Softwaretechnik / Software-Engineering

Lecture 8: Scenarios & Use Cases

2019-05-27

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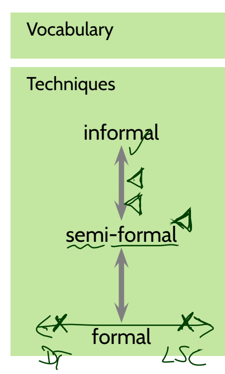
Topic Area Requirements Engineering: Content

VL 5
- **Introduction**
- Definition: **Software** & **SW Specification**
- **Requirements Specification**
  - Desired Properties
  - Kinds of Requirements
  - Analysis Techniques

VL 6
- **Documents**
  - Dictionary, Specification
- **Specification Languages**
  - Natural Language
  - Decision Tables
    - Syntax, Semantics (VL 7)
    - Completeness, Consistency, ...
  - Scenarios (VL 8)
    - User Stories, Use Cases
    - Live Sequence Charts
      - Syntax, Semantics (VL 9)
- **Wrap-Up**

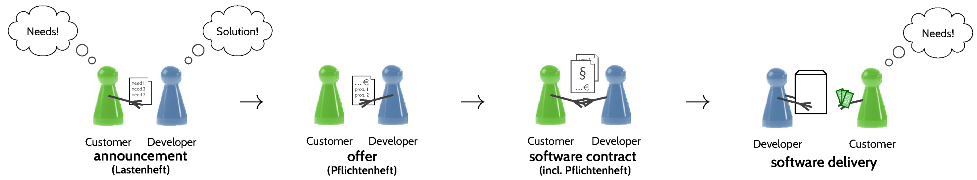


Content

Informatik III
(Automata Theory)

Scenarios

Recall: The Crux of Requirements Engineering



One quite effective approach:

try to **approximate** the requirements with positive and negative **scenarios**.

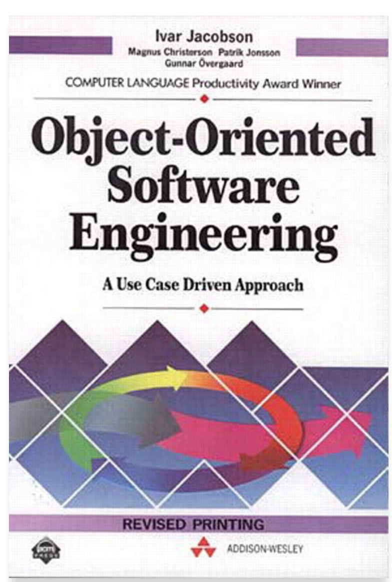
- Dear customer, please describe example usages of the desired system.

  Customer intuition: **"If the system is not at all able to do this, then it's not what I want."**

- Dear customer, please describe behaviour that the desired system must not show.

  Customer intuition: **"If the system does this, then it's not what I want."**

- From there on, refine and generalise:
  what about exceptional cases? what about corner-cases? etc.
- Prominent early advocate: **OOSE** (Jacobson, 1992).



Notations for Scenarios

- The idea of **scenarios** (sometimes without **negative** or **anti-scenarios**) (re-)occurs in many process models or software development approaches.

- In the following, we will discuss two-and-a-half notations:

  - **Use Cases** and Use Case Diagrams (**OOSE**)

  - **User Stories** (part of **Extreme Programming**)

  - **Sequence Diagrams** (here: **Live Sequence Charts** (Damm and Harel, 2001))

Use Cases

Use Case: Definition

Use Case — A **sequence of interactions** between an actor (or actors) and a system triggered by a specific actor, **which produces a result** for an actor. (Jacobson, 1992)

Use Case: More Precisely

- A use case has **participants**: the **system** and at least one **actor**.
- **Actor**: an actor represents what interacts with the system.
  - An actor is a **role**, which a **user** or an **external system** may assume when interacting with the system under design.
  - Actors are not part of the system, thus they are **not described in detail**.
  - Actions of actors are **non-deterministic** (possibly constrained by domain model).
- A use case is triggered by a **stimulus** as input by the **main actor**.
- A use case is **goal oriented**, i.e. the main actor wants to reach a particular goal.
- A use case describes **all interactions** between the system and the participating actors that are needed to achieve the goal (or fail to achieve the goal for reasons).
- A use case **ends** when the desired goal is achieved, or when it is clear that the desired goal cannot be achieved.

name	…
goal	…
pre-condition	…
post-condition	…
post-cond. in exceptional case	…
actors	…
open questions	…
normal case	1. … 2. … 3. …

Use Case Example: ATM Authentication

http://commons.wikimedia.org (CC-by-sa 4.0, Dirk Ingo Franke)

name	Authentication
goal	the client wants access to the ATM
pre-condition	the ATM is operational, the welcome screen is displayed, card and PIN of client are available
post-condition	client accepted, services of ATM are offered
post-cond. in exceptional case	access denied, card returned or withheld, welcome screen displayed
actors	client (main actor), bank system
open questions	none
normal case	1. client inserts card 2. ATM read card, sends data to bank system 3. bank system checks validity 4. ATM shows PIN screen 5. client enters PIN 6. ATM reads PIN, sends to bank system 7. bank system checks PIN 8. ATM accepts and shows main menu
exception case 2a	card not readable 2a.1 ATM displays "card not readable" 2a.2 ATM returns card 2a.3 ATM shows welcome screen

exc. case 2b	card readable, but not ATM card
exc. case 2c	no connection to bank system
exc. case 3a	card not valid or disabled
exc. case 5a	client cancels
exc. case 5b	client doesn't react within 5 s
exc. case 6a	no connection to bank system
exc. case 7a	first or second PIN wrong
exc. case 7b	third PIN wrong

(Ludewig and Lichter, 2013)

