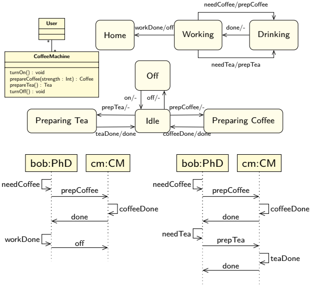
Guided Merging of Sequence Diagrams

Magdalena Widl

Knowledge-Based Systems Group
Vienna University of Technology

Motivation and Scope



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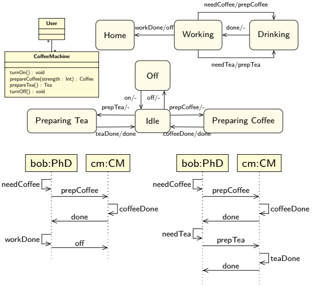

Model-Driven Engineering

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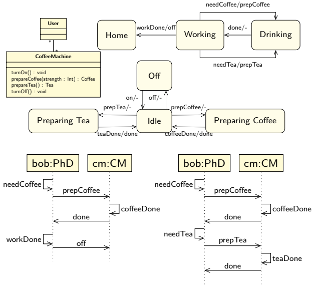
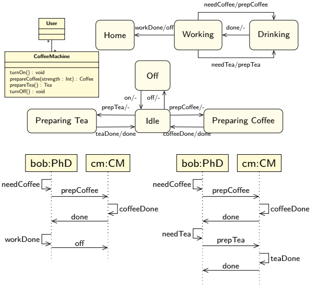


Model-Driven Engineering

Model Evolution

Motivation and Scope



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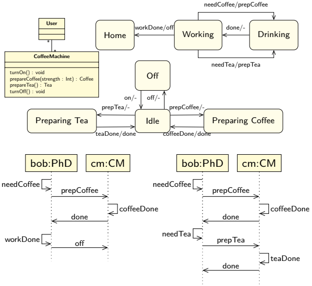

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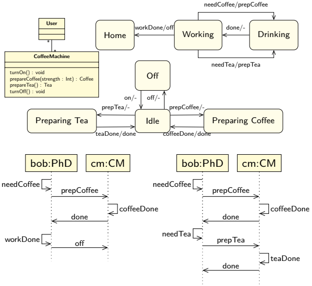

Model-Driven Engineering

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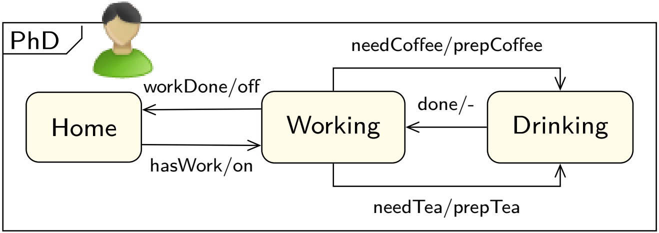
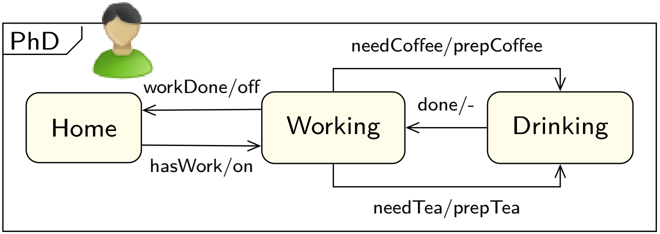
Multi-View Modelling

Example


PhD
needCoffee/prepCoffee
workDone/off
done/-
Home
Working
Drinking
hasWork/on
needTea/prepTea

Example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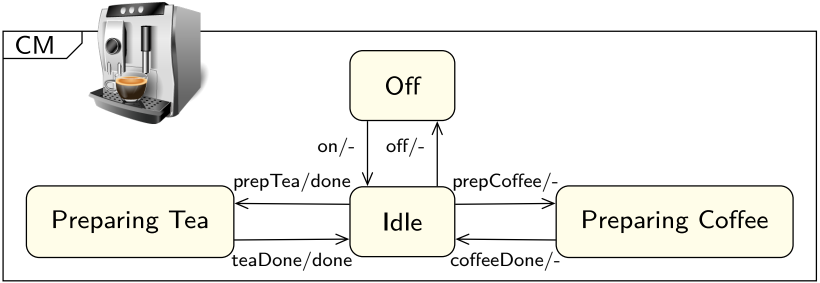
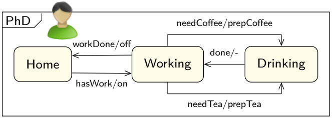

CM
Off
on/-
off/-
prepTea/done
prepCoffee/-
Preparing Tea
Idle
Preparing Coffee
teaDone/done
coffeeDone/-

