CS 744: DATAFLOW

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Fall 2022

ADMINISTRIVIA

Grading In Progress

- Assignment 2
- Course project proposal → Soon as in this week!

About the Midterm

- It was too long!

MID-SEMESTER FEEDBACK

More frequent change in paper reading group could be beneficial.
It was hard to find time for paper discussions, given the random assignments and fixed teammates
I would have liked to have chosen my reading group. I find it somewhat difficult to organize
…

I would like if more time was given for exam
Exams should be longer in time duration, very less time to actually think deep
…

It would've been nice if we had to … list any questions we had about the paper in the paper review form.

More time for in-class discussions.
Concentrating for 1.25 hours continuously is hard. A break in the middle for discussion?

maybe in-class quizzes?? → Not doing this

PAPER REVIEW GROUPS

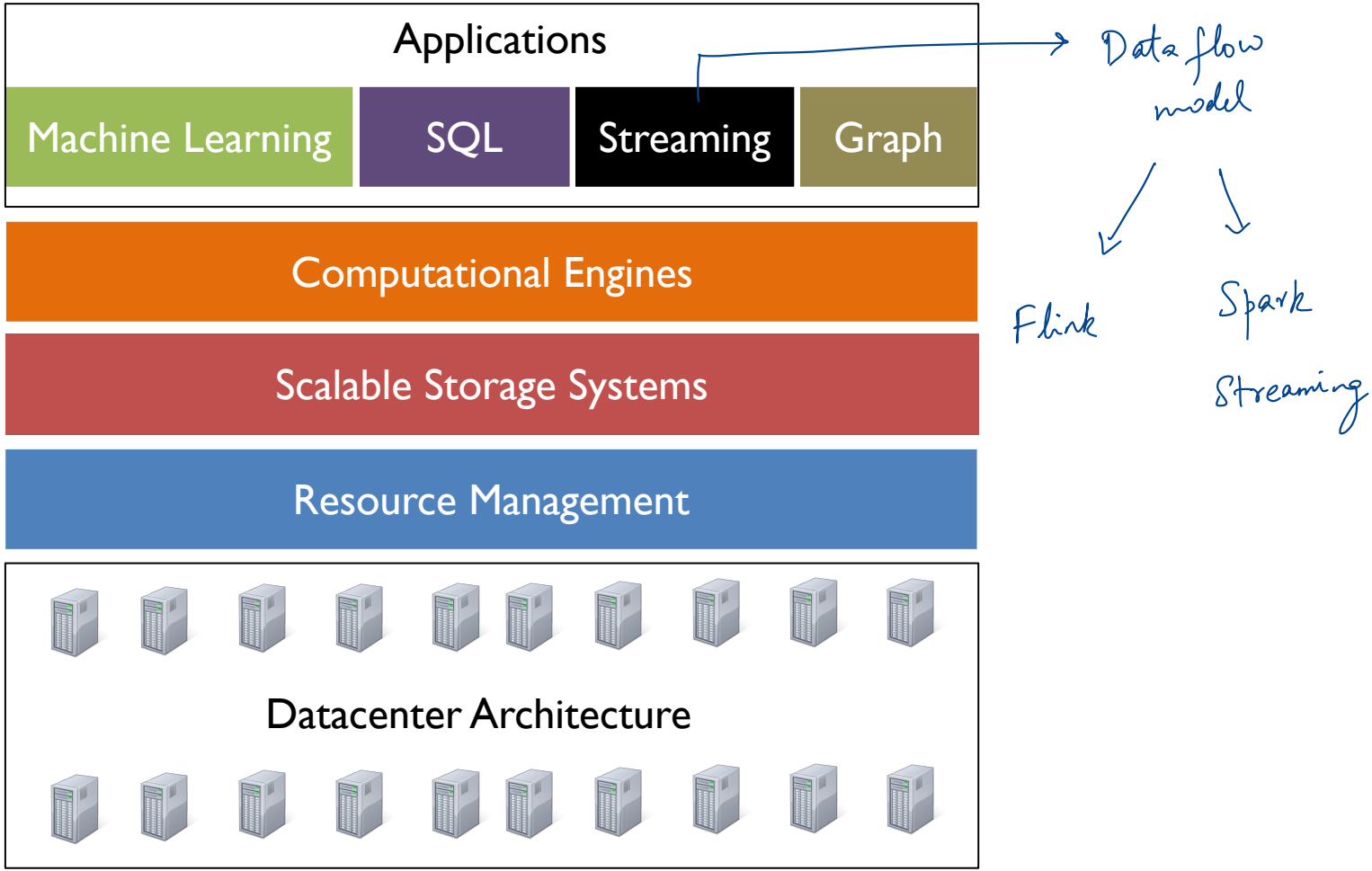
Optional from next class (Nov 3rd)

Re-shuffle groups to have new "suggested" groups

You can do any of

- Use (part of) suggested group
- Discuss with your own group
- Read on your own!

