# Software Design, Modelling and Analysis in UML

## Lecture 17: Reflective Description of Behaviour, Live Sequence Charts I

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## Contents & Goals

**Last Lecture:**

- Hierarchical State Machines
- **Later:** Remaining pseudo-states, such as shallow/deep history; active vs. passive; behavioural feature.

**This Lecture:**

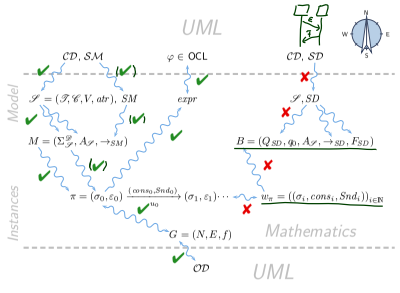
- **Educational Objectives:** Capabilities for following tasks/questions.
  - What does this LSC mean?
  - Are this UML model's state machines consistent with the interactions?
  - Please provide a UML model which is consistent with this LSC.
  - What is: activation, hot/cold condition, pre-chart, etc.?
- **Content:**
  - Reflective description of behaviour.
  - LSC concrete and abstract syntax.
  - LSC intuitive semantics.
  - Symbolic Büchi Automata (TBA) and its (accepted) language.



*You are here.*



## Course Map






## Motivation: Reflective, Dynamic Descriptions of Behaviour



## Recall: Constructive vs. Reflective Descriptions

[Harel, 1997] proposes to distinguish constructive and reflective descriptions:

- *"A language is* **constructive** *if it contributes to the dynamic semantics of the model. That is, its constructs contain information needed in executing the model or in translating it into executable code."*

  A constructive description tells **how** things are computed (which can then be desired or undesired).
- *"Other languages are* **reflective** *or* **assertive***, and can be used by the system modeler to capture parts of the thinking that go into building the model – behavior included –, to derive and present views of the model, statically or during execution, or to set constraints on behavior in preparation for verification."*

  A reflective description tells **what** shall or shall not be computed.

**Note:** No sharp boundaries!

## Recall: What is a Requirement?

**Recall**:

- The **semantics** of the **UML model** $\mathcal{M} = (\mathscr{CD}, \mathscr{SM}, \mathscr{OD})$ is the **transition system** $(S, \rightarrow, S_0)$ constructed according to discard/dispatch/commence-rules.
- The **computations of** $\mathcal{M}$, denoted by $[\![\mathcal{M}]\!]$, are the computations of $(S, \rightarrow, S_0)$.

**Now**:

A reflective description tells **what** shall or shall not be computed.

**More formally**: a requirement $\vartheta$ is a property of computations, sth. which is either satisfied or not satisfied by a computation

$$\pi = (\sigma_0, \varepsilon_0) \xrightarrow{(cons_0, Snd_0)} (\sigma_1, \varepsilon_1) \xrightarrow{(cons_1, Snd_1)} \cdots \in [\![\mathcal{M}]\!],$$

denoted by $\pi \models \vartheta$ and $\pi \not\models \vartheta$, resp.



## OCL as Reflective Description of Certain Properties

- **invariants**:
  $\mathcal{M} \vDash \vartheta$ iff $\forall \pi \in [\![\mathcal{M}]\!] \, \forall i \in \mathbb{N} : \pi^i \models \vartheta$, (the $i$-th $(\sigma,\varepsilon)$-pair in $\pi$)
- **non-reachability of configurations**:
  $$\nexists \pi \in [\![\mathcal{M}]\!] \, \nexists i \in \mathbb{N} : \pi^i \models \vartheta$$
  $$\iff \forall \pi \in [\![\mathcal{M}]\!] \, \forall i \in \mathbb{N} : \pi^i \models \neg\vartheta$$
- **reachability of configurations**:
  $$\exists \pi \in [\![\mathcal{M}]\!] \, \exists i \in \mathbb{N} : \pi^i \models \vartheta$$
  $$\iff \neg(\forall \pi \in [\![\mathcal{M}]\!] \, \forall i \in \mathbb{N} : \pi^i \models \neg\vartheta)$$

where

- $\vartheta$ is an OCL expression or an object diagram and
- "$\models$" is the corresponding OCL satisfaction
  or the "is represented by object diagram" relation.



