On Parallel Processing of Aggregate and Scalar Functions in Object-Relational DBMS

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Overview:

- Introduction to user-defined functions
- Parallel processing of UDFs
  - a parallel processing scheme for user-defined aggregate functions
  - a classification of user-defined data partitioning functions
  - parallel sorting as preprocessing step for aggregate functions

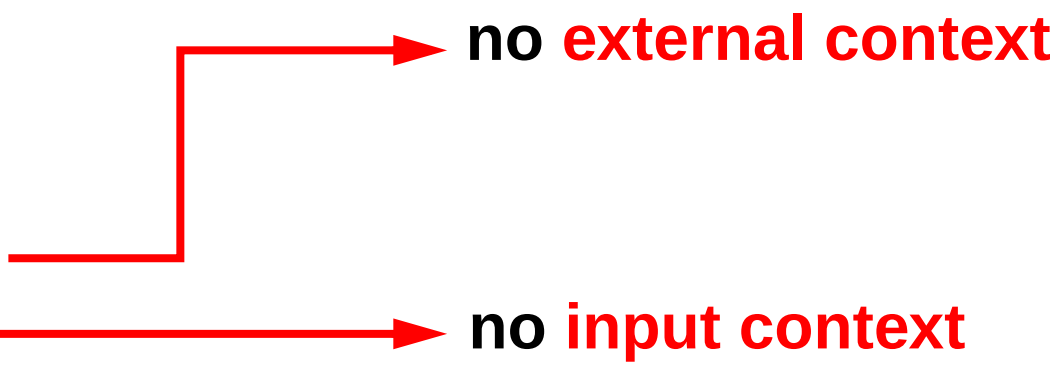
User-Defined Functions (UDFs) in ORDBMS

- User-defined scalar functions (UDSFs):
  - f: data items ➡ data item
  - examples: concat, +, ceiling, hex, rand, dayofyear, ...
- User-defined aggregate functions (UDAFs):
  - f: set of data items ➡ data item
  - examples: avg, sum, count, max, min, variance, ...
- Not covered here:
  - user-defined table functions
  - user-defined support functions (for internal purposes)

Registration of UDFs

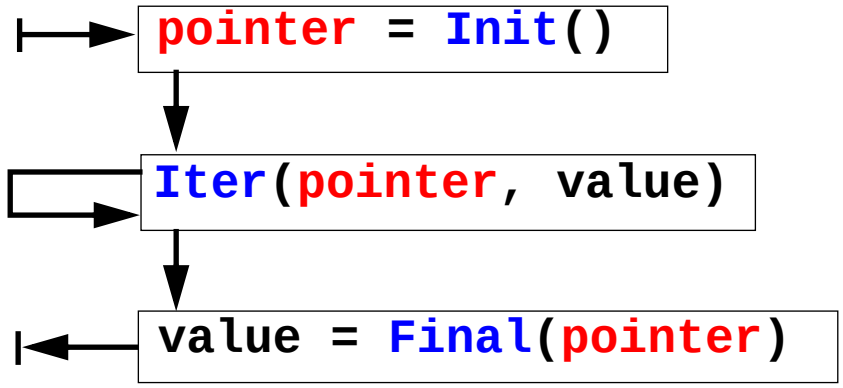
- Registration: define a new UDF and provide metadata for it
- Example (DB2 UDB):

```
CREATE FUNCTION distance (point, point)
RETURNS double
EXTERNAL NAME ‘point!distance’
LANGUAGE C
PARAMETER STYLE DB2SQL
NOT VARIANT
NOT FENCED
NOT NULL CALL
NO SQL
NO EXTERNAL ACTION
NO SCRATCHPAD
NO FINAL CALL;
```