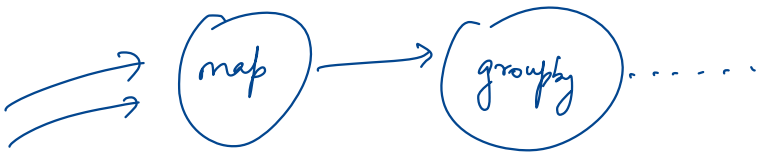
from next review onwards


Applications
Machine Learning
SQL
Streaming
Graph
Computational Engines
Scalable Storage Systems
Resource Management
Datacenter Architecture
Data flow model
Flink
Spark Streaming

Spark or SCOPE

"Data flow"

data is flowing through this DAG



DATAFLOW MODEL (?)

Streaming data or Unbounded data

- Temperature / sensor readings ...
- Logs generated by services
- Shared service with user sessions (game multiplayer)

MOTIVATION

Streaming Video Provider

- How much to bill each advertiser ?
- Need per-user, per-video viewing sessions
- Handle out of order data

→ how long did user watch ads

→ which ads were shown to which user

Goals

- Easy to program → similar to PyTorch
- Balance correctness, latency and cost

Out of order data arrival

- very very common
- design systems to handle this!

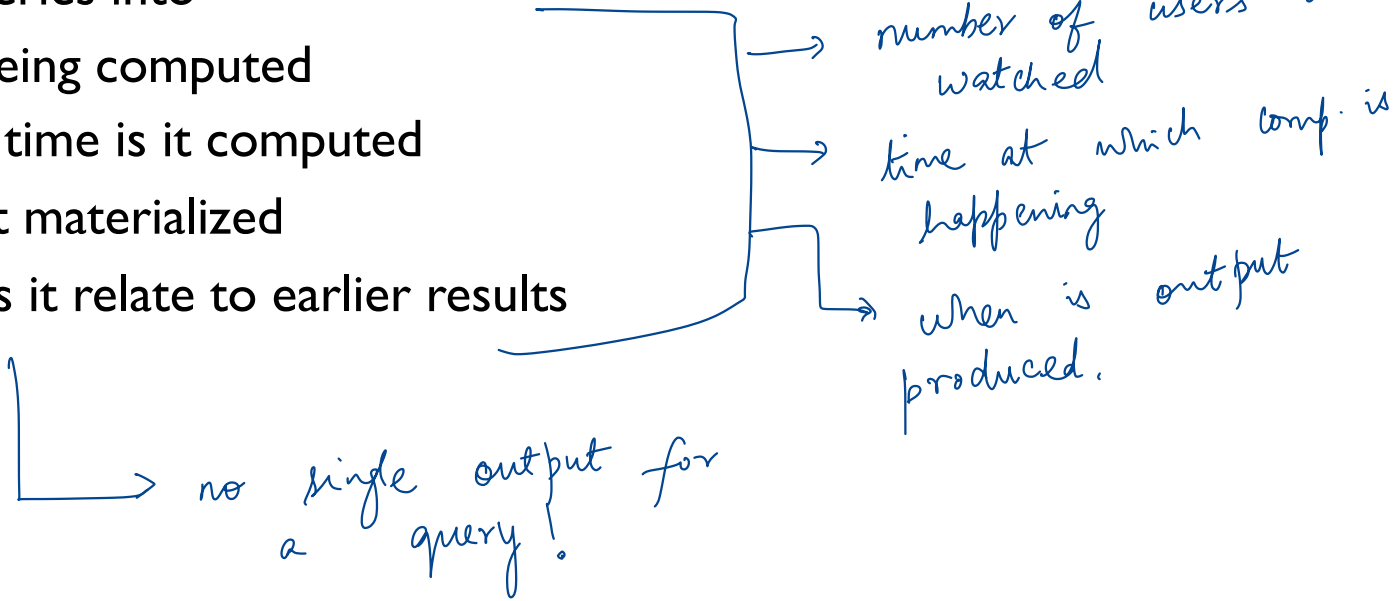
APPROACH

unbounded data + out-of-order arrival

Separate user API from execution

Decompose queries into

- What is being computed
- Where in time is it computed
- When is it materialized
- How does it relate to earlier results