Example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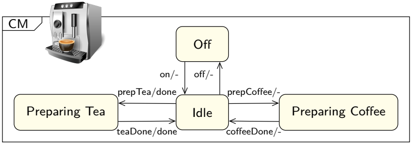
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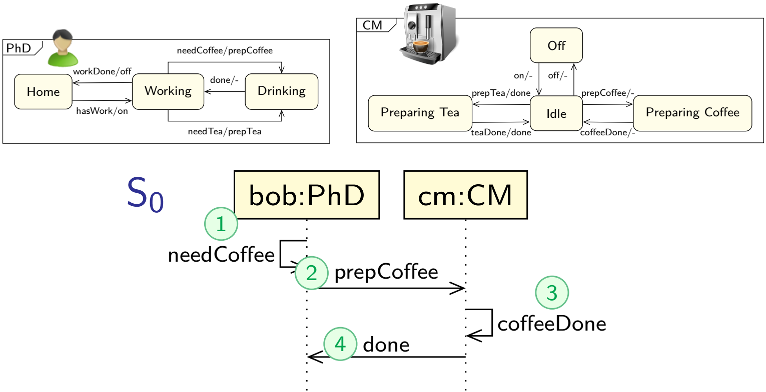
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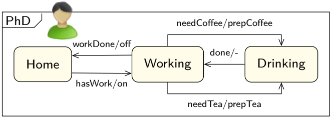
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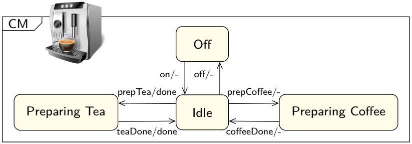
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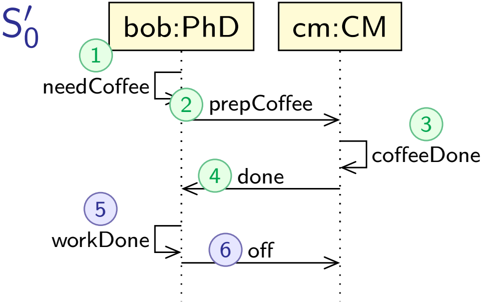
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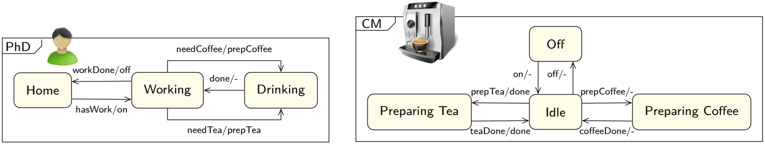

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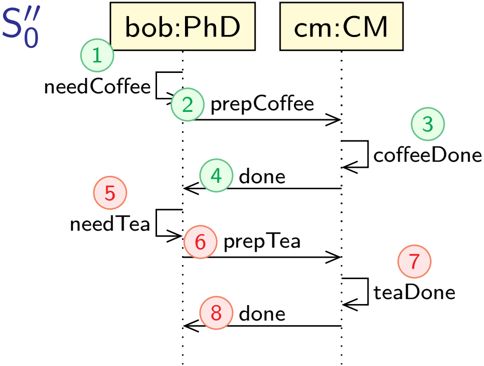

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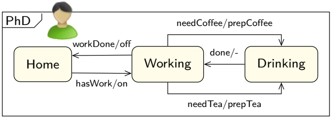
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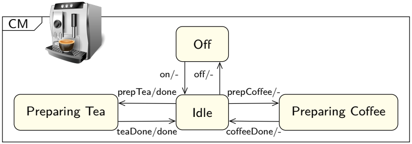
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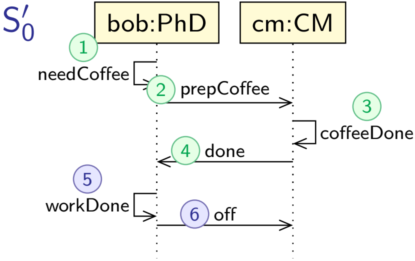
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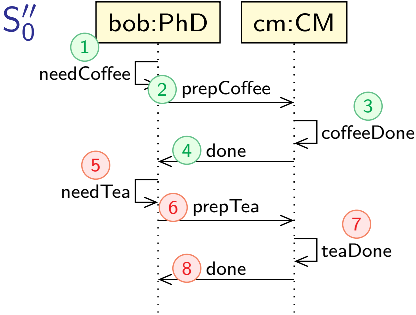
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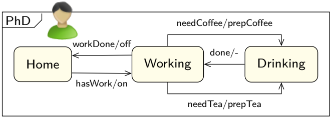
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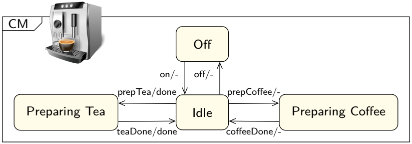
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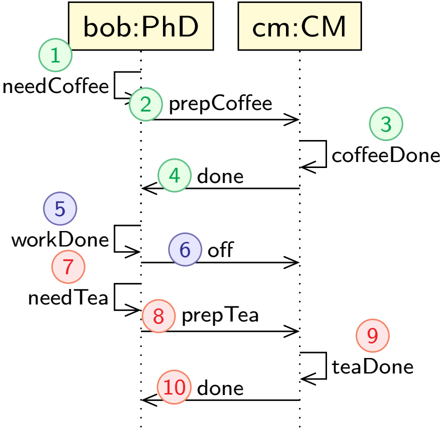
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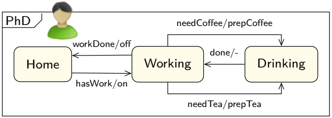
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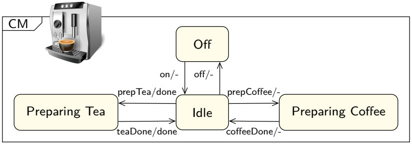
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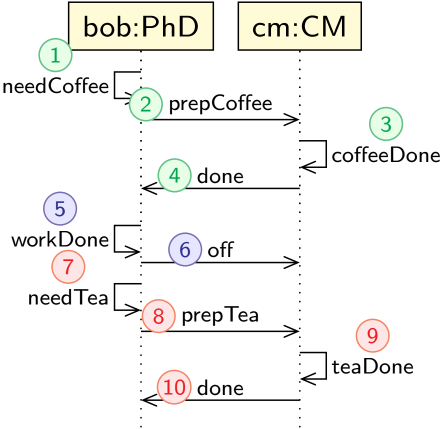
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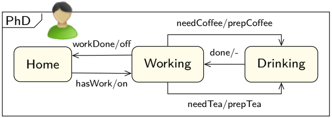