Sequential Processing of UDAFs

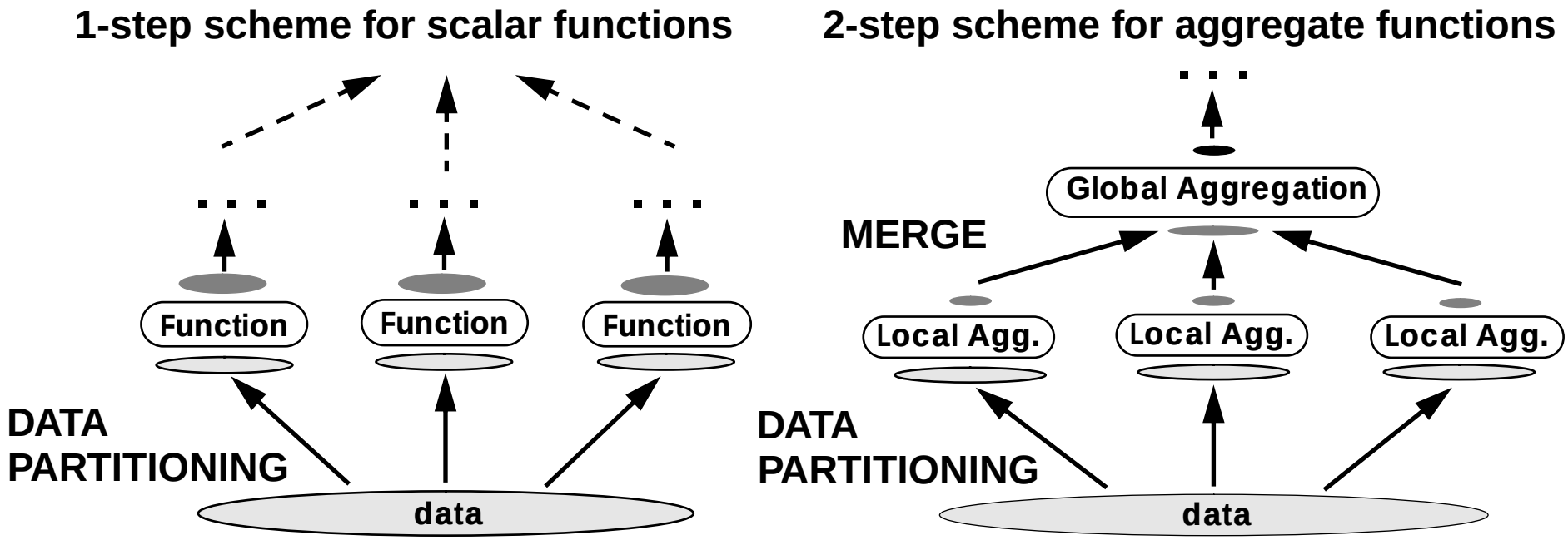
- UDAFs processed by means of iterator concept (one tuple at a time)
- ☞ Aggregation needs temporary storage for intermediate results (of sum, count, avg, ...)
- Example (Illustra):
  Initialize and terminate aggregation by means of functions that are provided with the registration: Init, Iter and Final



- ☞ All functions that compute aggregate functions have an input context

Parallel Processing of Built-in Functions

- Goal: partitioned parallelism
- Data partitioning and parallel processing schemes



☞ Fixed, built-in parallel processing schemes

2-Step Parallel Aggregation for UDAFs

- Goal: enable parallel processing of user-defined aggregate functions
- Idea: make traditional 2-step processing scheme available for UDAFs
- Difference between built-in and user-defined aggregate functions:
  Developer has to define local and global aggregate functions

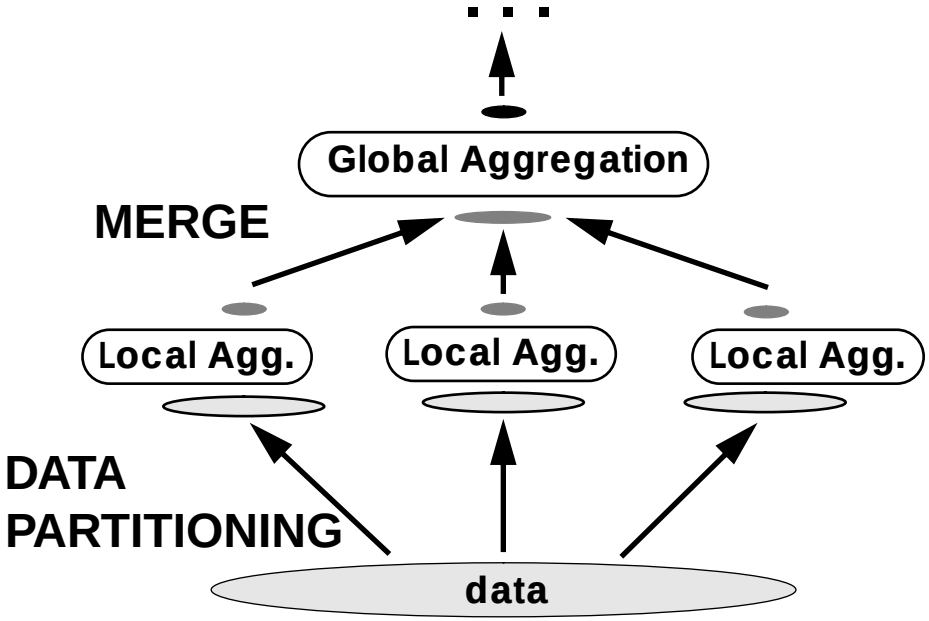
☞ Extend the CREATE AGGREGATE statement:

```
CREATE AGGREGATE <function-name>
(
LOCAL <Init, Iter, and Final function definition>
GLOBAL <Init, Iter, and Final function definition>
)
```