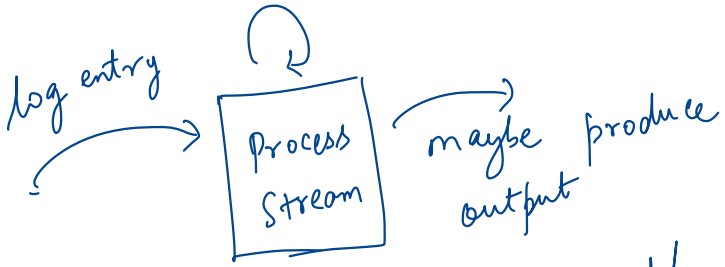


STREAMING VS. BATCH

Streaming

→ Flink, Naiad, Timely Dataflow

Record-at-a-time,
Event-based systems



- produce outputs quickly
- how to get high throughput

Batch

MapReduce, Spark, SCOPE

- Wait for a fixed time t.
  Gather all inputs
- Run a batch job. Produce outputs
- Simple model

If t = 10 mins, then outputs only appear every ≥ 10 mins

TIMESTAMPS

Event time:

↳ Time at which an event happend

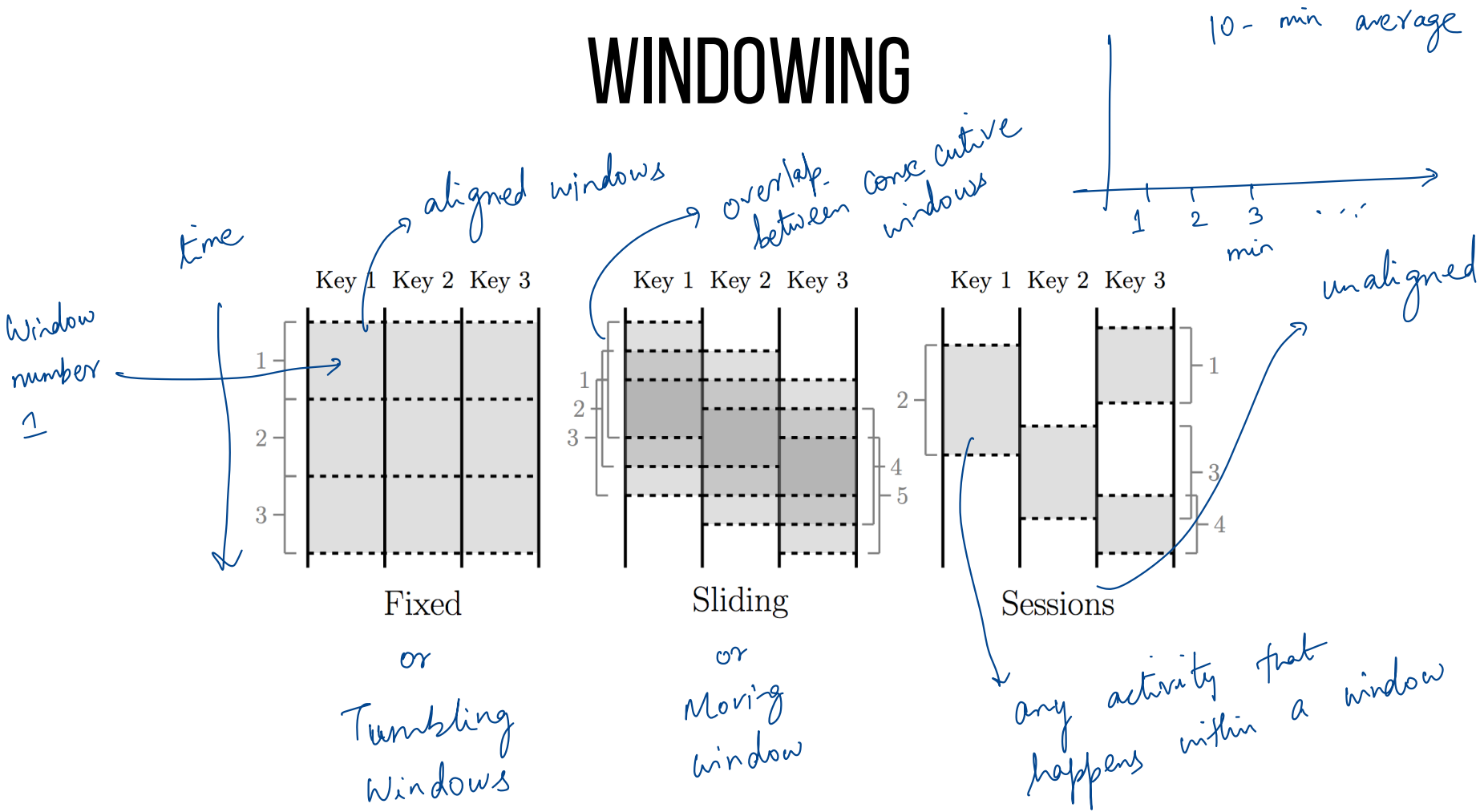
↳ when the user watched the video

Processing time:

