Vertically Scalable solutions illustrated via EPL and Esper
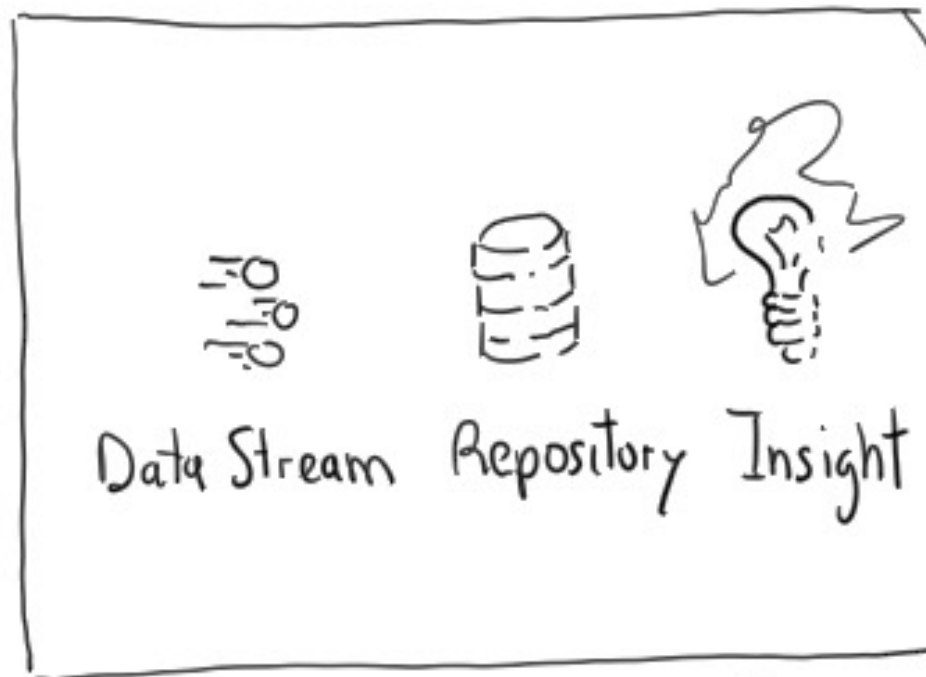
Emanuele Della Valle

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Positioning this lecture
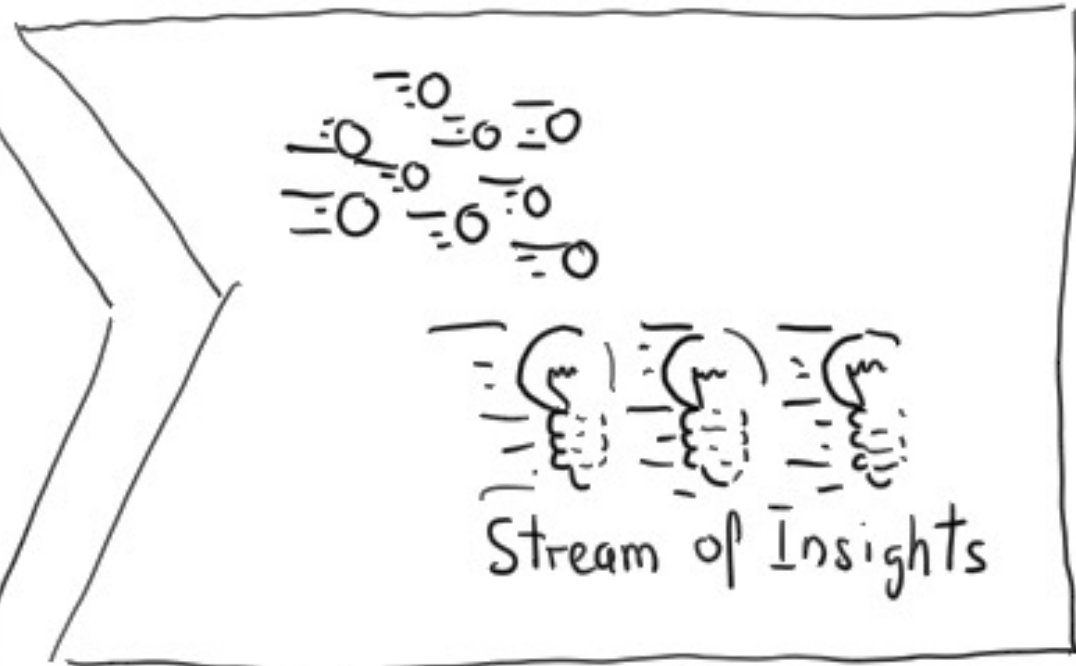
1st premises: continuity matters

