CHAIR FOR COMPILER CONSTRUCTION

ohua

cfaed CENTER FOR ADVANCING ELECTRONICS DRESDEN

Ohua-Powered, Semi-Transparent UDF's in the Noria Database

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Motivation

State is useful!

Aggregation

Windowing

Efficiency

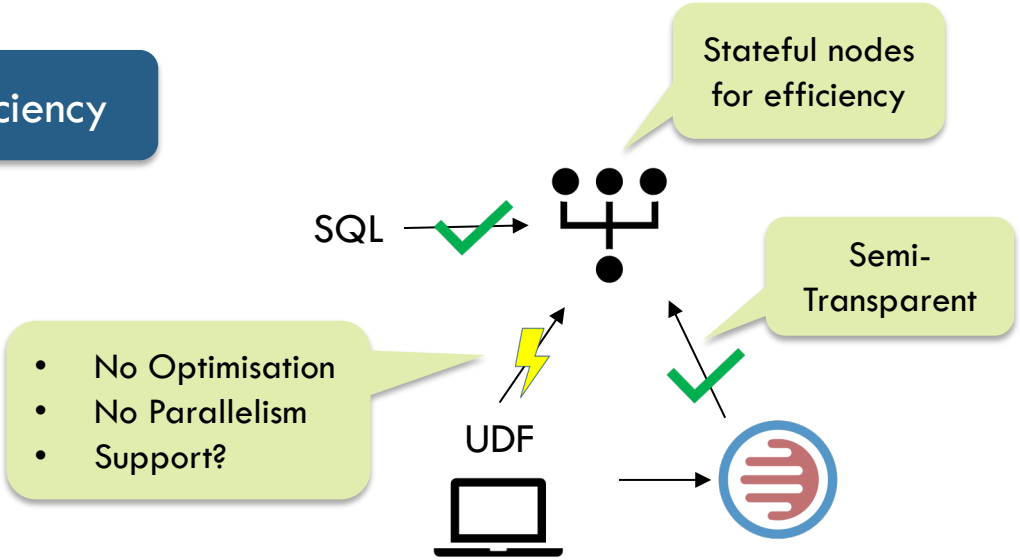
Fundamental

Intuitive Code

Counting

Deduplication

Caching



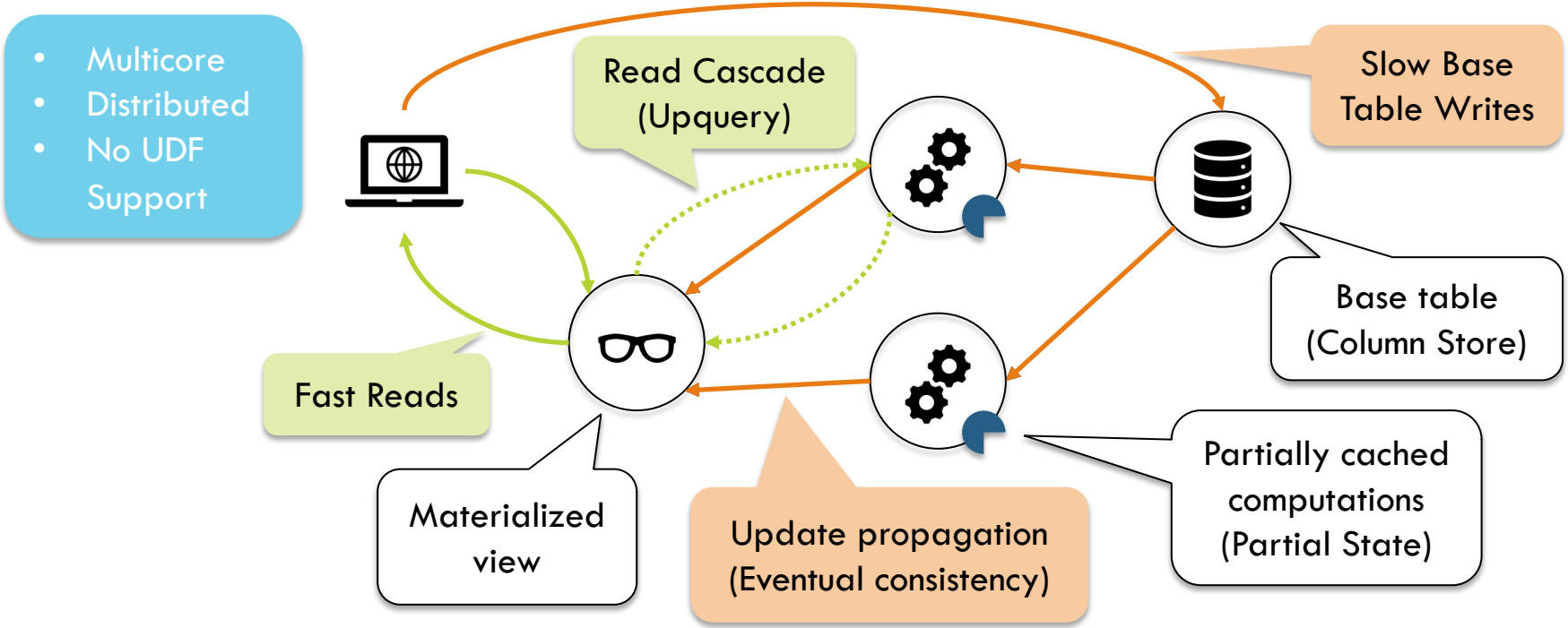
Example UDF – Clickstream Analysis

```
fn click_ana(
    start_cat: Category,
    end_cat: Category,
    clicks: Stream<(UID, Category, Time)>
) -> f64 {
    let click_streams = group_by::<0>(clicks);
    click_streams.map(|stream| {
        let state = iseq::Seq::new();
        for (_, cat, time) in stream {
            if cat == start_cat {
                state.start(time)
            } else if cat == end_cat {
                state.end(time)
            } else {
                state.record(time)
            }
        }
        state
            .complete_intervals()
            .map(Interval::len)
            .average()
        }
    )
}
```

- From SQL/MapReduce[1] paper
  - Complicated in SQL
  - Inefficient in SQL
- Non trivial but simple
- Business query
- State is paramount
- Contains SQL element