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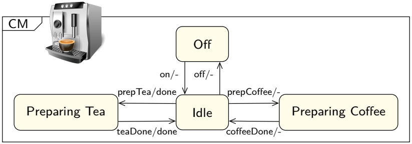

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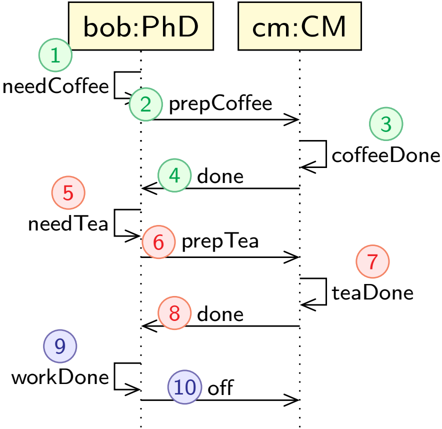

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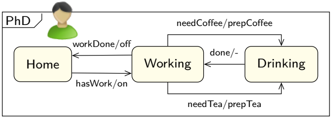

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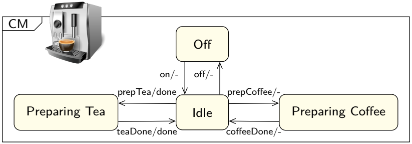

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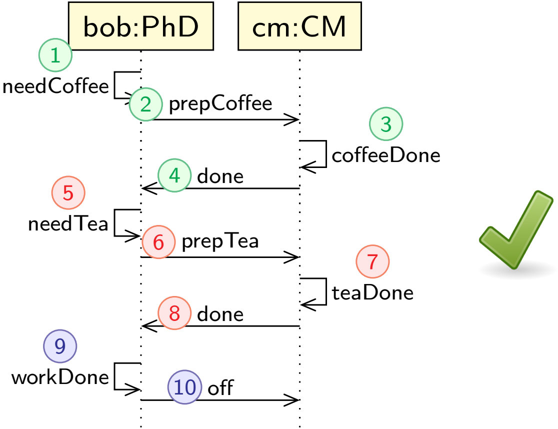

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Guided Merging of Sequence Diagrams

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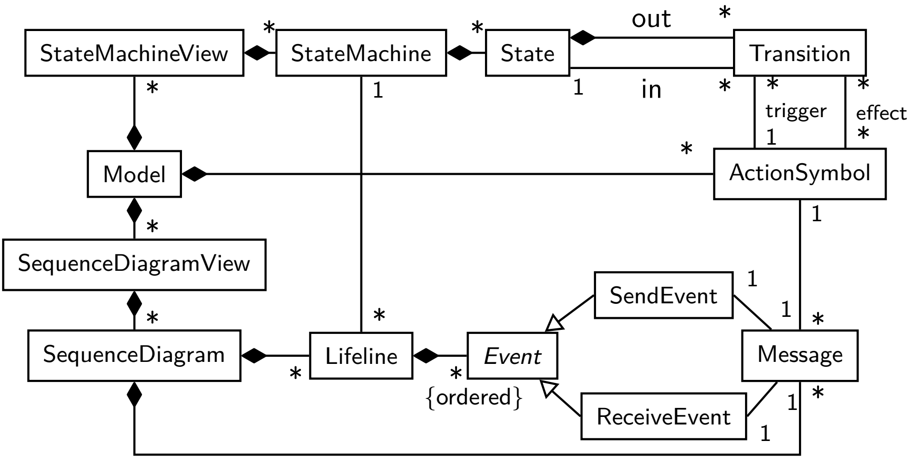
Formalization

The *tMVML* Metamodel



Formalization

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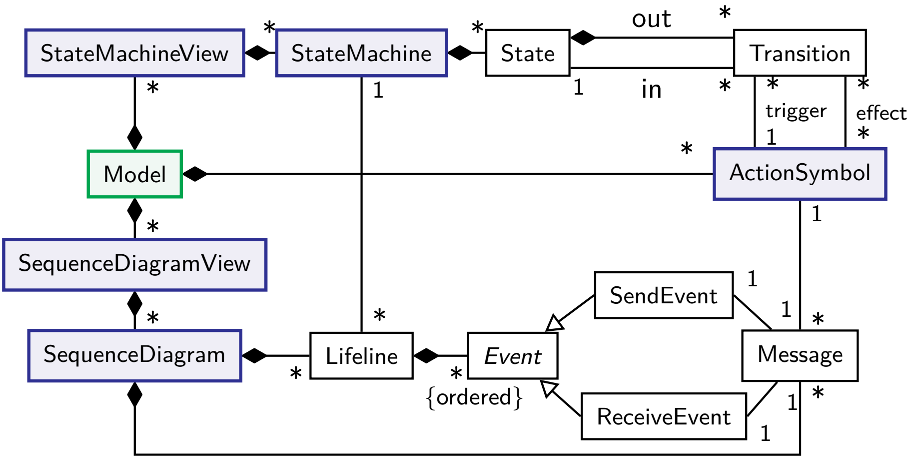