Kafka

Spark

horizontally

KSQL DB

Kafka proc

COMPLEXITY

low   DSMS   high

pub/sub   O→☆: ☼
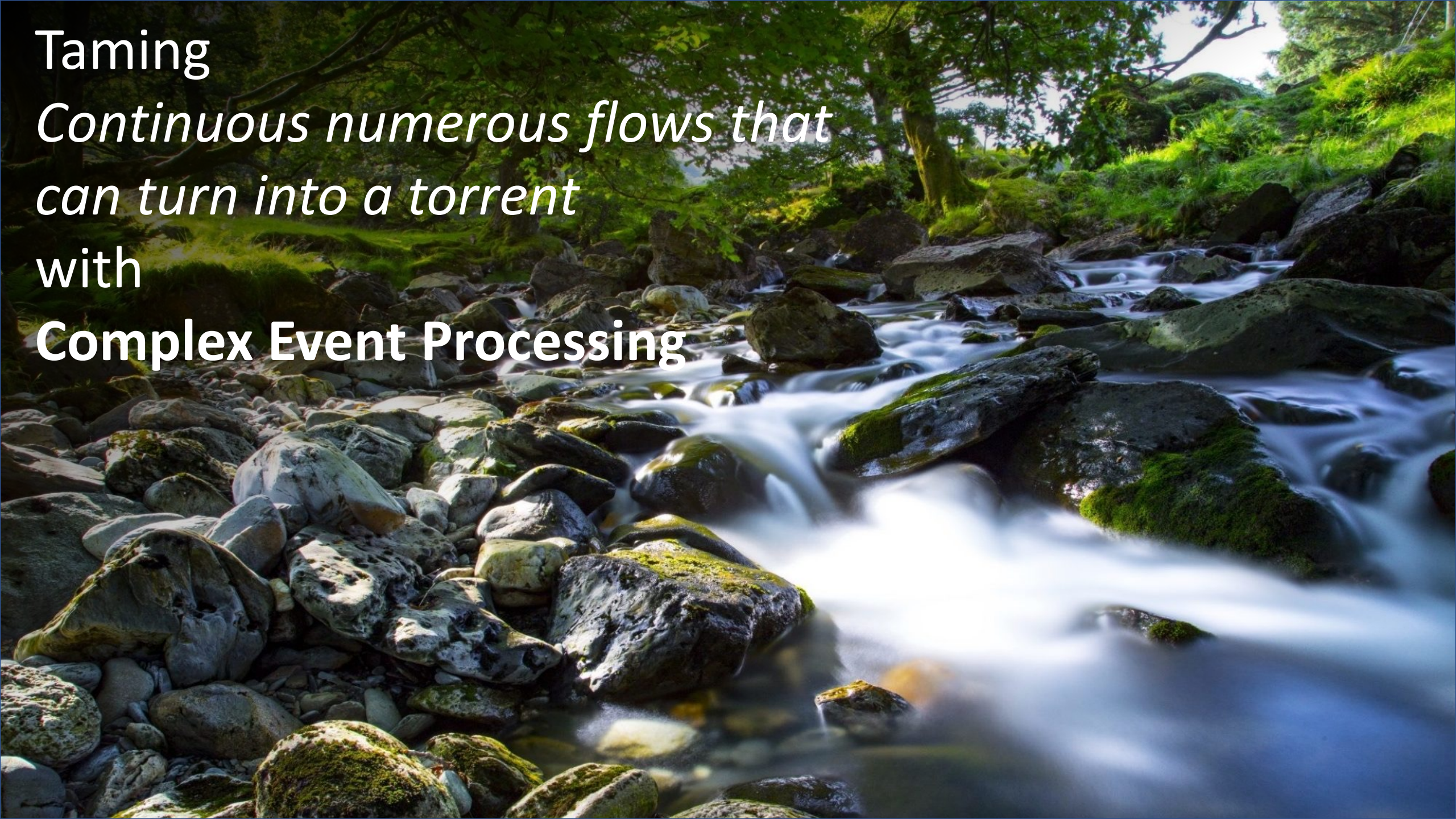
Data Stream

ABILITY TO SCALE vertically

Esper : EPL

CEP
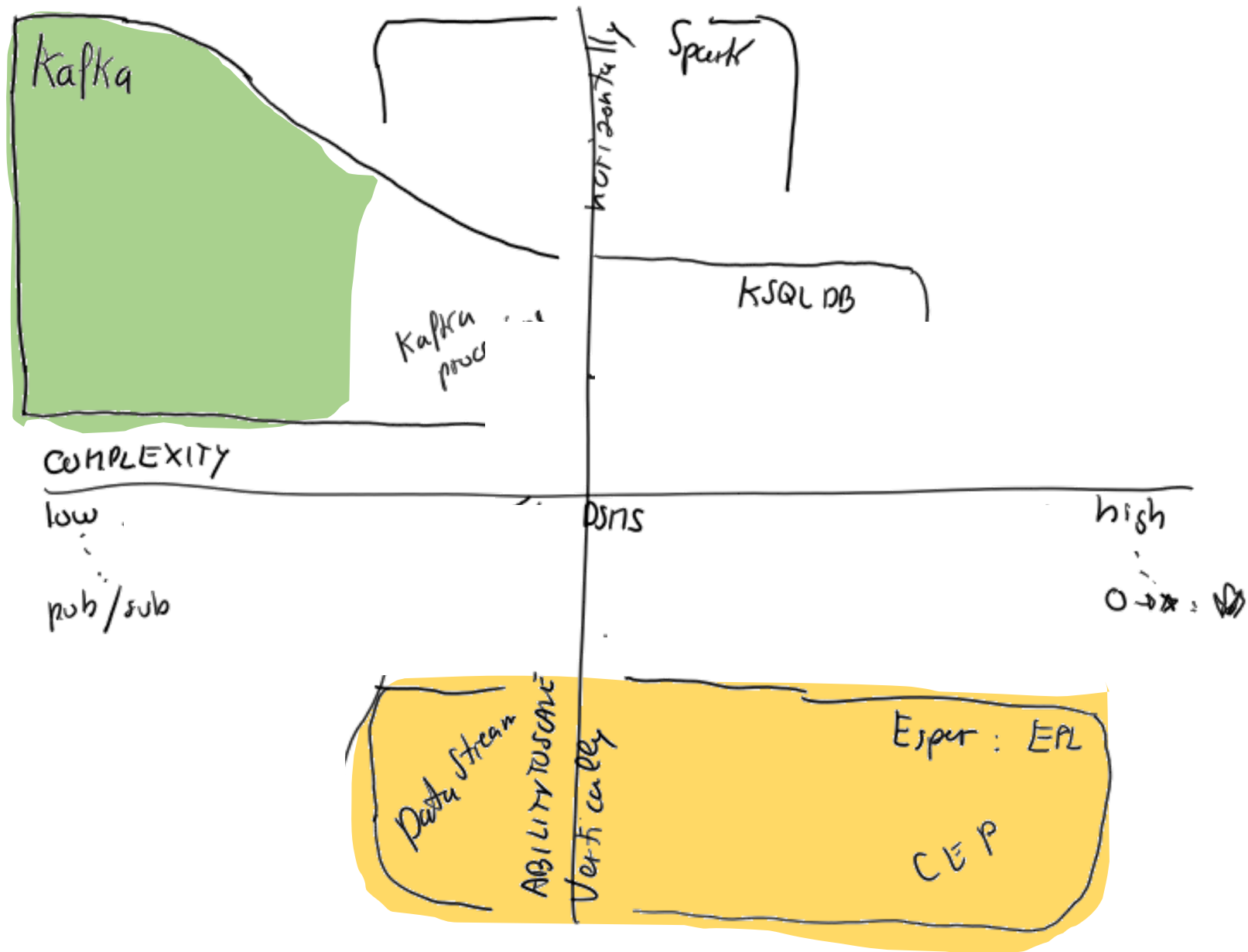
Taming
Continuous numerous flows that can turn into a torrent
with
Complex Event Processing

The Event Processing Language & its reference implementation Esper

Esper in a nutshell

- Implemented as a Java library
  - Can be embedded in any JVM application

- Designed for performance
  - High throughput
  - Low latency

- Tree-based recognition algorithm

- Inverted indexes to dispatch incoming events to EPL statements

- Builds indexes to quickly retrieve events with given properties among those stored

Esper in a nutshell (cont.)

