Vertically Scalable solutions illustrated via EPL and Esper

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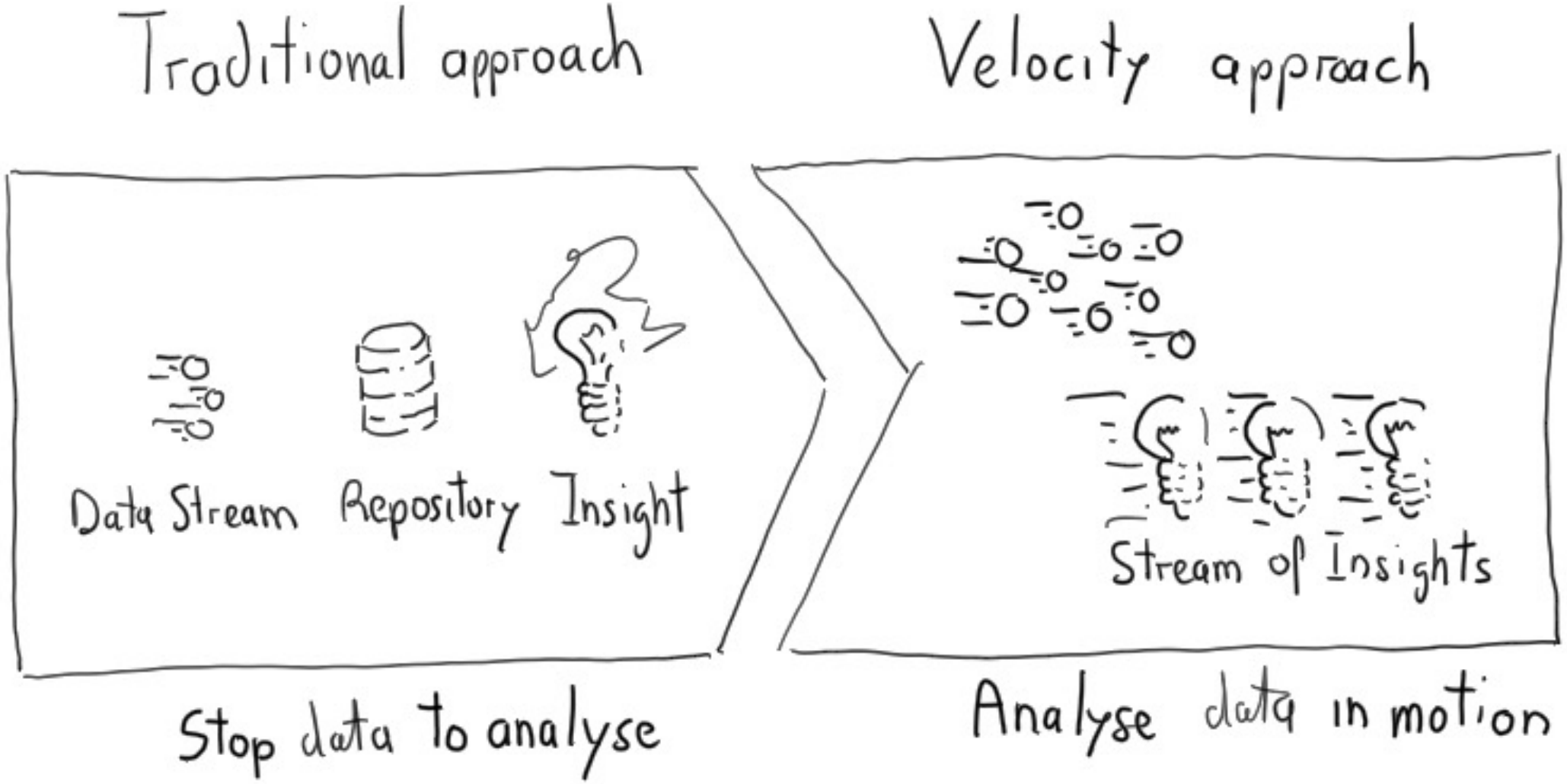
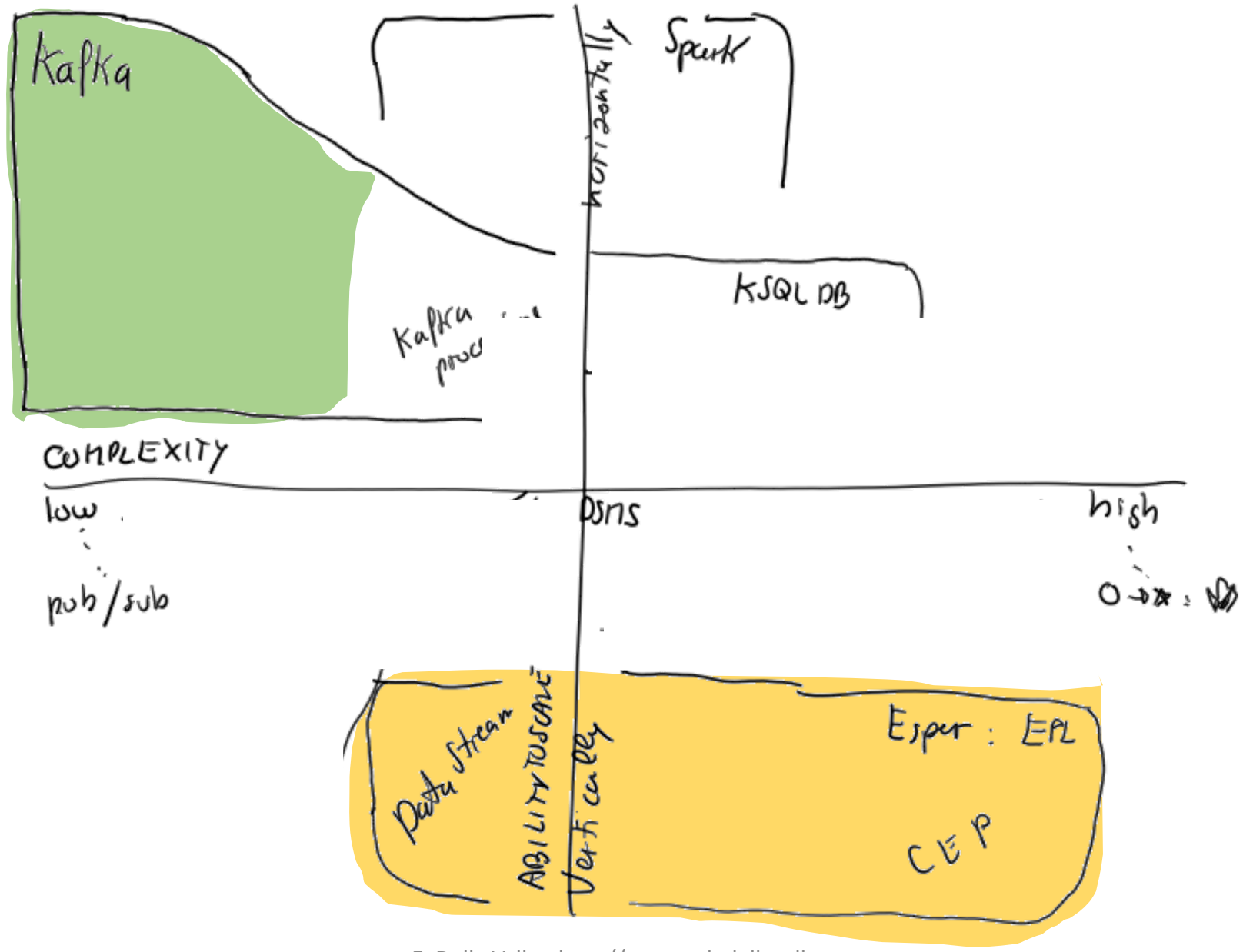
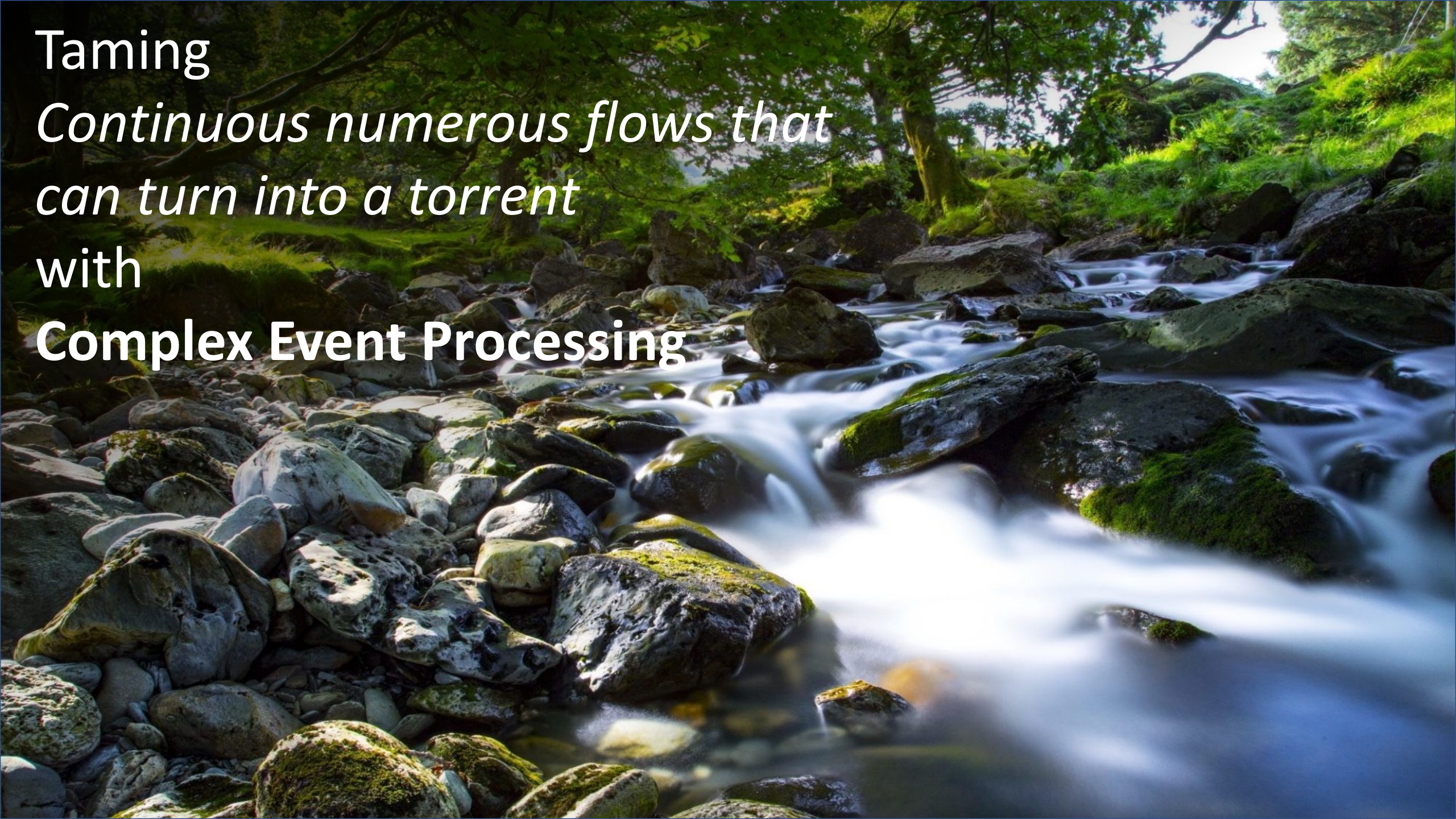
Positioning this lecture