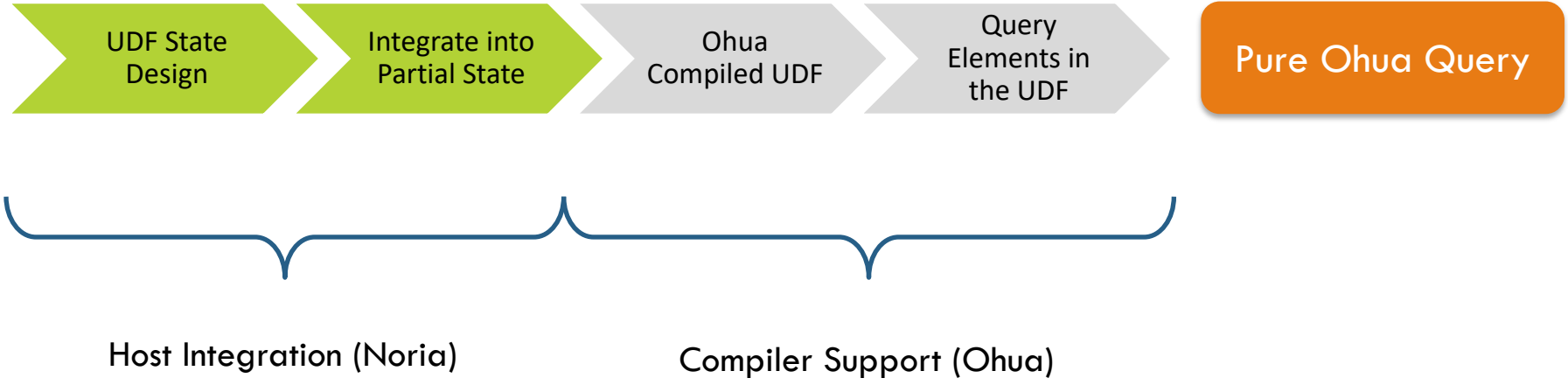
1. Eric Friedman, Peter Pawlowski, and John Cieslewicz. 2009. SQL/MapReduce: a practical approach to self-describing, polymorphic, and parallelizable user-defined functions. *Proc. VLDB Endow.* 2, 2 (August 2009), 1402-1413.

Noria



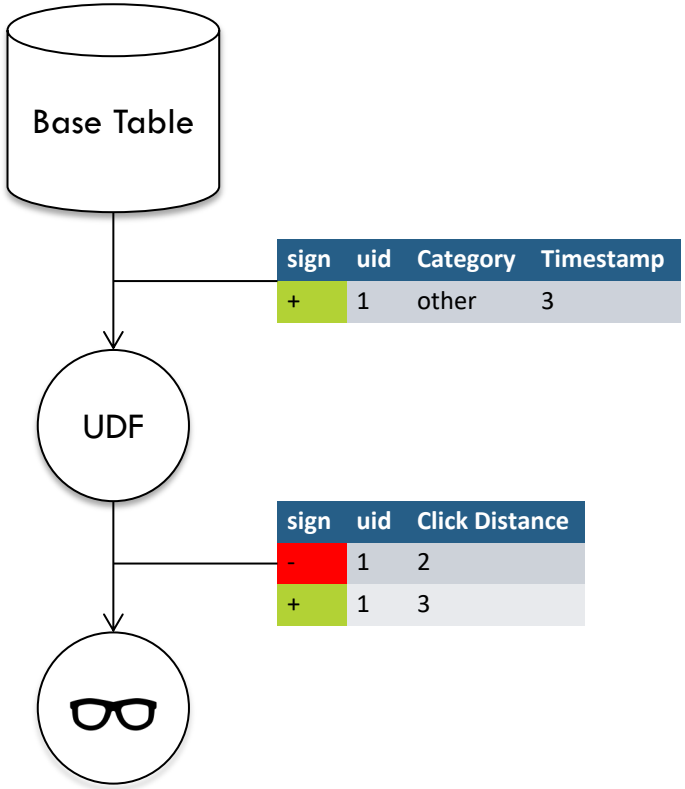
1. Jon Gjengset et al. 2018. Noria: dynamic, partially-stateful data-flow for high-performance web applications. In *Proceedings of the 12th USENIX conference on Operating Systems Design and Implementation* (OSDI'18). USENIX Association, Berkeley, CA, USA, 213-231.

Roadmap


UDF State Design
Integrate into Partial State
Ohua Compiled UDF
Query Elements in the UDF
Pure Ohua Query
Host Integration (Noria)
Compiler Support (Ohua)

