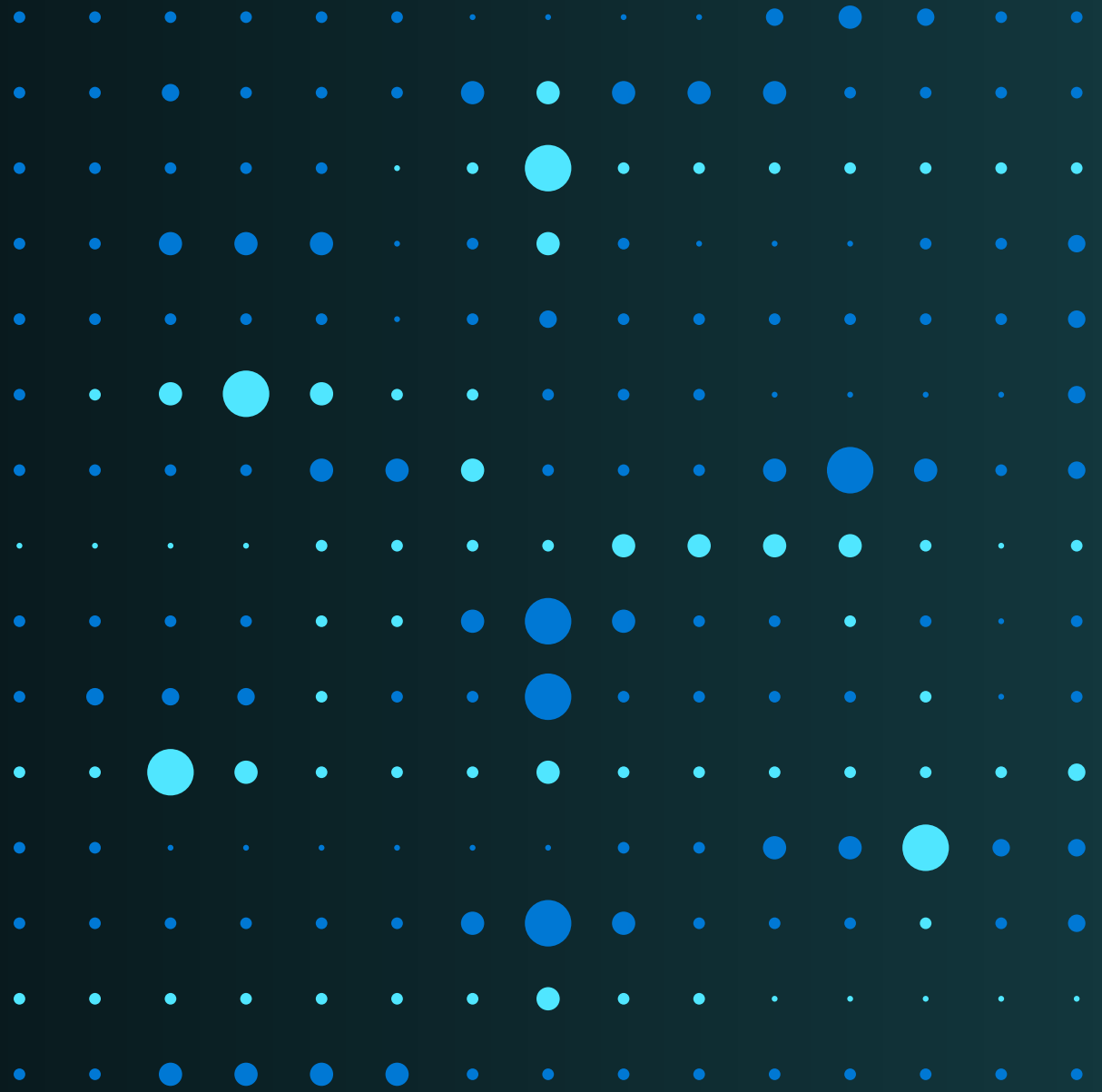
Microsoft



# Introduction to Intelligent Query Processing

John Deardurff

# John Deardurff

Microsoft Customer Engineer (Global Technical Team)
Microsoft Certified Trainer (Regional Lead)
MVP: Data Platform (2016 – 2018)