↳ Time at which the event is processed / used in computation

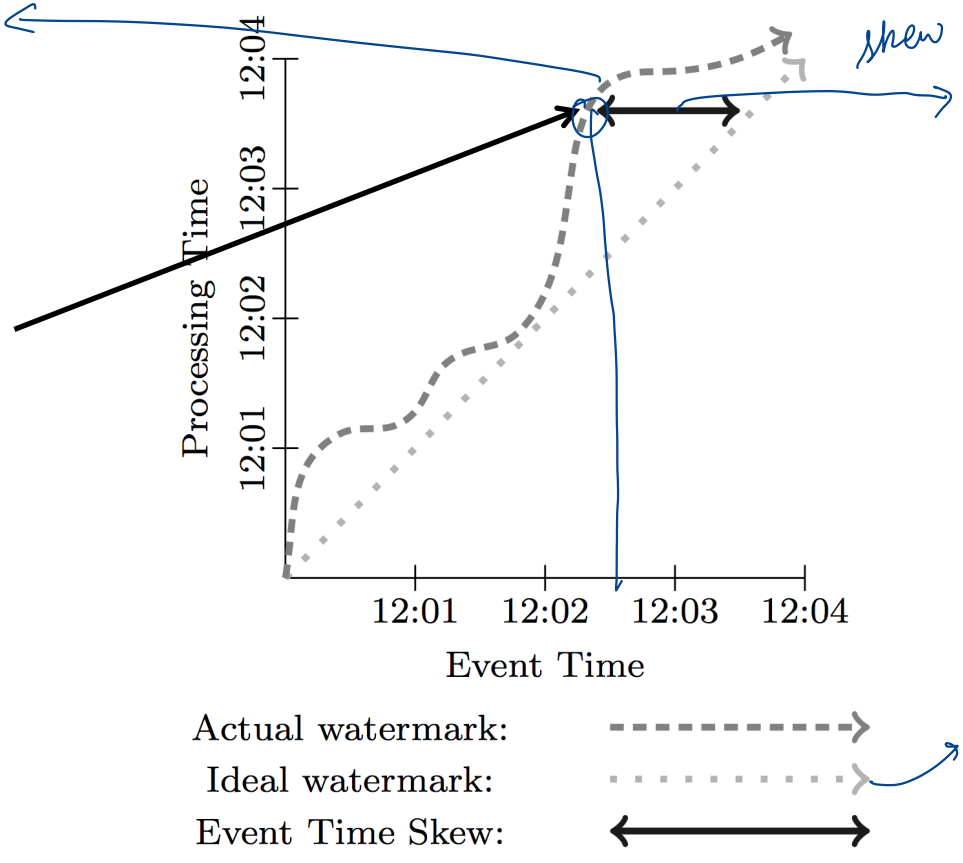
→ Processing time ≥ Event time

WINDOWING


10- min average
1
2
3
min
time
aligned windows
overlap between consecutive windows
Window number
1
Key 1
Key 2
Key 3
1
2
3
Fixed
or
Tumbling Windows
Key 1
Key 2
Key 3
1
2
3
4
5
Sliding
or
Moving window
Key 1
Key 2
Key 3
2
1
3
4
Sessions
unaligned
any activity that happens within a window

WATERMARK OR SKEW

heuristic based



how far behind is processing time from event time

System has processed all events up to 12:02:30

ideally we process events as they happen

API

ParDo: Map operator

GroupByKey: group tuples by key

Windowing

AssignWindow → puts tuples into windows

MergeWindow → useful for sessions

EXAMPLE

Key Value event time windows

$(k_1, v_1, 13{:}02, [0, \infty))$,
$(k_2, v_2, 13{:}14, [0, \infty))$,
$(k_1, v_3, 13{:}57, [0, \infty))$,
$(k_1, v_4, 13{:}20, [0, \infty))$

↓ *AssignWindows(Sessions(30m))*

$(k_1, v_1, 13{:}02, [13{:}02, 13{:}32))$,
$(k_2, v_2, 13{:}14, [13{:}14, 13{:}44))$,
$(k_1, v_3, 13{:}57, [13{:}57, 14{:}27))$,
$(k_1, v_4, 13{:}20, [13{:}20, 13{:}50))$

(t, t+30)