Noria Execution Model

uid	Category	Timestamp
1	start	1
1	other	5
1	end	10
1	other	3



sign	uid	Category	Timestamp
+	1	other	3

sign	uid	Click Distance
-	1	2
+	1	3

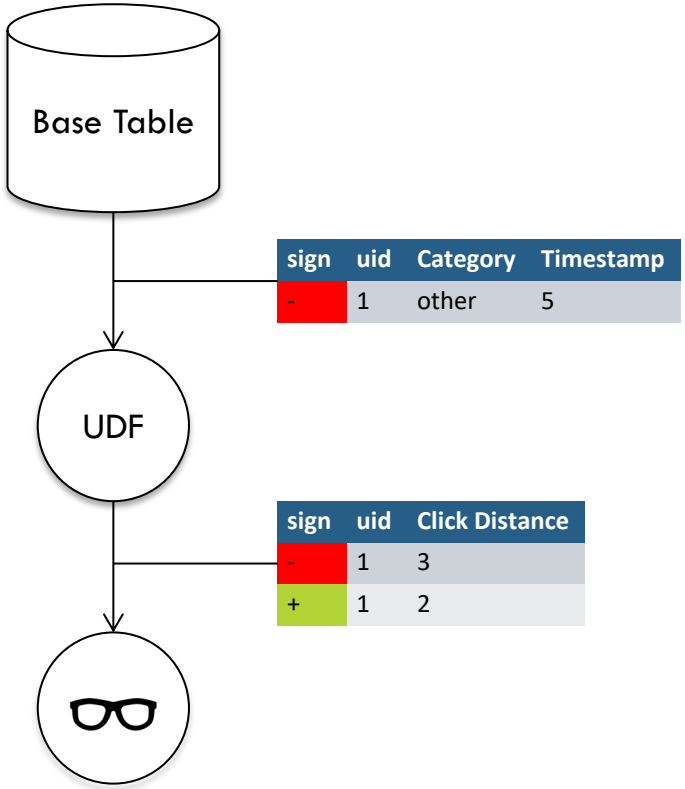
uid	Click Distance
1	3

Update Path (Insert)

```
INSERT (1, other, 3)
INTO ‘Base Table’;
```

Noria Execution Model

uid	Category	Timestamp
1	start	1
1	other	5
1	end	10
1	other	3



sign	uid	Category	Timestamp
-	1	other	5

sign	uid	Click Distance
-	1	3
+	1	2

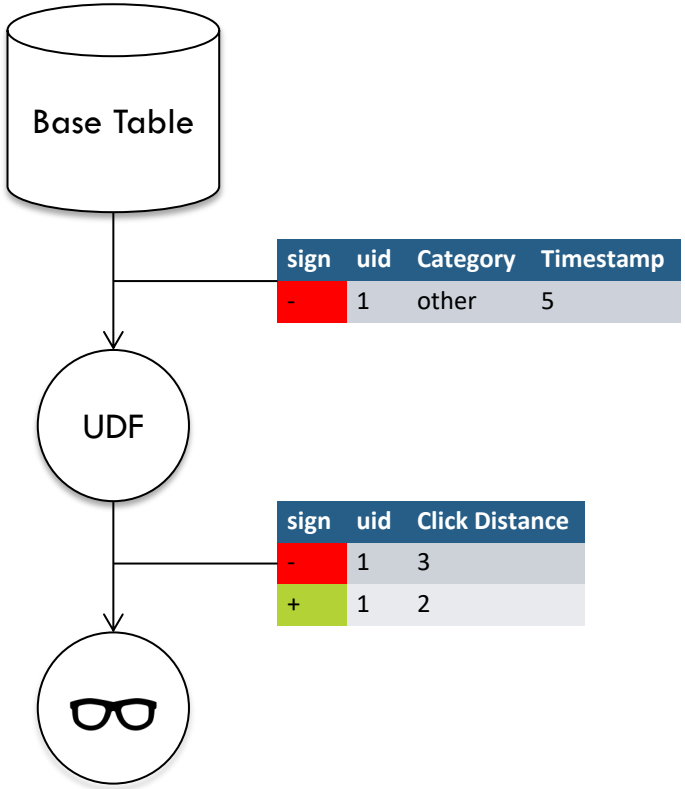
uid	Click Distance
1	2

Update Path (Delete)

```
DELETE (1, other, 3)
FROM ‘Base Table’;
```

Noria Execution Model

uid	Category	Timestamp
1	start	1
1	other	5
1	end	10
1	other	3



sign	uid	Category	Timestamp
-	1	other	5

sign	uid	Click Distance
-	1	3
+	1	2

uid	Click Distance
1	2

- On-line inserts
- On-line deletes
- Order is random

- Commutative
- Incremental
- Reversible Operations

UDF State Design

```
let state = iseq::Seq::new();

for (_, cat, time) in stream {

    if cat == start_cat {
        state.start(time)
    } else if cat == end_cat {
        state.end(time)
    } else {
        state.record(time)
    }

}
```

State S

Defines actions
A: {Start, End, Record}

Projection
$f : input \rightarrow A$

Affected by sign

Not affected by sign

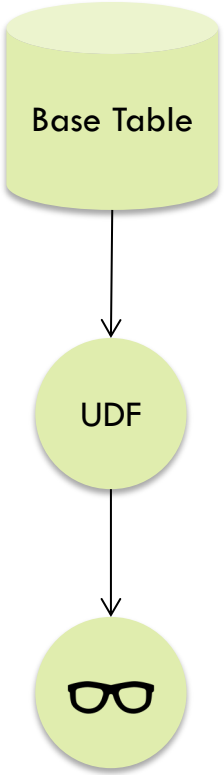
Successively apply all actions and sign to state
$app : \pm A \times S \rightarrow S$

```
state
    .complete_intervals()
    .map(Interval::len)
    .average()
```

Computation
$comp: S \rightarrow output$

$$UDF: [\pm input] \rightarrow output$$

Interval Sequence as State



uid	Category	Timestamp
1	start	1
1	other	5
1	end	10
1	other	3

```
[[5,3,10].length()].average() == 3
```

uid	Click Distance
1	3

s: $[\,[l_0, u_0), [l_1, u_1), [l_2, u_2)]$

$t \in T$ such that

- $t \geq \begin{cases} l_1 & \text{if } l_1 \text{ exists} \\ u_0 & \text{otherwise} \end{cases}$
- $t < \begin{cases} u_1 & \text{if } u_1 \text{ exists} \\ l_2 & \text{otherwise} \end{cases}$