Once Again: Use Case Definition

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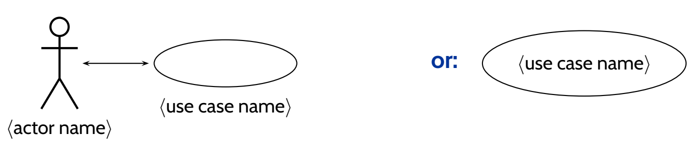
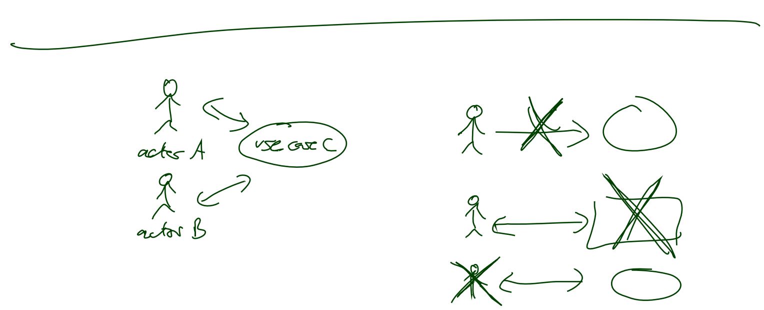
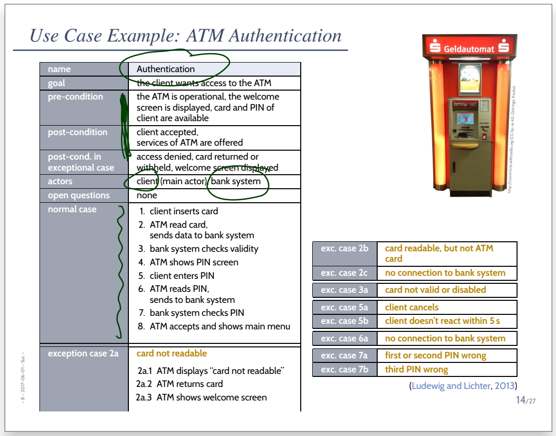
Use Case Diagrams

Use Case Diagrams: Basic Building Blocks







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(Ludewig and Lichter, 2013)

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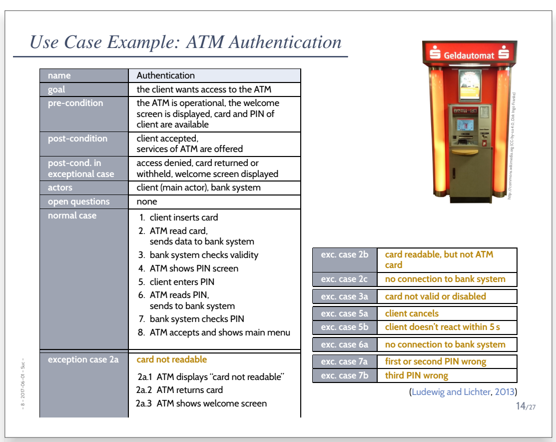

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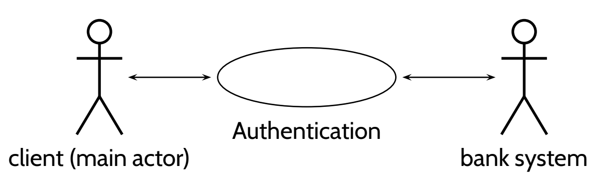
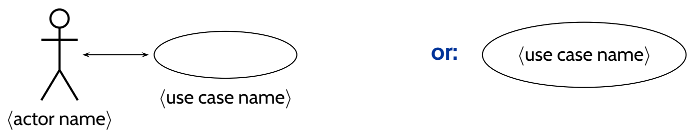
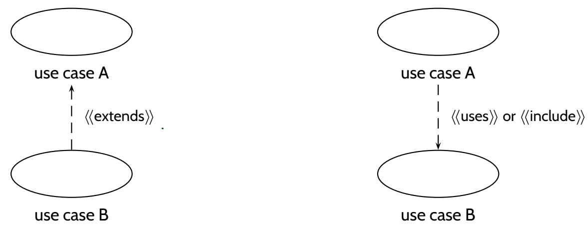


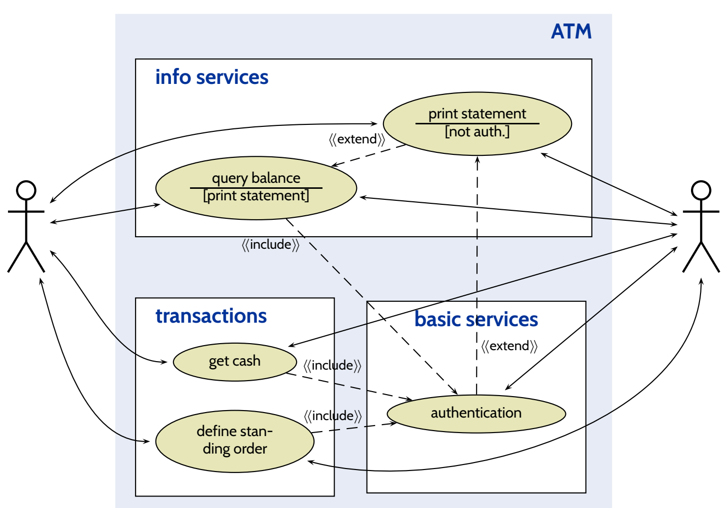
Use Case Diagrams: More Building Blocks



More notation:



Use Case Diagram: Bigger Examples



(Ludewig and Lichter, 2013)

Content

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User Stories

User Stories (Beck, 1999)

*"A User Story is a **concise, written description** of a **piece of functionality** that will be **valuable to a user** (or owner) of the software."*

Per **user story**, use one **file card** — **proposed card layout** (front side):

priority	unique identifier, name	estimation
	As a [role] I want [something] so that [benefit].	
risk		real effort

with

- the **user story**, e.g. following the pattern:

As a [role] I want [something] so that [benefit].

and in addition:

- **unique identifier** (e.g. unique number),
- **priority** (from 1 (highest) to 10 (lowest)) **assigned by customer**,
- **effort**, **estimated by developers**,

- back side of file card: (acceptance) **test case(s)**, i.e., how to tell whether the user story has been realised.