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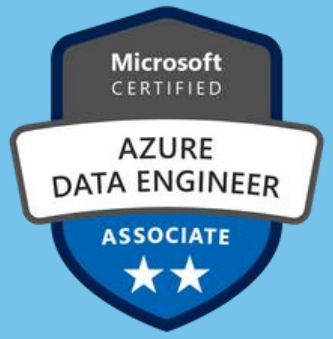
GitHub: github.com\SQLMCT








# What is in the session?

- A History of Intelligent Query Processing?
- Enabling and Disabling Features
- Adaptive Query Processing (2017)
- Intelligent Query Processing (2019)
- New Features of IQP (2022)

# Learn more

Learn more about SQL Server 2022

aka.ms/sqlserver2022

Watch a technical deep-dive on SQL Server 2022

aka.ms/sqlserver2022mechanics

Don’t miss out on Data Exposed (Look for SQL Server 2022 – Episode 3)

aka.ms/dataexposed

More information on Intelligent Query Processing
(Currently does not have 2022 information.)

aka.ms/IQP

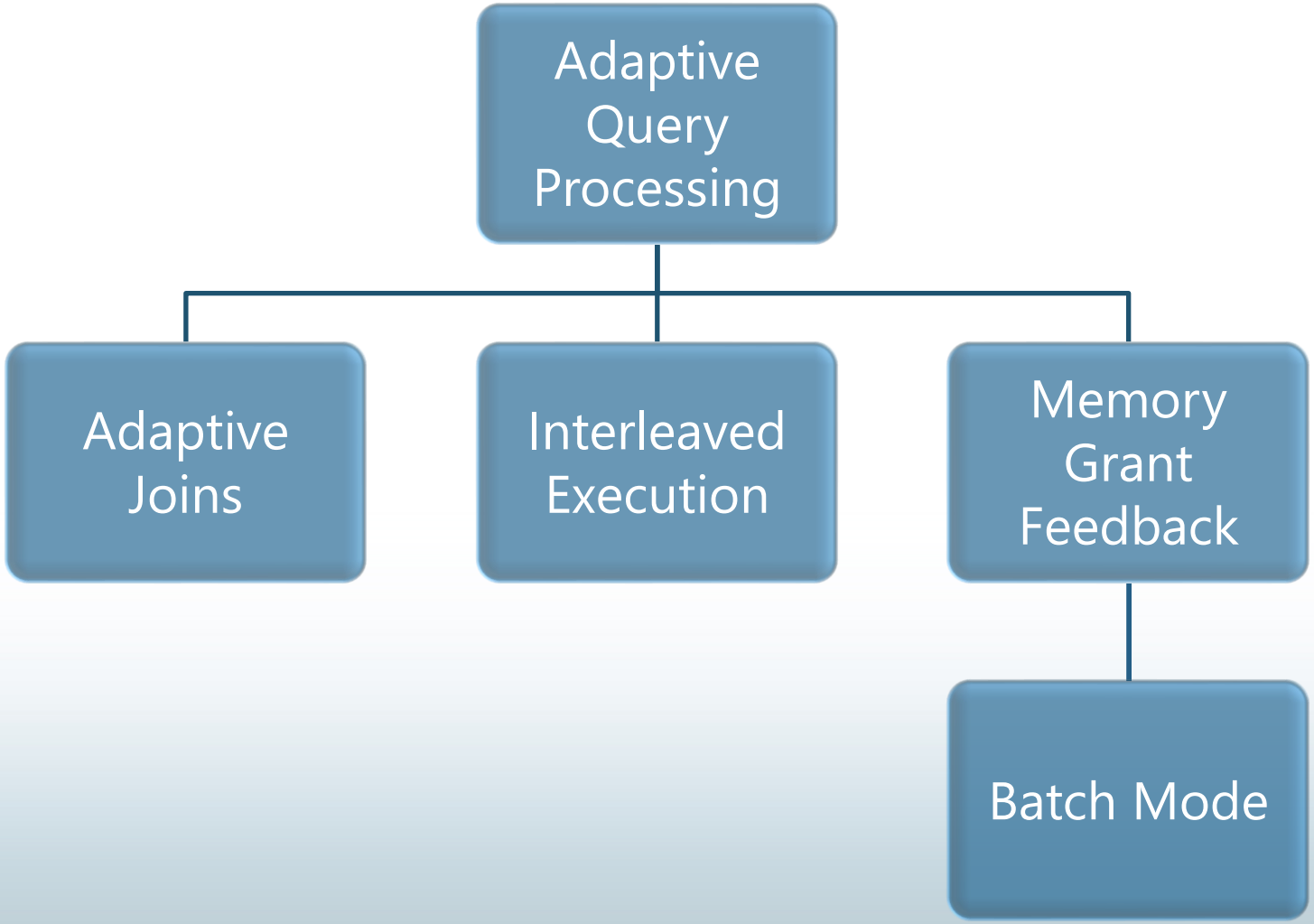
https://aka.ms/IQPDemos

https://aka.ms/SQLCE

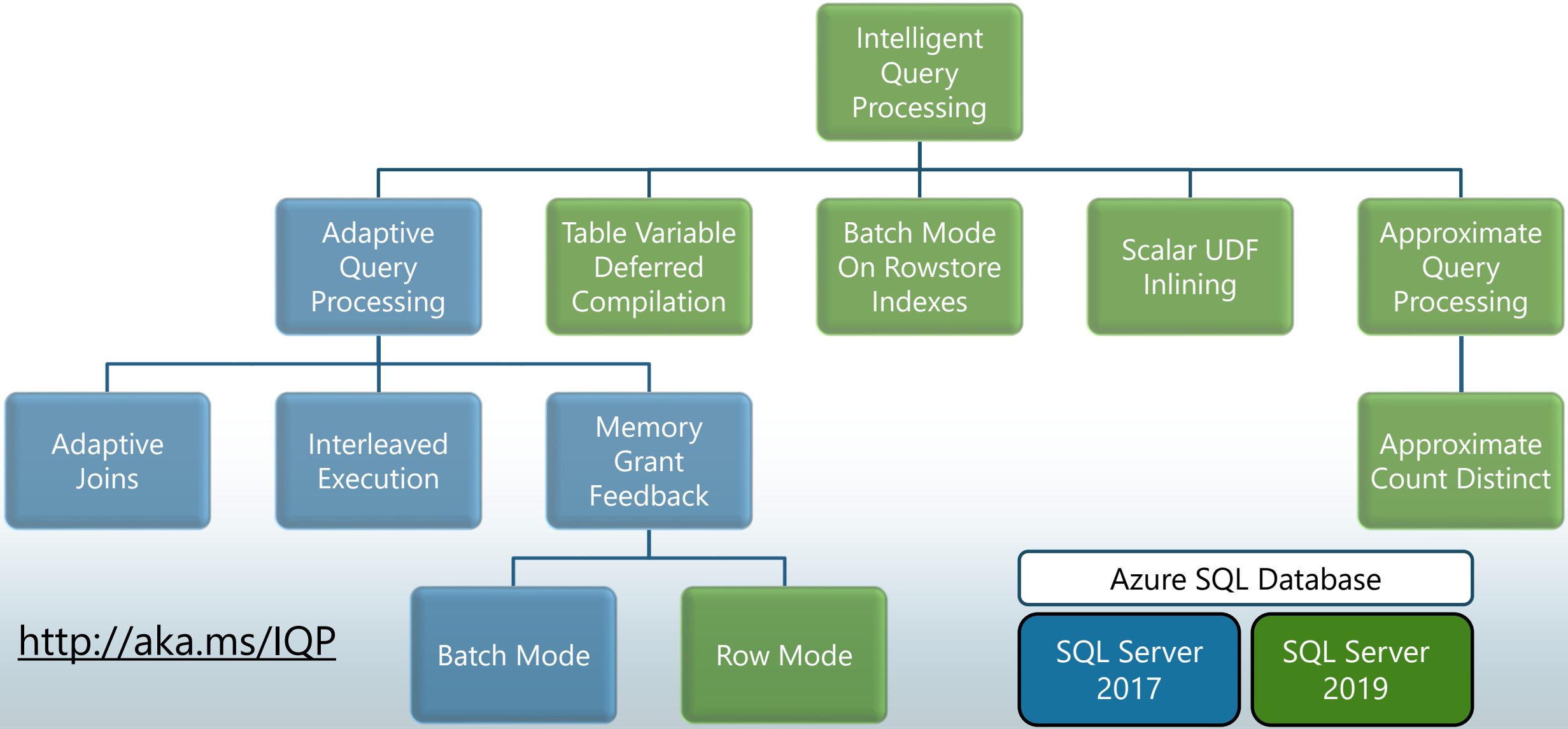
# In a World… before IQP



# Adaptive Query Processing (2017)



# Intelligent Query Processing (2019)



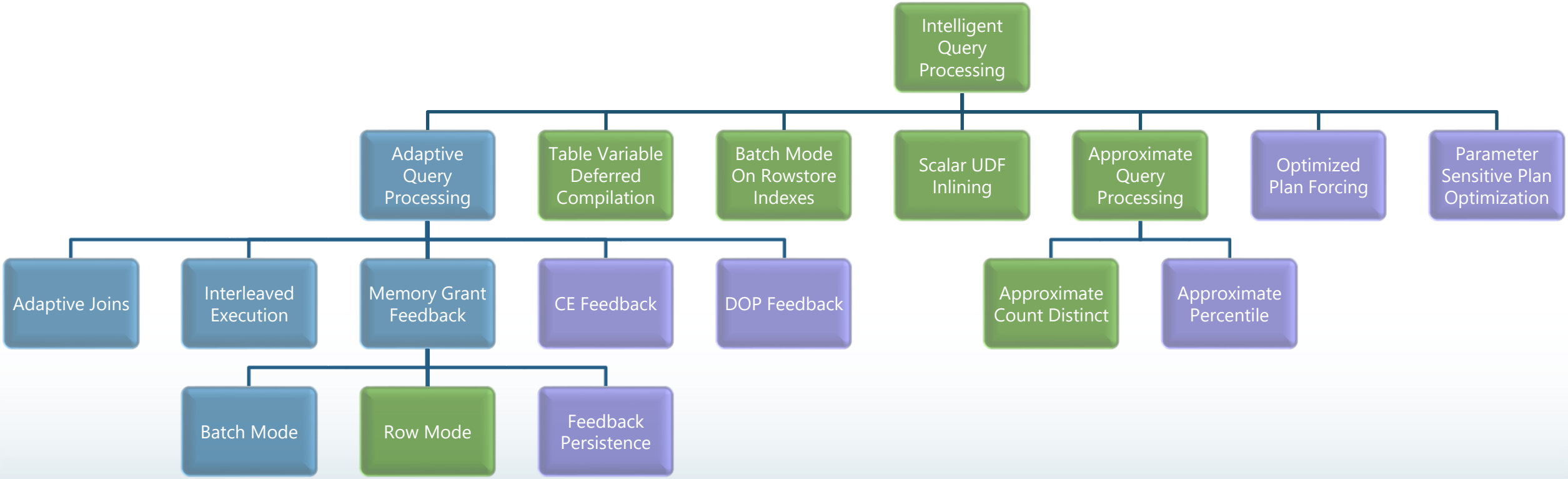

http://aka.ms/IQP

Azure SQL Database

SQL Server 2017

SQL Server 2019

# Intelligent Query Processing (2022)




Azure SQL Database

2017 | 2019 | 2022

# Enabling and Disabling – Instance Level

| | |
|---|---|
| For SQL Server 2017 Features | • Enabled by default in Compatibility level 140 or higher<br>• To disable change compatibility level to 130 or lower |
| For SQL Server 2019 Features | • Enabled by default in Compatibility level 150 or higher<br>• To disable change compatibility level to 140 or lower |
| For SQL Server 2022 Features | • Enabled by default in Compatibility level 160 or higher<br>• To disable change compatibility level to 150 or lower |

# Enabling and Disabling – Database Level

Different settings for 2017 vs Azure SQL, SQL Server 2019 and higher

```
ALTER DATABASE SCOPED CONFIGURATION SET DISABLE_BATCH_MODE_ADAPTIVE_JOINS = ON|OFF;
```

```
ALTER DATABASE SCOPED CONFIGURATION SET BATCH_MODE_ADAPTIVE_JOINS = ON|OFF;
```

