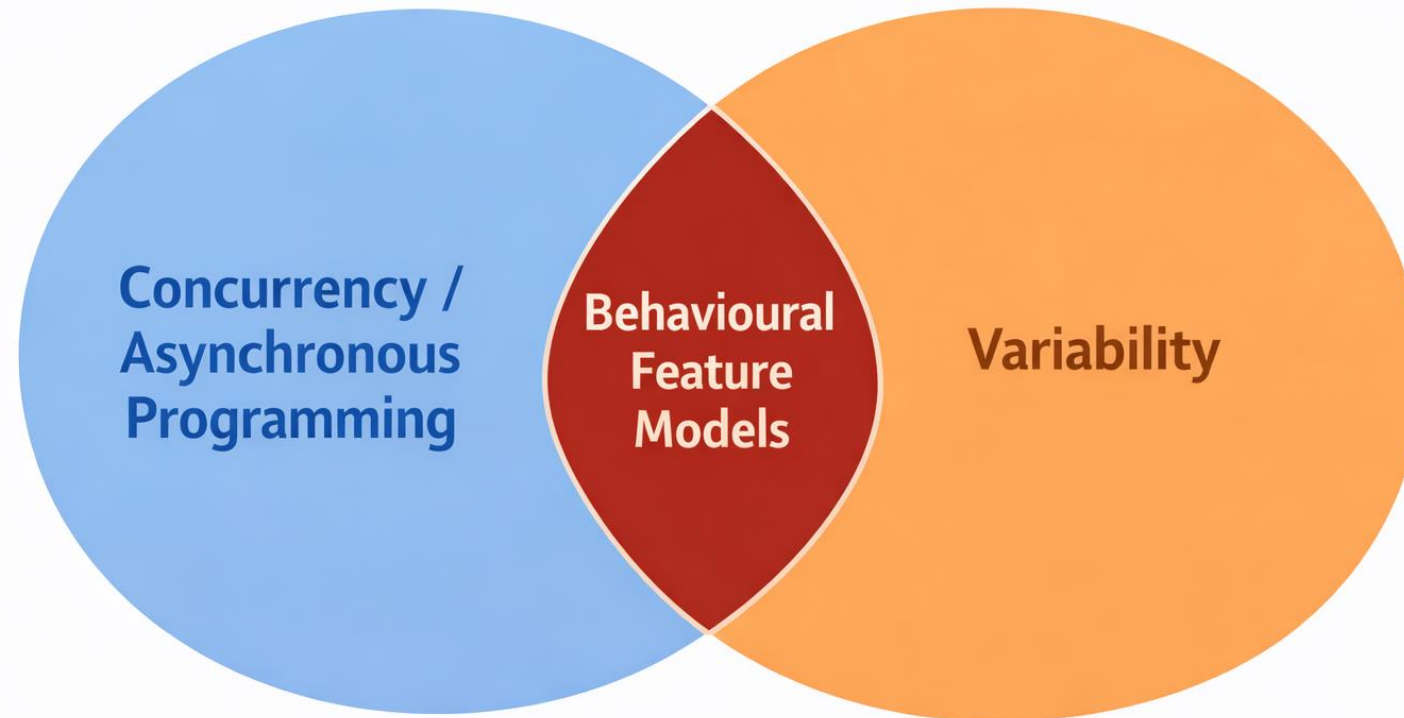
Behavioural Feature Models: Sneak Preview

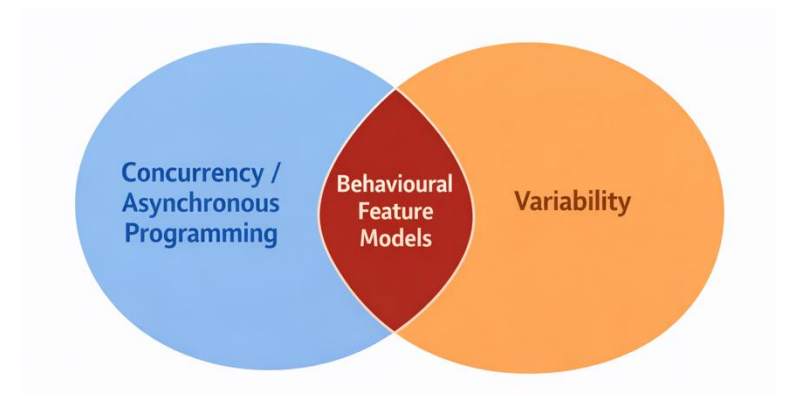
**Juliane Päßler, Sophie Fortz, Maurice H. ter Beek,
Ferruccio Damiani, Einar Broch Johnsen,
Mohammad Reza Mousavi, Silvia Lizeth Tapia Tarifa**

APM 2026, Turin, Italy

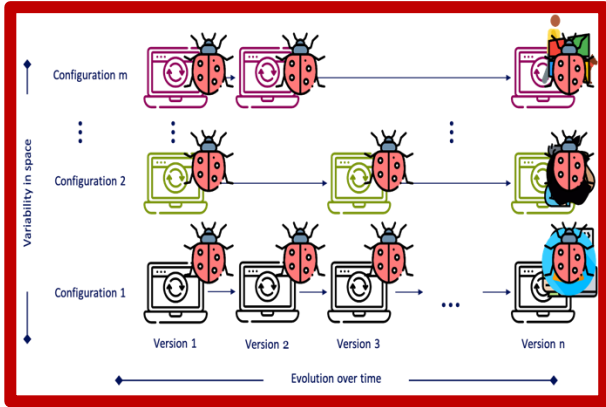
Einar's Axiom

“Every good talk has a Venn Diagram!”

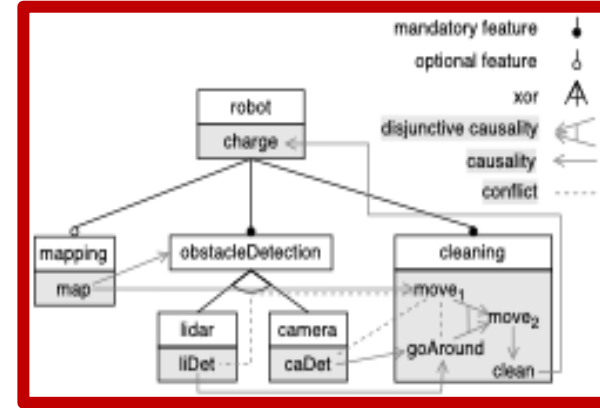




Marrying **concurrency theory** with **variability modelling** leads to **behavioural variability model** that is **compositional, expressive, and succinct**.