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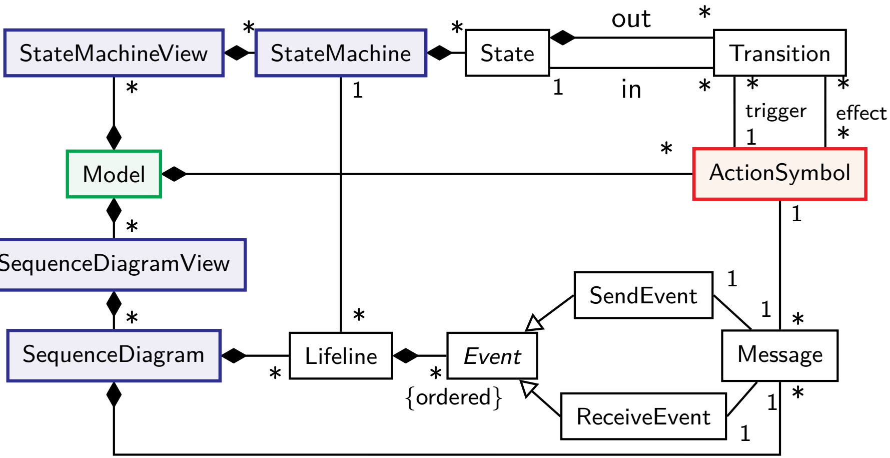

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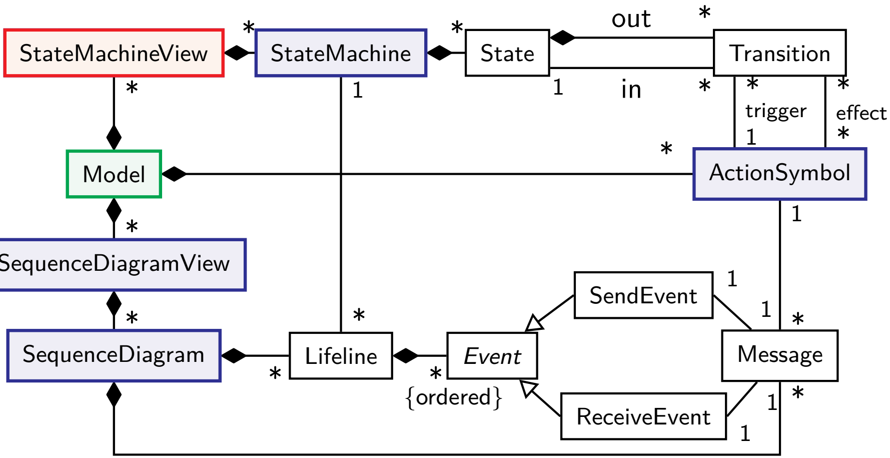

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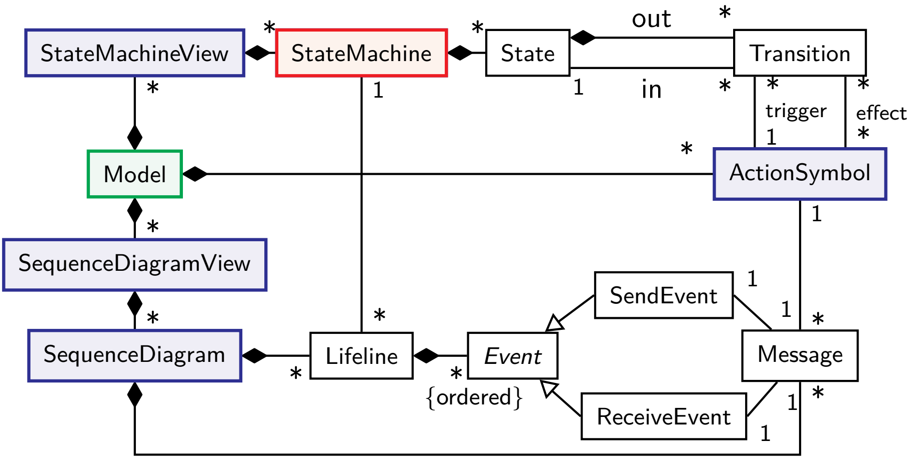

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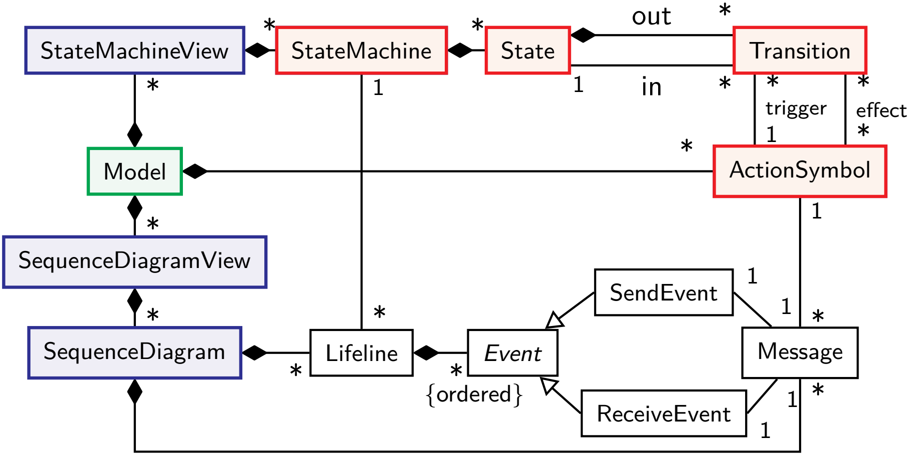
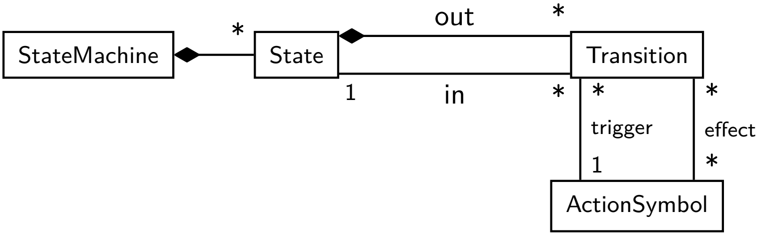


