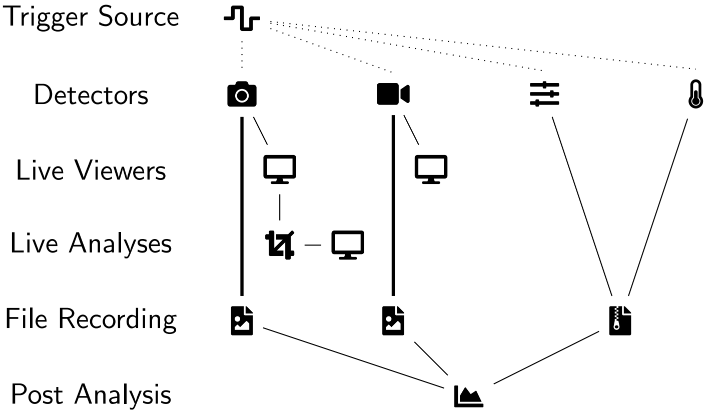
dranspose: distributed event formation with dynamic map-reduce

Felix Engelmann

felix.engelmann@maxiv.lu.se

30th November 2023

Existing Infrastructure



Limitations of Live Analysis

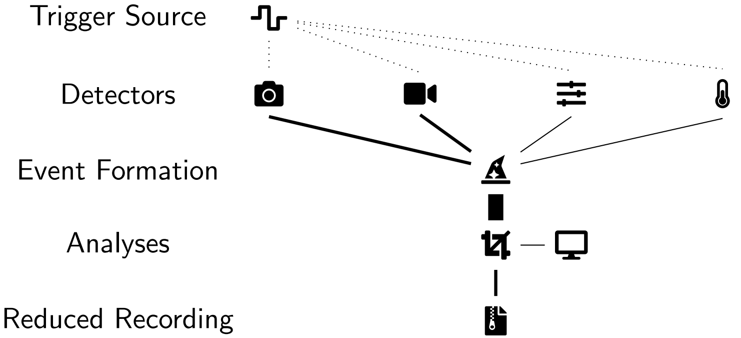
Single Data Stream

- only one detector data available
- simple tools, e.g. azint, crop, time integration
- beyond limits: normalisation to I_0, sorting by motor position

Custom Modules

- module development by SciDa
- custom deployment/integration
- custom live viewer interaction (mostly REST)

Event Formation



Frame/Worker Matrix Transformation

Frame Stream

	1	2	3	4	5
	1	2	3	4	5
	1			2	
	1		2		3

Event Stream

Event 1	 1	 1	 1	 1
Event 2	 2	 2		
Event 3	 3	 3		 2
Event 4	 4	 4	 2	
Event 5	 5	 5		 3

Stream

- matrix is sequentially filled column by column
- possibly unknown size (reactive scanning)

Bandwidth and Latency

Limitations

- TCP connection max 60 Gbit/s
- ZMQ connection measured ca. 30 Gbit/s

Bottleneck

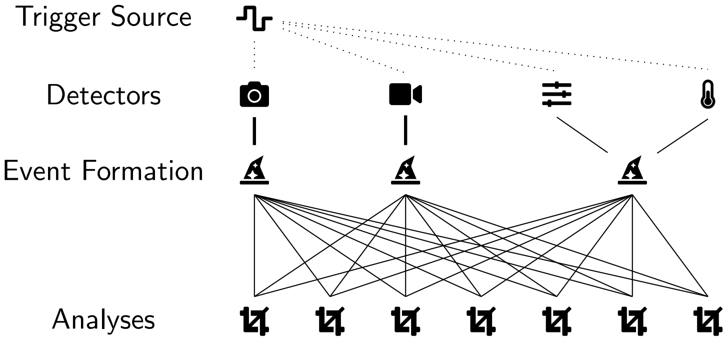
Event Formation

Analyses

Processing Delay

- acquisition at $\approx 100 - 1000$ Hz
- processing at $\approx$ 5-10 Hz

Parallelisation



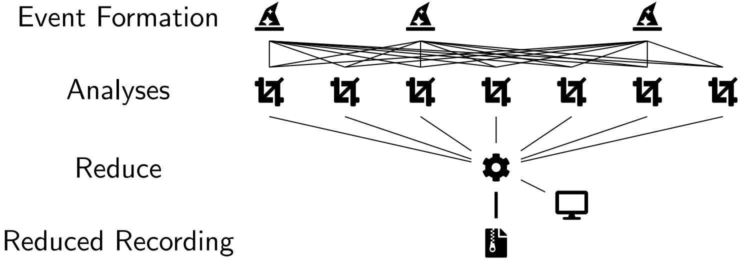
Inter Event Analysis

- time integration
- temporal correlations

Sequential Reduce

Operations at Acquisition Speed

- append to list
- sum



Intense Inter Event Computation

Examples

- aligning images (correlation)
- temporal fourier transform

Stateful Workers

- load balance with constraints
- e.g. worker selected for event n will also get $n+1$

Worker 1	1	1	1	1
Worker 1	2	2		
Worker 2	3	3		2
Worker 2	4	4	2	
Worker 1	5	5		3

Trigger Map

Event Definitions

Which *frames* from which *detectors* belong to the same *event* and have to be processed by the same *worker*?