Variability Modelling



Behavioural Feature Models



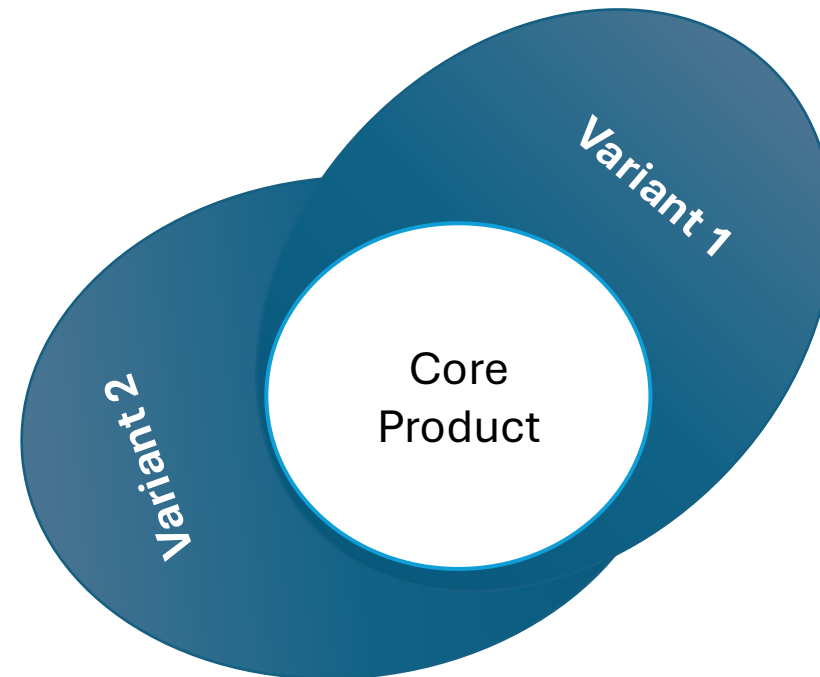
Evaluation



Road Ahead

Variability: Incremental

- Neat structure
- Limited variability
- Reasonable analysis possibilities



[Simao and Petrenko,
Fault Coverage-Driven Incremental Test Generation,
The Computer J., 2010]

[Kästner, Apel, Kuhlemann.
Granularity in Software Product Lines, ICSE 2008]

Variability: Annotational

- Less clear structure
- More expressive:
(space and time variability)
- Difficulties with
analysing deletion
and modifications

```
delta dStore {
  adds {
}
}

delta dSingleStore {
  modifies store.Store {
}
}

delta dMultiStore {
  modifies store.Store {
}
}

delta dAccessControl {
  modifies store.Store {
    adds private boolean sealed = false;
    modifies read() {
      if(!sealed) {
        return original();
      }
    }
    modifies readAll() {
      if(!sealed)
        return original();
    }
    modifies set(Object value) {
      if(!sealed)
        original();
    }
  }
}
```

[Varshosaz, Beohar, MRM,
Delta-Oriented FSM-Based Testing, ICFEM 2015]

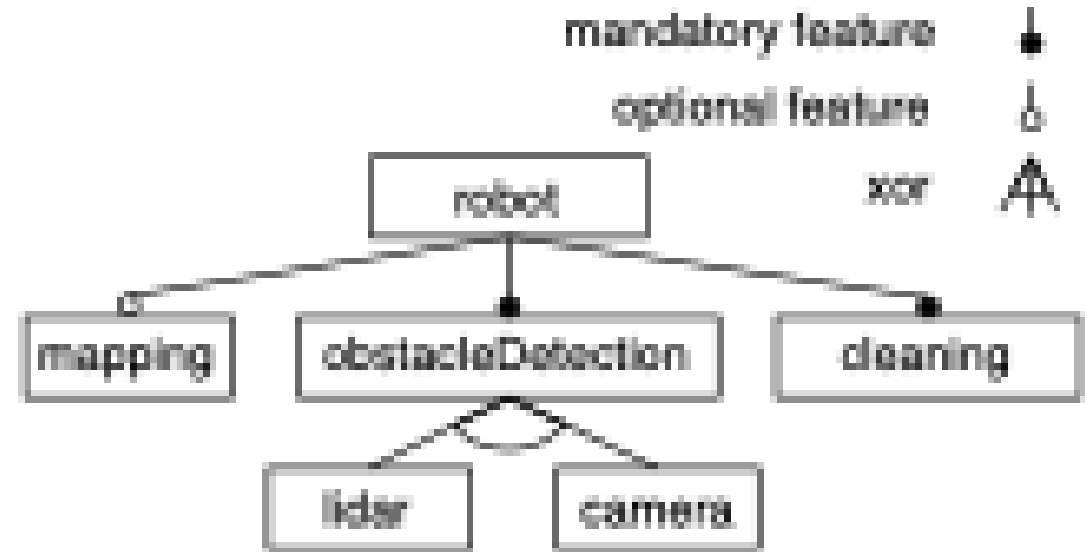
[Schaefer et al. Delta-Oriented Prog., SPLS
2010]

[Apel et al. Strategies for product-line
verification:

Case studies and experiments]