- Interaction with static / historical data

- Configurable push or pull communication

- Several adapters for input/output
  - CSV, JMS in/out, API, DB, Socket, HTTP

- Esper HA
  - High Availability
  - Ensures that the state is recoverable in the case of failure

EPL in a nutshell

- EPL: rich language to express rules (a.k.a., statementa)
- Grounded on the DSMS approach
  - Windowing
  - Relational select, join, aggregate, …
  - Relation-to-stream operators to produce output
- Queries can be combined to form a graph
- Includes complex event recognition abstractions
  - Pattern detection

Esper & EPL
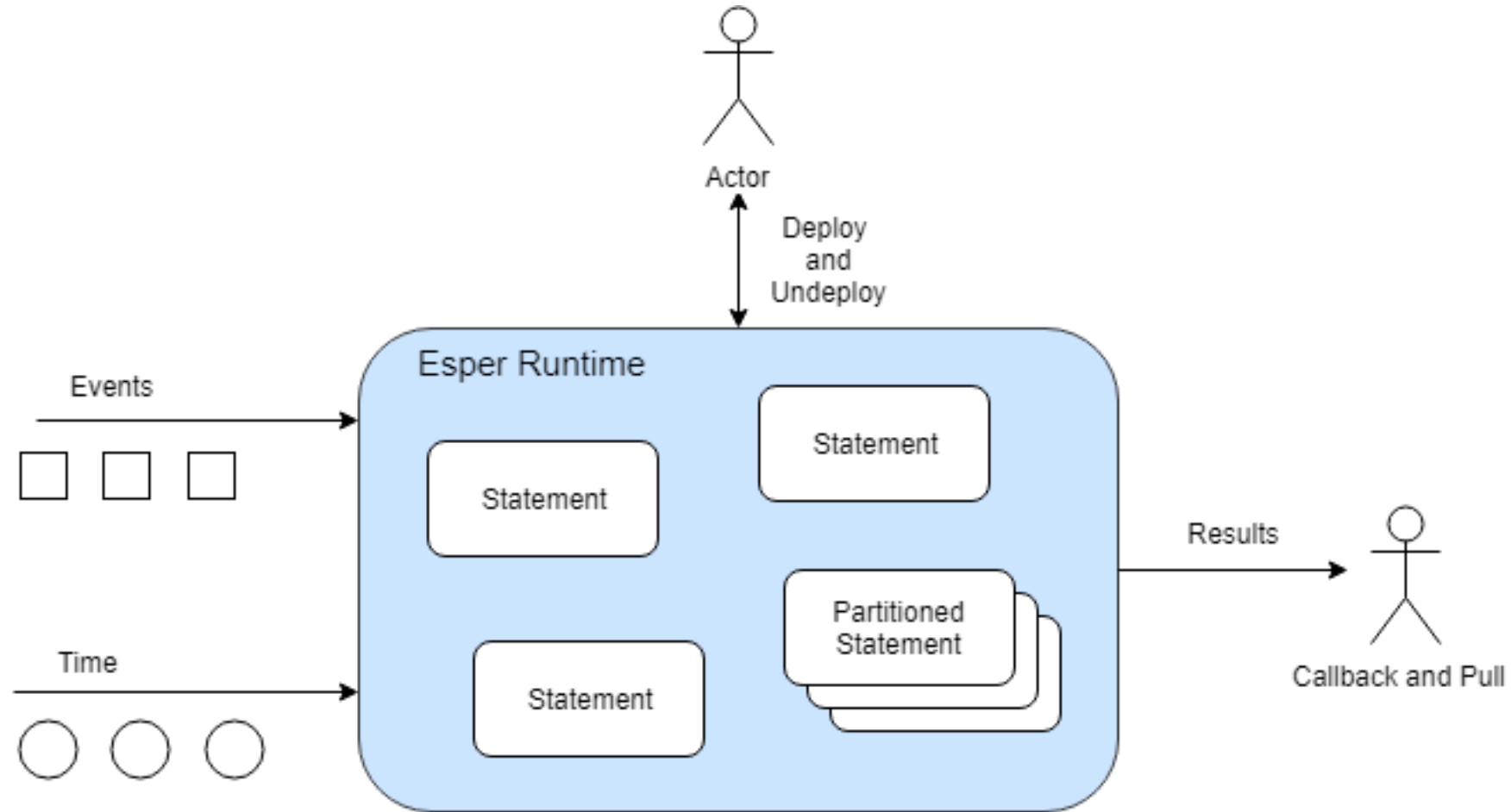
The **Basics** of
the **E**vent **P**rocessing **L**anguage

Running example

- Count the number of fires detected using a set of smoke and temperature sensors in the last 10 minutes

- Events
  - Smoke event: String sensor, boolean state
  - Temperature event: String sensor, double temperature
  - Fire event: String sensor, boolean smoke, double temperature

- Condition:
  - Fire: at the same sensor smoke followed by temperature>50 within 2 minutes

Declare event types

- Two ways
  - EPL *create schema clause*
  - Runtime configuration API *addEventType*

- Syntax
  ```
  create schema
  schema_name [as]
  (property_name property_type
  [,property_name property_type [,...])
  [inherits inherited_event_type
  [, inherited_event_type] [,...]]
  ```

Running example

```
create schema SmokeSensorEvent(
      sensor string,
      smoke boolean
);

create schema TemperatureSensorEvent(
      sensor string,
      temperature double
);

create schema FireComplexEvent(
      sensor string,
      smoke boolean,
      temperature double
);
```

Event Processing Language (EPL)