To get a list of Database Scoped Configuration settings

```
SELECT * From sys.database_scoped_configurations;
```

| configuration_id | name | value |
|---|---|---|
| 7 | INTERLEAVED_EXECUTION_TVF | 1 |
| 8 | BATCH_MODE_MEMORY_GRANT_FEEDBACK | 1 |
| 9 | BATCH_MODE_ADAPTIVE_JOINS | 1 |
| 10 | TSQL_SCALAR_UDF_INLINING | 1 |
| 16 | ROW_MODE_MEMORY_GRANT_FEEDBACK | 1 |
| 18 | BATCH_MODE_ON_ROWSTORE | 1 |
| 19 | DEFERRED_COMPILATION_TV | 1 |
| 28 | PARAMETER_SENSITIVE_PLAN_OPTIMIZATION | 1 |
| 31 | CE_FEEDBACK | 1 |
| 33 | MEMORY_GRANT_FEEDBACK_PERSISTENCE | 1 |
| 34 | MEMORY_GRANT_FEEDBACK_PERCENTILE_GRANT | 1 |
| 35 | OPTIMIZED_PLAN_FORCING | 0 |

# Enabling and Disabling – Statement Level

You can disable features at the statement scope if necessary.

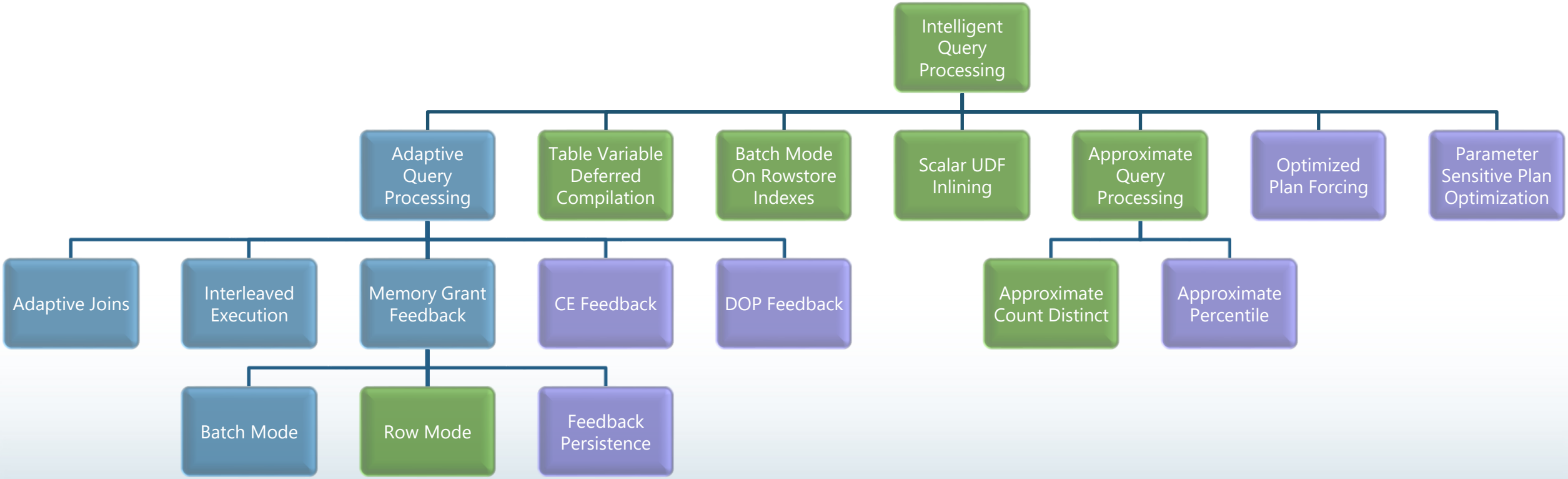
```
<statement>
OPTION (USE HINT('DISABLE_BATCH_MODE_ADAPTIVE_JOINS'));
```

To get a list of valid query use hints

```
SELECT * FROM sys.dm_exec_valid_use_hints;
```

| name |
| --- |
| DISABLE_INTERLEAVED_EXECUTION_TVF |
| DISABLE_BATCH_MODE_MEMORY_GRANT_FEEDBACK |
| DISABLE_BATCH_MODE_ADAPTIVE_JOINS |
| DISABLE_ROW_MODE_MEMORY_GRANT_FEEDBACK |
| DISABLE_DEFERRED_COMPILATION_TV |
| DISABLE_TSQL_SCALAR_UDF_INLINING |
| ASSUME_FULL_INDEPENDENCE_FOR_FILTER_ESTIMATES |
| ASSUME_PARTIAL_CORRELATION_FOR_FILTER_ESTIMATES |
| DISABLE_CE_FEEDBACK |
| DISABLE_MEMORY_GRANT_FEEDBACK_PERSISTENCE |
| DISABLE_DOP_FEEDBACK |
| DISABLE_OPTIMIZED_PLAN_FORCING |