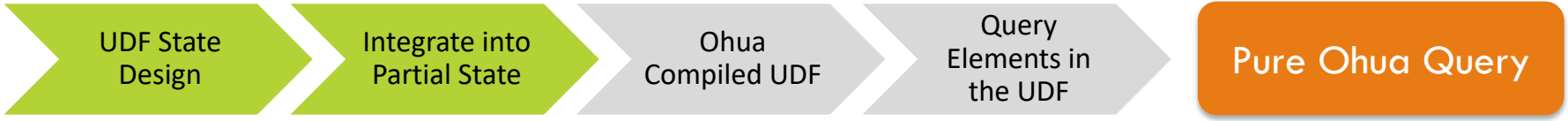
Invariants

- l_1 or u_0 must exist
- u_1 or l_2 must exist

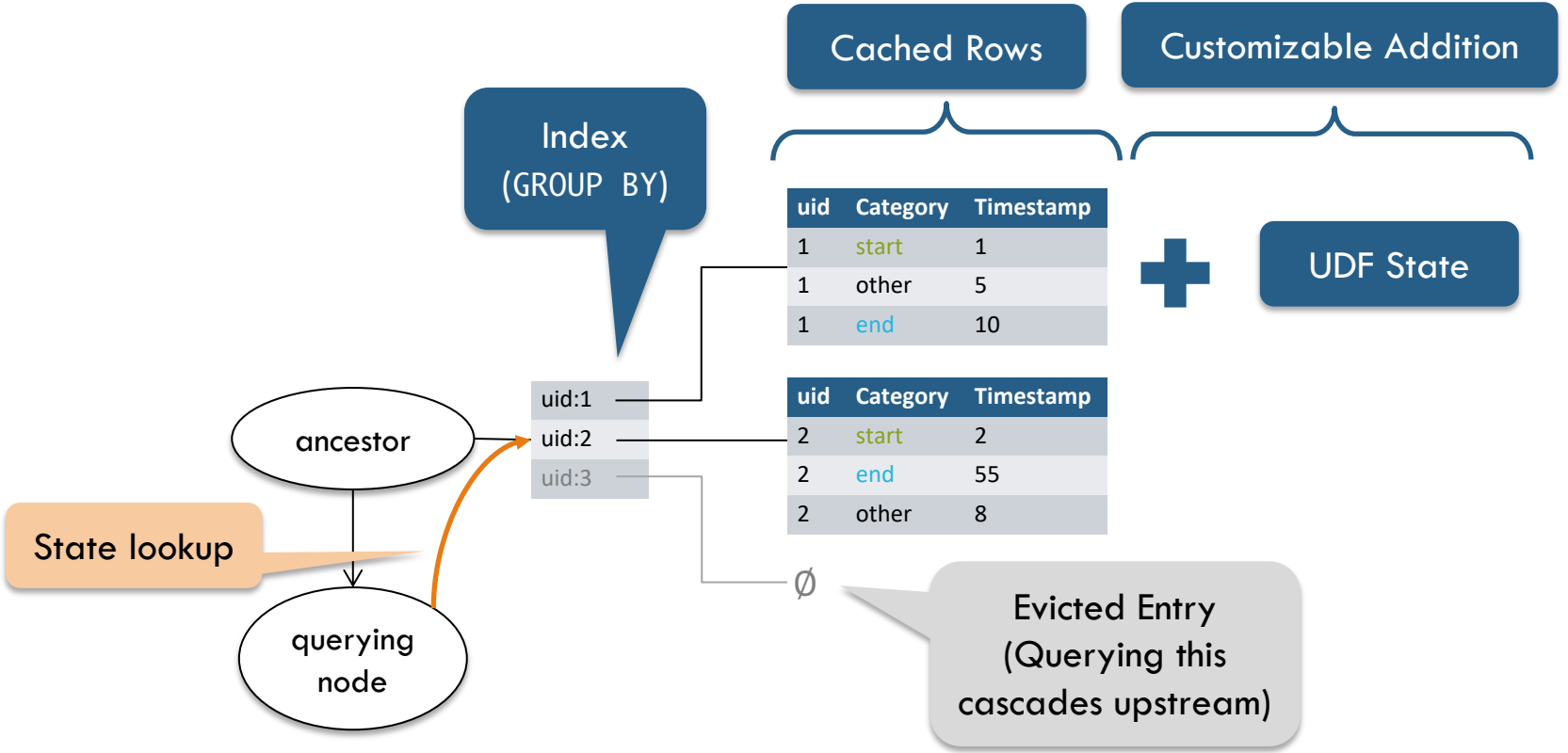
⇒ Merge intervals to maintain

Conclusions

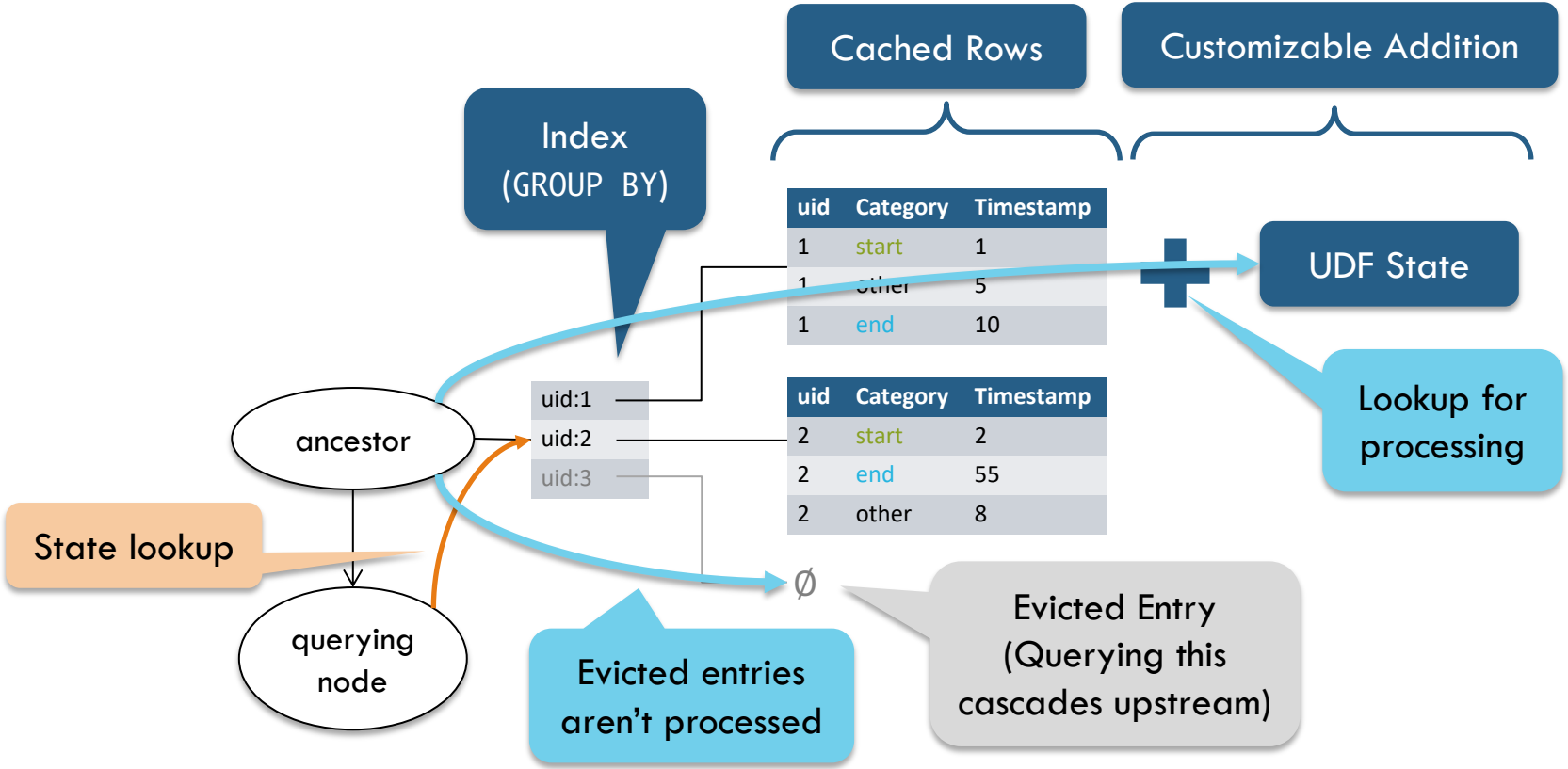
Must be
- Reversible