↓ *DropTimestamps*

$(k_1, v_1, [13{:}02, 13{:}32))$,
$(k_2, v_2, [13{:}14, 13{:}44))$,
$(k_1, v_3, [13{:}57, 14{:}27))$,
$(k_1, v_4, [13{:}20, 13{:}50))$

GroupByKey

$(k_1, [(v_1, [13{:}02, 13{:}32)),$
$(v_3, [13{:}57, 14{:}27)),$
$(v_4, [13{:}20, 13{:}50))]),$
$(k_2, [(v_2, [13{:}14, 13{:}44))])$

grouped by key

Check if windows overlap

↓ *MergeWindows(Sessions(30m))*

if so merge

$(k_1, [(v_1, [\mathbf{13{:}02}, \mathbf{13{:}50})),$
$(v_3, [13{:}57, 14{:}27)),$
$(v_4, [\mathbf{13{:}02}, \mathbf{13{:}50}))]),$
$(k_2, [(v_2, [13{:}14, 13{:}44))])$

↓ *GroupAlsoByWindow*

$(k_1, [([\mathbf{v_1}, \mathbf{v_4}], [13{:}02, 13{:}50)),$
$([\mathbf{v_3}], [13{:}57, 14{:}27))]),$
$(k_2, [([\mathbf{v_2}], [13{:}14, 13{:}44))])$

↓ *ExpandToElements*

$(k_1, [v_1, v_4], \mathbf{13{:}50}, [13{:}02, 13{:}50))$,
$(k_1, [v_3], \mathbf{14{:}27}, [13{:}57, 14{:}27))$,
$(k_2, [v_2], \mathbf{13{:}44}, [13{:}14, 13{:}44))$