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Natural Language Patterns

Natural language requirements can be (tried to be) written as an instance of the **pattern** "$\langle A\rangle$ $\langle B\rangle$ $\langle C\rangle$ $\langle D\rangle$ $\langle E\rangle$ $\langle F\rangle$." (German grammar) where

A	clarifies when and under what conditions the activity takes place
B	is MUST (obligation), SHOULD (wish), or WILL (intention); also: MUST NOT (forbidden)
C	is either "the system" or the concrete name of a (sub-)system
D	one of three possibilities: • "does", description of a system activity, • "offers", description of a function offered by the system to somebody,

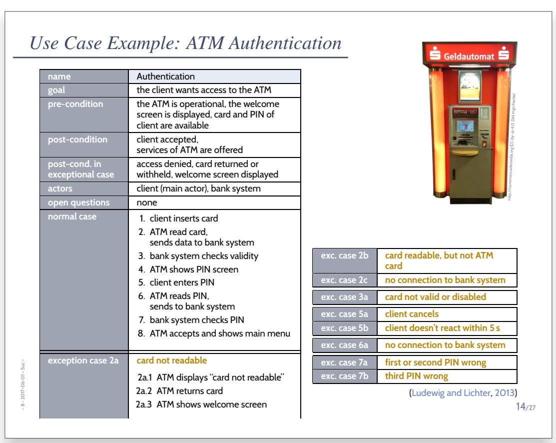
User Stories: Discussion

- ✔ easy to create, small units
- ✔ close contact to customer
- ✔ objective / testable: by fixing test cases early

- ✘ may get difficult to keep overview over whole system to be developed
  $\rightarrow$ maybe best suited for changes / extensions (after first iteration).
- ✘ not designed to cover non-functional requirements and restrictions
- ✘ agile spirit: strong dependency on competent developers
- ✘ estimation of effort may be difficult

(Balzert, 2009)

*Customer **and** Developer Happy?*



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Content

- **Scenarios: The Idea**
- **Use Cases**
  - Use Case Diagrams
- **User Stories**
- **Sequence Diagrams**
  - A Brief History
  - **Live Sequence Charts**
    - LSC Body **Syntax**:
      - LSC Model Elements, Locations
      - Well-Formedness
    - Towards **Semantics**:
      - Cuts, Firedsets
      - Automaton Construction
    - **Excursion**: Symbolic Büchi Automata

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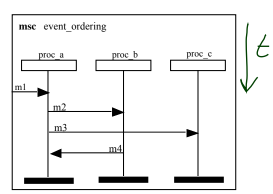
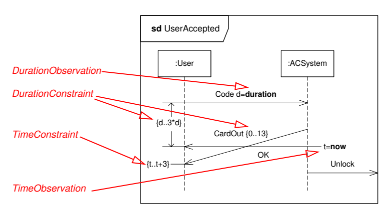
Sequence Diagrams

A Brief History of Sequence Diagrams



(ITU-T, 2011)

- **Message Sequence Charts**,
  ITU standardized in different versions (ITU Z.120, 1st edition: 1993); often accused of lacking a formal semantics.



(OMG, 2007)

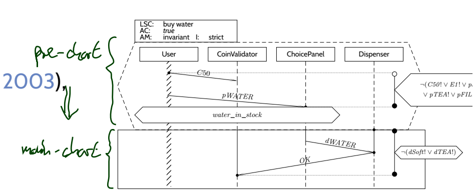
- **Sequence Diagrams** of UML 1.x
  (one of three main authors: I. Jacobson)

- **SDs of UML 2.x** address **some** issues, yet the standard exhibits unclarities and even contradictions
  (Harel and Maoz, 2007; Störrle, 2003)

- For the lecture, we consider

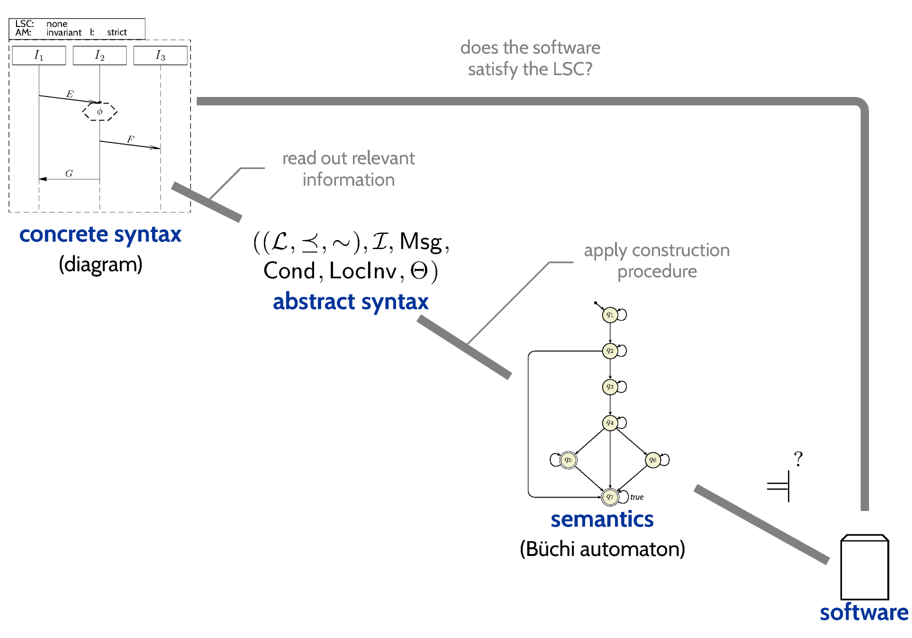
  Live Sequence Charts (LSCs)

  (Damm and Harel, 2001; Klose, 2003; Harel and Marelly, 2003),
  LSCs have a common fragment with UML 2.x SDs:
  (Harel and Maoz, 2007).