Virtual Workers

- virtual workers are dynamically assigned to real workers
- special *all* workers (stream headers), or discard frame with $\emptyset$
- *none* if stream has no frame for event

	all	1	3	5	7	8
	all	2	4	6	7	9
	all	all	none	none	$\emptyset$	none
	all	$\{1,2\}$	none	$\{5,6\}$	none	$\{8,9\}$

Scanning

trigger map specified by scanning software, append-only extendable

Development: Events

ease of use/development by SciDa and beamline staff

Event Structure

```python
StreamName = NewType("StreamName", str)
EventNumber = NewType("EventNumber", int)

class StreamData(BaseModel):
    typ: str
    frames: list[zmq.Frame]

class EventData(BaseModel):
    event_number: EventNumber
    streams: dict[StreamName, StreamData]
```

Development: Worker

```python
class FluorescenceWorker:
    def __init__(self):
        self.number = 0

    def process_event(self, event: EventData,
                      parameters=None):
        print(event)
        # parse zmq frames
        # fit spectra to get concentrations
        # extract motor position
        return {"position": mot, "concentrations": ...}
```

reinstantiated for every scan (new Trigger Map)

Development: Reducer

```python
class FluorescenceReducer:
    def __init__(self):
        self.publish = {"map": {}}

    def process_result(self,
                       result: ResultData,
                       parameters=None):
        print(result.event_number)
        print(result.worker)
        print(result.parameters_uuid)
        data = result.payload
        self.publish["map"][data["position"]] = \
            data["concentrations"]
```

reinstantiated for every scan (new Trigger Map)

Development: Viewer

Jupyter Notebook

```
import requests, pickle
import matplotlib.pyplot as plt

params = {}
requests.post("http://<ns>-ctrl.../params", json=params)
# start scan
r = requests.get("http://<ns>-reducer.../result/pickle")
data = pickle.loads(r.content)
# data = FluorescenceReducer.publish

plt.imshow(data["map"])
```

Development: Silx based Viewer

Parameters

- set parameters
- influence slow processing

Partial Views

- keep large accumulated data set on reducer
- query specific slice of `reducer.publish`
- e.g. `http://<ns>-reducer.../result/map/100:110,:`

Development: Testing

Recording

ingesters optionally write all zmq frames to disk (sequential pickle dumps)

Replay

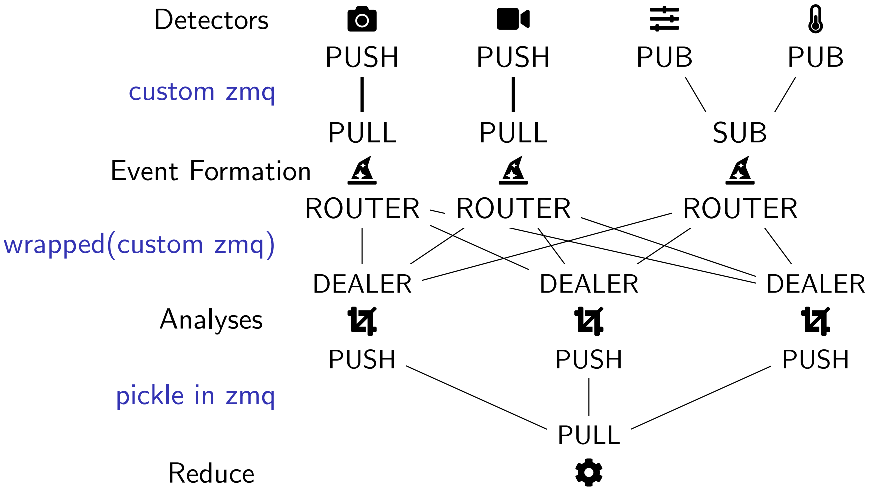
- from recorded zmq frames
- from hdf5 files

Local

run file-based ingesters, workers and reducer locally

Internals

Architecture, ZMQ



Architecture, redis

config

- components publish config (connected peers, trigger map version, zmq url)
- timeout for liveness probe

updates

- controller notifies of new mapping/parameters

ready

- workers notify readyness after event processed

assign

event_number: EventNumber

assignments: dict[StreamName, list[WorkerName]]

Event Coordination

Controller

- wait for new entry in ready
- assign worker to first unassigned virtual worker (and *all*)
- distribute WorkAssignment in assign

Ingester

- filter assignment for own streams
- combine all local streams
- copy event to specified workers (ROUTER)

Worker

- filter assignment for own work
- listen to ingesters with participating streams
- assemble EventData
- call custom code
- send pickled result to reducer
- send ready message to ready

Common Modules

ZMQ Format / STINS

- unpacking of (mulit-part) zmq frames to numpy arrays

Calibration

- installed as python modules

Middlewares

process_event → parse zmq → callibration → azint → normalise → custom

- maybe register required parameters?
- registered in Worker `__init__`

Tests

End-to-End

- stream fake zmq frames
- full scan test

Protocols

- Pydantic BaseModel (similar to dataclass)
- all messages defined and validated
- no `dicts` with random fields

Typing

- type hint annotations
- `mypy` strict

Deployment

Docker

- install custom dependencies
- end-to-end build latency multiple minutes

K8s

- HELM chart for beamline
- restart pulls new version
- different containers for different experiments

Versioning

- add git commit hash to reduced data
- add parameters to h5 file

Performance

Bandwidth

- 10 Gbit/s from b-daq-cn2 and b-daq-cn3
- 8 workers

horizontally scalable if each stream $\leq$ 30 Gbit/s

Latency

- $\approx$ 2 kHz with enough workers

practically limited to $\approx n$ workers $\Rightarrow$ max worker runtime $\frac{n}{\text{acquisition rate [Hz]}}\text{s}$

Virtual Worker Distribution

$\forall \text{st}_0 \in \mathbb{N}, h \in [|\text{workers}|, \infty)$:

$$|\{M_{\text{ev},\text{st}} : \text{st}_0 \leq \text{ev} < (\text{st}_0 + h), \text{st} \in \text{streams}\}| > h - \epsilon$$

Outlook

File Writing

- custom by developers?

Autoscaling

- observability of workers (queues)
- duty cycle of workers
- non-deterministic worker functions
- integration with k8s

Scan Integration

- publish trigger map
- append to trigger map