1st premises: continuity matters




Kafka
Spark
KSQL DB
COMPLEXITY
low
high
pub/sub
Data Stream
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

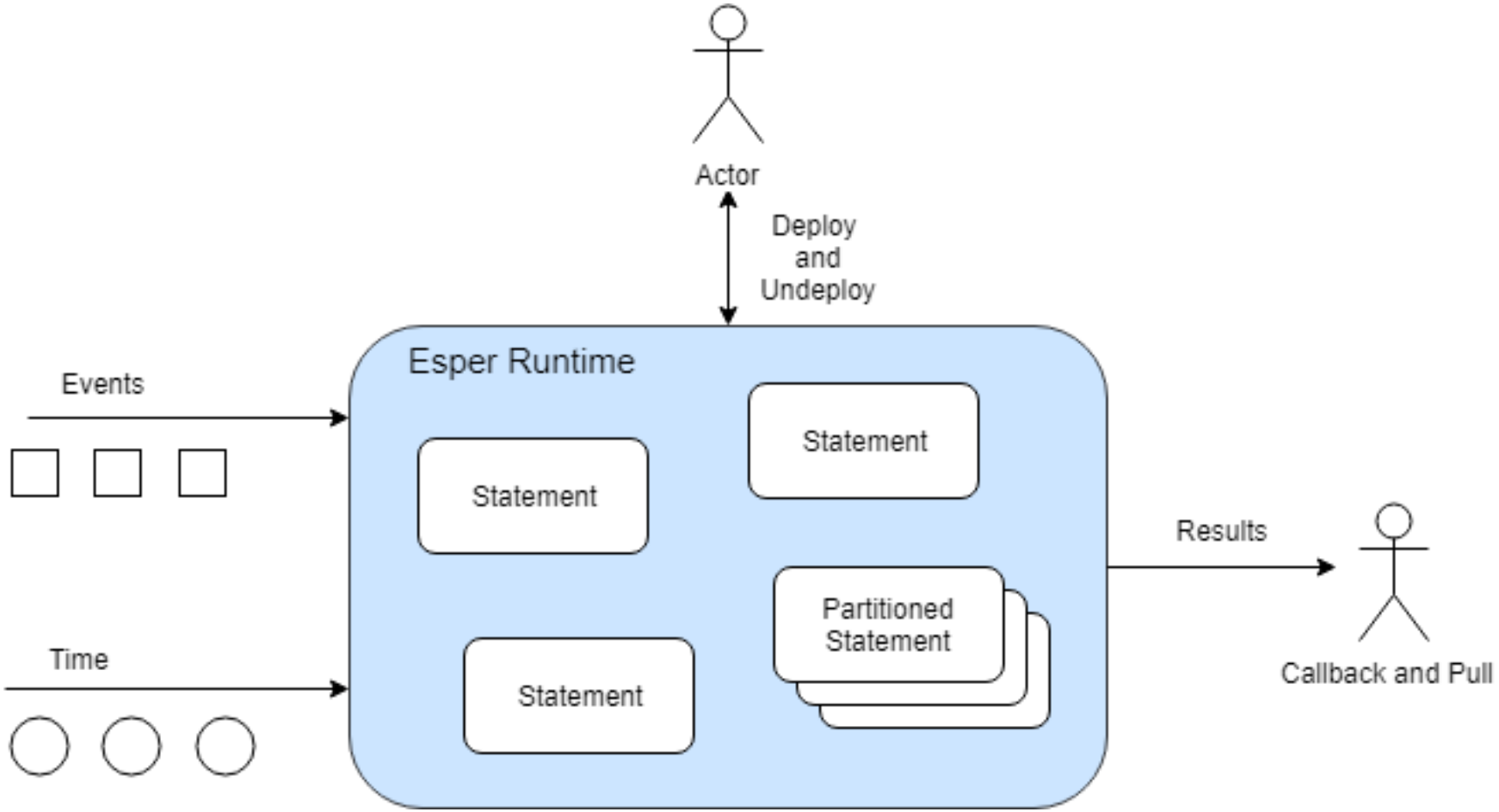
Esper in a nutshell (cont.)

- 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


Actor
Deploy
and
Undeploy
Esper Runtime
Events
Statement
Statement
Statement
Partitioned
Statement
Time
Statement
Results
Callback and Pull

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)

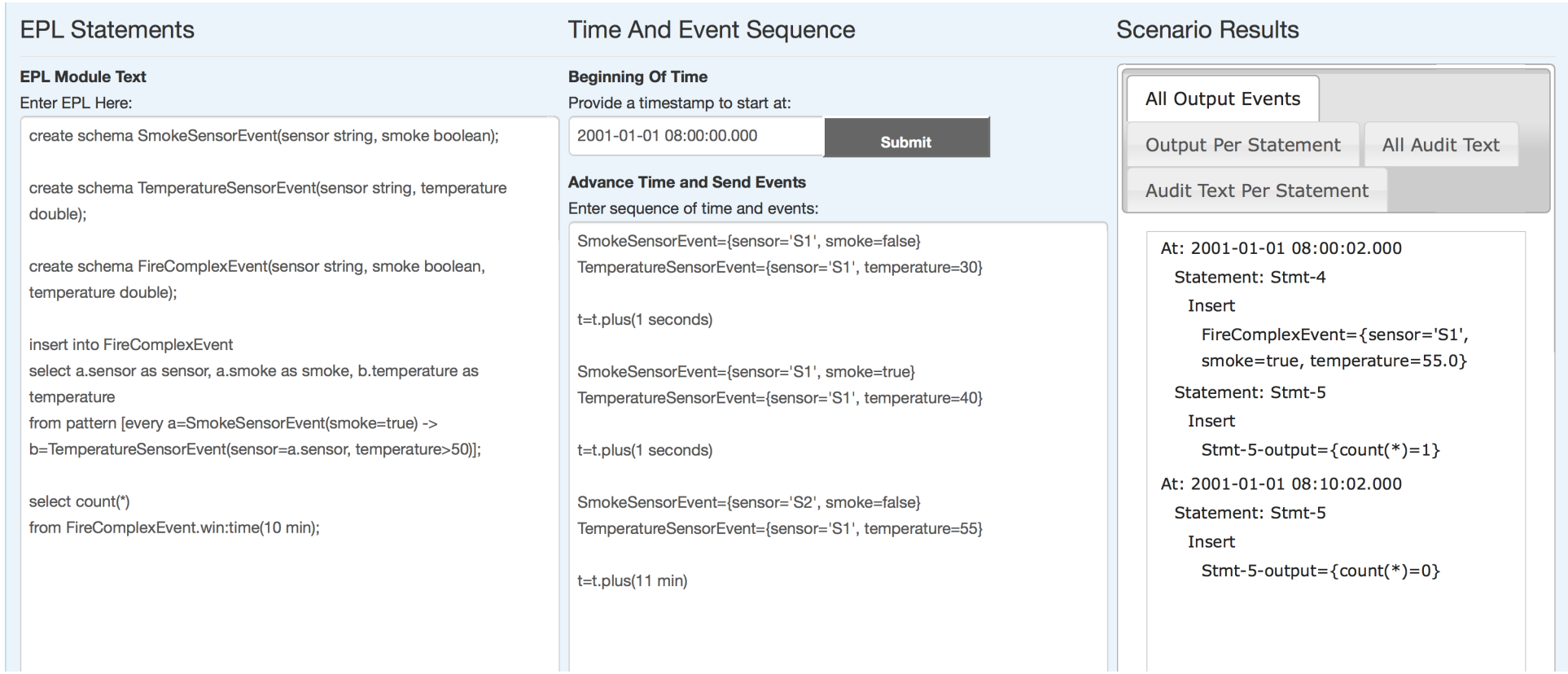
- EPL is similar to SQL
  - Select, where, …
- Event streams and views instead of tables
  - Views define the data available for the query
  - Views can represent windows over streams
  - Views can also sort events, derive statistics from event attributes, group events, …

