UNIVERSITÄT ZU LÜBECK
INSTITUTE FOR SOFTWARE ENGINEERING
AND PROGRAMMING LANGUAGES

isp

TeSSLa: A Real-Time Specification Language for Runtime Verification of Non-synchronized Streams

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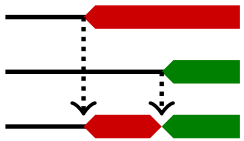
Temporal Stream-based Specification Language

- Reasons over a set of **non-synchronized real-time streams**
- **Declarative** style: Specification rather than implementation
- **Modularity**: Allowing abstractions based on six core operators
- **Time** as first-class citizen
- Abstraction for both, **events** and **signals**
- **Recursion** to reason about the past
- Implementable with **limited memory**

TeSSLa core operators



default, defaultFrom

- Initialize streams
- Start of recursion

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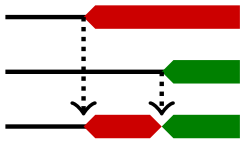

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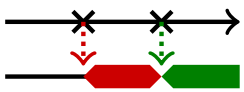

time

- Get timestamps of stream
- Replaces data values with timestamps
- Only way to read timestamps

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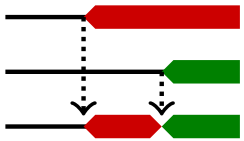

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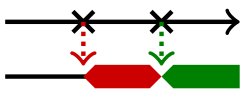

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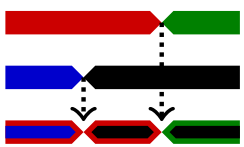


lift

- Lifts standard functions to streams
- Used to manipulate data, events, ...

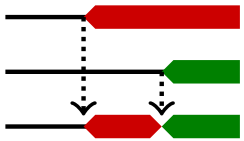
TeSSLa: Lifted Addition

Lift arbitrary functions to streams with signal semantics.

$$\mathsf{lift}_{\mathbb{D}_1,\ldots,\mathbb{D}_n,\mathbb{D}'} : (\mathbb{D}_1 \times \cdots \times \mathbb{D}_n \rightharpoonup \mathbb{D}') \to (\mathcal{S}_{\mathbb{D}_1} \times \cdots \times \mathcal{S}_{\mathbb{D}_n} \to \mathcal{S}_{\mathbb{D}'})$$

$$\mathsf{add} : \mathbb{Z} \times \mathbb{Z} \to \mathbb{Z},$$
$$z = \mathsf{lift}(\mathsf{add})(x, y)$$

TeSSLa core operators



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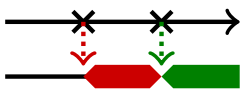

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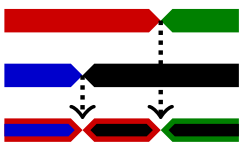

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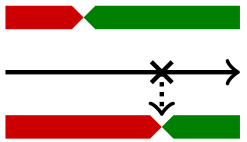
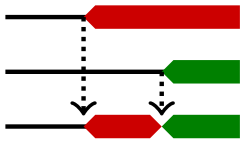


last

- Refers to previous value of a stream
- Recursion

TeSSLa core operators



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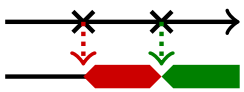

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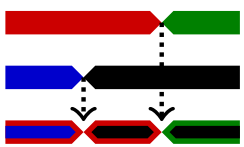

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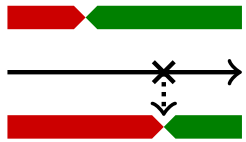

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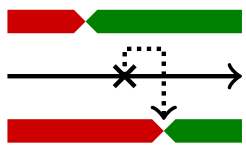


delayedLast

- Only way to create events
- Takes a stream and delays events by its current value
- Output events have the previous value of another given stream

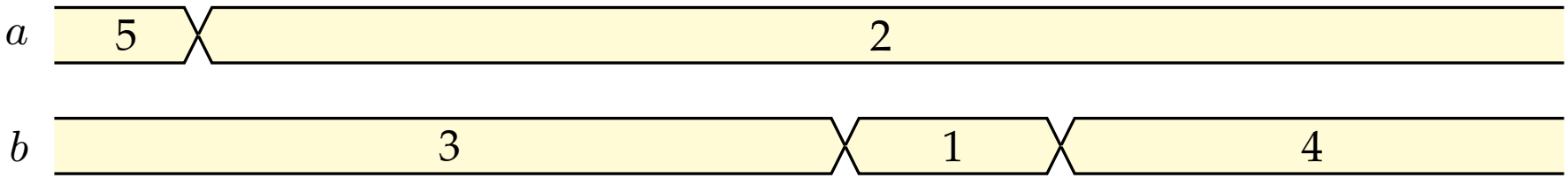
TeSSLa: easy example

Let $a \in \mathcal{S}_{\text{Int}}$ be an input stream, $x, y \in \mathcal{S}_{\text{Int}}$ be intermediate streams and $z \in \mathcal{S}_{\text{Int}}$ be the output stream.