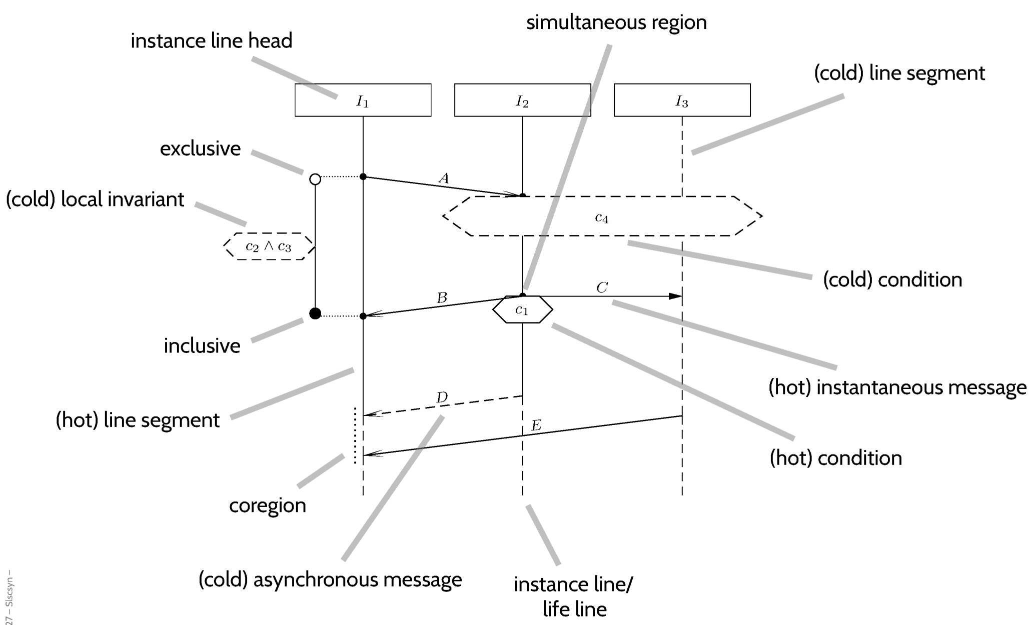
Live Sequence Charts
(2018 Edition)

The Plan: A Formal Semantics for a Visual Formalism



LSC Body Syntax

LSC Body Building Blocks



LSC Body: Abstract Syntax

Definition. [*LSC Body*]
Let $\mathcal{E}$ be a set of events and $\mathcal{C}$ a set of atomic propositions, $\mathcal{E} \cap \mathcal{C} = \emptyset$.
An LSC body over $\mathcal{E}$ and $\mathcal{C}$ is a tuple

$$((\mathcal{L}, \preceq, \sim), \mathcal{I}, \mathsf{Msg}, \mathsf{Cond}, \mathsf{LocInv}, \Theta)$$

where

- $\mathcal{L}$ is a finite, non-empty set of locations with
  - a partial order $\preceq \subseteq \mathcal{L} \times \mathcal{L}$,
  - a symmetric simultaneity relation $\sim \subseteq \mathcal{L} \times \mathcal{L}$ disjoint with $\preceq$, i.e. $\preceq \cap \sim = \emptyset$,
- $\mathcal{I} = \{I_1, \dots, I_n\}$ is a partitioning of $\mathcal{L}$; elements of $\mathcal{I}$ are called instance line,
- $\mathsf{Msg} \subseteq \mathcal{L} \times \mathcal{E} \times \mathcal{L}$ is a set of messages with $(l, E, l') \in \mathsf{Msg}$ only if $(l, l') \in \prec \cup \sim$;
  message (l, E, l') is called instantaneous iff $l \sim l'$ and asynchronous otherwise,
- $\mathsf{Cond} \subseteq (2^{\mathcal{L}} \setminus \emptyset) \times \Phi(\mathcal{C})$ is a set of conditions
  with $(L, \phi) \in \mathsf{Cond}$ only if $l \sim l'$ for all $l \neq l' \in L$,
- $\mathsf{LocInv} \subseteq \mathcal{L} \times \{\circ, \bullet\} \times \Phi(\mathcal{C}) \times \mathcal{L} \times \{\circ, \bullet\}$ is a set of local invariants
  with $(l, \iota, \phi, l', \iota') \in \mathsf{LocInv}$ only if $l \prec l'$, $\circ$: exclusive, $\bullet$: inclusive,
- $\Theta : \mathcal{L} \cup \mathsf{Msg} \cup \mathsf{Cond} \cup \mathsf{LocInv} \to \{\mathsf{hot}, \mathsf{cold}\}$
  assigns to each location and each element a temperature.