EPL syntax

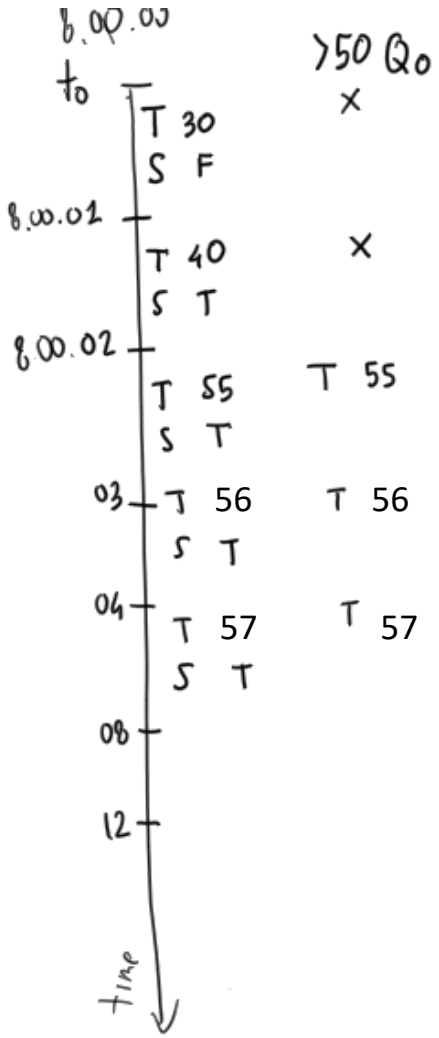
```
[insert into insert_into_def]
select select_list
from stream_def [as name]
[, stream_def [as name]] [,...]
[where search_conditions]
[group by grouping_expression_list]
[having grouping_search_conditions]
[output output_specification]
[order by order_by_expression_list]
[limit num_rows]
```