- EPL is similar to SQL
  - Select, where, …

- Event streams and views instead of tables
  - Views define the data available for the query
  - Views can represent windows over streams
  - Views can also sort events, derive statistics from event attributes, group events, …
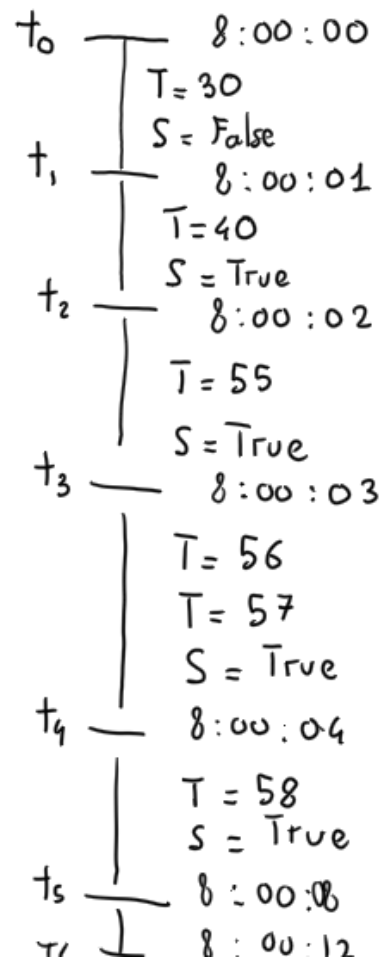
EPL syntax

[insert into *insert_into_def*]
select *select_list*
from *stream_def* [as name]

[, *stream_def* [as name]] [,...]

[where *search_conditions*]
[group by *grouping_expression_list*]
[having *grouping_search_conditions*]
[output *output_specification*]
[order by *order_by_expression_list*]
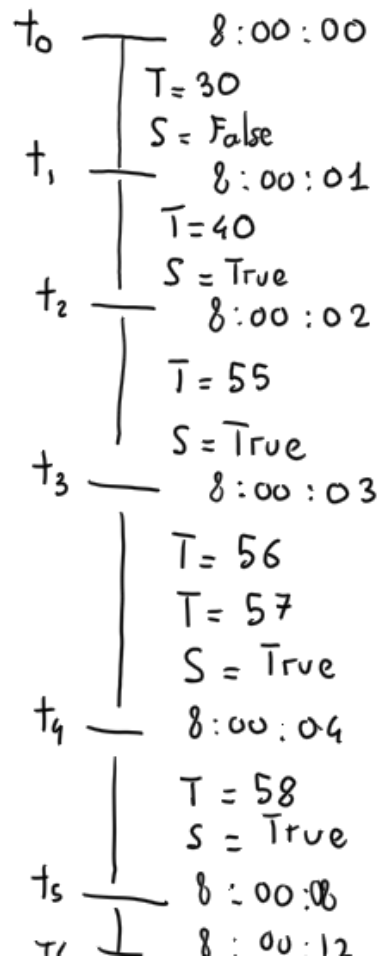[limit *num_rows*]

Running example

http://esper-epl-tryout.appspot.com/epltryout/mainform.html

EPL Statements

EPL Module Text
Enter EPL Here:

```
create schema SmokeSensorEvent(sensor string, smoke boolean);

create schema TemperatureSensorEvent(sensor string, temperature double);

create schema FireComplexEvent(sensor string, smoke boolean, temperature double);

insert into FireComplexEvent
select a.sensor as sensor, a.smoke as smoke, b.temperature as temperature
from pattern [every a=SmokeSensorEvent(smoke=true) ->
b=TemperatureSensorEvent(sensor=a.sensor, temperature>50)];

select count(*)
from FireComplexEvent.win:time(10 min);
```

Time And Event Sequence

Beginning Of Time
Provide a timestamp to start at:

2001-01-01 08:00:00.000   **Submit**

Advance Time and Send Events
Enter sequence of time and events:

```
SmokeSensorEvent={sensor='S1', smoke=false}
TemperatureSensorEvent={sensor='S1', temperature=30}

t=t.plus(1 seconds)

SmokeSensorEvent={sensor='S1', smoke=true}
TemperatureSensorEvent={sensor='S1', temperature=40}

t=t.plus(1 seconds)

SmokeSensorEvent={sensor='S2', smoke=false}
TemperatureSensorEvent={sensor='S1', temperature=55}

t=t.plus(11 min)
```

Scenario Results

All Output Events
Output Per Statement   All Audit Text
Audit Text Per Statement

```
At: 2001-01-01 08:00:02.000
  Statement: Stmt-4
    Insert
      FireComplexEvent={sensor='S1',
      smoke=true, temperature=55.0}
  Statement: Stmt-5
    Insert
      Stmt-5-output={count(*)=1}
At: 2001-01-01 08:10:02.000
  Statement: Stmt-5
    Insert
      Stmt-5-output={count(*)=0}
```