Product Lines: Compositional

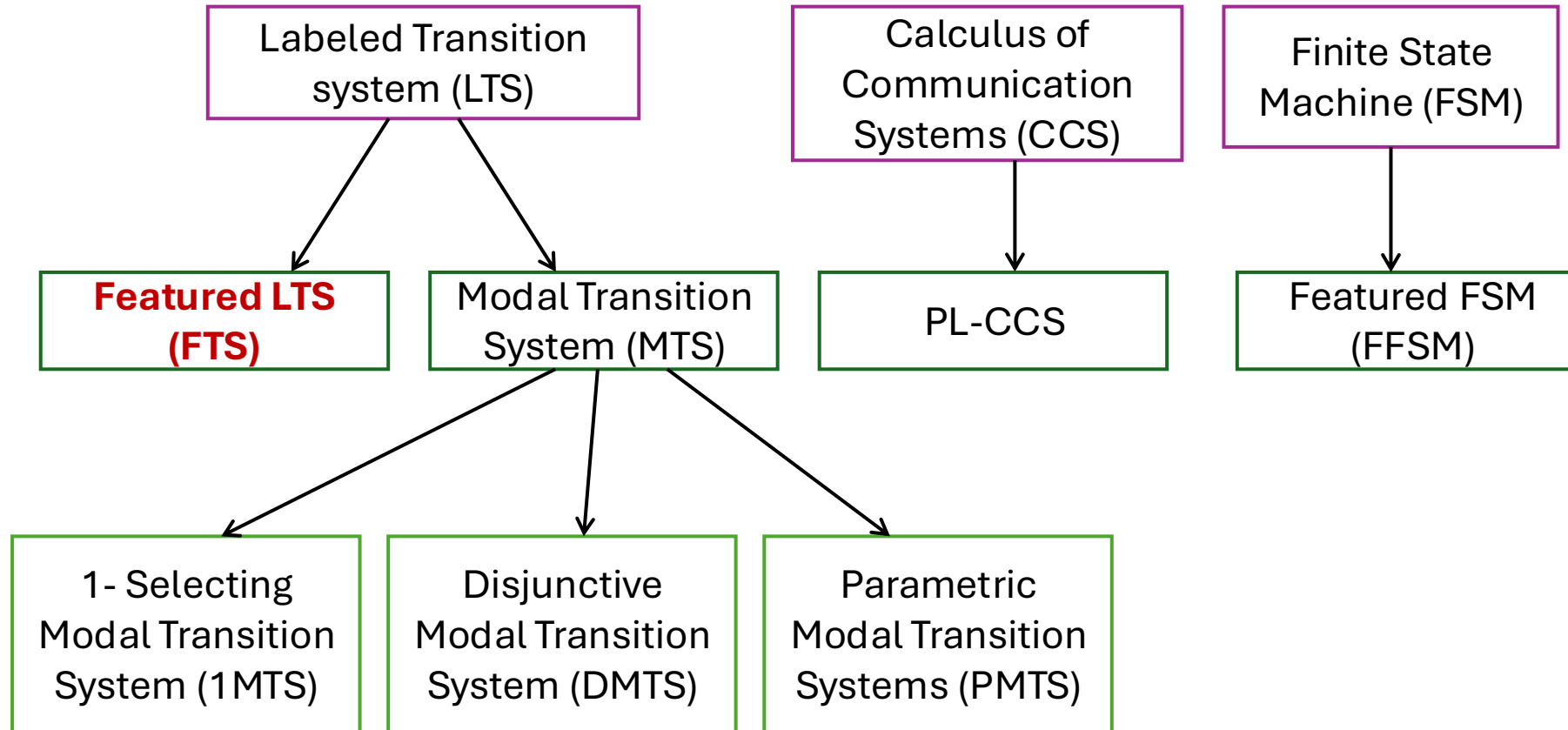
- Clear structure
- Very expressive
- Difficult to implement and analyse



[Beohar and MRM, Spinal Test-Suited for Software Product Lines]

[ter Beek, Damiani, Lienhardt, Mazzanti, Paolini, Efficient Static Analysis and Verification of Featured Transition Systems]

Behavioural Variability



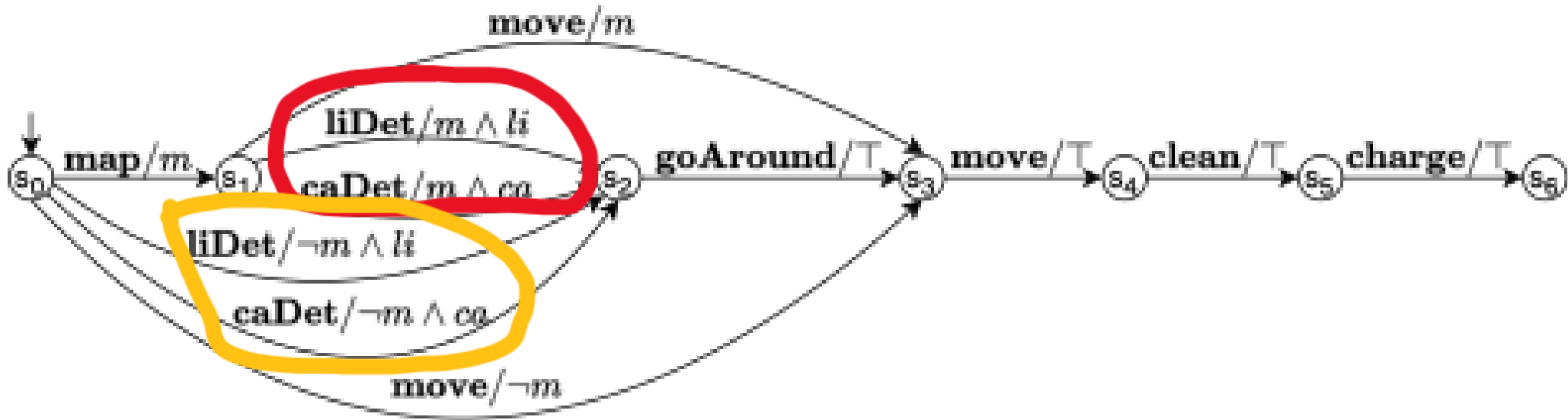
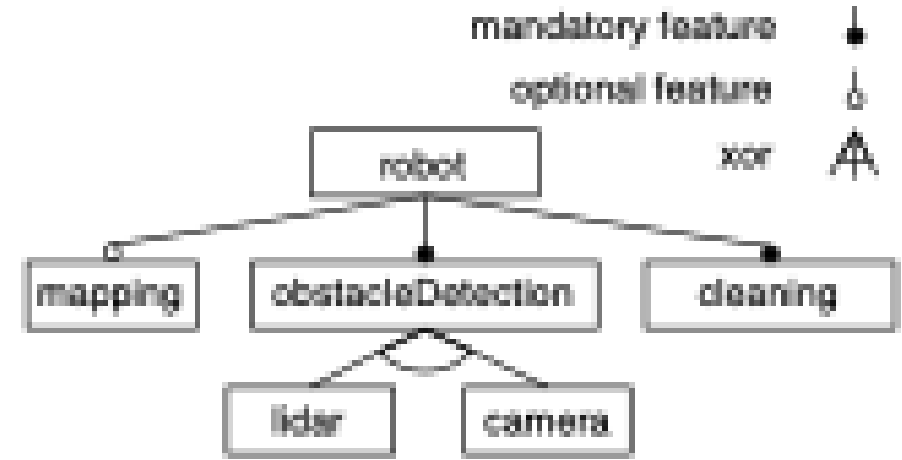
[Ghassemi and MRM, Product line process theory]

[Beohar, Varshosaz. MRM, Basic Behavioral Models for Software Product Lines: Expressiveness and Testing Pre-Orders]

[Varshosaz, Luthmann, Mohr, Lochau, MRM, Modal transition system encoding of featured transition systems]

[ter Beek, Damiani, Gnesi, Mazzanti, Paolini, On the Expressiveness of Modal Transition Systems with Variability Constraints]