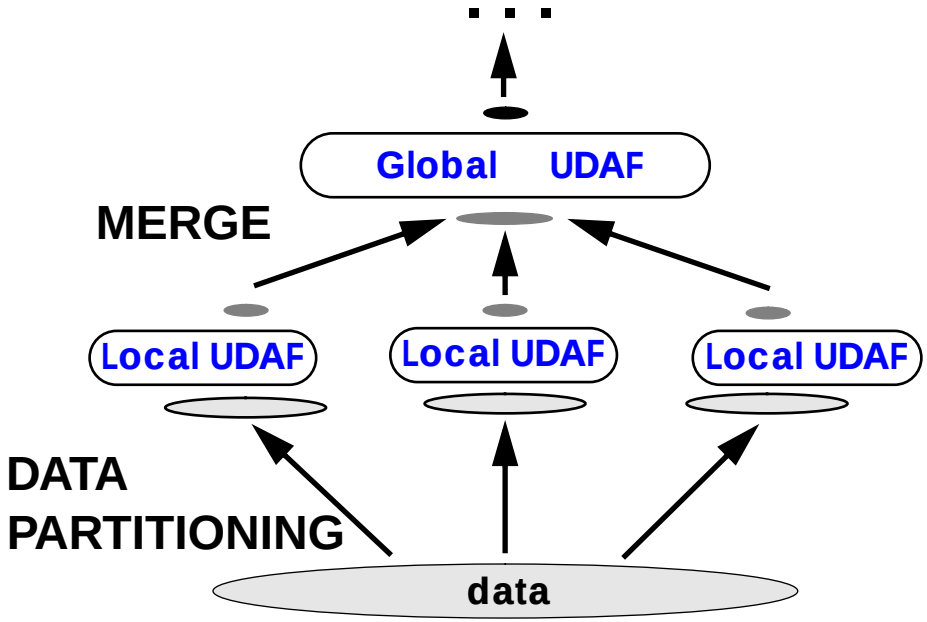
☞ Straightforward extension of current ORDBMS

Extension of the 2-Step Processing Scheme

built-in aggregate functions



user-defined aggregate functions



Data Partitioning: A Limit of the 2-Step Scheme for UDAFs

- Example: compute the most frequent value of a set
- Approach: implement Most_Frequent with the 2-step processing scheme
  - **local aggregation:** compute number of the most frequent value for each partition
  - **global aggregation:** select the value with the highest local frequency

✗ **Problem:** if the same value occurs in several partitions, the result is not correct

☞ For some UDFs it is not correct to use an **arbitrary** partitioning of the data

☞ Developer has to tell the DBMS, how the data partitioning has to be done for a given UDF

Data Partitioning and UDFs

- **Goal: extensibility of parallel processing schemes with respect to data partitioning**
- **Data partitioning can be described by means of partitioning functions**
- **Idea: allow user-defined partitioning functions**

- **First approach:**
  developer specifies only a single specific data partitioning function for each UDF

- **Problem: if several UDFs have to be computed data repartitioning is necessary**

  ➠ **not the best solution**

Classes of Data Partitioning Functions

- Goal: avoid data repartitioning
- Idea: classification of partitioning functions;
  developer specifies a class of applicable partitioning functions
- Classes of data partitioning functions:
  - ANY round robin, random
  - EQUAL hash
  - RANGE range partitioning

  ➠ ANY ⊃ EQUAL ⊃ RANGE

- If no class can be applied for a UDF, try
  - a single, specific user-defined data partitioning function
    for example a spatial data partitioning function