From Concrete to Abstract Syntax

- locations $\mathcal{L}$,
- $\preceq \subseteq \mathcal{L} \times \mathcal{L}$, $\sim \subseteq \mathcal{L} \times \mathcal{L}$
- $\mathcal{I} = \{I_1, \dots, I_n\}$,
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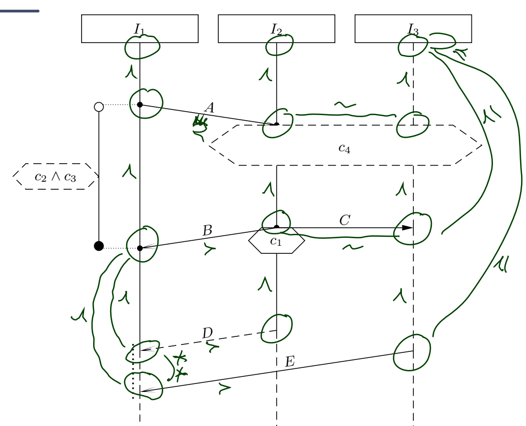

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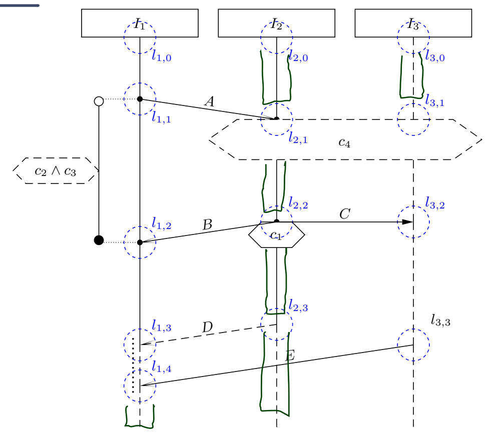

$\Theta(l_{1,0})$ = hot

$\Theta(l_{1,3})$ = cold

- $\mathcal{L} = \{l_{1,0}, l_{1,1}, l_{1,2}, l_{1,3}, l_{1,4}, \; l_{2,0}, l_{2,1}, l_{2,2}, l_{2,3}, \; l_{3,0}, l_{3,1}, l_{3,2}, l_{3,3}\}$

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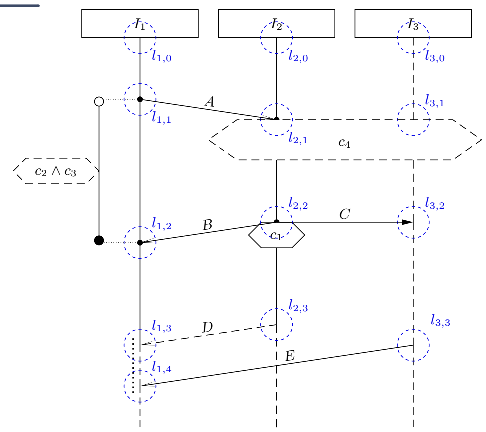
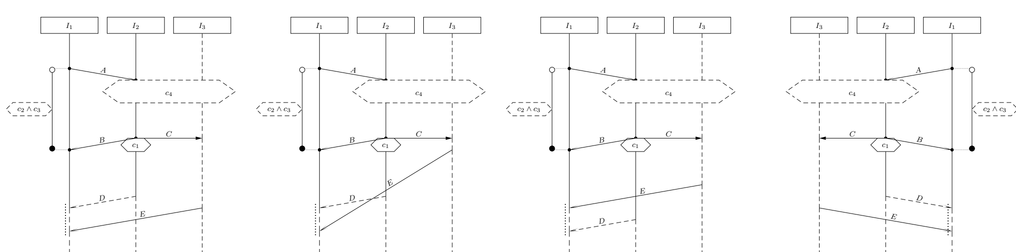


- $\mathcal{L} = \{l_{1,0}, l_{1,1}, l_{1,2}, l_{1,3}, l_{1,4},\ l_{2,0}, l_{2,1}, l_{2,2}, l_{2,3},\ l_{3,0}, l_{3,1}, l_{3,2}, l_{3,3}\}$
- $l_{1,0} \prec l_{1,1} \prec l_{1,2} \prec l_{1,3}$, $l_{1,2} \prec l_{1,4}$, $l_{2,0} \prec l_{2,1} \prec l_{2,2} \prec l_{2,3}$, $l_{3,0} \prec l_{3,1} \prec l_{3,2} \prec l_{3,3}$, $l_{1,1} \prec l_{2,1}$, $l_{2,2} \prec l_{1,2}$, $l_{2,3} \prec l_{1,3}$, $l_{3,2} \prec l_{1,4}$, $l_{2,1} \sim l_{3,1}$, $l_{2,2} \sim l_{3,2}$,
- $\mathcal{I} = \{\{l_{1,0}, l_{1,1}, l_{1,2}, l_{1,3}, l_{1,4}\}, \{l_{2,0}, l_{2,1}, l_{2,2}, l_{2,3}\}, \{l_{3,0}, l_{3,1}, l_{3,2}, l_{3,3}\}\}$,
- Msg $= \{(l_{1,1}, A, l_{2,1}), (l_{2,2}, B, l_{1,2}), (l_{2,2}, C, l_{3,2}), (l_{2,3}, D, l_{1,3}), (l_{3,3}, E, l_{1,4})\}$
- Cond $= \{(\{l_{2,1}, l_{3,1}\}, c_4), (\{l_{2,2}\}, c_1)\}$,
- LocInv $= \{(l_{1,1}, \circ, c_2 \wedge c_3, l_{1,2}, \bullet)\}$