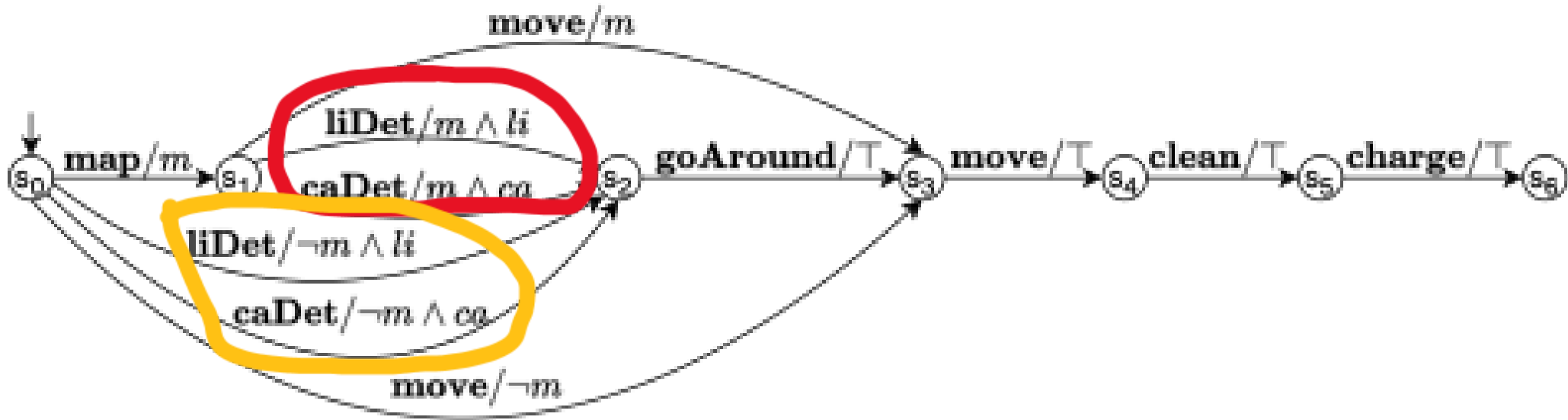
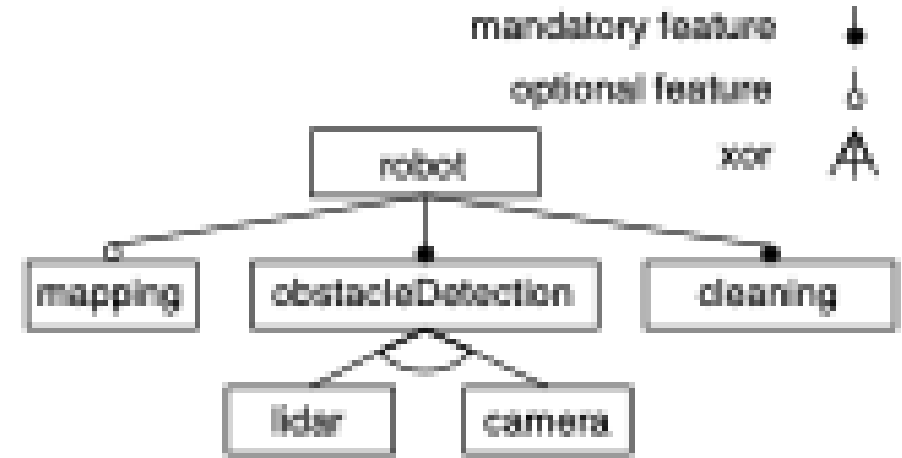
Featured Transition Systems



[Classen, Cordy, Schobbens, Heymans, Legay, Raskin, Featured Transition Systems: Foundations for Verifying Variability-Intensive Systems and Their Application to LTL Model Checking]

Featured Transition Systems

What is the behavioural model for the feature cleaning (c)?
How about mapping (m)?

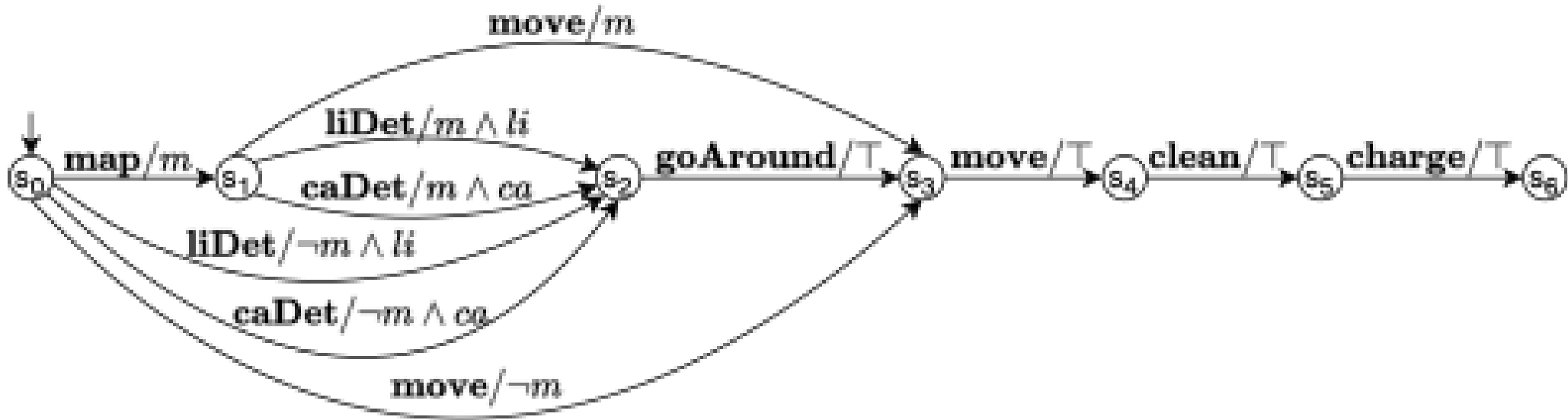
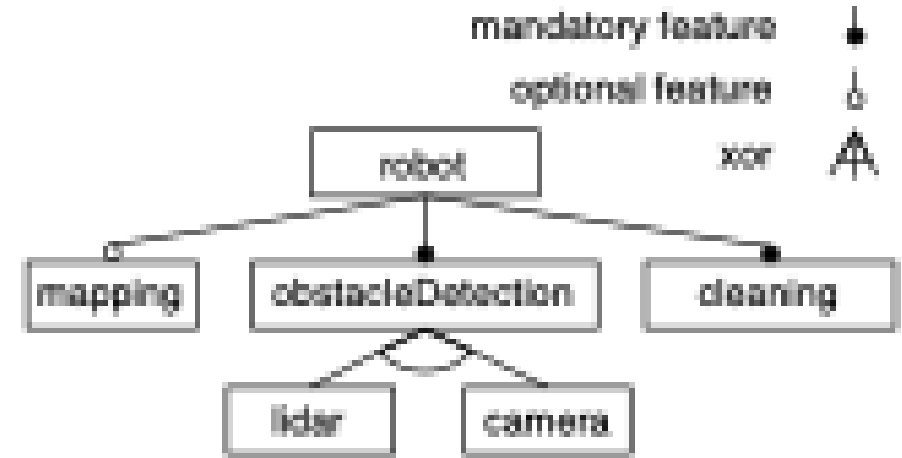