Time line

t_0 —— 8:00:00

T = 30
S = False

t_1 —— 8:00:01

T = 40
S = True

t_2 —— 8:00:02

T = 55

S = True

t_3 —— 8:00:03

T = 56
T = 57
S = True

t_4 —— 8:00:04

T = 58
S = True

t_5 —— 8:00:08
t_6 —— 8:00:12

Filtering

to — 8:00:00
T = 30
S = False

t₁ — 8:00:01
T = 40
S = True

t₂ — 8:00:02
T = 55
S = True

t₃ — 8:00:03
T = 56
T = 57
S = True

t₄ — 8:00:04
T = 58
S = True
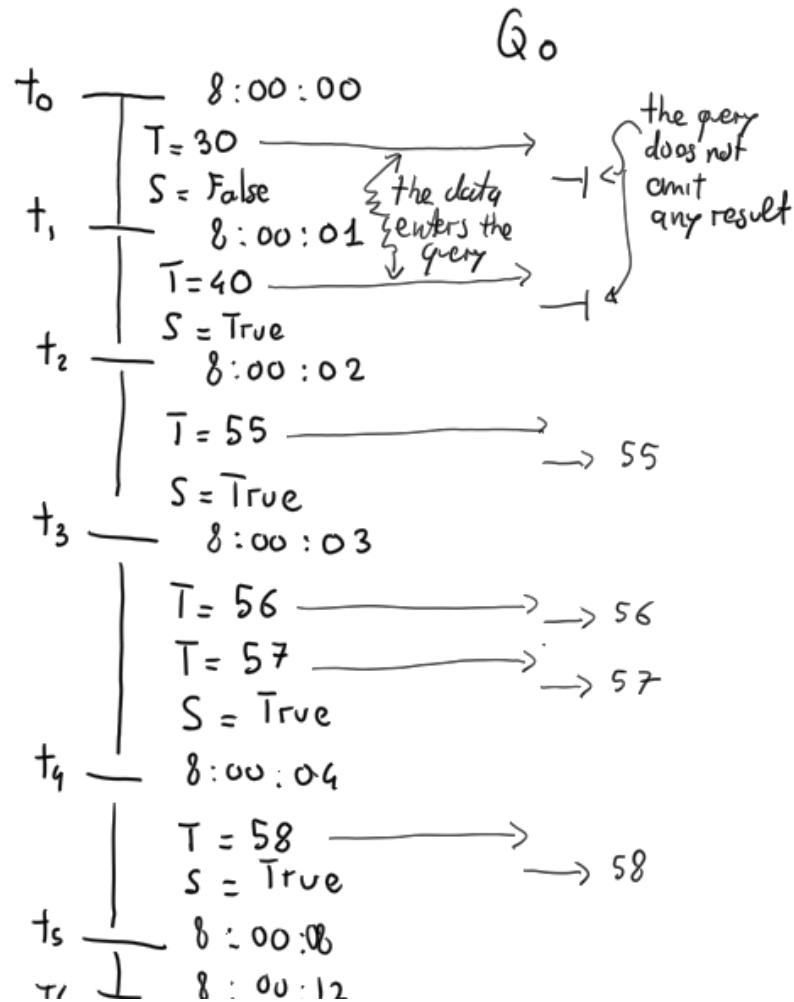
t₅ — 8:00:08
      8:00:12

Q0 - the SQL-style

```
select *
from TemperatureSensorEvent
where temperature > 50;
```

Q0bis - the Event-Based System Style

```
select *
from TemperatureSensorEvent(temperature > 50) ;
```
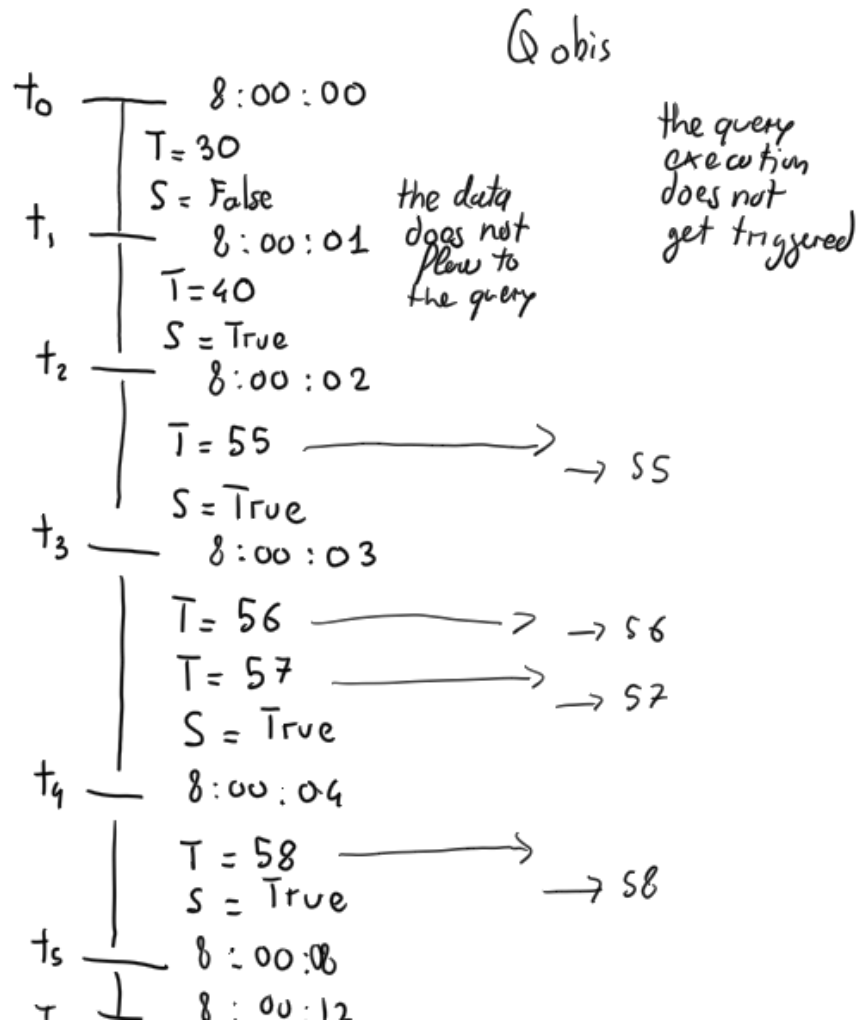
Filtering the SQL style

Q0 - the SQL-style

```
select *
from TemperatureSensorEvent
where temperature > 50;
```