Formalization

State Machine



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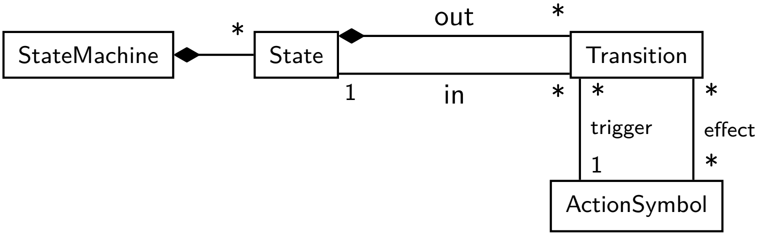

Given an alphabet $\mathcal{A}_A$, a state machine is a quadruple (S, A^{tr}, A^{eff}, T), where

- S is a set of states,
- $A^{tr}, A^{eff} \subseteq \mathcal{A}_A$ are sets of action symbols, and
- $T \subseteq (S \times A^{tr} \times \mathcal{P}(A^{eff}) \times S)$ is a relation representing the transitions between states.

Formalization

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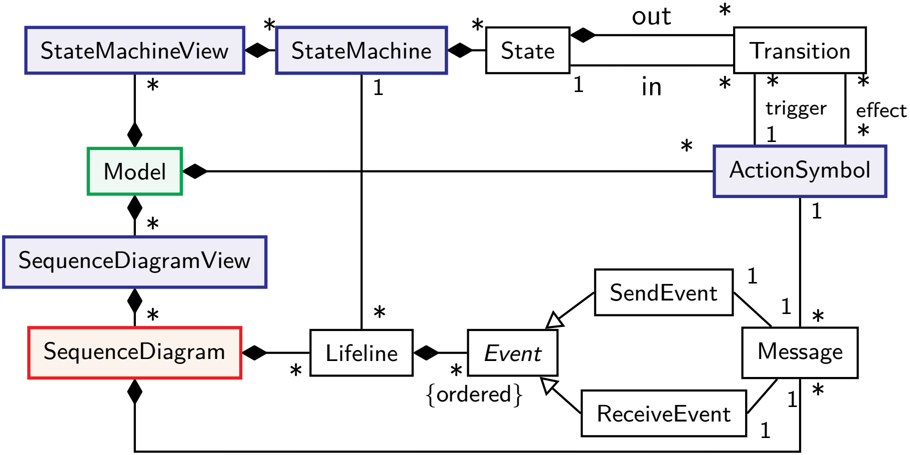

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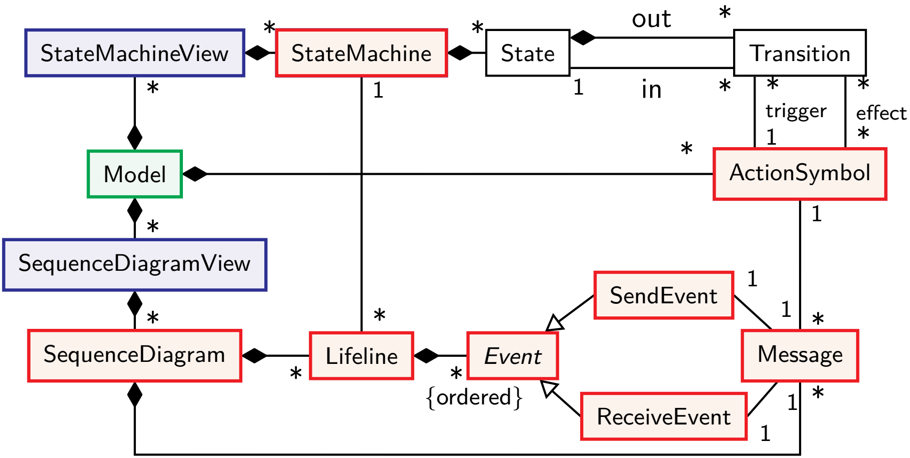
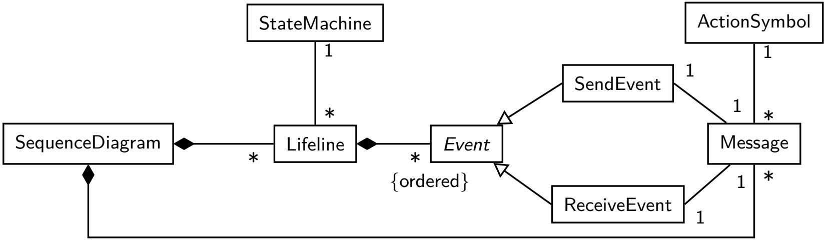


Formalization

Sequence Diagram



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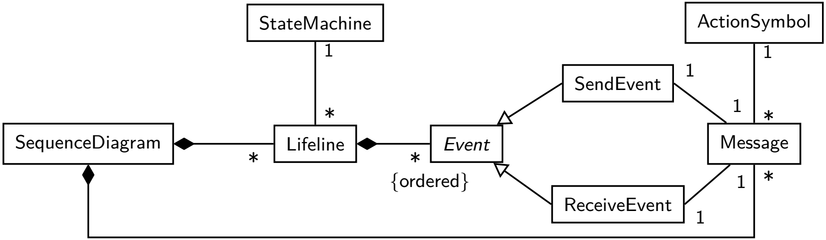

Given the alphabets $\mathcal{A}_A$ and $\mathcal{A}_E$, and a set $\mathcal{SM}$ of state machines, a sequence diagram is a quadruple $(L, M, \mathsf{life}, \mathsf{msg})$, where

- L is a set of lifelines,
- M is a set of messages,
- life : $L \to (\mathcal{SM} \times \mathcal{P}(\mathcal{A}_E) \times \mathcal{P}(\mathcal{A}_E) \times \mathcal{P}(\mathcal{A}_E \times \mathcal{A}_E))$
- msg : $M \to (\mathcal{A}_A \times \bigcup_{l \in L} \pi_2(\mathsf{life}(l)) \times \bigcup_{l \in L} \pi_3(\mathsf{life}(l)))$.