[Classen, Cordy, Schobbens, Heymans, Legay, Raskin, Featured Transition Systems: Foundations for Verifying Variability-Intensive Systems and Their Application to LTL Model Checking]

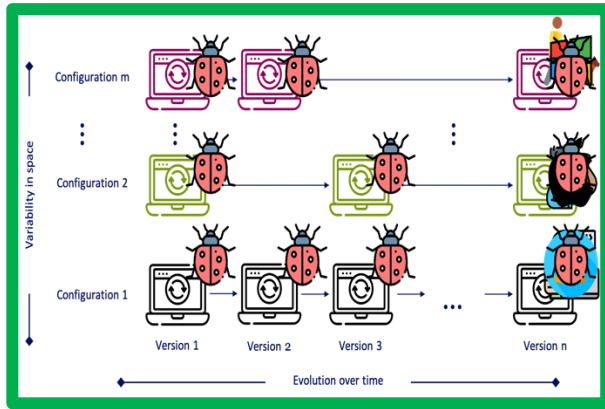
Featured Transition Systems

Moral of the story:

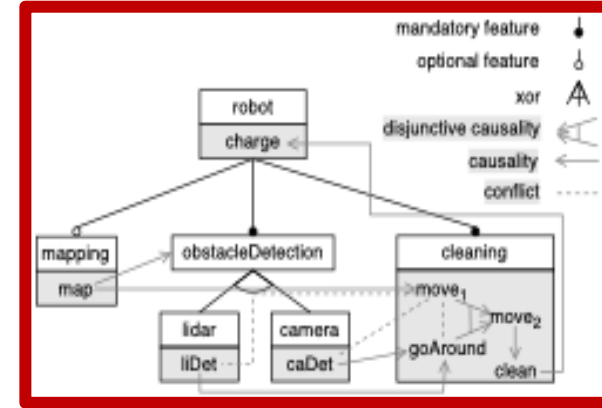
There is **too much happening** in a Featured Transition System!



[Classen, Cordy, Schobbens, Heymans, Legay, Raskin, Featured Transition Systems: Foundations for Verifying Variability-Intensive Systems and Their Application to LTL Model Checking]