- Commutative



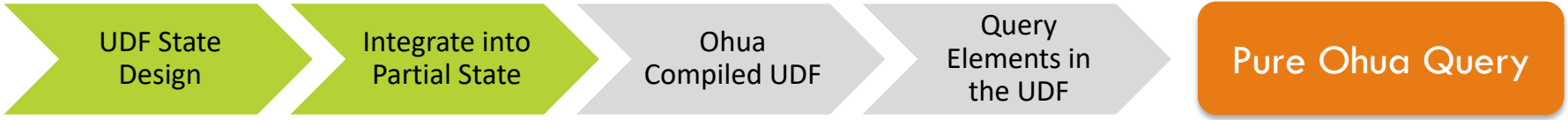
Partial State integration



Partial State integration

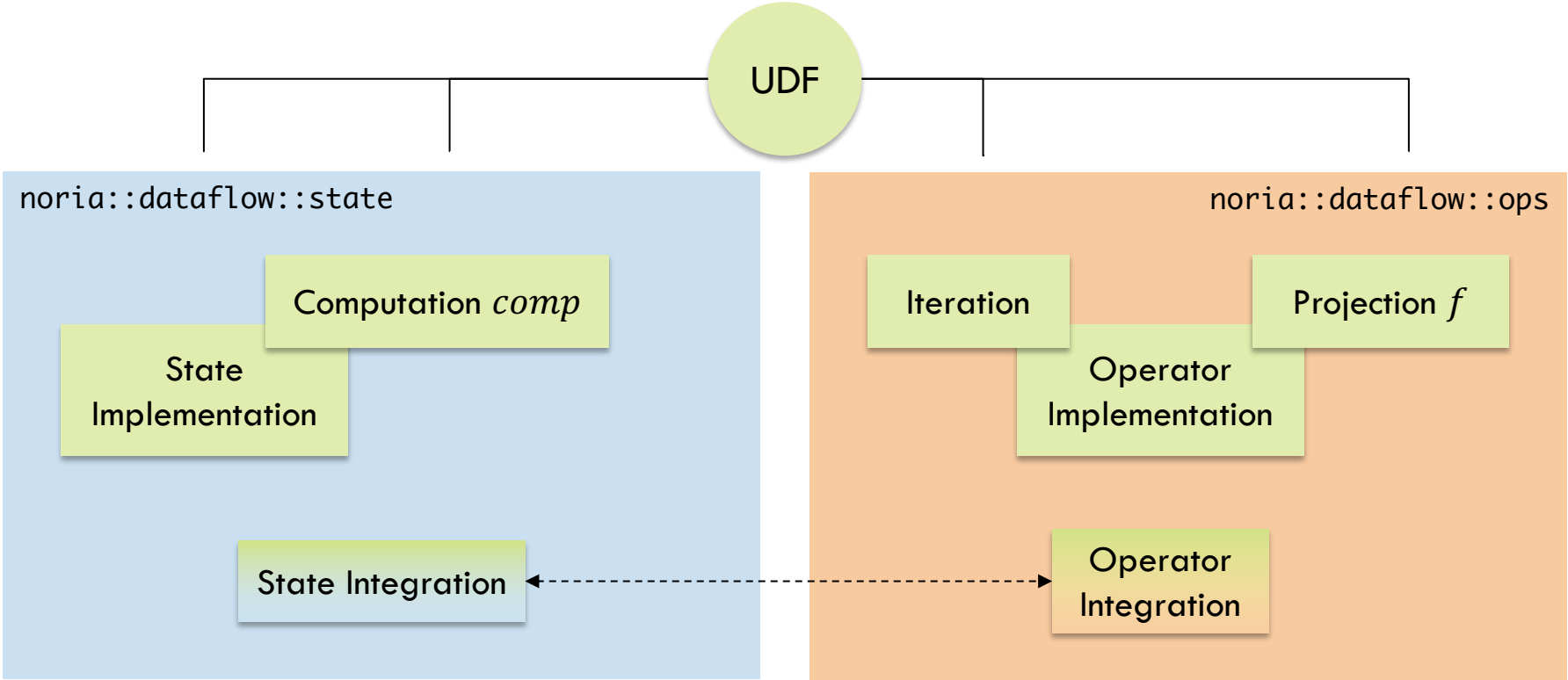


Conclusions

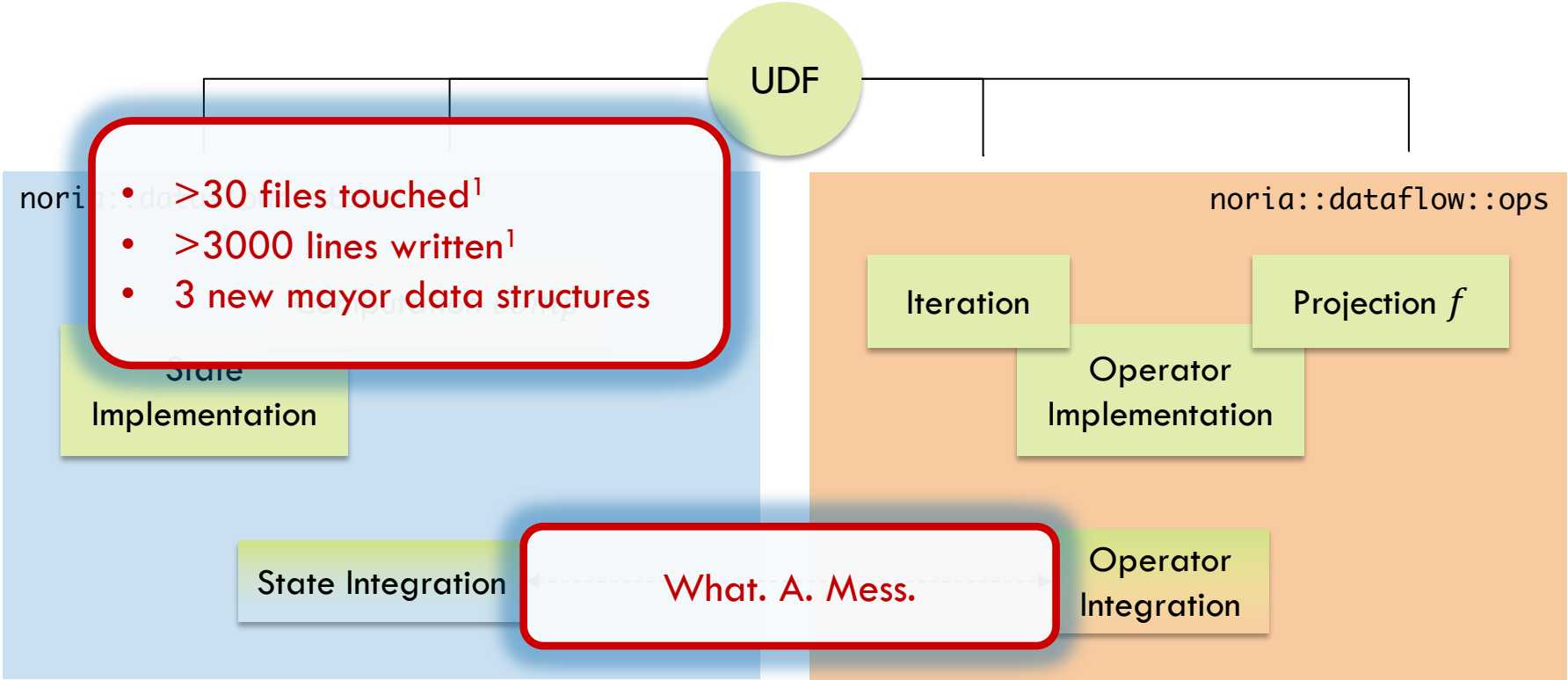


To Support
- Eviction
- Lookups