Running example

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



Filtering



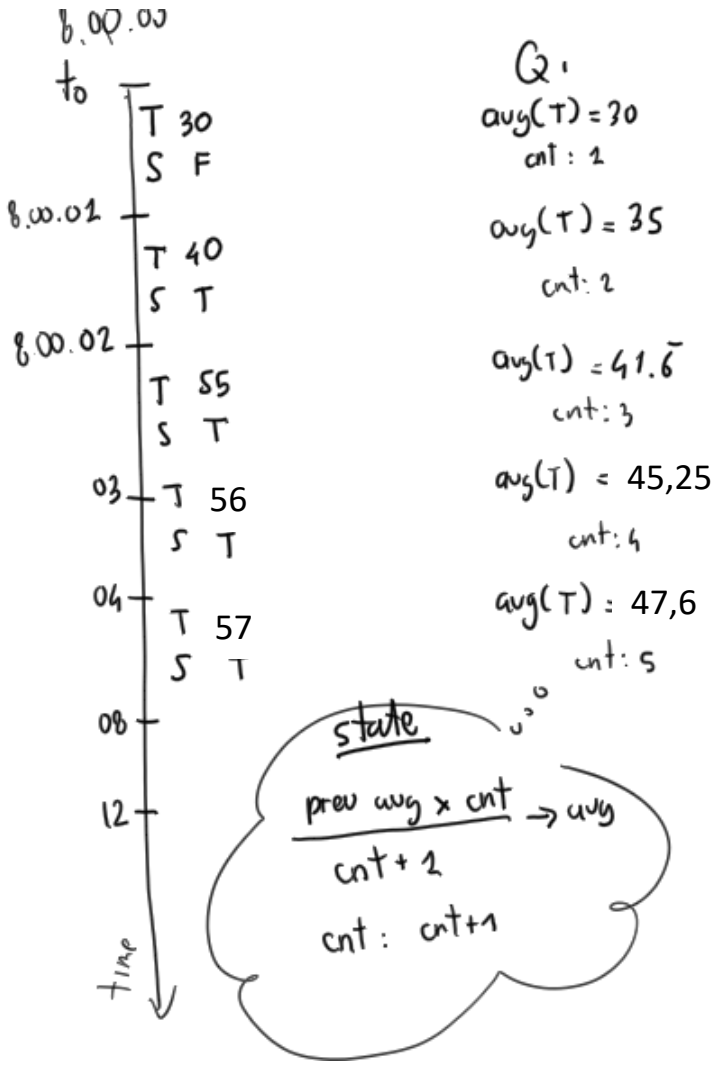
the SQL-style

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

the Event-Based System Style

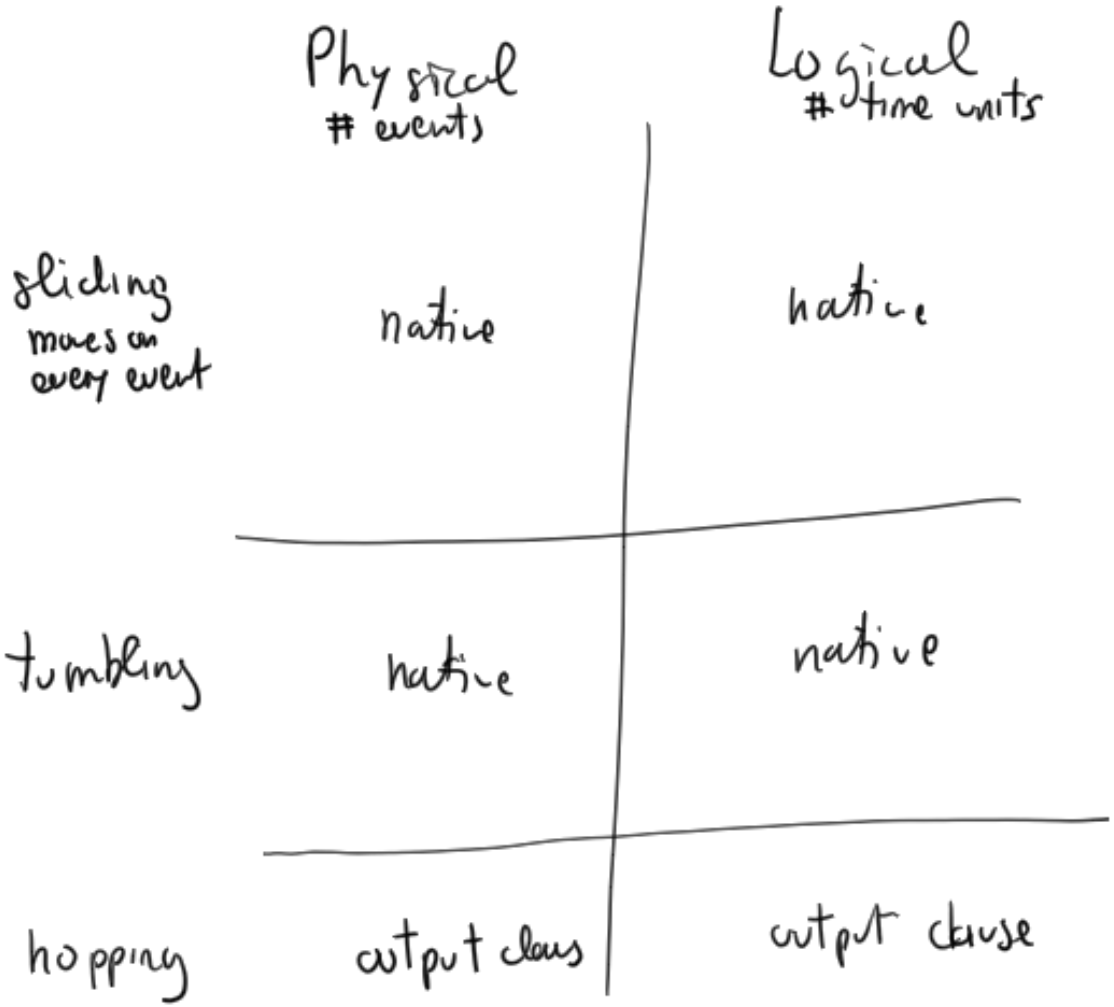
```
select *
from TemperatureSensorEvent(temperature > 50) ;
```