Execution mode

Data points enter the query that filters them

Filtering the Event-Based System Style

Q obis

t_0 — 8:00:00
T = 30
S = False
t_1 — 8:00:01   the data does not flow to the query
T = 40
S = True
t_2 — 8:00:02
T = 55 ———→ → SS
S = True
t_3 — 8:00:03
T = 56 ———→ → 56
T = 57 ———→ → 57
S = True
t_4 — 8:00:04
T = 58 ———→ → 58
S = True
t_5 — 8:00:08
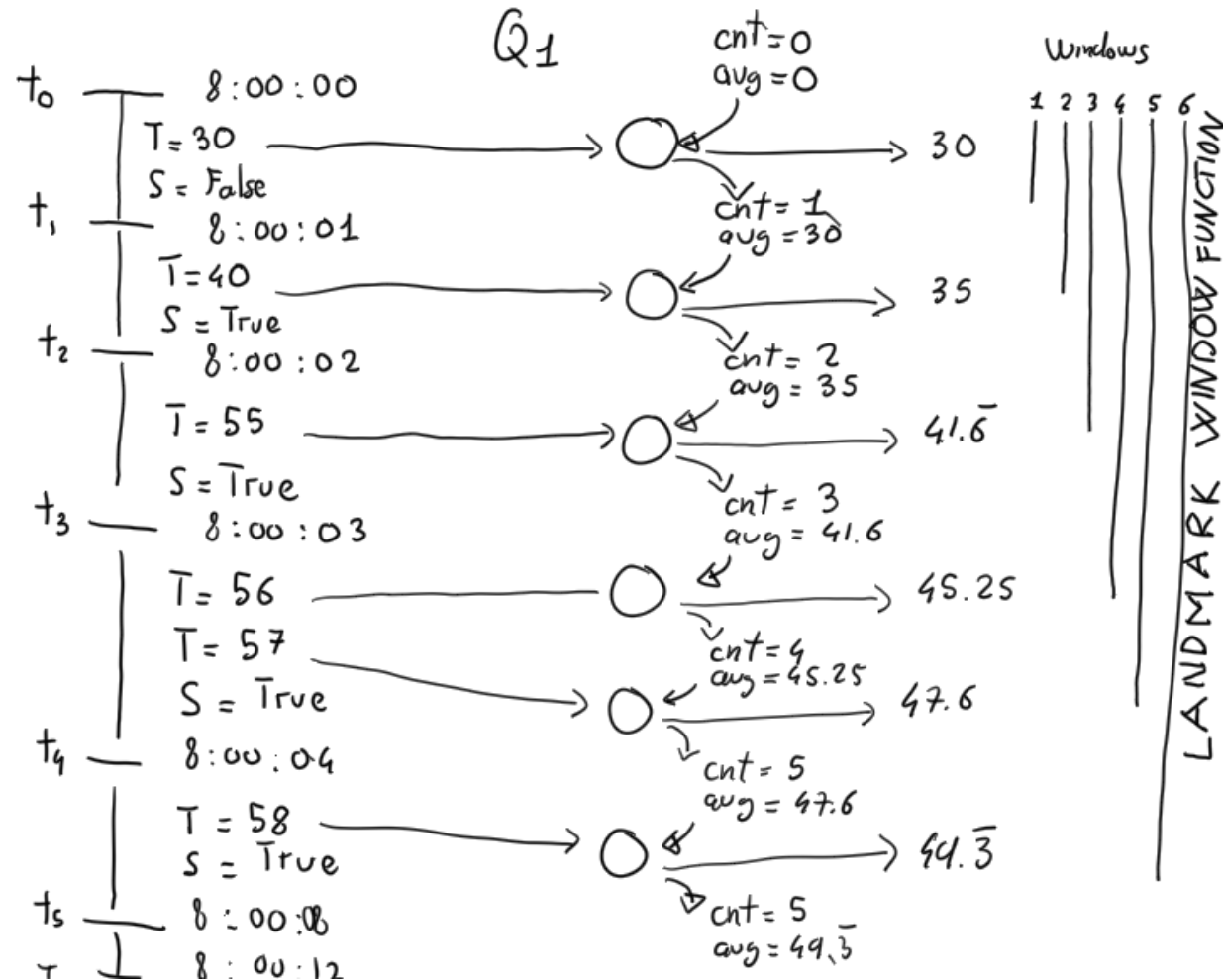t — 8:00:12

the query execution does not get triggered

Q0bis - the Event-Based System Style

```
select *
from TemperatureSensorEvent(temperature > 50)
;
```

Execution mode

Data points are filtered before flowing into the query and the query execution does not get triggered

Basic Aggregation

select sensor, **avg(temperature)**

from TemperatureSensorEvent

group by sensor;

Execution mode

From a **logical** perspective, **data points cumulate in the landmark window,** and the query emits a new avg for every data point

From a **physical** perspective, **the query is evaluated incrementally** and **maintains a state** that captures the number of events (cnt) seen so far and the previous avg. The new average only depends on the state and the new data point entering the query. Old data can be forgotten.
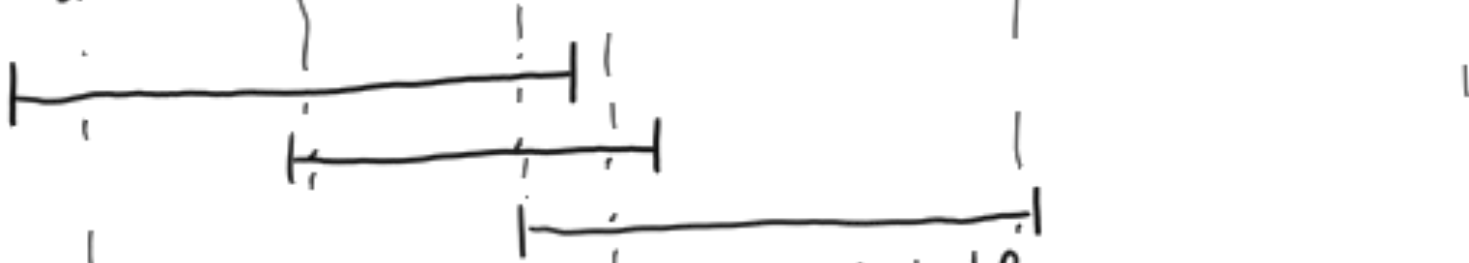
Data Windowing

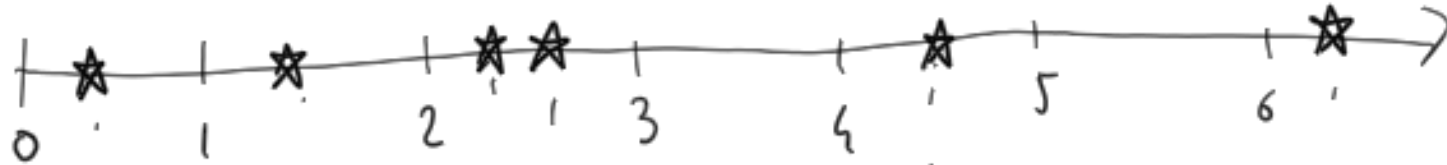|	Physical # events	Logical # time units
sliding moves on every event	native	native
tumbling	native	native
hopping	output claus	output clause

Physical windows
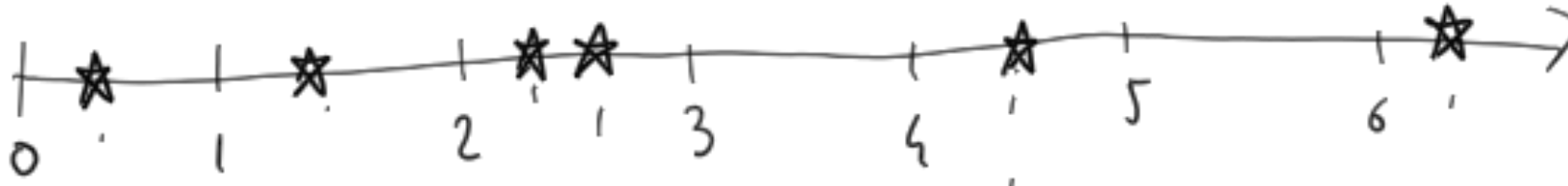
Physical windows: stream-only time model
e.g. a window of 3 events, sliding every event

e.g. a window of 3 events tumbling.