TeSSLa specifications can be seen as a system of equations:

```
x = last(z, a)
y = default(x, 0)
z = y + a
```

TeSSLa by Example



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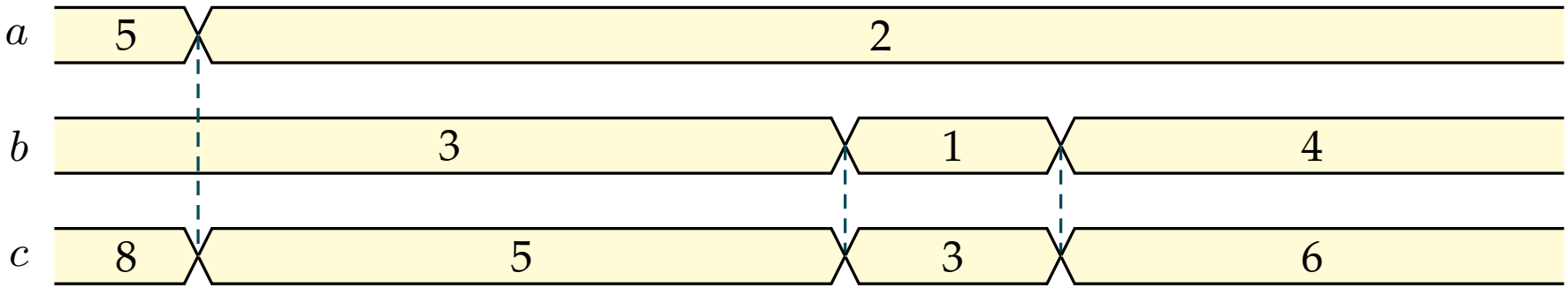


```
def c := a + b
```

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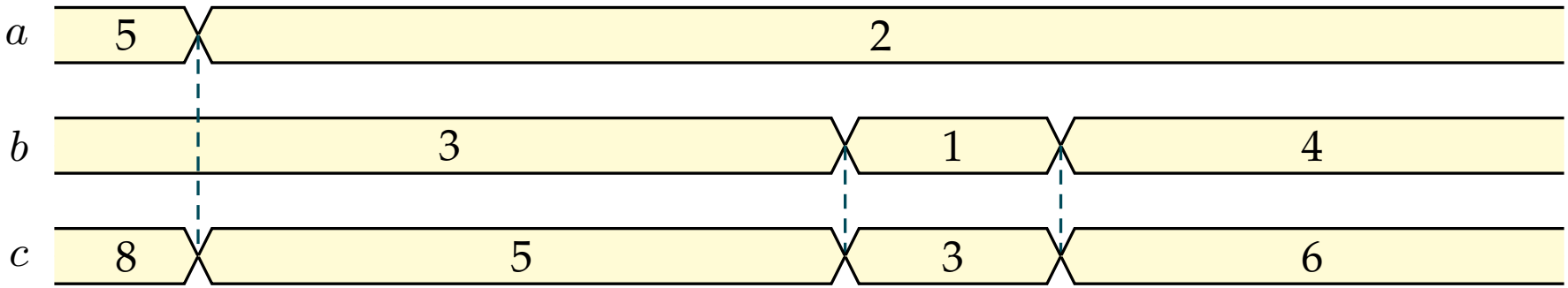


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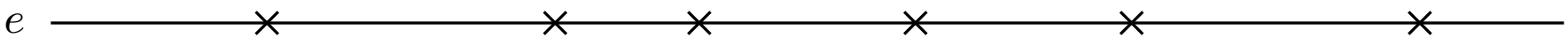

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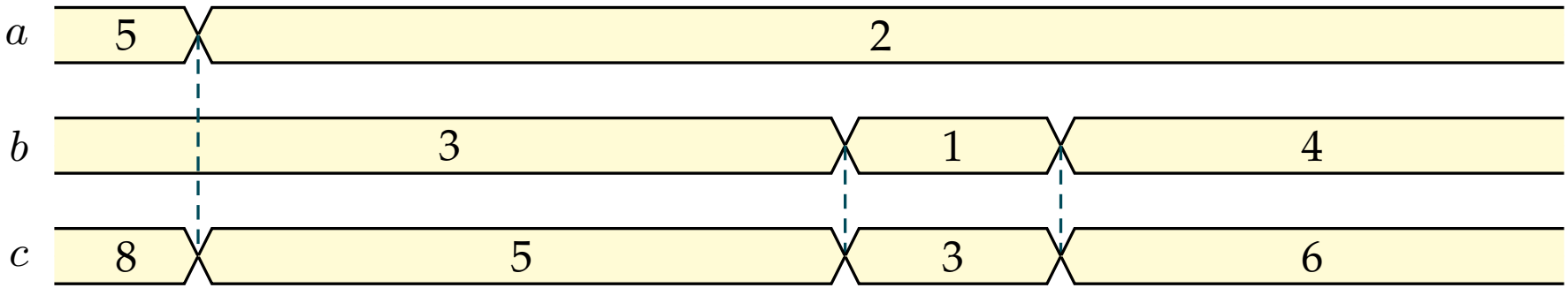