Basic Aggregation

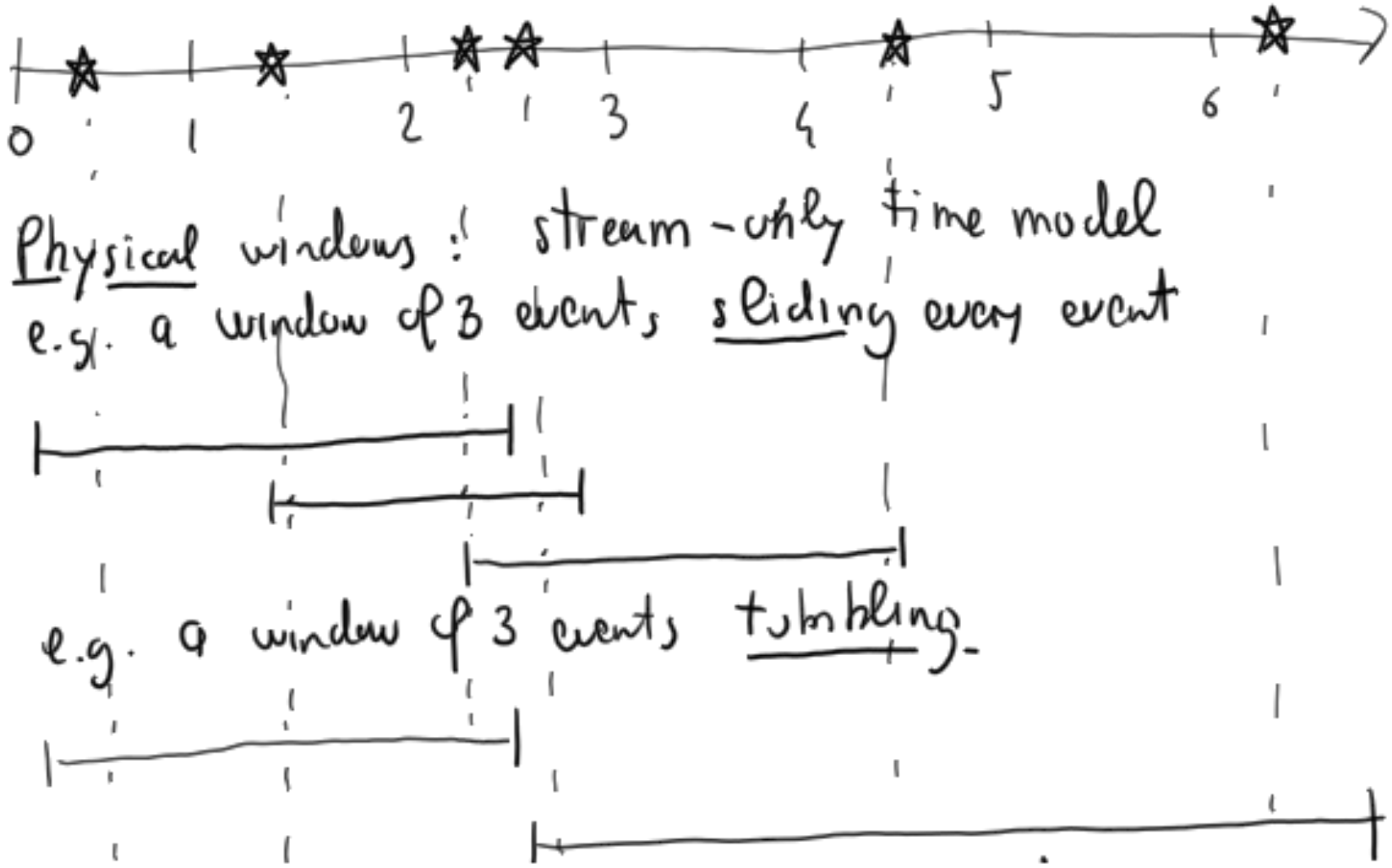



```
select sensor, avg(temperature)
from TemperatureSensorEvent
group by sensor;
```