Variability Modelling ✓



Behavioural Feature Models

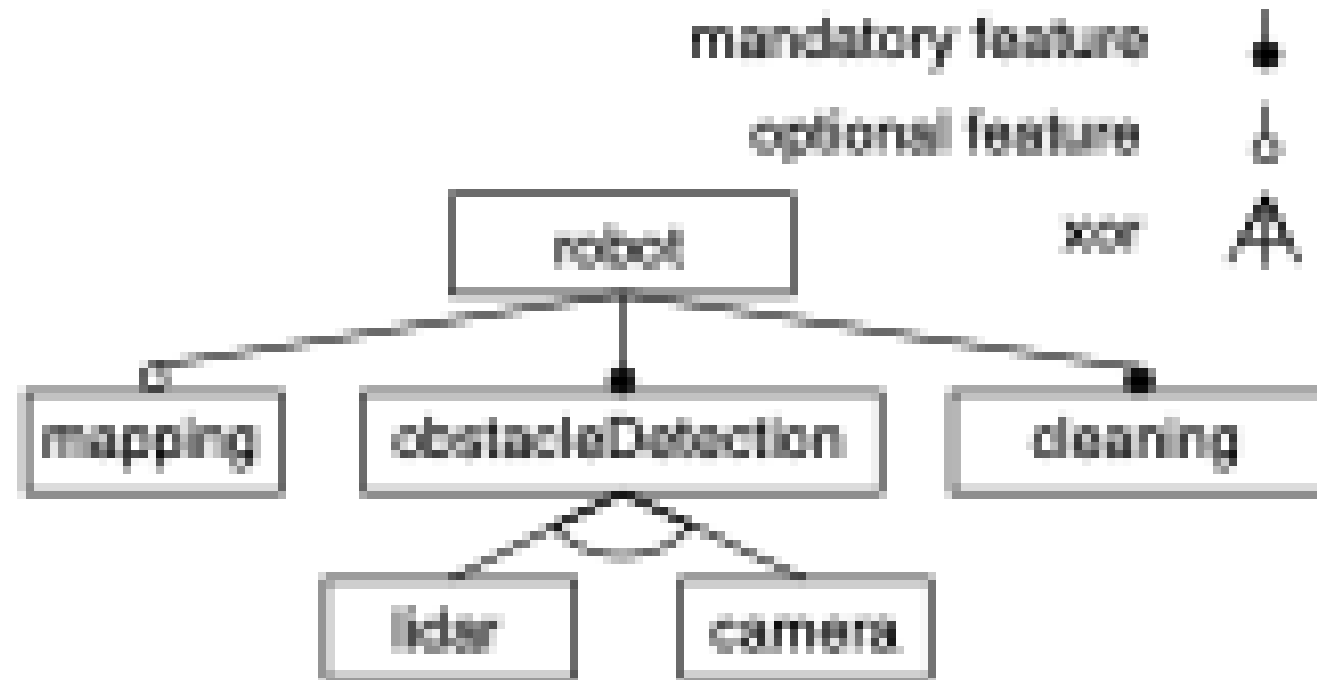


Evaluation

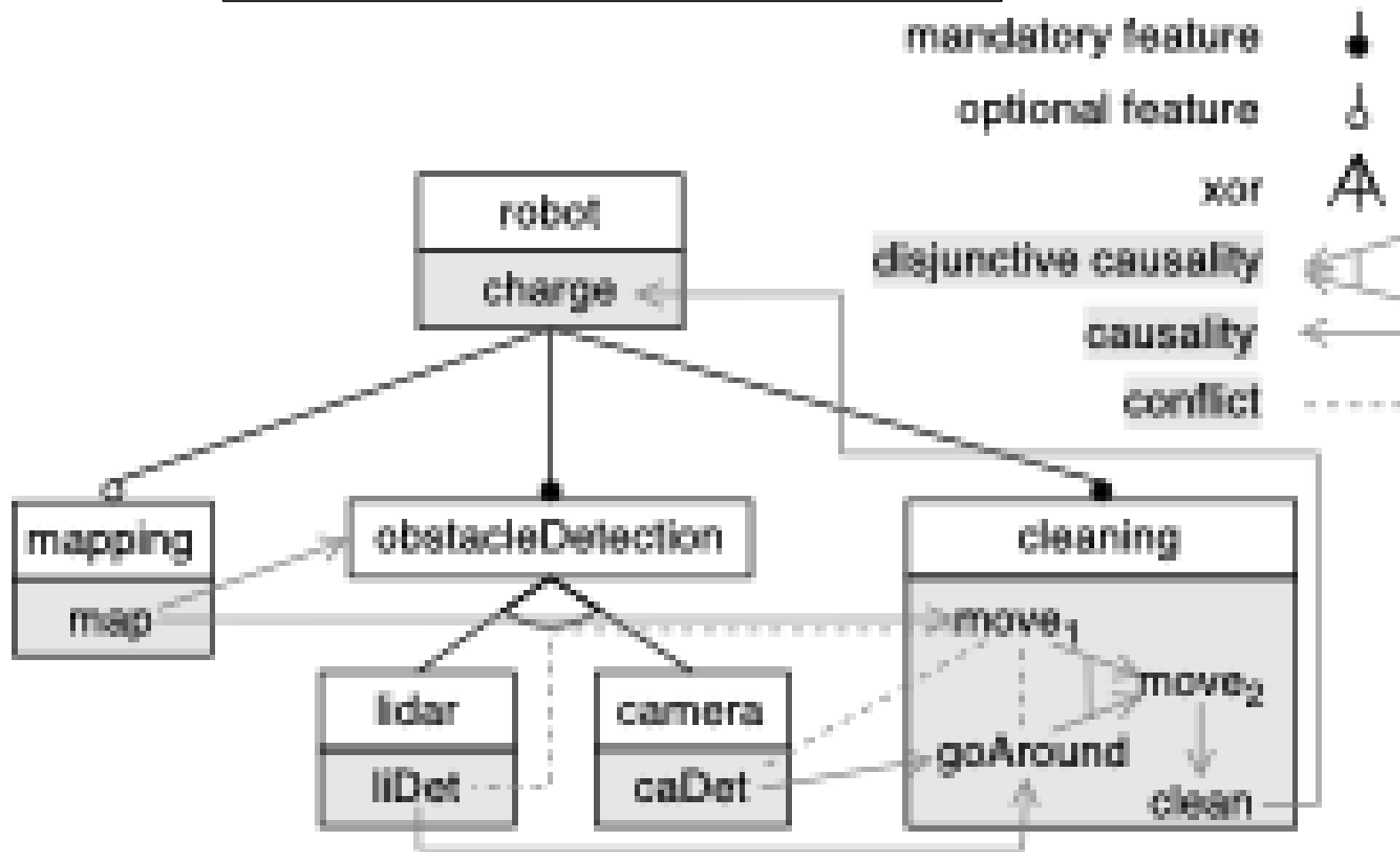


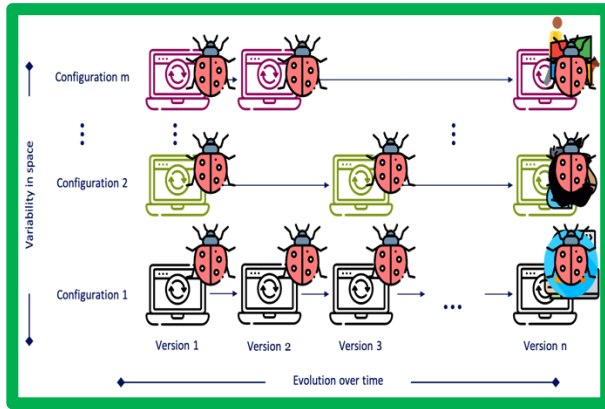
Road Ahead

Feature Models

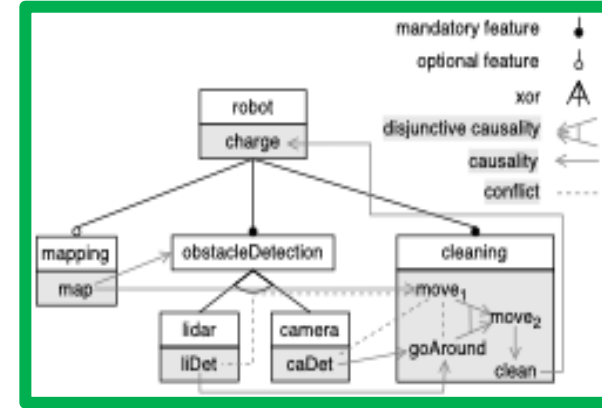


Behavioural Feature Models





Variability Modelling ✓



Behavioural Feature Models ✓



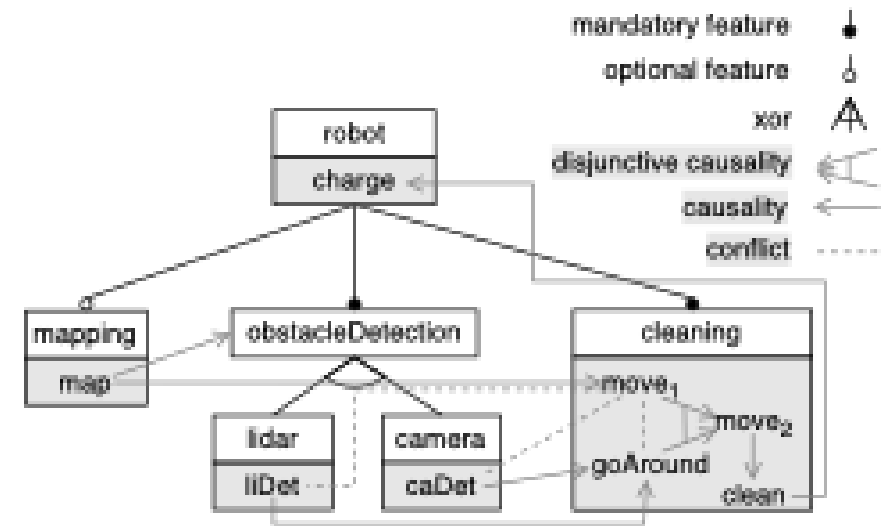
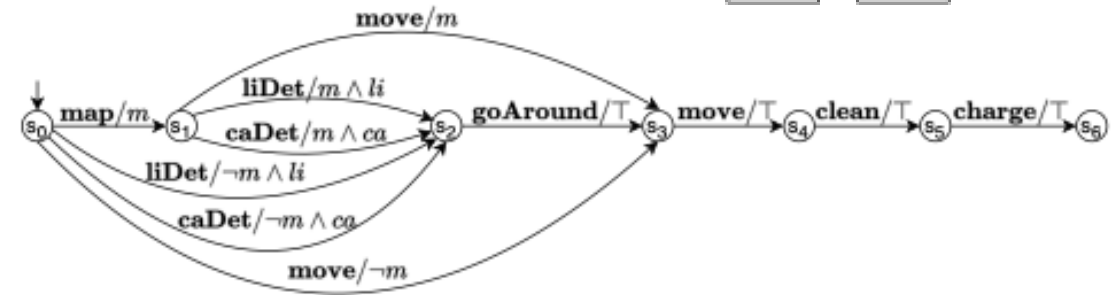
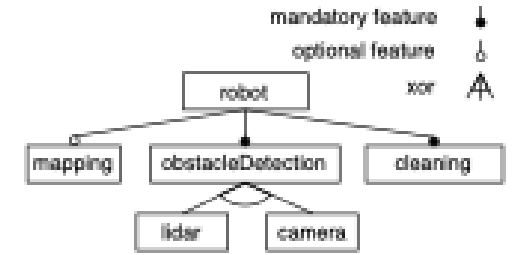
Evaluation