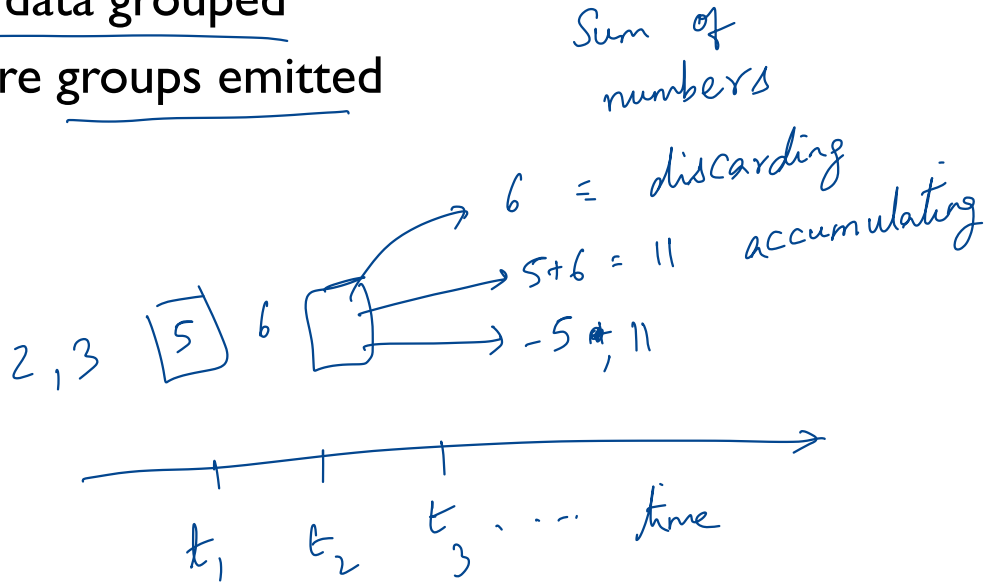
TRIGGERS AND INCREMENTAL PROCESSING

Windowing: where in event time are data grouped

Triggering: when in processing time are groups emitted

Strategies

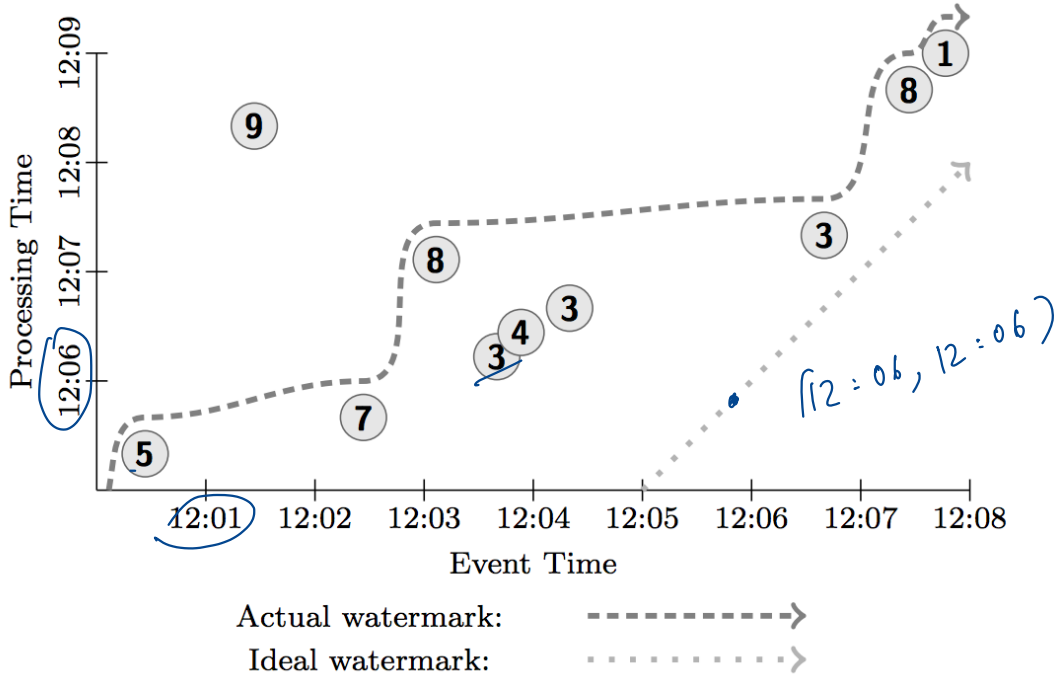
- Discarding
- Accumulating
- Accumulating & Retracting



RUNNING EXAMPLE

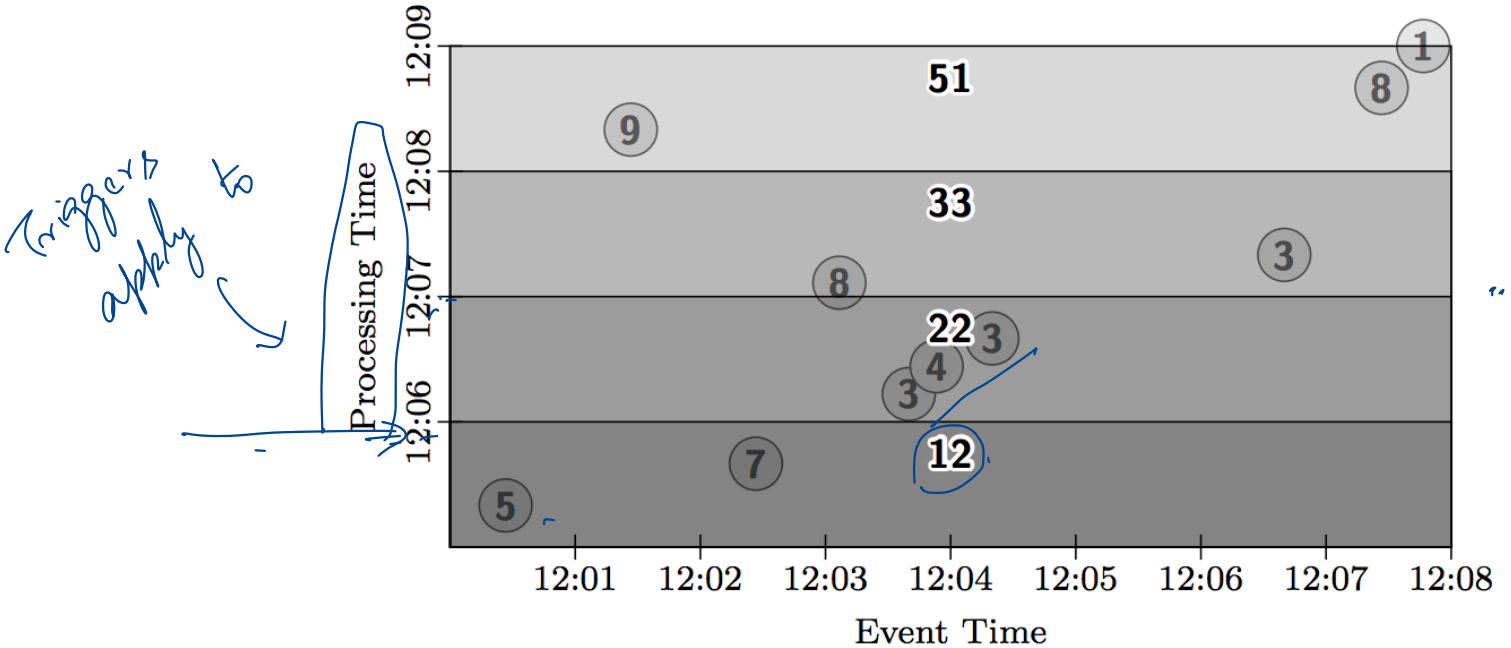
```
PCollection<KV<String, Integer>> input = IO.read(...);
PCollection<KV<String, Integer>> output =
        input.apply(Sum.integersPerKey());
```