Formalization

Sequence Diagram

Lifeline conformance: For each lifeline, the sequence of received message symbols is a path of triggers in the attached state machine.

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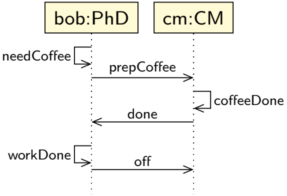

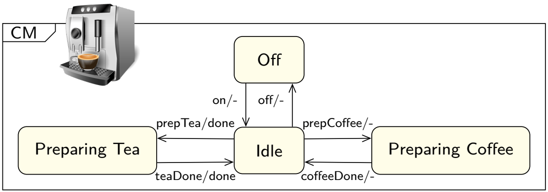

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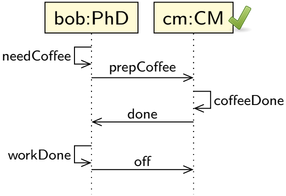
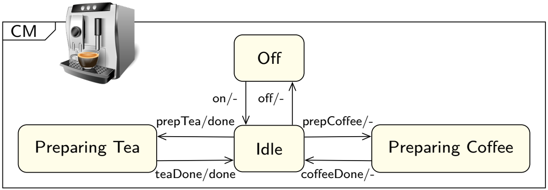
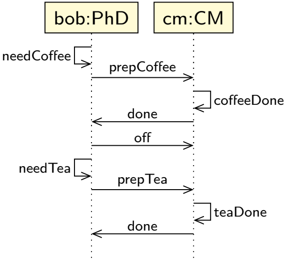


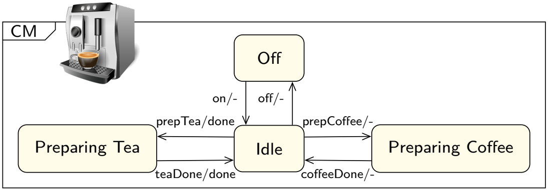


Formalization

Sequence Diagram

Lifeline conformance: For each lifeline, the sequence of received message symbols is a path of triggers in the attached state machine.





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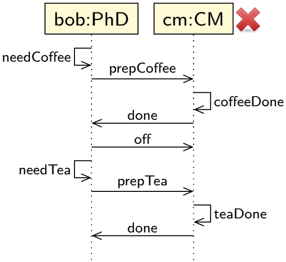
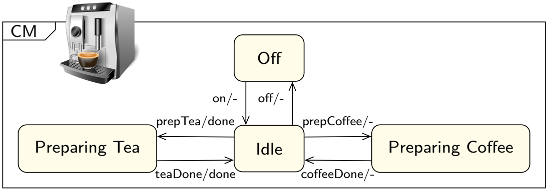
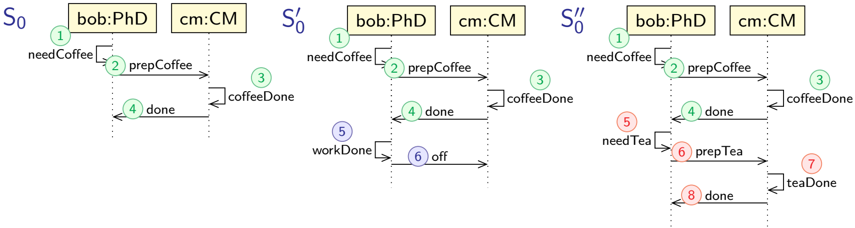




Problem statement

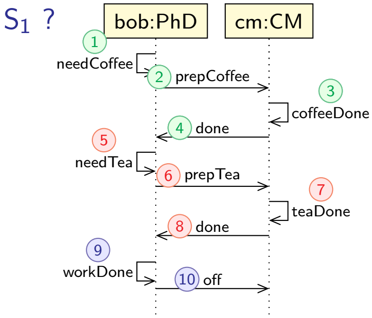
Instance: A sequence diagram and two of its *revisions*.

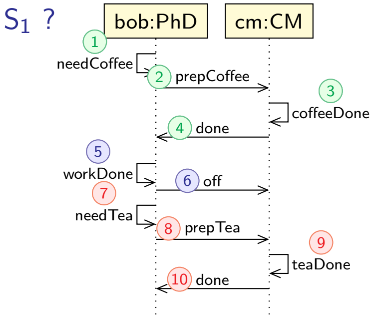


Problem statement

Objective: Find a *consolidated version*

- Contains all original and added messages and lifelines
- Lifelines conform to state machines





Guided Merging of Sequence Diagrams

Our Contributions

- Formalization of state machine, sequence diagram, formal problem statement
- **Translation to propositional SAT Problem**
- Implementation and evaluation

Translation to propositional SAT

Three types of variables

- m_i, m: message, i: position
- c_i^s, s: state in state machine, i: position, c: “source”
- t_i^s, s: state in state machine, i: position, t: “target”

Translation to propositional SAT

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Propositional formula consists of constraints that describe legal solutions, e.g.

$$(m_1 \vee m_2 \vee m_3) \wedge (\neg m_1 \vee \neg m_2) \wedge (\neg m_2 \vee \neg m_3) \wedge (\neg m_1 \vee \neg m_3)$$

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$$m_1 \rightarrow ((c_1^{s1} \wedge t_1^{s2}) \vee (c_1^{s3} \wedge t_1^{s4}))$$

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The encoding is polynomial in the input size.
Satisfying assignments of the formula can be directly translated back into a solution of our problem.