Example: Registration of the Function Most_Frequent

- Registration of the (local) Iter function with partitioning class EQUAL for the UDAF Most_Frequent:

```
CREATE FUNCTION Most_Frequent_ITER_LOCAL(POINTER, INTEGER)
RETURNS POINTER
EXTERNAL NAME 'libfuncs!mf_iter_local'
ALLOW PARALLEL WITH PARTITIONING CLASS EQUAL $2
LANGUAGE C ...;
```

Avoiding Data Repartitioning

- **Example: use partitioning classes to avoid data repartitioning**

SELECT Count(*), Most_Frequent(Job)
FROM Staff

Count(*): **ANY**
Most_Frequent: **EQUAL**

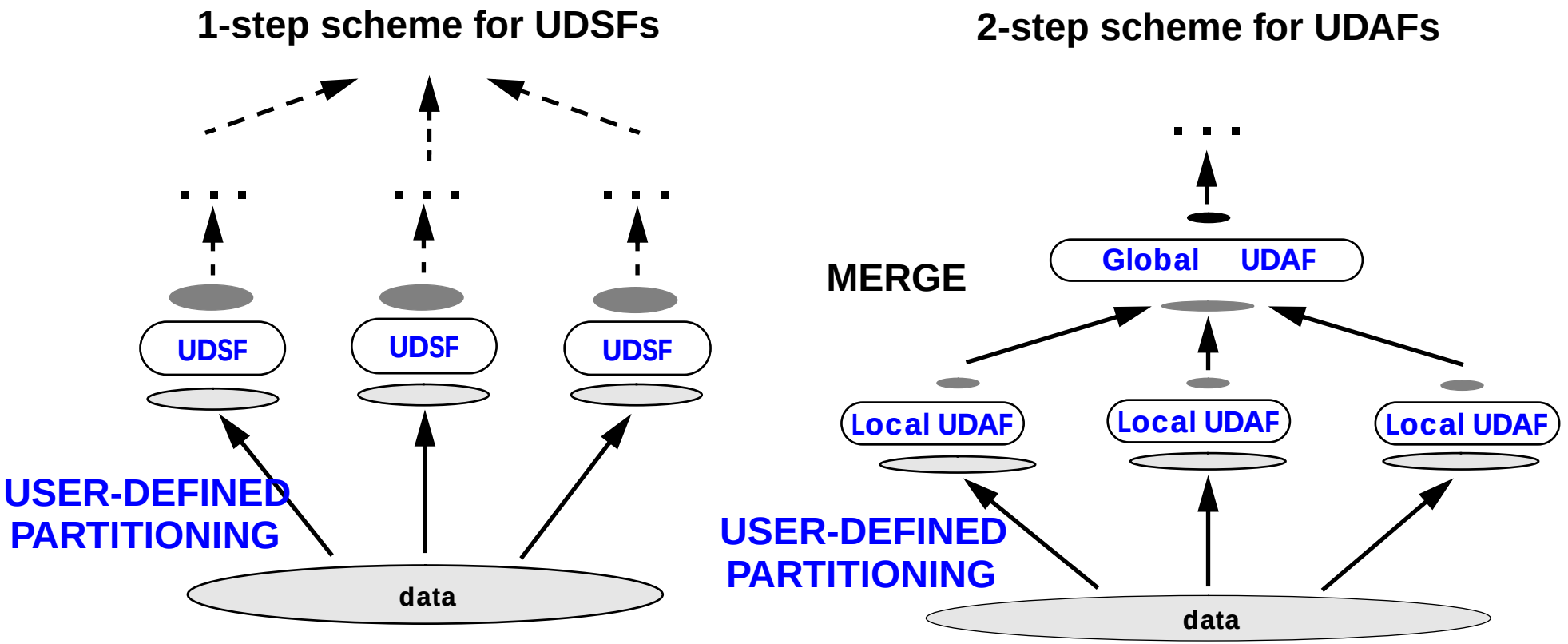
- **Query optimizer:**

ANY ∩ EQUAL = EQUAL

Partitionable UDFs

- Goal: describe which UDFs can be processed in parallel
- A UDSF is *partitionable for class C*, iff the function
  - can be processed in parallel
    using any partitioning function of class C
- A UDAF is *partitionable for class C*, iff the function
  - can be processed using the 2-step processing scheme
    (local and global aggregation)
    and
  - the local aggregate function can be processed in parallel
    using any partitioning function of class C