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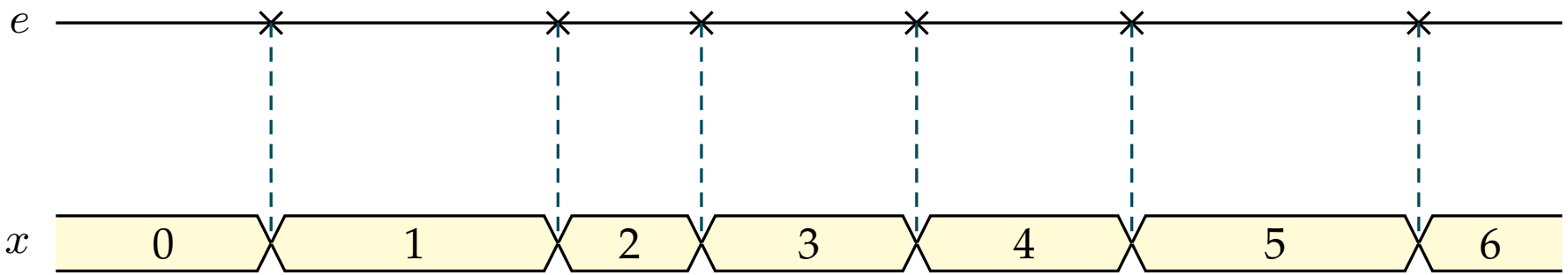


```
def x := eventCount(e)
```

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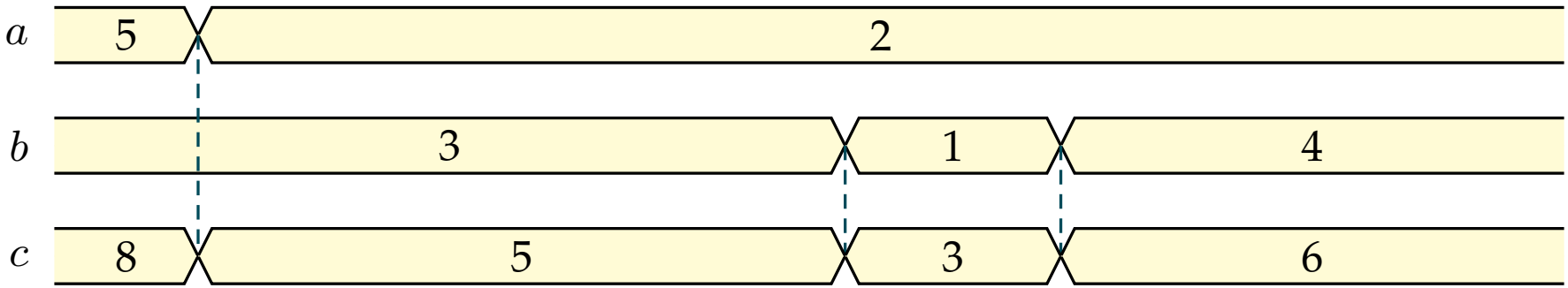


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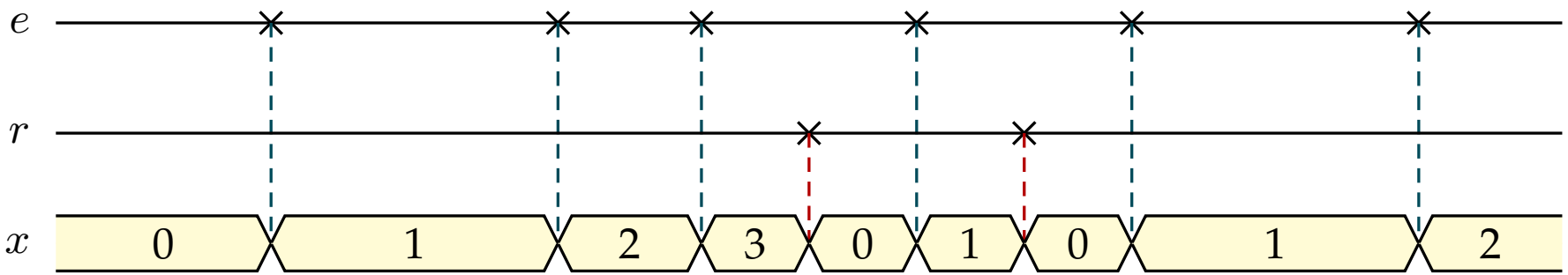


```
def x := eventCount(e, reset = r)
```

TeSSLa Standard Library

Counting events until reset

```
def eventCount(values, reset) :=
  default(
    if default(time(reset) > time(values), false)
    then 0
    else if default(time(reset) == time(values), false)
    then 1
    else last(eventCount, values) + 1
  , 0)
```

Outlook

In the future, the following features would be desirable for TeSSLa:

- High level data structures like maps and queues
- Possibility to handle gaps and uncertainties in streams
- ...

This will result in

$$\underset{\text{Bounded maps / queues, ...}}{\text{TeSSLa}_{\text{Hardware}}} \subset \underset{\text{Effectively monitorable}}{\text{TeSSLa}_{\text{Software}}} \subseteq \text{TeSSLa}$$