Translation to propositional SAT

$$\bigwedge_{m \in M} \left(\bigvee_{i \in \mathsf{allow}(m)} m_i \right) \wedge \bigwedge_{m \in M} \bigwedge_{\substack{i,j \in \mathsf{allow}(m) \\ i \neq j}} \left(\neg m_i \vee \neg m_j \right)$$

$$\bigwedge_{x \in \{o, \alpha, \beta\}} \bigwedge_{m \in M^x} \bigwedge_{i \in \mathsf{allow}(m)} \left(\neg m_i \vee \bigvee_{\substack{n \in M^x, \\ n \succ m}} \bigvee_{\substack{j > i, \\ j \in \mathsf{allow}(n)}} n_j \right)$$

$$\bigwedge_{i \in \mathsf{allow}(m)} \left(\neg m_i \vee \bigvee_{t \in \mathsf{trans}(m)} \left(c_i^{\pi_1(t)} \wedge t_i^{\pi_4(t)} \right) \right)$$

$$\bigwedge_{i=1}^{k} \left(\left(\bigvee_{c_i^s \in \mathsf{vc}} c_i^s \right) \wedge \left(\bigvee_{t_i^s \in \mathsf{vt}} t_i^s \right) \wedge \bigwedge_{s \in S_{all}} \bigwedge_{r \in S_{all} \setminus s} \left((\neg c_i^s \vee \neg c_i^r) \wedge (\neg t_i^s \vee \neg t_i^r) \right) \right)$$

$$\bigwedge_{i=1}^{k-1} \bigwedge_{M \in \mathcal{SM}} \bigwedge_{s \in \pi_1(SM)} \left(\left(t_i^s \rightarrow \bigwedge_{r \in \pi_1(SM) \setminus s} \neg c_{i+1}^r \right) \wedge \left(\bigwedge_{j=1}^{i} \left(t_i^s \wedge \bigwedge_{l=1}^{j} \neg c_l^s \rightarrow \bigwedge_{r \in \pi_1(SM) \setminus s} \neg c_{j+1}^r \right) \right) \right)$$

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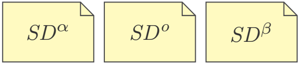

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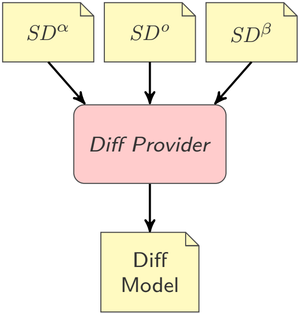

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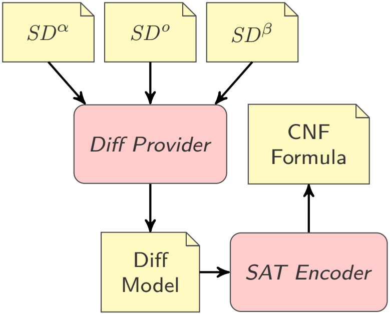

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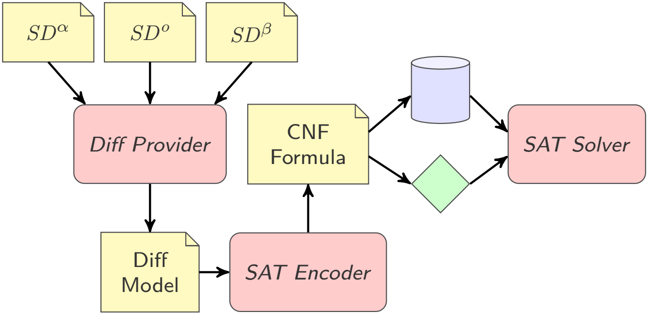

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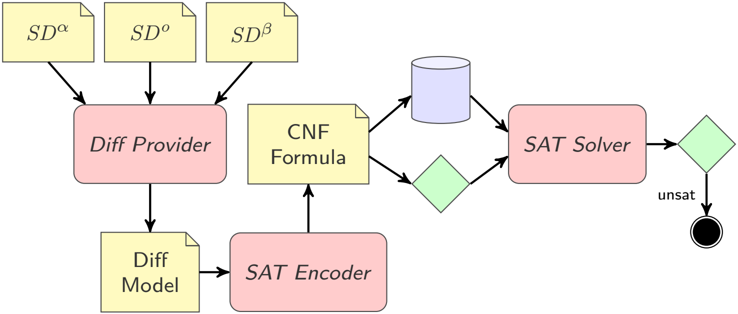

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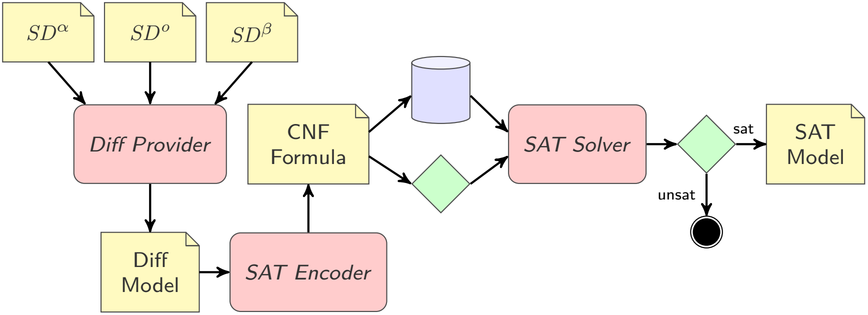