## In General Not OCL: Temporal Properties

**Dynamic** (by example)

- **reactive behaviour**
  - **"for each $C$ instance, each reception of $E$ is finally answered by $F$"**
    $$\forall \pi \in [\![\mathcal{M}]\!] : \pi \models \vartheta$$
- **non-reachability** of system configuration **sequences**
  - **"there mustn't be a system run where $C$ first receives $E$ and then sends $F$"**
    $$\nexists \pi \in [\![\mathcal{M}]\!] : \pi \models \vartheta$$
- **reachability** of system configuration **sequences**
  - **"there must be a system run where $C$ first receives $E$ and then sends $F$"**
    $$\exists \pi \in [\![\mathcal{M}]\!] : \pi \models \vartheta$$

**But**: what is "$\models$" and what is "$\vartheta$"?

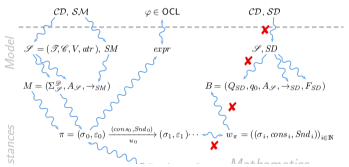


## Interactions: Problem and Plan

**In general**: $\forall(\exists)\ \pi \in [\![\mathcal{M}]\!] : \pi \models(\not\models)\ \vartheta$
**Problem**: what is "$\models$" and what is "$\vartheta$"?

**Plan**:

- Define the **language** $\mathcal{L}(\mathcal{I})$ of an **interaction** $\mathcal{I}$ — via Büchi automata.
- Define the **language** $\mathcal{L}(\mathcal{M})$ of a **model** $\mathcal{M}$ — basically its computations. Each computation $\pi \in [\![\mathcal{M}]\!]$ corresponds to a **word** $w_\pi$.
- Then (conceptually) $\pi \models \vartheta$ if and only if $w_\pi \in \mathcal{L}(\mathcal{I})$.

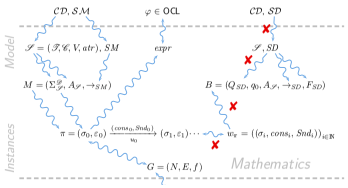





## Interactions: Plan

- In the following, we consider **Sequence Diagrams** as **interaction** $\mathcal{I}$,
- more precisely: **Live Sequence Charts** [Damm and Harel, 2001].
- We define the **language** $\mathcal{L}(\mathcal{I})$ of an LSC — via Büchi automata.
- Then (conceptually) $\pi \models \vartheta$ if and only if $w_\pi \in \mathcal{L}(\mathcal{I})$.

Why LSC, relation LSCs/UML SDs, other kinds of interactions: **later**.






## Live Sequence Charts — Concrete Syntax

## Example

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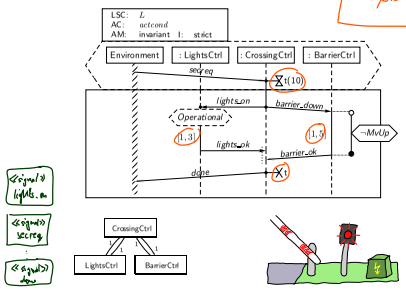
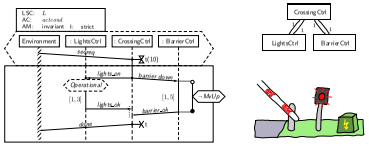




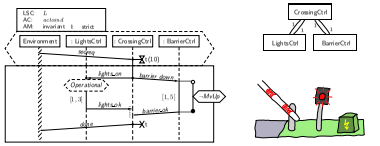

## Example: What Is Required?



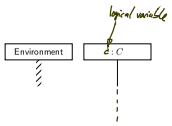
- **Whenever** the CrossingCtrl has consumed a 'secreq' event
- **then** it shall finally send 'lights_on' and 'barrier_down' to LightsCtrl and BarrierCtrl,
- if LightsCtrl **is not** 'operational' when receiving that event,
  the rest of this scenario doesn't apply; maybe there's another LSC for that case.
- if LightsCtrl **is** 'operational' when receiving that event,
  it shall reply with 'lights_ok' within 1–3 time units,
- the BarrierCtrl shall reply with 'barrier_ok' within 1–5 time units, during this time (dispatch time not included) it shall not be in state 'MvUp',
- 'lights_ok' and 'barrier_ok' may occur in any order.
- After having consumed both, CrossingCtrl may reply with 'done' to the environment.