Concrete vs. Abstract Syntax



- $\mathcal{L} = \{l_{1,0}, l_{1,1}, l_{1,2}, l_{1,3}, l_{1,4},\ l_{2,0}, l_{2,1}, l_{2,2}, l_{2,3},\ l_{3,0}, l_{3,1}, l_{3,2}, l_{3,3}\}$
- $l_{1,0} \prec l_{1,1} \prec l_{1,2} \prec l_{1,3}$, $l_{1,2} \prec l_{1,4}$, $l_{2,0} \prec l_{2,1} \prec l_{2,2} \prec l_{2,3}$, $l_{3,0} \prec l_{3,1} \prec l_{3,2} \prec l_{3,3}$, $l_{1,1} \prec l_{2,1}$, $l_{2,2} \prec l_{1,2}$, $l_{2,3} \prec l_{1,3}$, $l_{3,2} \prec l_{1,4}$, $l_{2,1} \sim l_{3,1}$, $l_{2,2} \sim l_{3,2}$,
- $\mathcal{I} = \{\{l_{1,0}, l_{1,1}, l_{1,2}, l_{1,3}, l_{1,4}\}, \{l_{2,0}, l_{2,1}, l_{2,2}, l_{2,3}\}, \{l_{3,0}, l_{3,1}, l_{3,2}, l_{3,3}\}\}$,
- Msg $= \{(l_{1,1}, A, l_{2,1}), (l_{2,2}, B, l_{1,2}), (l_{2,2}, C, l_{3,2}), (l_{2,3}, D, l_{1,3}), (l_{3,3}, E, l_{1,4})\}$
- Cond $= \{(\{l_{2,1}, l_{3,1}\}, c_4), (\{l_{2,2}\}, c_1)\}$,
- LocInv $= \{(l_{1,1}, \circ, c_2 \wedge c_3, l_{1,2}, \bullet)\}$

Well-Formedness

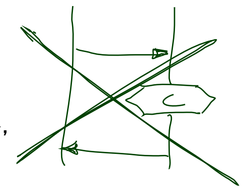
Bondedness/no floating conditions: (could be relaxed a little if we wanted to)

- For each location $l \in \mathcal{L}$, **if** l is the location of
  - a **condition**, i.e. $\exists (L, \phi) \in \mathsf{Cond} : l \in L$, or
  - a **local invariant**, i.e. $\exists (l_1, \iota_1, \phi, l_2, \iota_2) \in \mathsf{LocInv} : l \in \{l_1, l_2\}$,

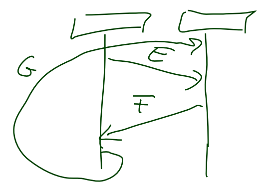
  then there is a location l' **simultaneous** to l, i.e. $l \sim l'$, which is the location of

  - an **instance head**, i.e. l' is minimal wrt. $\preceq$, or
  - a **message**, i.e.

$$\exists (l_1, E, l_2) \in \mathsf{Msg} : l \in \{l_1, l_2\}.$$



Note: if messages in a chart are **cyclic**, then there doesn't exist a partial order (so such diagrams **don't even have** an abstract syntax).



Content

Informatik III
(Automata Theory)

LSC Semantics: Towards Automaton Construction

LSC Semantics: It's in the Cuts!

Definition. Let $((\mathcal{L}, \preceq, \sim), \mathcal{I}, \mathsf{Msg}, \mathsf{Cond}, \mathsf{LocInv}, \Theta)$ be an LSC body.

A non-empty set $\emptyset \neq C \subseteq \mathcal{L}$ is called a **cut** of the LSC body iff C

- is **downward closed**, i.e.

$$\forall l, l' \in \mathcal{L} \bullet l' \in C \wedge l \preceq l' \implies l \in C,$$

- is **closed** under **simultaneity**, i.e.

$$\forall l, l' \in \mathcal{L} \bullet l' \in C \wedge l \sim l' \implies l \in C, \text{ and}$$

- comprises at least **one location per instance line**, i.e.

$$\forall I \in \mathcal{I} \bullet C \cap I \neq \emptyset.$$

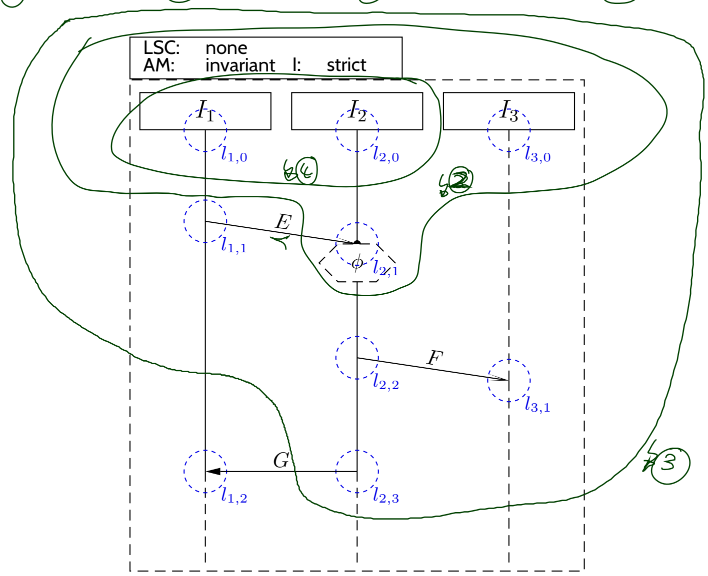
The temperature function is extended to cuts as follows:

$$\Theta(C) = \begin{cases} \mathsf{hot} & \text{if } \exists l \in C \bullet (\nexists l' \in C \bullet l \prec l') \wedge \Theta(l) = \mathsf{hot} \\ \mathsf{cold} & \text{otherwise} \end{cases}$$

that is, C is **hot** if and only if at least one of its maximal elements is hot.