Sum all values shown here



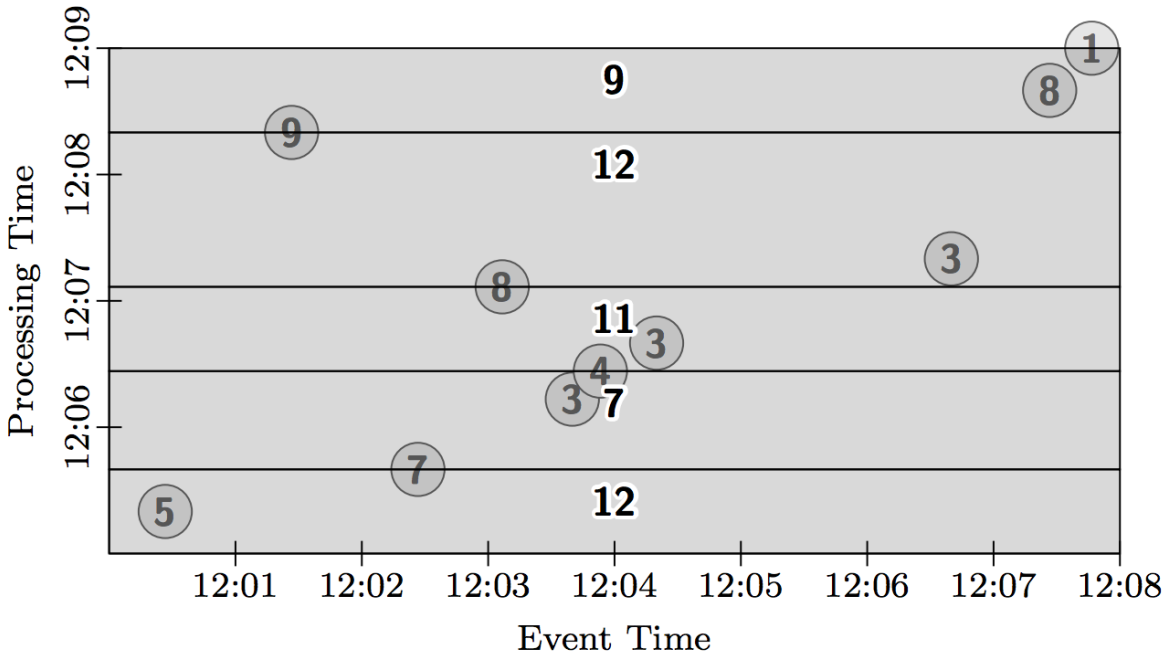
GLOBAL WINDOWS, ACCUMULATE

```
PCollection<KV<String, Integer>> output = input
    .apply(Window.trigger(Repeat(AtPeriod(1, MINUTE))
                  .accumulating())
    .apply(Sum.integersPerKey());
```



GLOBAL WINDOWS, COUNT, DISCARDING

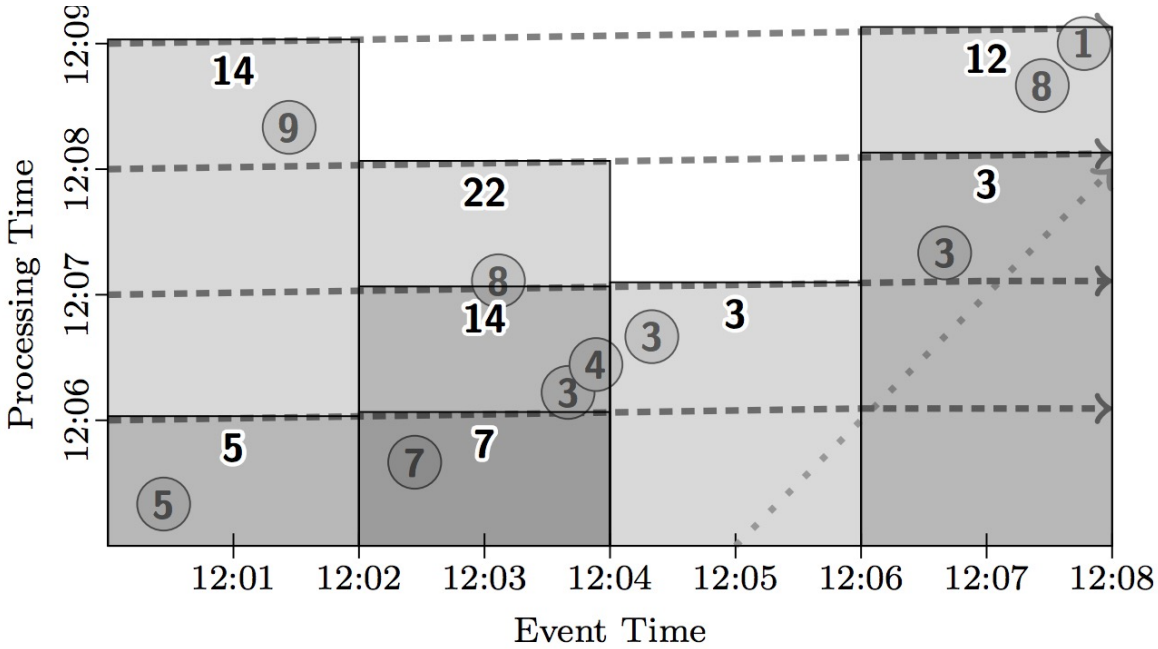
```
PCollection<KV<String, Integer>> output = input
    .apply(Window.trigger(Repeat(AtCount(2)))
                  .discarding())
    .apply(Sum.integersPerKey());
```