Manual Implementation

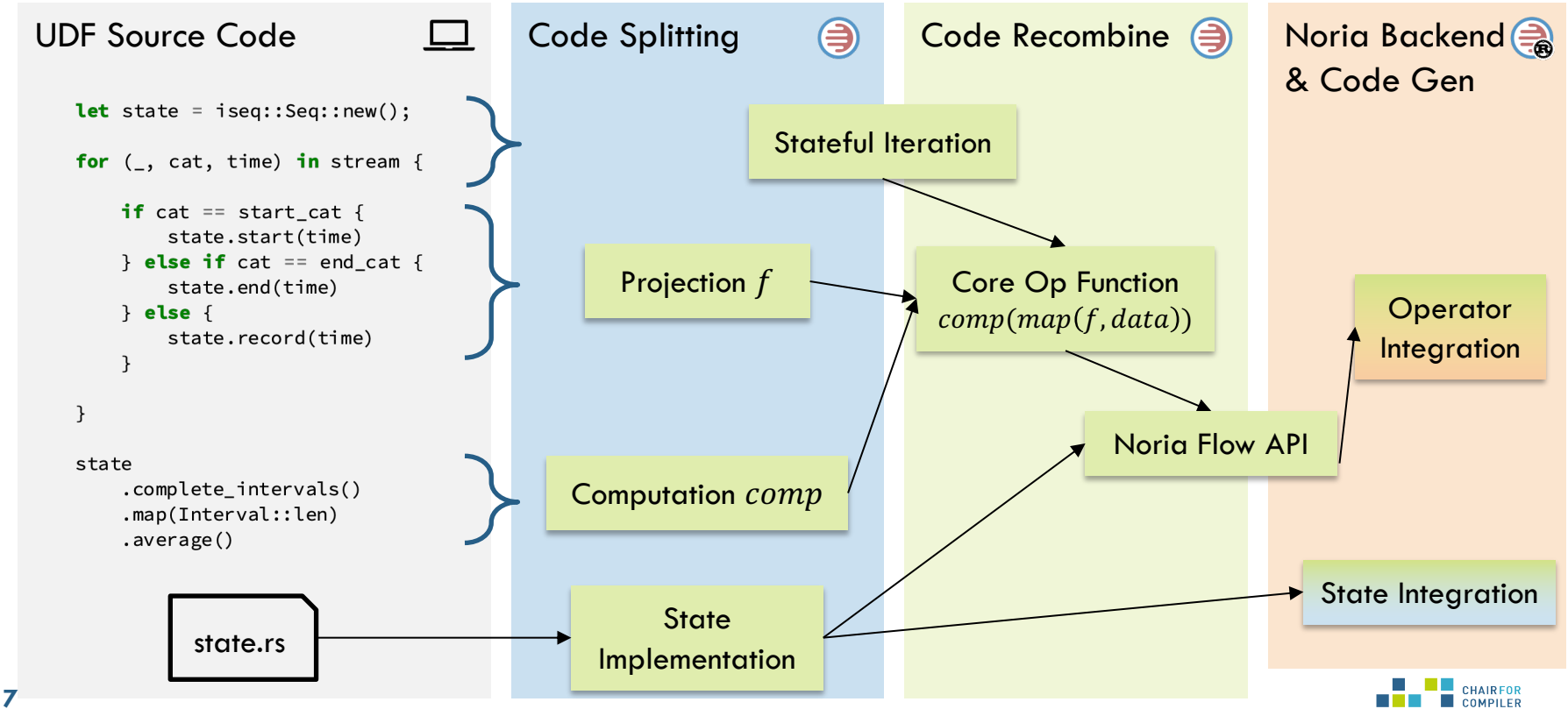


Manual Implementation

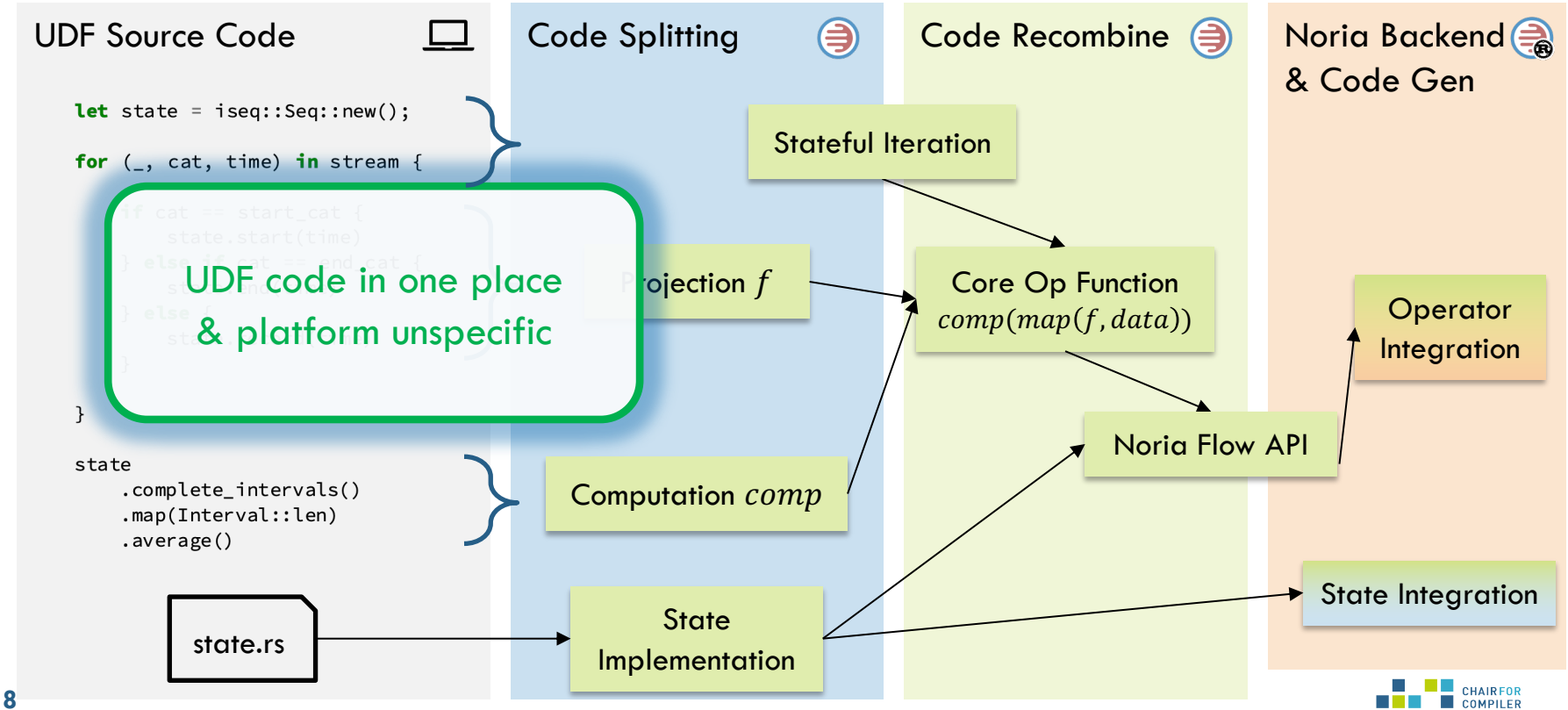


1. For whole implementation including intermediate prototypes and test code. Approximately 50% used exclusively for UDF.