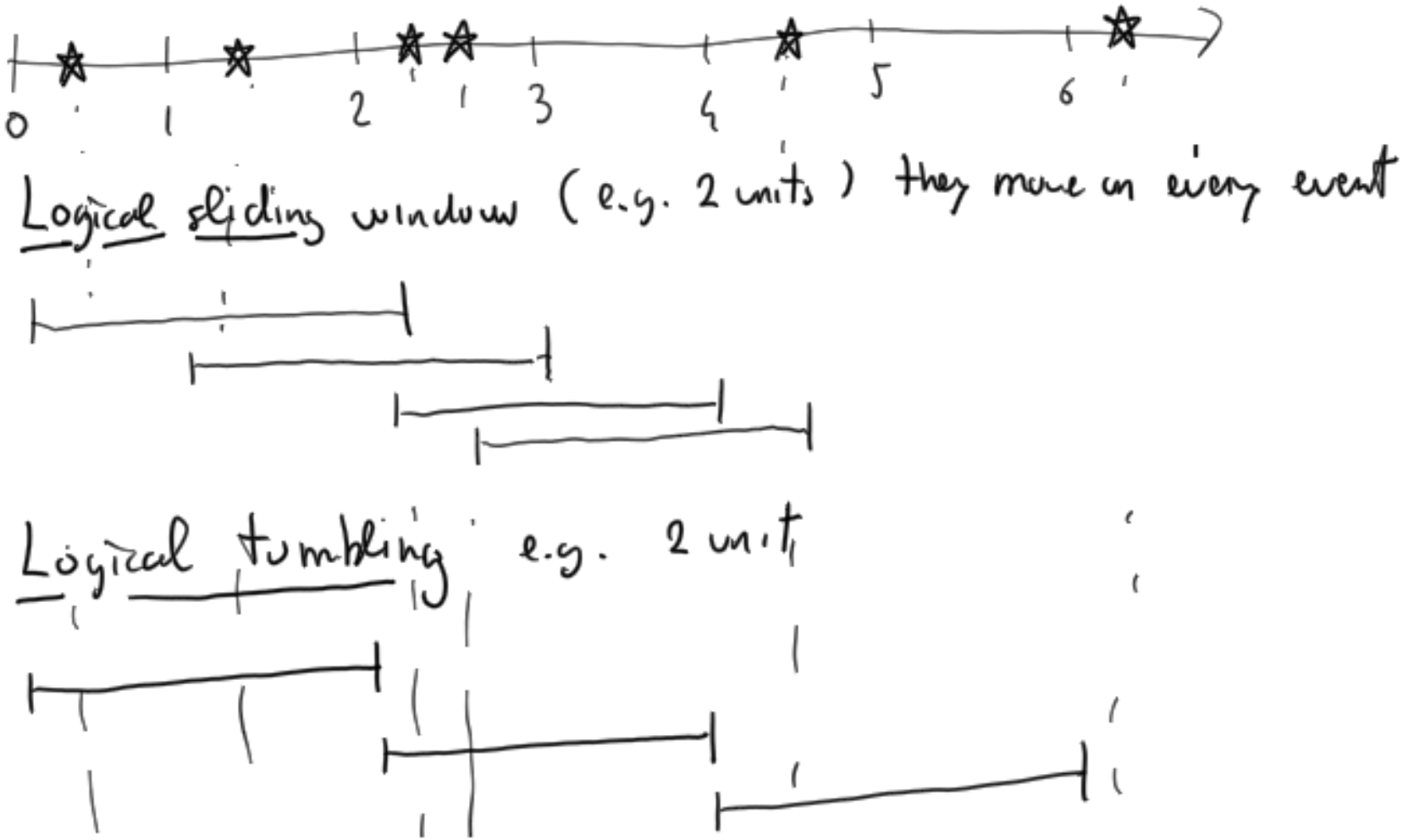
Data Windowing



Physical windows



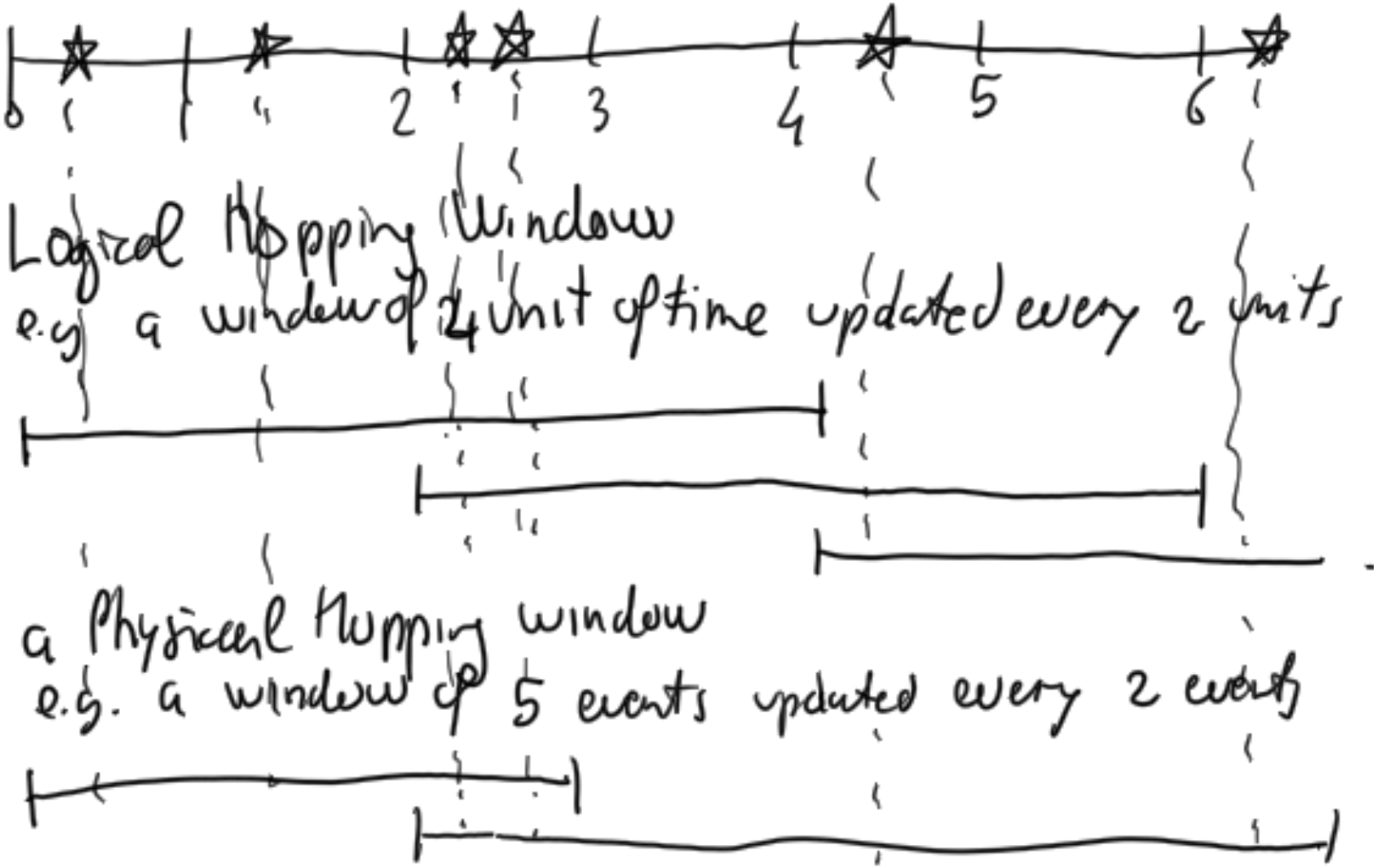
Logical windows



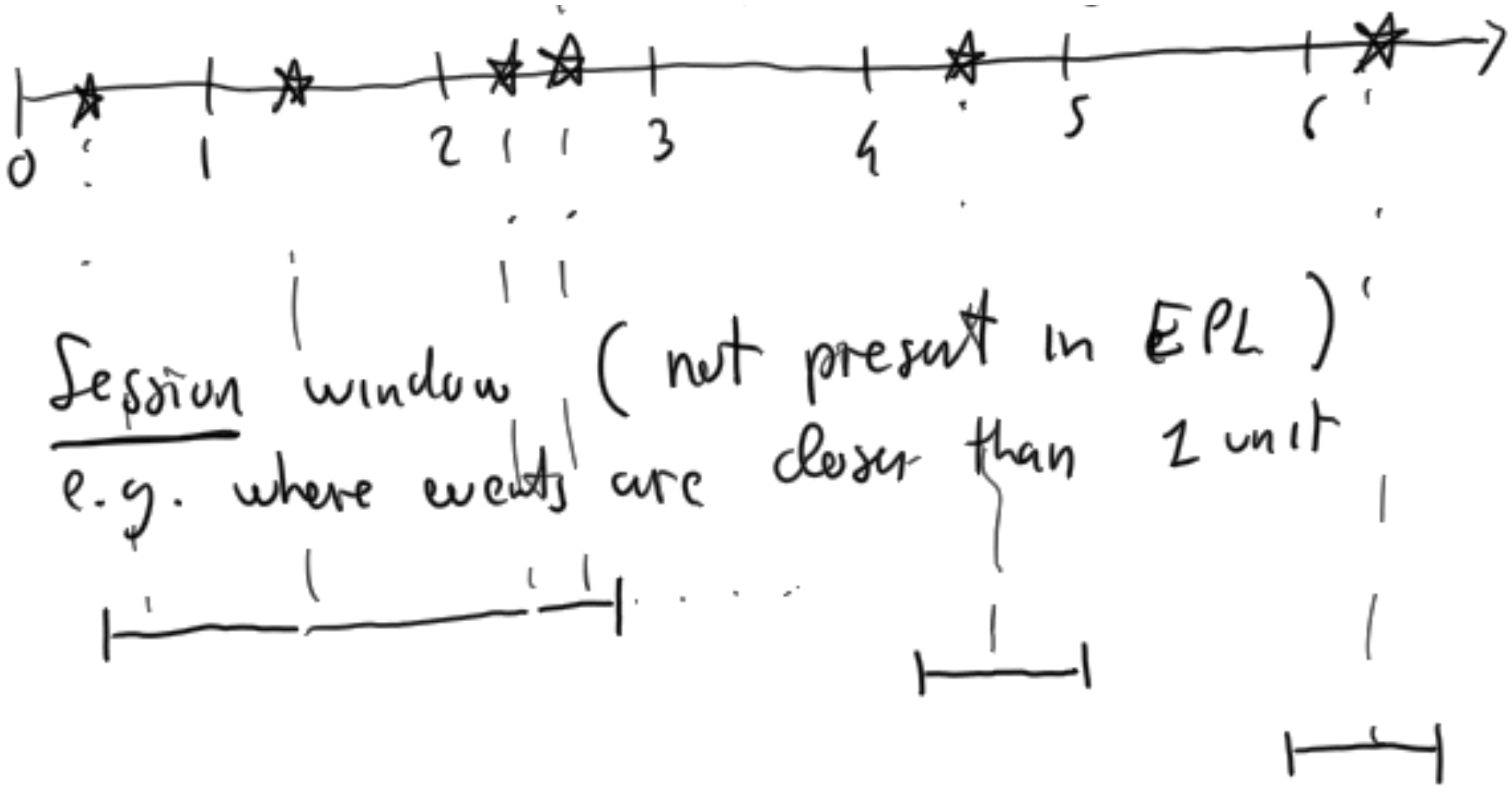
Data Windowing

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



Session windows (not supported in EPL)



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]
```

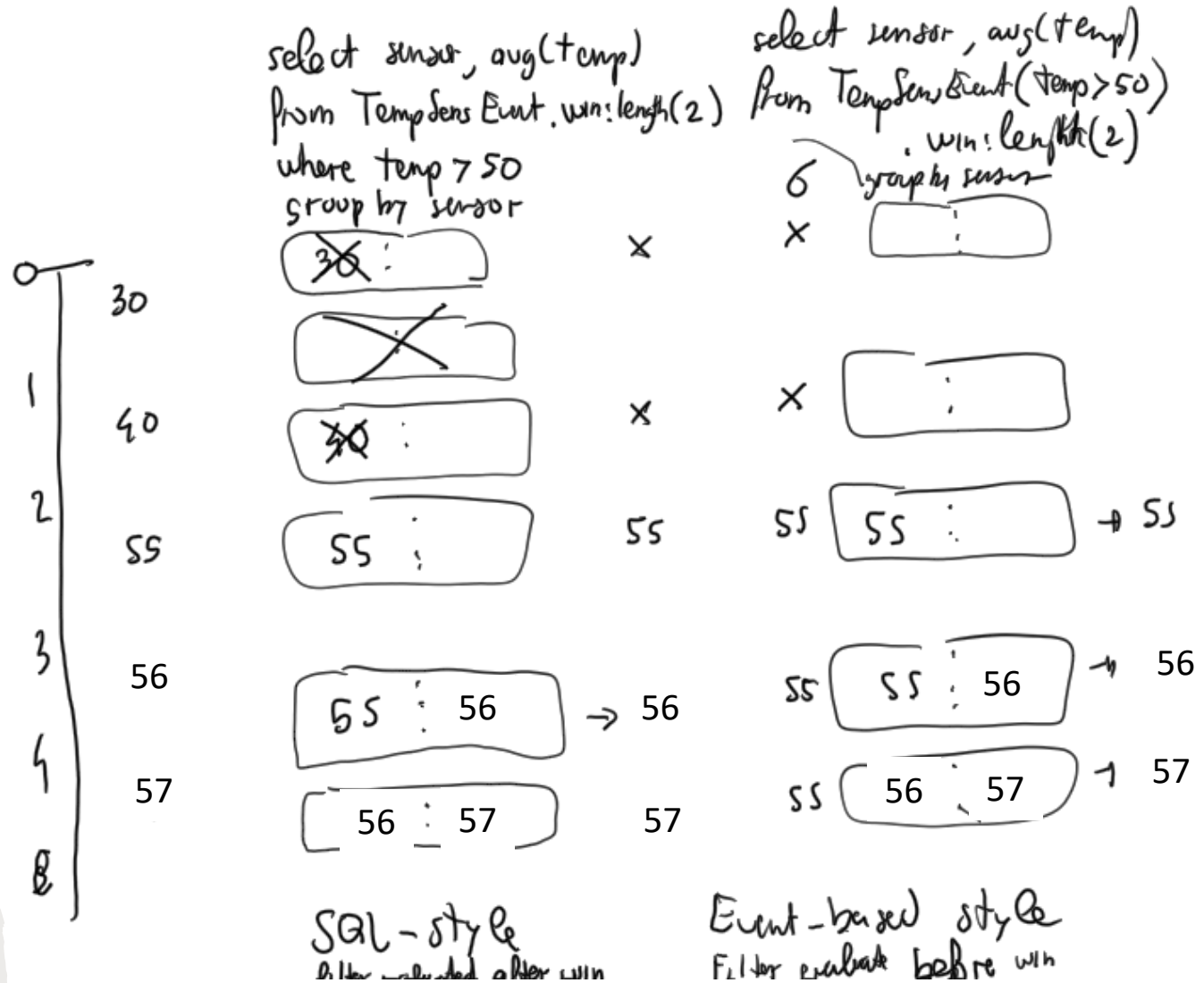
Output control and Hopping Windows

- 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

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

Fires after 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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- The original slides where prepared by Alessandro Margara for the PhD course on “Stream and Complex Event Processing in the Big Data Era” offered in 2019

http://streamreasoning.org/events/scep2019

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