Road Ahead

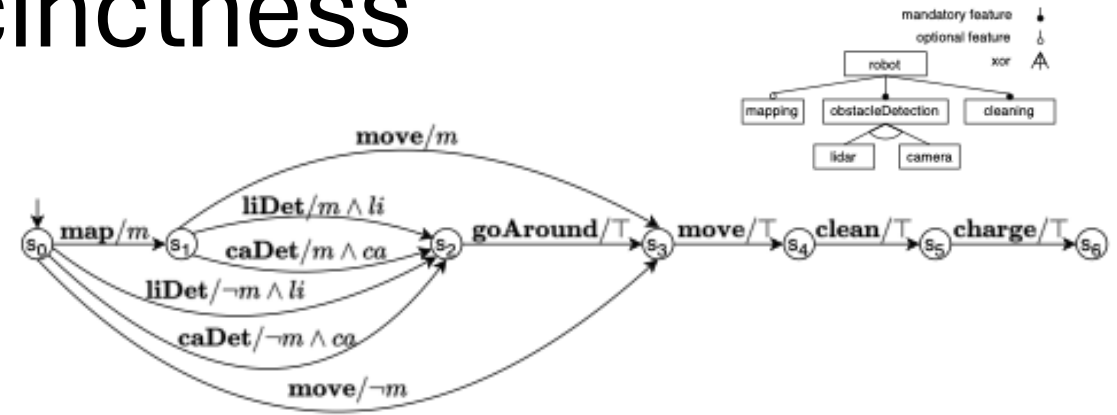
Research Questions

- **RQ1.** How do the **expressiveness** and **succinctness** of BFM compare to FTSs?
- **RQ2.** In practice, how does the **size** of a BFM compare to the size of an FTS?

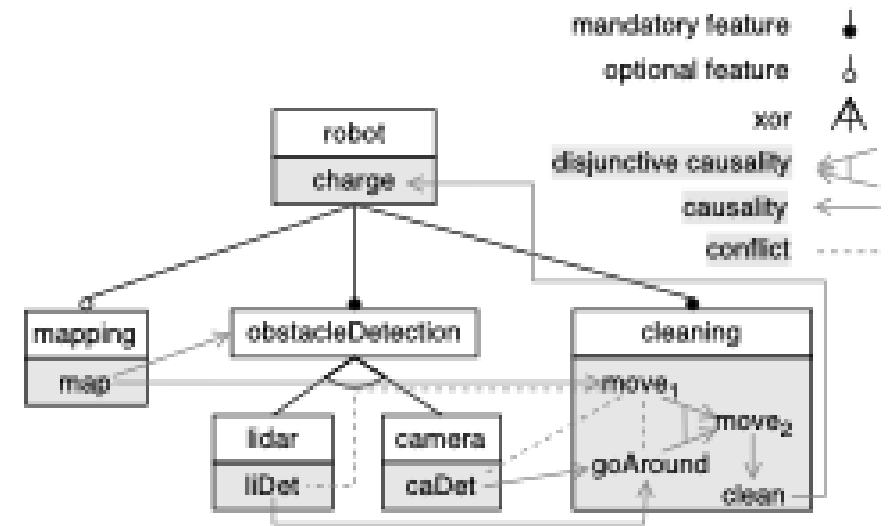


RQ1: Expressiveness, Succinctness

- For every **acyclic FTS**, there is a **trace-equivalent BFM** with at most **polynomial growth** in size.



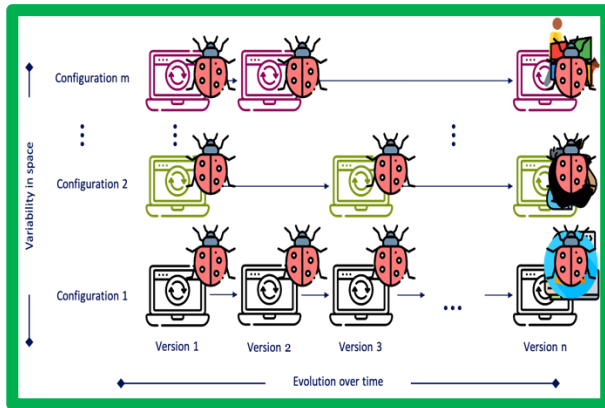
- For every **BFM**, there is a **trace-equivalent FTS**, with an **exponential blow-up** in size.



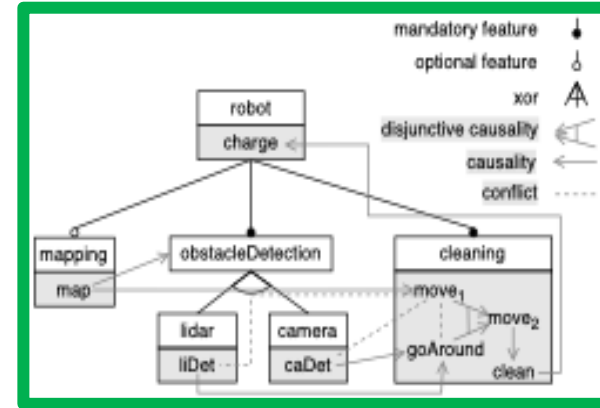
RQ2: Practical Size

Mine Pump system in parallel composition with synchronization over common events

C M	33	66	137	236	115	33	30 (29)	31	94	642.395 ms
C P	37	27	38	102	115	37	35 (35)	36	108	16.094 ms
C W	38	68	130	236	120	38	40 (35)	36	114	509.015 ms
C M W	40	204	526	770	127	40	40 (35)	37	117	19.659 s
C P M	39	81	168	288	122	39	35 (35)	37	111	908.914 ms
C P W	34	60	110	204	127	34	31 (31)	32	97	260.106 ms
C S M	66	150	292	508	261	66	53 (57)	61	180	4.111 s
C S P	71	55	71	197	261	71	56 (59)	67	194	58.699 ms
C S W	90	152	276	518	266	90	78 (74)	85	253	3.754 s
C P M W	36	180	450	666	134	36	31 (31)	33	100	12.822 s
C S M W	92	456	1132	1680	273	92	78 (74)	86	256	3.181 min
C S P M	73	165	323	561	268	73	56 (59)	68	197	5.360 s
C S P W	68	112	198	378	273	68	53 (60)	63	184	1.217 s
C S P M W	70	336	818	1224	280	70	53 (60)	64	187	1.188 min