Operator Compilation

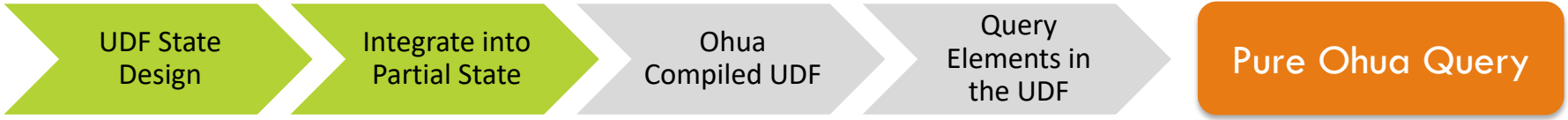


Operator Compilation

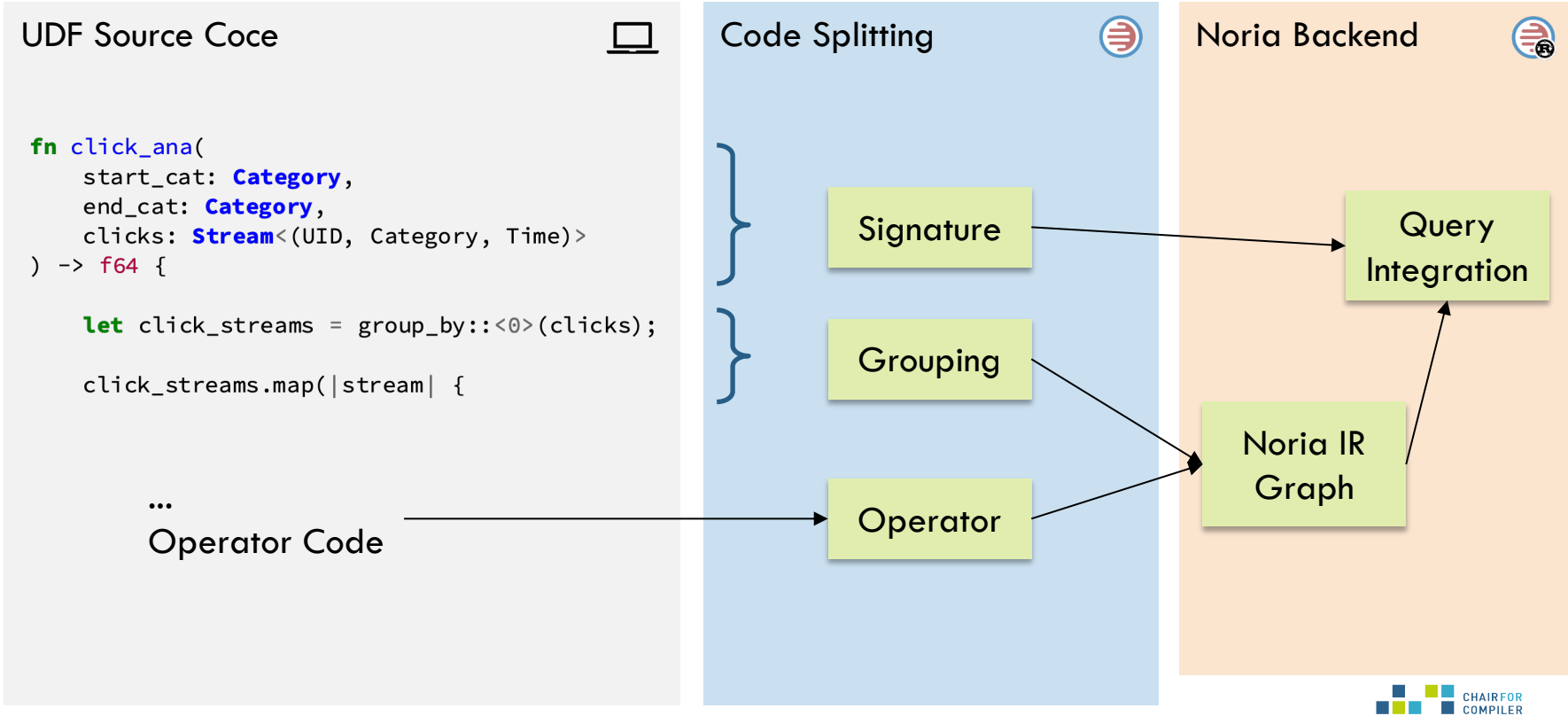


Conclusions

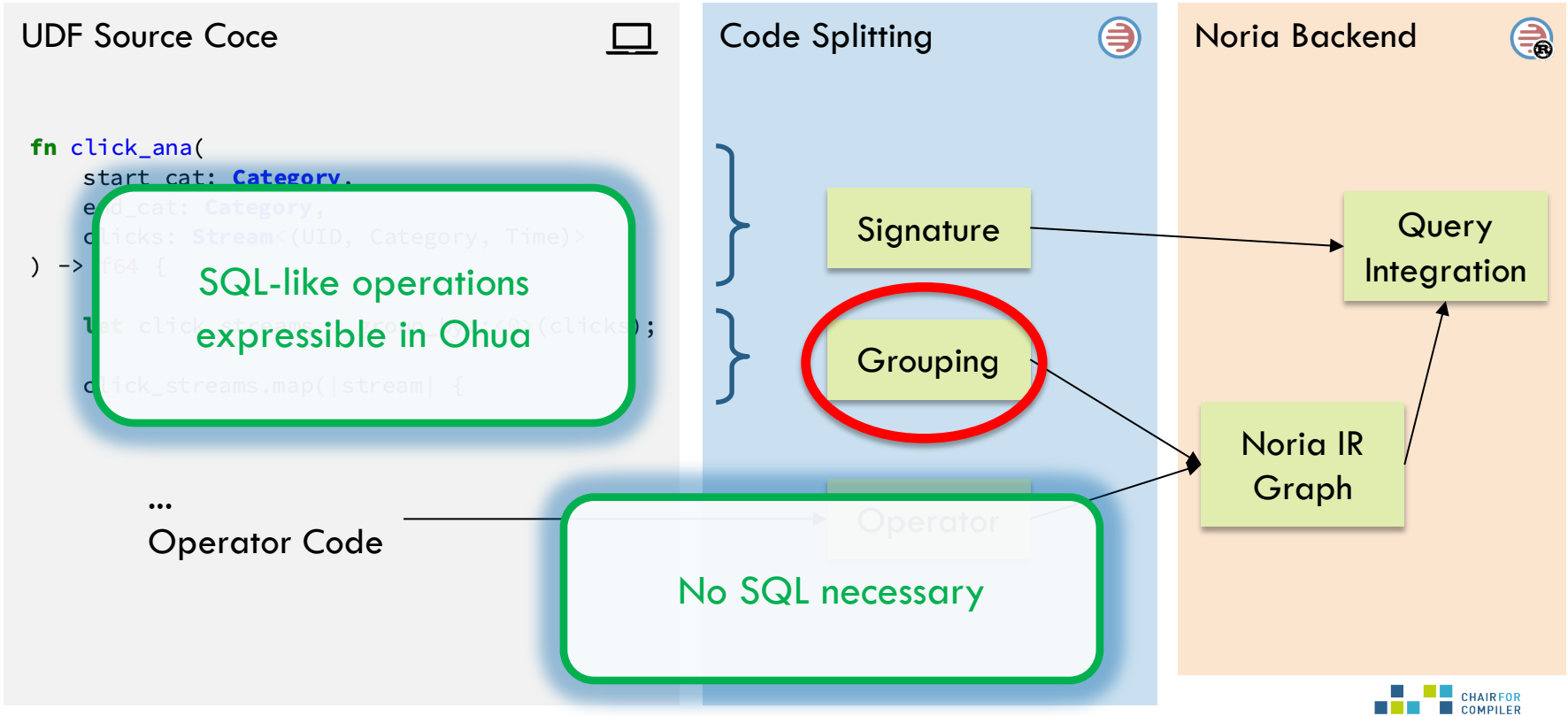
- Abstraction
- Conciseness
- Code Locality