Cut Examples

$\emptyset \neq C \subseteq \mathcal{L}$ — downward closed — simultaneity closed — at least one loc. per instance line



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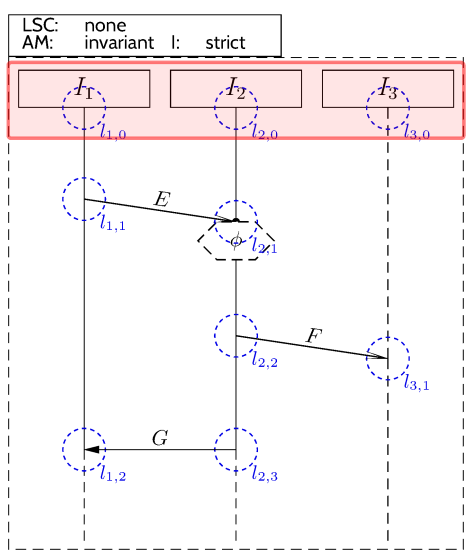

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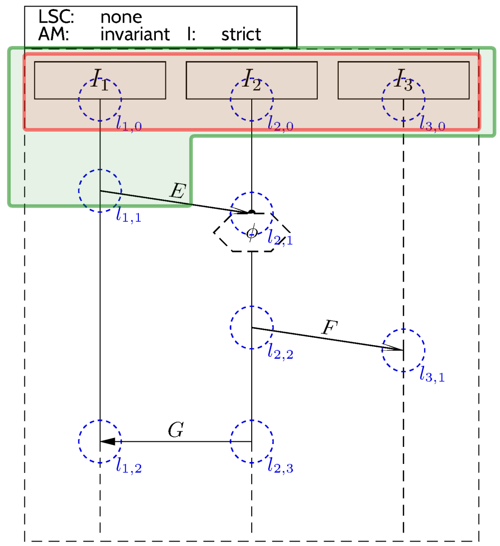

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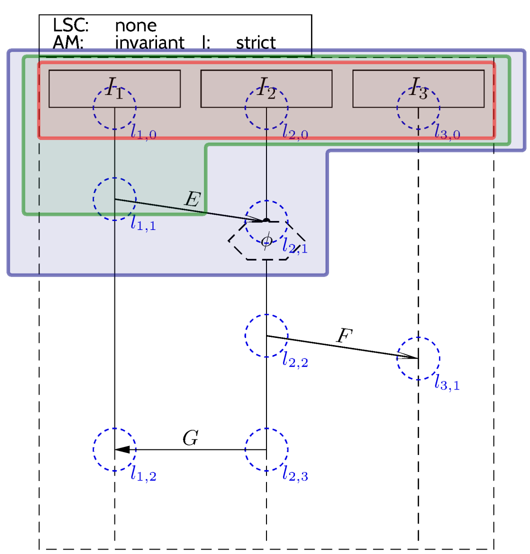

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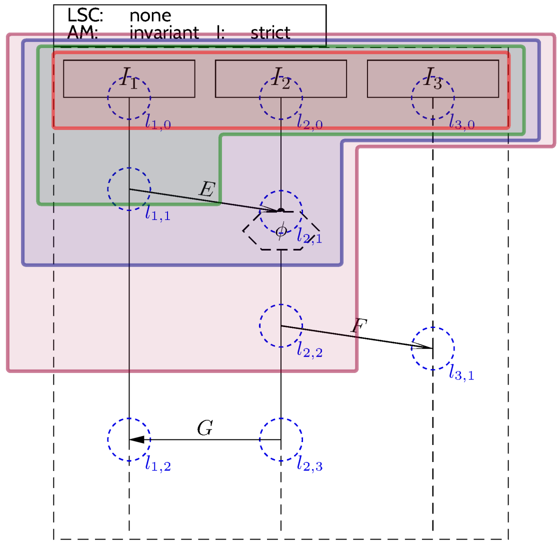

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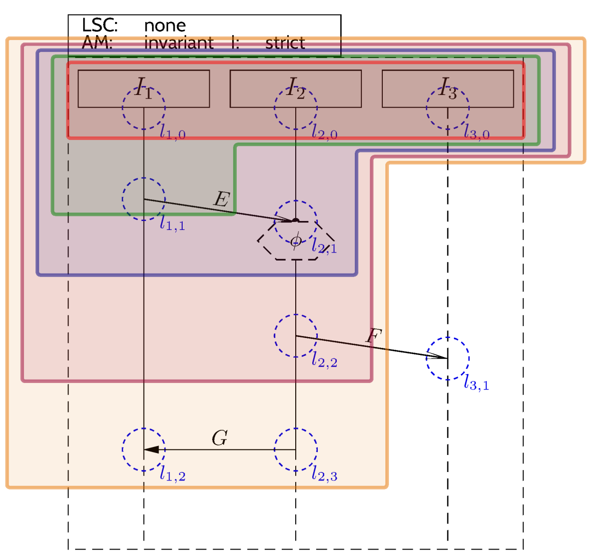

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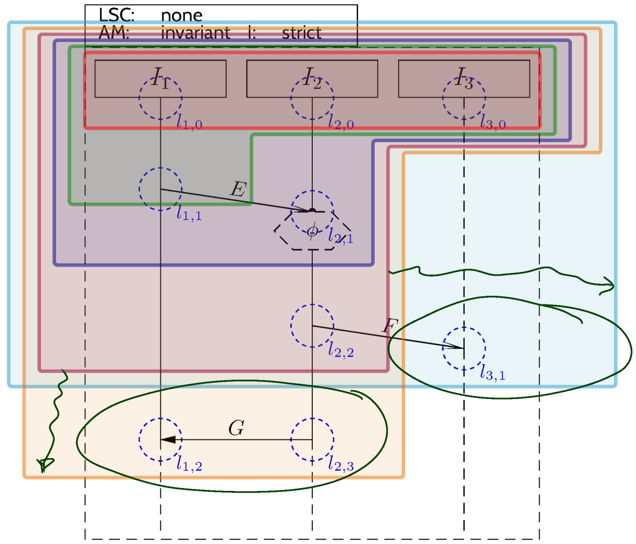