FIXED WINDOWS, MICRO BATCH

```
PCollection<KV<String, Integer>> output = input
    .apply(Window.into(FixedWindows.of(2, MINUTES))
                .trigger(Repeat(AtWatermark())))
                .accumulating())
```

Figure 1.1



SUMMARY/LESSONS

Design for unbounded data: Don't rely on completeness

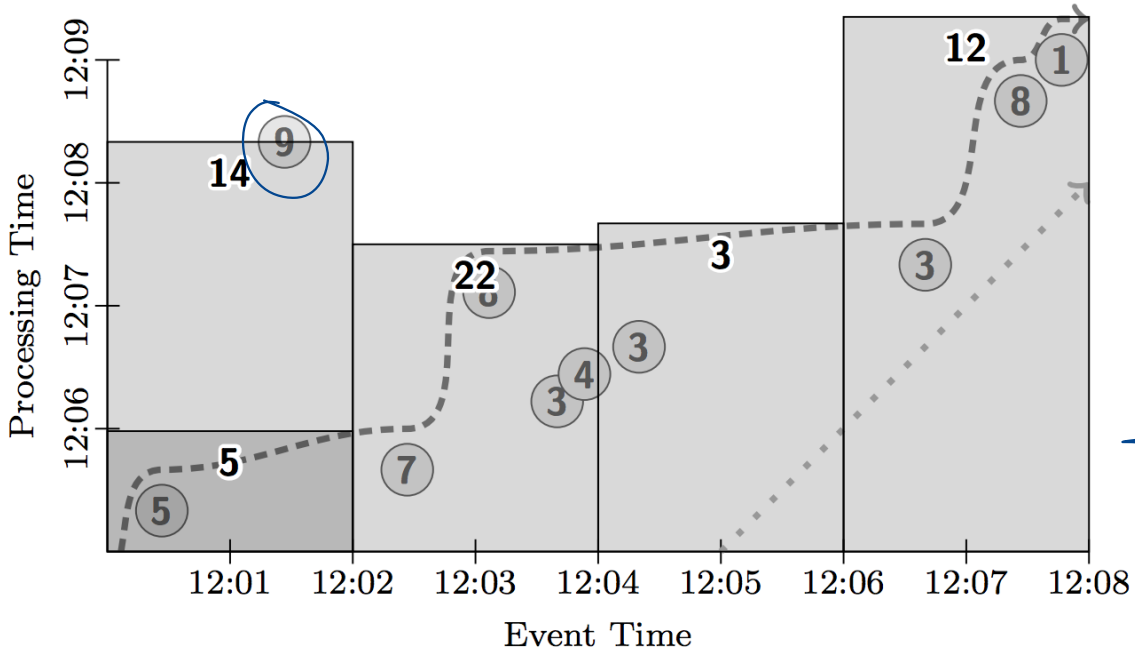
Be flexible, diverse use cases

- Billing
- Recommendation
- Anomaly detection

Windowing, Trigger API to simplify programming on unbounded data

DISCUSSION

https://forms.gle/gUKw3ZP36JjBciABA



Wait longer for watermark but you get "one" result

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fast to trigger for late arrivals

Consider you are implementing a micro-batch streaming API on top of Apache Spark. What are some of the bottlenecks/challenges you might have in building such a system?

NEXT STEPS

Next class: Flink