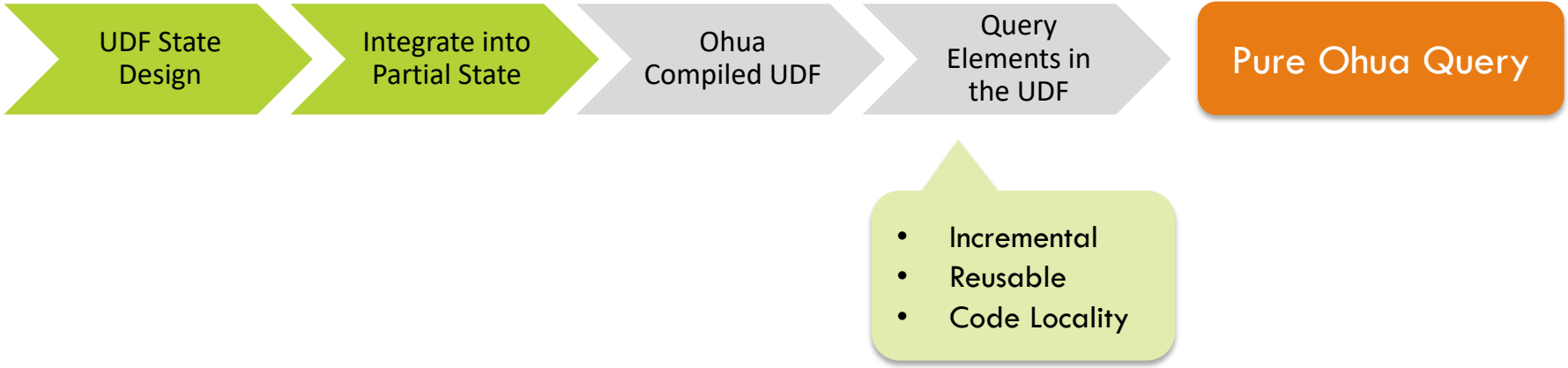
UDF Compilation



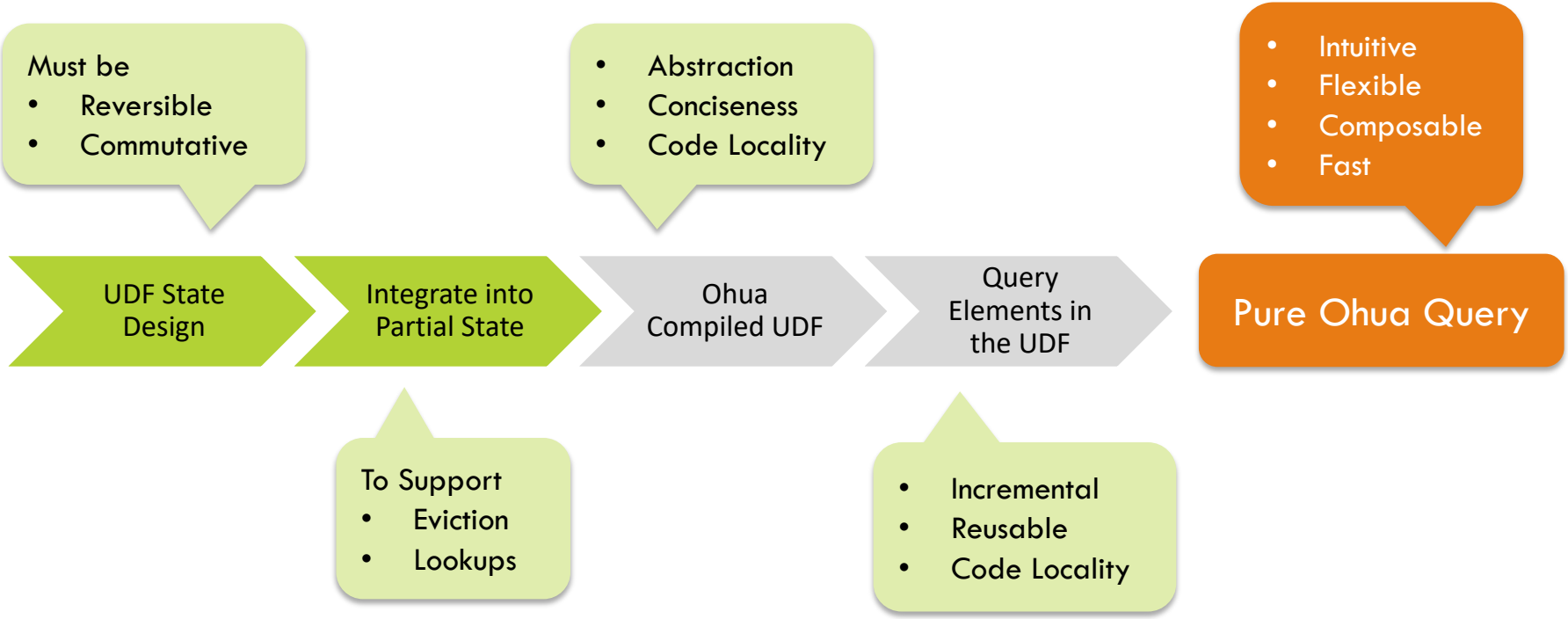
UDF Compilation



Conclusions



Conclusions



Conclusions