Logical windows

Logical sliding window (e.g. 2 units) they move on every event

Logical tumbling e.g. 2 unit

Data Windowing

Type	Syntax	Description
Logical Sliding	win:time(*time_period*)	Sliding window that covers the specified time interval into the past
Logical Tumbling	win:time_batch(*time_period* [, *reference point*] [, *flow control*])	Tumbling window that batches events and releases them every specified time interval, with flow control options
Physical Sliding	win:length(*size*)	Sliding window that covers the specified number of elements into the past
Physical Tumbling	win:length_batch(*size*)	Tumbling window that batches events and releases them when a given minimum number of events has been collected

Hopping windows
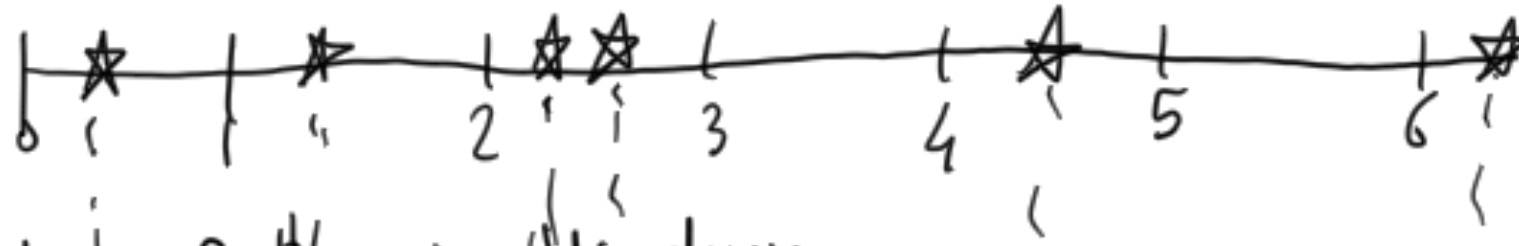
Logical Hopping Window
e.g. a window of 4 unit of time updated every 2 units

a Physical Hopping window
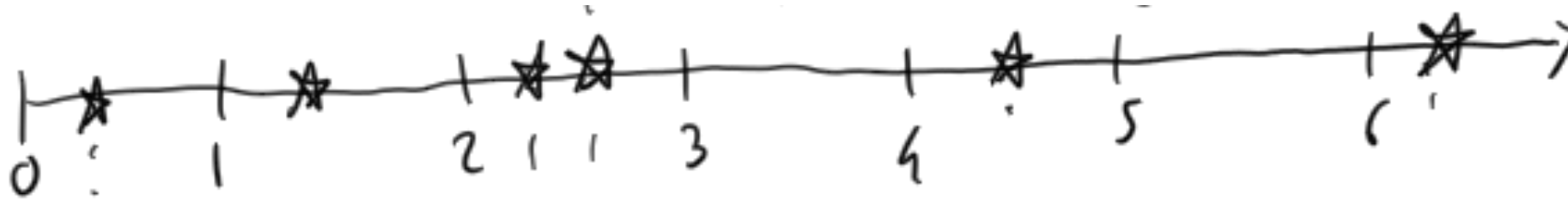e.g. a window of 5 events updated every 2 events

Session windows (not supported in EPL)

Session window (not present in EPL)
e.g. where events are closer than 1 unit

Output control

- The *output* clause is optional in Esper

- It is used to
    - Control the output rate
    - Suppress output events

```
output      [all | first | last | snapshot]
every output_rate [seconds | events]
```

Output control and Hopping Windows

- Control advancement of sliding windows

```
select      avg(temperature)
from        TemperatureSensorEvent.win:length(4)
output      snapshot every 2 events
```

```
select      avg(temperature)
from        TemperatureSensorEvent.win:time(4 sec)
output      snapshot every 2 sec
```