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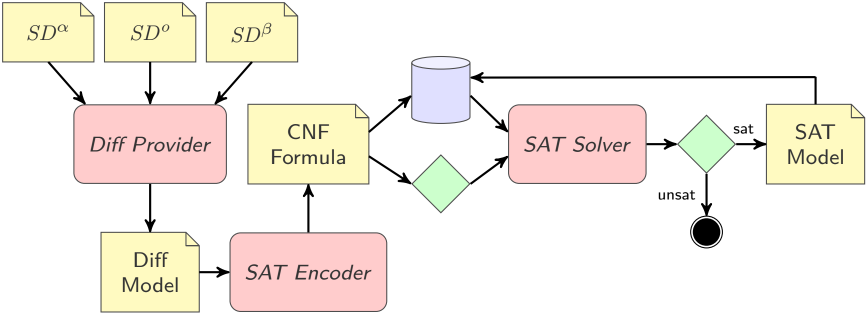

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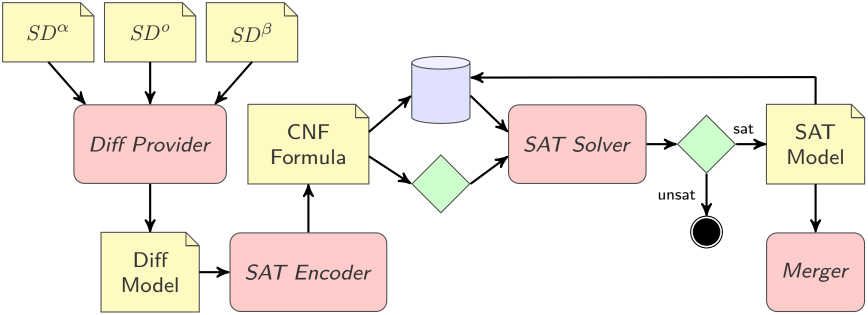

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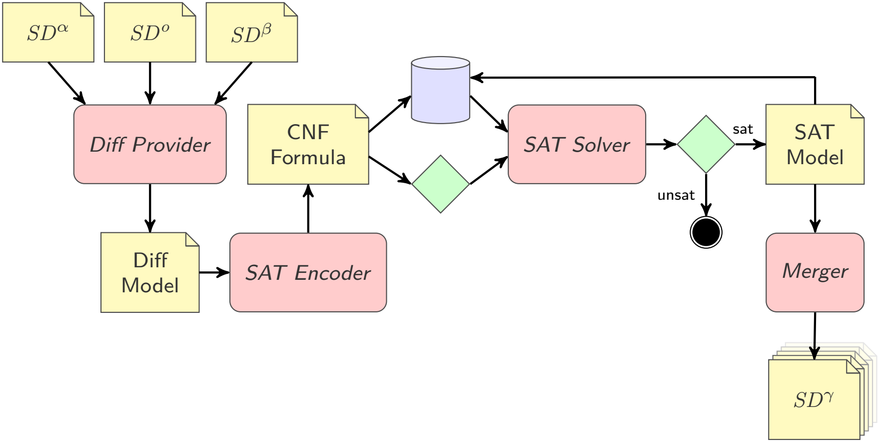

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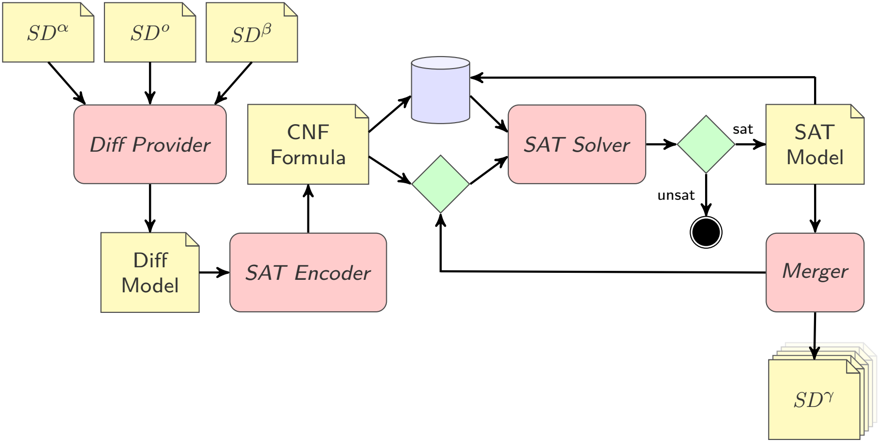

Evaluation

- Benchmark set with 45 instances

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Results

- Between 0.06s and 0.2s per solution depending on instance
- Some instances have many solutions (>1,000)

Summary and Future Work

We

- Formalized a subset of the UML in our language *tMVML*

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- Integration of other UML concepts
- Visualization

Related Work

Model merging:

- *Gerth et al.*, Merge support for business process models using term rewriting systems
- *Cicchetti et al.*, Definition of conflict patterns
- *Nejati et al.*, Merging of state machines

Consistency checking:

- *Diskin et al.*, Category theory based framework
- *Van der Straeten et al.*, Inconsistency detection between class and sequence diagrams using Kodkod
- *Sabatzadeh et al.*, Consistency checks between overlapping models
- *Tsoliakis*, Integration of constraints of other views into sequence diagrams
- *Brosch et al.*, Model checking on state machines and sequence diagrams