Variability Modelling 



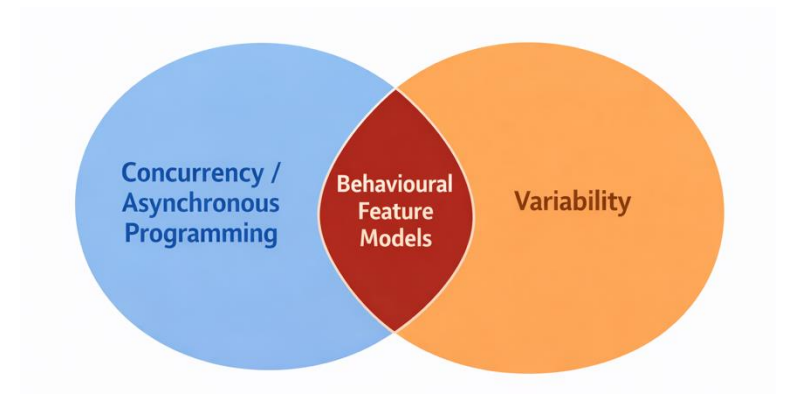
Behavioural Feature Models 



Evaluation 



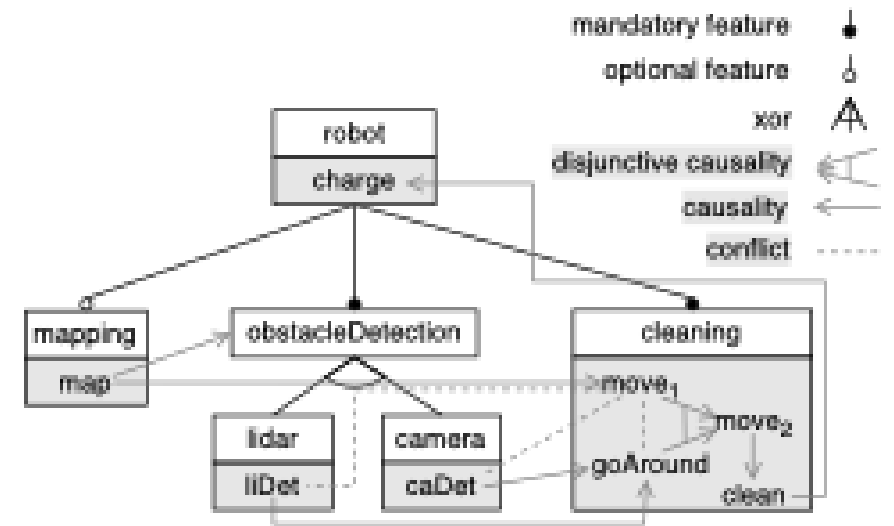
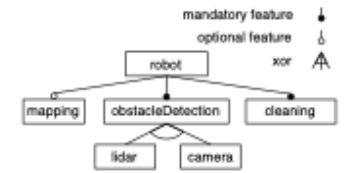
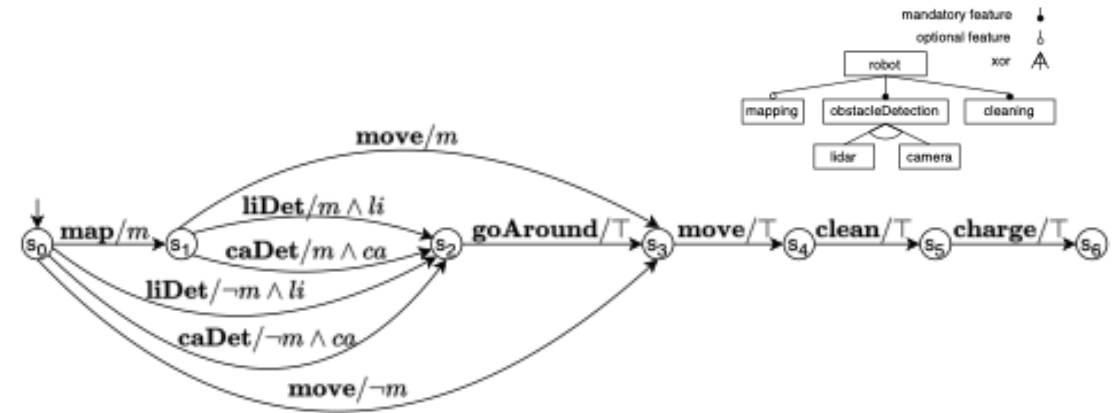
Road Ahead



Marrying **concurrency theory** with **variability modelling** leads to **behavioural variability model** that is **compositional, expressive, and succinct**.

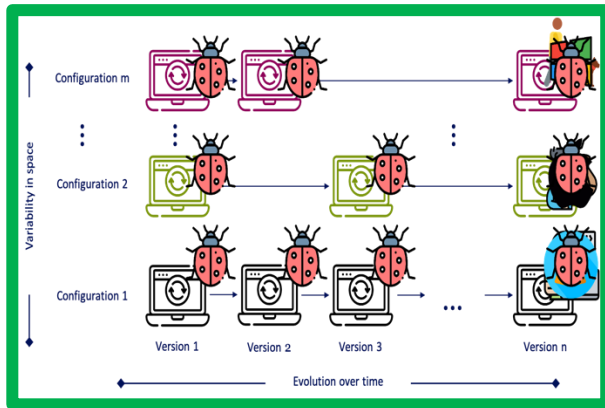
Future Work

- Other **composition operators**
- Compositional **model-checking**
- Compositional **model learning**

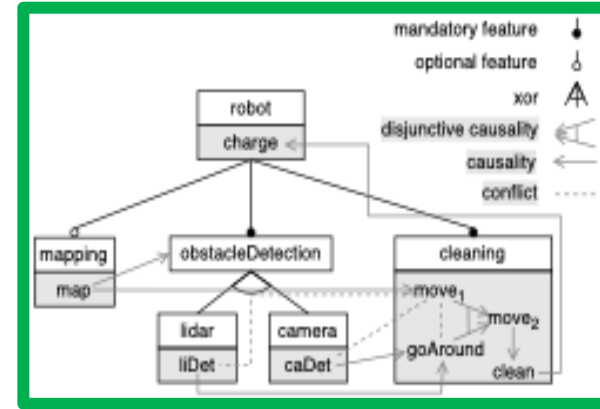


Henry, MRM, Neele, Sammartino.

Compositional Active Learning of Synchronizing Systems through Automated Alphabet Refinement.



Variability Modelling 



Behavioural Feature Models 



Evaluation 



Road Ahead 

Thank you

Mohammad Mousavi

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