## Building Blocks

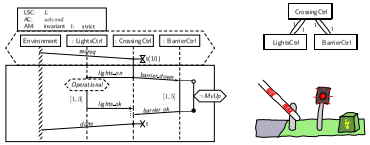


- **Instance Lines:**

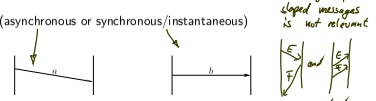





## Building Blocks



- **Messages:** (asynchronous or synchronous/instantaneous)

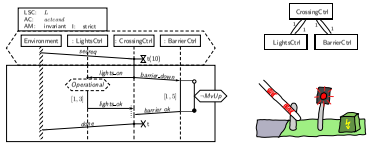



Note: angle of slanted messages is not relevant

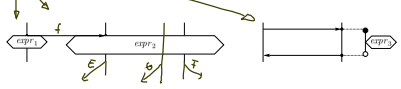





## Building Blocks



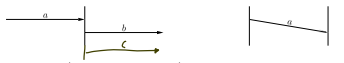
- **Conditions and Local Invariants:** $(expr_1, expr_2, expr_3 \in Expr_{\mathcal{F}})$



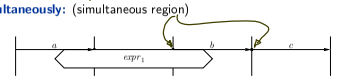



## Intuitive Semantics: A Partial Order on Simclasses

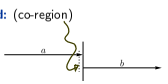
(i) **Strictly After:**




(ii) **Simultaneously:** (simultaneous region)

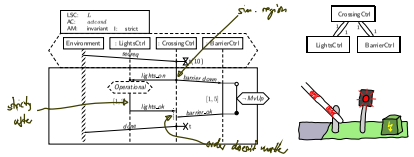



(iii) **Explicitly Unordered:** (co-region)




**Intuition:** A computation path **violates** an LSC if the occurrence of some events doesn't adhere to the partial order obtained as the **transitive closure** of (i) to (iii).

## Partial Order Requirements

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- if LightsCtrl **is** 'operational' when receiving that event, it shall reply with 'lights_ok' ~~within 1–3 time units~~,
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- 'lights_ok' and 'barrier_ok' may occur in any order.
- After having consumed both, CrossingCtrl may reply with 'done' to the environment.

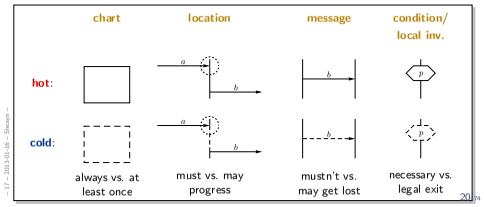


## LSC Specialty: Modes

With LSCs,

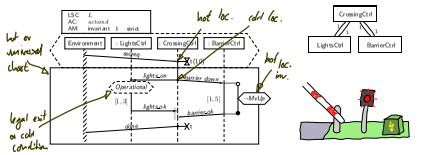
- whole charts,
- locations, and
- elements

have a **mode** — one of **hot** or **cold** (graphically indicated by outline).






## Example: Modes

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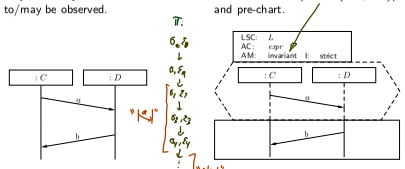
## LSC Specialty: Activation

One **major defect** of **MSCs and SDs**: they don't say **when** the scenario has to/may be observed.

**LSCs**: Activation condition (AC $\in Expr_{\mathscr{S}}$), activation mode (AM $\in \{init, inv\}$), and pre-chart.







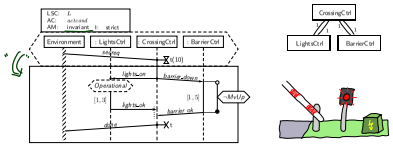
**Intuition**: (universal case)

- given a computation $\pi$, **whenever** $expr$ holds in a configuration $(\sigma_k, \varepsilon_k)$ of $\pi$
  - which is initial, i.e. $k = 0$, or ($AM = initial$)
  - whose $k$ is not further restricted, ($AM = invariant$)

  **and if** the pre-chart is observed from $k$ to $k + n$,
  **then** the main-chart has to follow from $k + n + 1$.



## Example: What Is Required?

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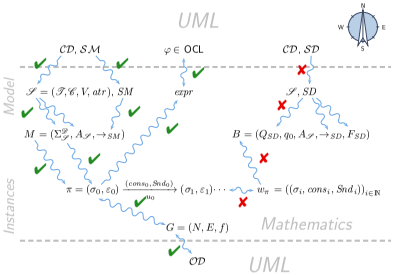

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