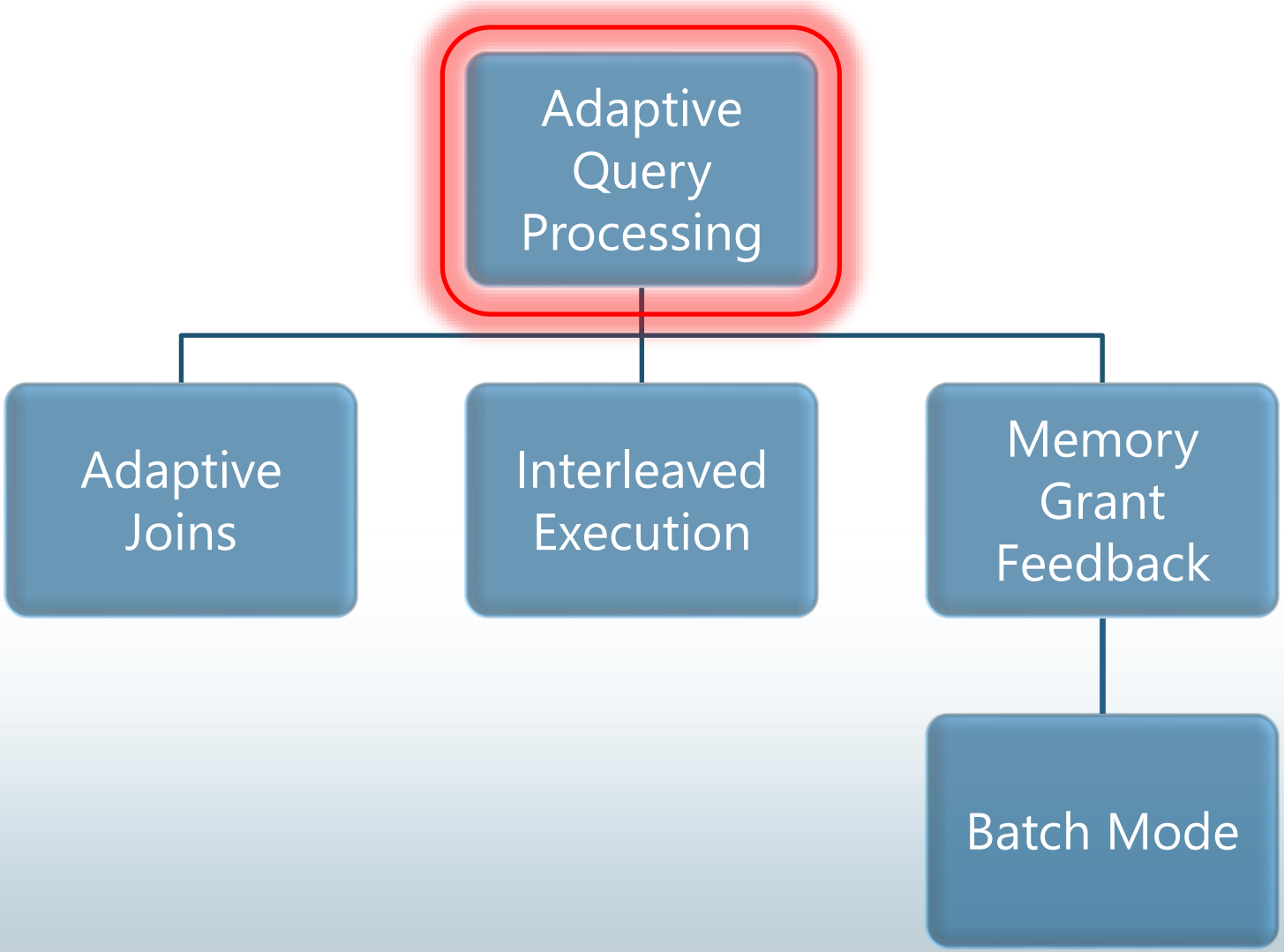
# Intelligent Query Processing




Azure SQL Database

2017 | 2019 | 2022

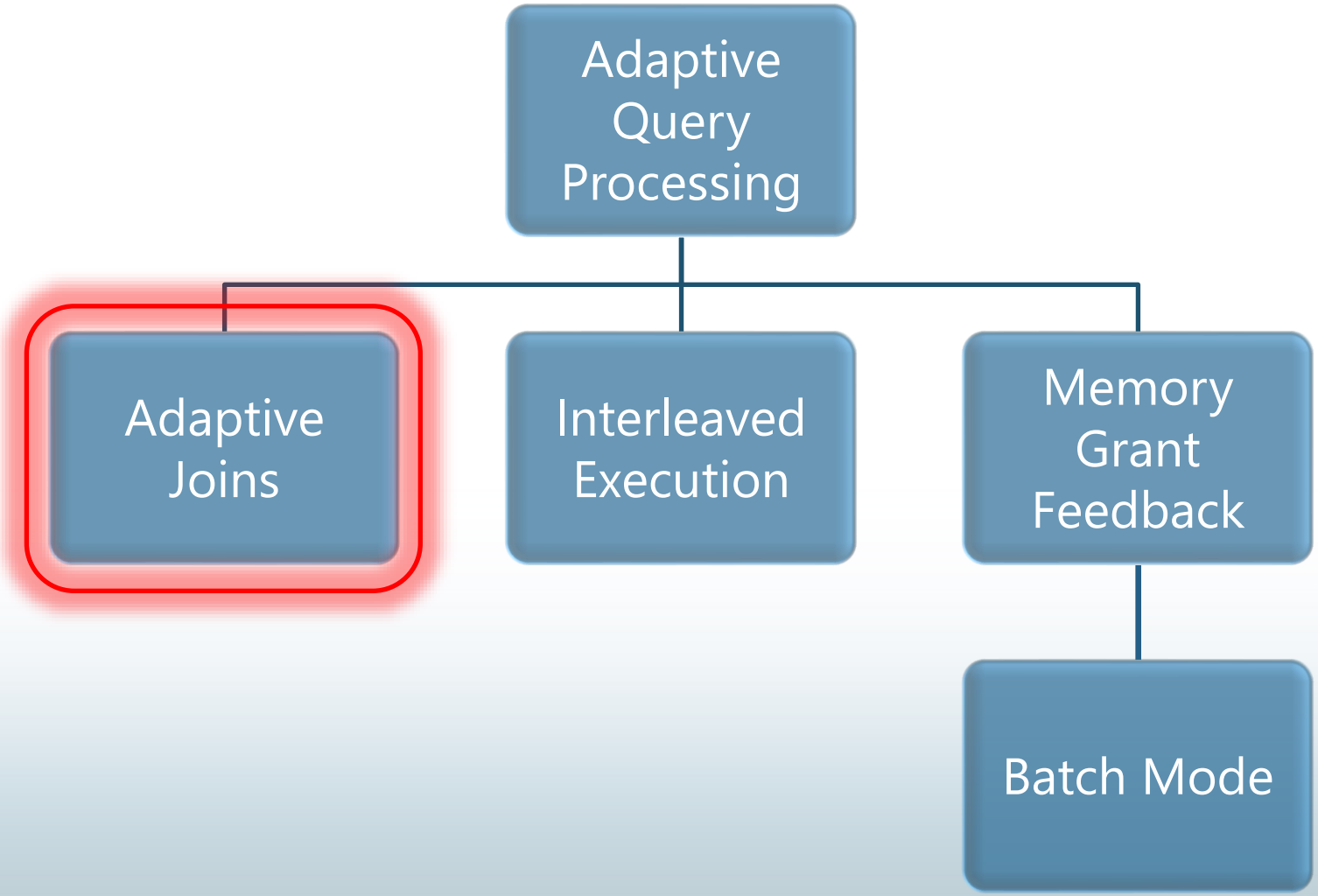
# Adaptive Query Processing (2017)




Addresses performance issues related to the cardinality estimation of an execution plan.