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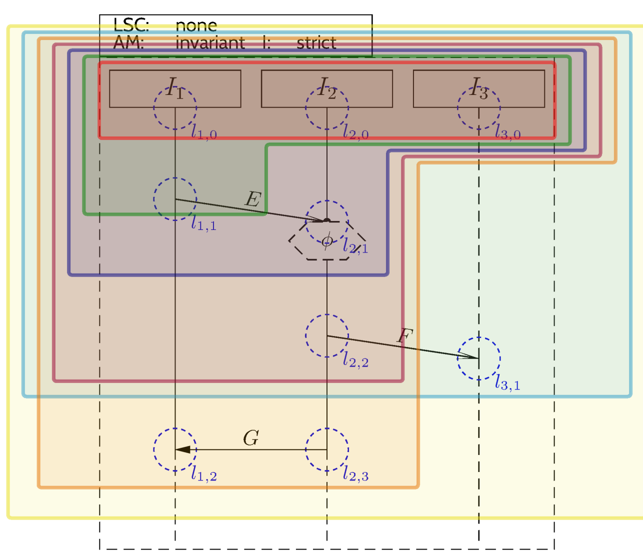


A Successor Relation on Cuts

The partial order "$\preceq$" and the simultaneity relation "$\sim$" of locations induce a **direct successor relation** on cuts of an LSC body as follows:

Definition.
Let $C \subseteq \mathcal{L}$ bet a cut of LSC body $((\mathcal{L}, \preceq, \sim), \mathcal{I}, \mathsf{Msg}, \mathsf{Cond}, \mathsf{LocInv}, \Theta)$.

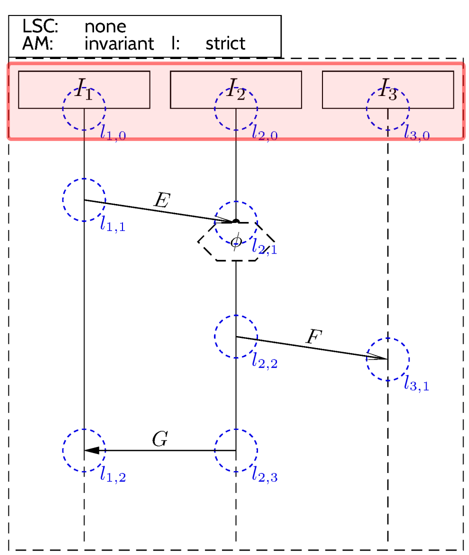
A set $\emptyset \neq \mathcal{F} \subseteq \mathcal{L}$ of locations is called **fired-set** $\mathcal{F}$ of cut C if and only if

- $C \cap \mathcal{F} = \emptyset$ and $C \cup \mathcal{F}$ is a cut, i.e. $\mathcal{F}$ is closed under simultaneity,
- all locations in $\mathcal{F}$ are direct $\prec$-successors of the front of C, i.e.
$$\forall\, l \in \mathcal{F}\, \exists\, l' \in C \bullet l' \prec l \wedge (\nexists\, l'' \in \mathcal{L} \bullet l' \prec l'' \prec l),$$
- locations in $\mathcal{F}$ that lie on the same instance line are pairwise unordered, i.e.
$$\forall\, l \neq l' \in \mathcal{F} \bullet (\exists\, I \in \mathcal{I} \bullet \{l, l'\} \subseteq I) \implies l \not\preceq l' \wedge l' \not\preceq l,$$
- for each asynchronous message reception in $\mathcal{F}$, the corresponding sending is already in C,
$$\forall\, (l, E, l') \in \mathsf{Msg} \bullet l' \in \mathcal{F} \implies l \in C.$$

The cut $C' = C \cup \mathcal{F}$ is called **direct successor of C via $\mathcal{F}$**, denoted by $C \rightsquigarrow_{\mathcal{F}} C'$.

Successor Cut Example

$C \cap \mathcal{F} = \emptyset$ — $C \cup \mathcal{F}$ is a cut — only direct $\prec$-successors — same instance line on front pairwise unordered — sending of asynchronous reception already in



Successor Cut Example

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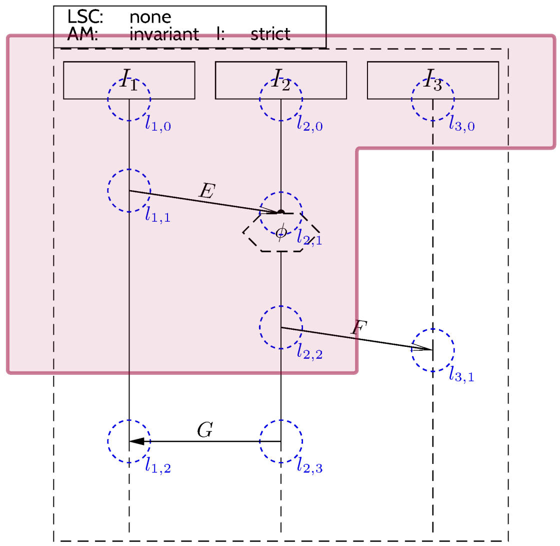

Content

Informatik III (Automata Theory)

Tell Them What You've Told Them...

- **Use-Cases**:
  - interactions between system and actors,
  - be sure to elaborate exceptions and corner cases,
  - in particular effective with customers lacking technical background.
  - **Use-Case Diagrams**:
    - visualise which participants are relevant for which use-case,
    - pretty **useless** without the underlying use-case.
- **User Stories**: simple example of scenarios
  - **strong point**: naming tests is necessary,
  - **weak point**: hard to keep overview; global restrictions.
- **Sequence Diagrams**:
  - a **visual formalism** for interactions, i.e.,
    - precisely defined syntax,
    - precisely defined semantics
      (construct automaton from abstract syntax)
  - Can be used to precisely describe the interactions of a **use-case**.

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