A digression on data windowing and SQL-style vs. Event-base style filtering
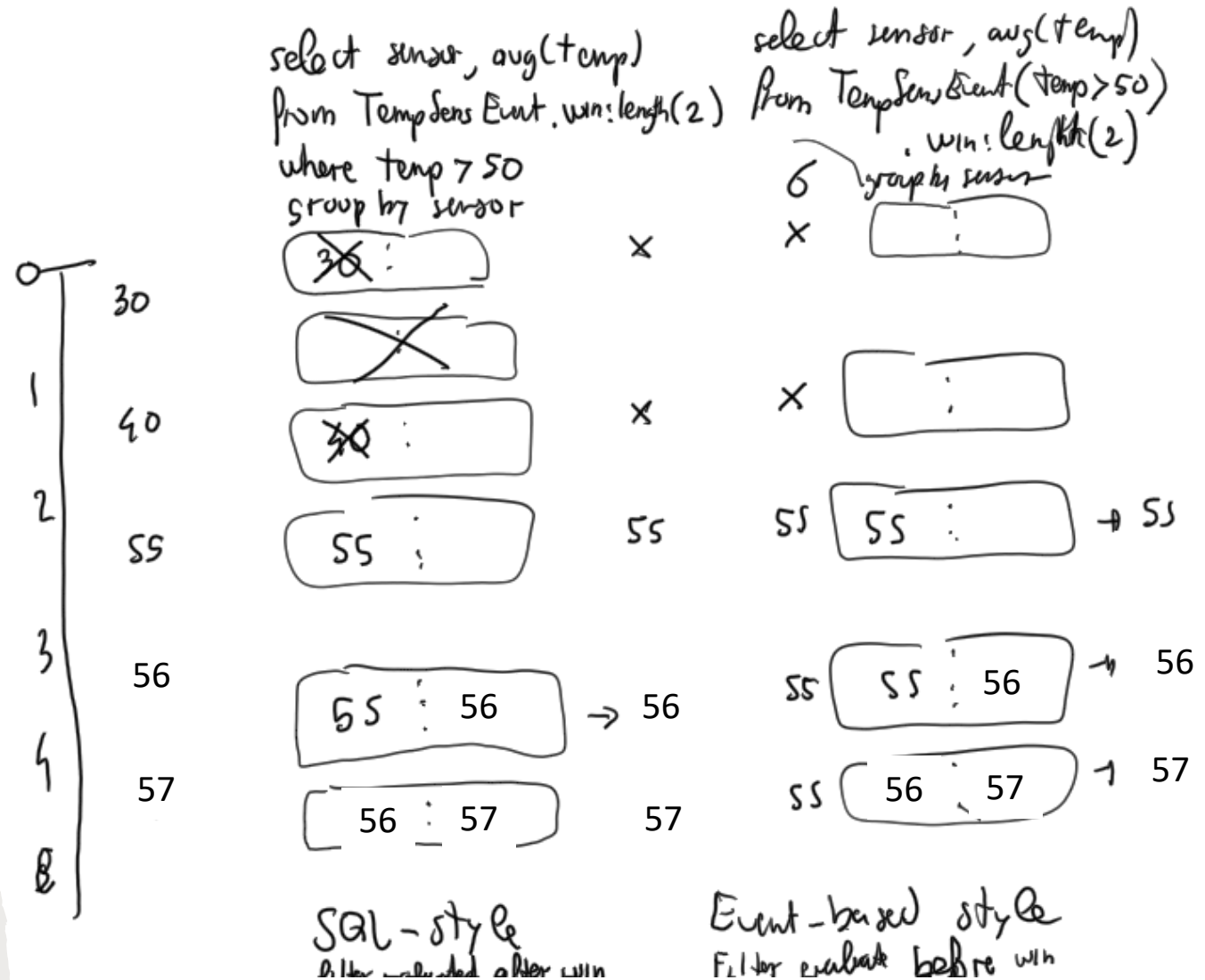
The **Pattern Matching** clause of the **E**vent **P**rocessing **L**anguage

Pattern matching

An event pattern emits when one or more event occurrences match the pattern definition, which can include

- Constraints on the content of events

- Constraints on the time of occurrence of events

- Conditions for pattern creation / termination

Pattern matching

- Content-based event selection

```
TempStream(sensor="S0", val>50)
```

- Time-based event observers specify time intervals or time schedules

Fires after 10 seconds

```
timer:interval(10 seconds)
```

```
timer:at(5, *, *, *, *)
```

Every 5 minutes
Syntax: minutes, hours, days of month, months, days of week

Pattern matching operators

- Logical operators
  - *and, or, not*

- Temporal operators that operate on event order
  - *-> (followed-by)*

- Creation/termination control
  - *every, every-distinct, [num] and until*

- Guards filter out events and cause termination
  - *timer:within, timer:withinmax* and *while*-expression

Pattern matching

```
select a.sensor from pattern
[every (
  a = SmokeEvent(smoke=true)
  ->
  TempEvent(val>50, sensor=a.sensor)
  where timer:within(2 min)
)]
```

Pattern matching

- *every expr*
  - When *expr* evaluates to true or false …
  - … the pattern matching for *expr* should re-start

- Without the every operator the pattern matching process does not re-start

Pattern matching

- This pattern fires when encountering an A event and then stops

```
A
```

- This pattern keeps firing when encountering A events, and does not stop

```
every A
```

Pattern matching

A1   B1   B2   A2   A3   B3   A4   B4

`every (A -> B)`   Detect an event A followed by an event B: at the time when B occurs, the pattern matches and restarts looking for the next A event

B1	{A1, B1}
B3	{A2, B3}
B4	{A4, B4}

Pattern matching

A1   B1   B2   A2   A3   B3   A4   B4

```
every A -> B
```

The pattern fires for every A followed by a B event

B1	{A1, B1}
B3	{A2, B3}, {A3, B3}
B4	{A4, B4}

Pattern matching

A1   B1   B2   A2   A3   B3   A4   B4

`A -> every B`   The pattern fires for an A event followed by every B event

B1	{A1, B1}
B2	{A1, B2}
B3	{A1, B3}
B4	{A1, B4}

Pattern matching

A1   B1   B2   A2   A3   B3   A4   B4

`every A -> every B`   The pattern fires for every A event followed by every B event

B1	{A1, B1}
B2	{A1, B2}
B3	{A1, B3}, {A2, B3}, {A3, B3}
B4	{A1, B4}, {A2, B4}, {A3, B4}, {A4, B4}

Pattern matching

- With the every operator
  - Multiple (partial) instances of the same pattern can be active at the same time
  - Each instance can consume some resources when events enter the engine
- End pending instances whenever possible
  - With the *timer:within* construct
  - With the *and not* construct
- Note: the data windows on a pattern do not always limit pattern sub-expression lifetime

Pattern matching

A1   A2   B1

Pattern	Results
every A -> B	{A1, B1}, {A2, B1}
every A -> (B and not A)	{A2, B1}

The *and not* operator causes the sub-expression looking for {A1, B?} to end when A2 arrives

Pattern matching

A1@1   A2@3   B1@4

Pattern	Results
every A -> B	{A1, B1}, {A2, B1}
every A -> (B where timer:within(2 sec))	{A2, B1}

The *timer:within* operator causes the sub-expression looking for {A1, B?} to end after 2 seconds

Combine queries

- The insert into clause forwards events to other streams for further downstream processing

```
insert        into FireComplexEvent
select        a.sensor as sensor,
              a.smoke as smoke,
              b.temperature as temperature
from          pattern
              [every a=SmokeSensorEvent(smoke=true)
              ->
              b=TemperatureSensorEvent(
              sensor=a.sensor, temperature>50)];
select        count(*)
from          FireComplexEvent.win:time(10 min);
```

Reference

- Esper documentation online
  - https://esper.espertech.com/release-8.8.0/reference-esper/html_single/
- Esper EPL online
  - http://esper-epl-tryout.appspot.com/epltryout/mainform.html

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http://streamreasoning.org/events/scep2019

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