Parallel Processing Schemes for Partitionable UDFs



☞ **Parallel processing schemes can be made extensible by means of user-defined partitioning functions**

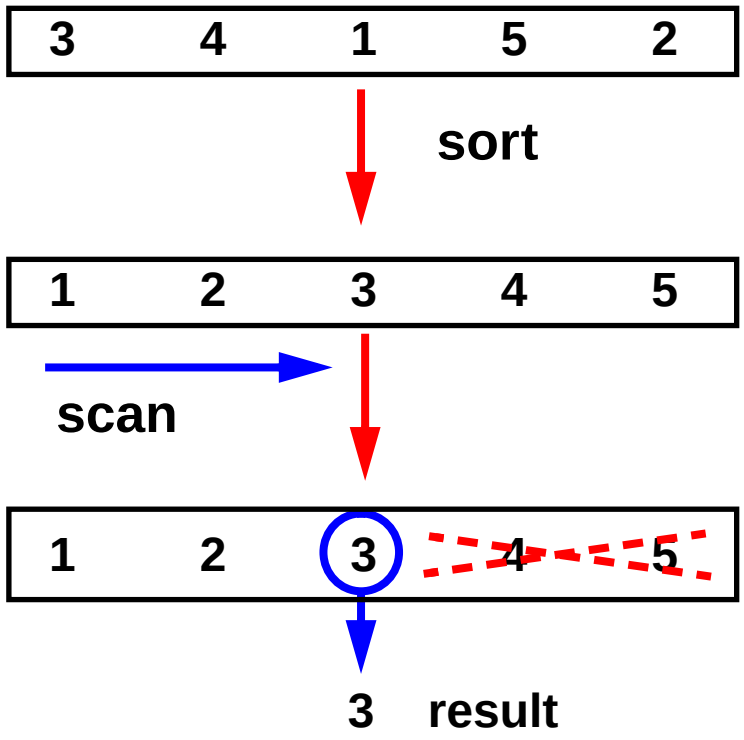
Limited Applicability of the 2-Step Scheme

- How to compute the median of a set in parallel with the 2-step scheme?

SELECT Median(P.Age, COUNT(*))
FROM Pers AS P

No suitable local aggregate function ?!?

- New approach based on parallel sorting:
  - sort the input set in parallel
  - scan the sorted input until the position of the median is reached
  - return the median



Parallel Sorting as a Preprocessing Step

- **Goal:** support limited “parallel” processing, if the 2-step scheme fails
- **Idea:** allow UDFs that operate on a sorted input;
  DBMS can sort in parallel as a preprocessing step
- An aggregate function f that requires a sorted input can be evaluated using the following scheme given an input set S:
  - sort the input set S; this can be done in parallel
  - compute f without parallelism on the sorted input
- Registration of the local Iter function for the UDAF Median:

```
CREATE FUNCTION MEDIAN_ITER_LOCAL(POINTER, INTEGER)
RETURNS POINTER
EXTERNAL NAME ‘libfuncs!median_iter_local’
ORDER BY $2
LANGUAGE C ...;
```

Related Work

- Goal: efficient computation of Data Cubes (Jim Gray et al)
- 3 disjoint classes of aggregate functions:

☞ **Distributive aggregate functions:**
sub-aggregates can be computed on arbitrary sub-sets with the aggregate function itself

➠ **partitionable for class ANY**

☞ **Algebraic aggregate functions:**
sub-aggregates with fixed size can be computed on arbitrary sub-sets

➠ **partitionable for class ANY**

☞ **Holistic aggregate functions**
sub-aggregates with fixed size cannot be computed on arbitrary sub-sets

➠ **partitionable for some data partitioning function (not ANY)**
or
not partitionable, but parallel sorting might help

Summary

- User-defined functions: context and parallel processing

<table>
<tr><th></th><th>Scalar Functions</th><th>Aggregate Functions</th></tr>
<tr><td>no context</td><td>partitionable for class ANY</td><td>-</td></tr>
<tr><td rowspan="3">input context</td><td rowspan="2">partitionable for some class</td><td>partitionable for some class with local and global aggregation</td></tr>
<tr><td>parallel sorting</td></tr>
<tr><td>not partitionable</td><td>not partitionable</td></tr>
<tr><td>external context</td><td colspan="2">not treated here</td></tr>
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