These options can provide improved join type selection, row-calculations for Multi-Statement Table-Valued Functions, and memory allocation of row storage.

# Batch Mode Adaptive Joins (2017)



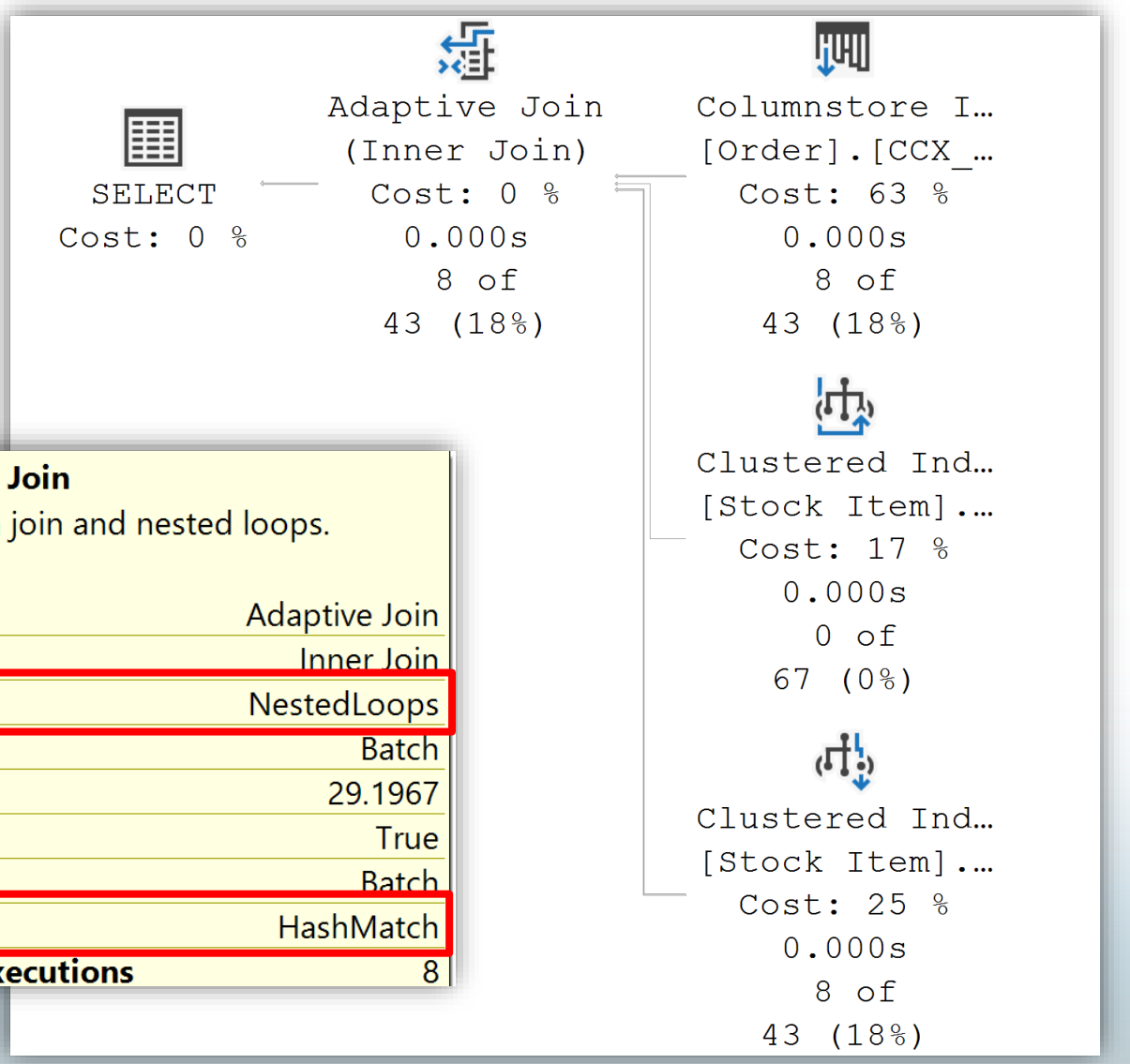

This feature enables the choice of either the Hash or the Nested Loop join type.

Decision is deferred until statement execution.

No need to use join hints in queries.

# Batch Mode Adaptive Joins (2017)

Adaptive Joins

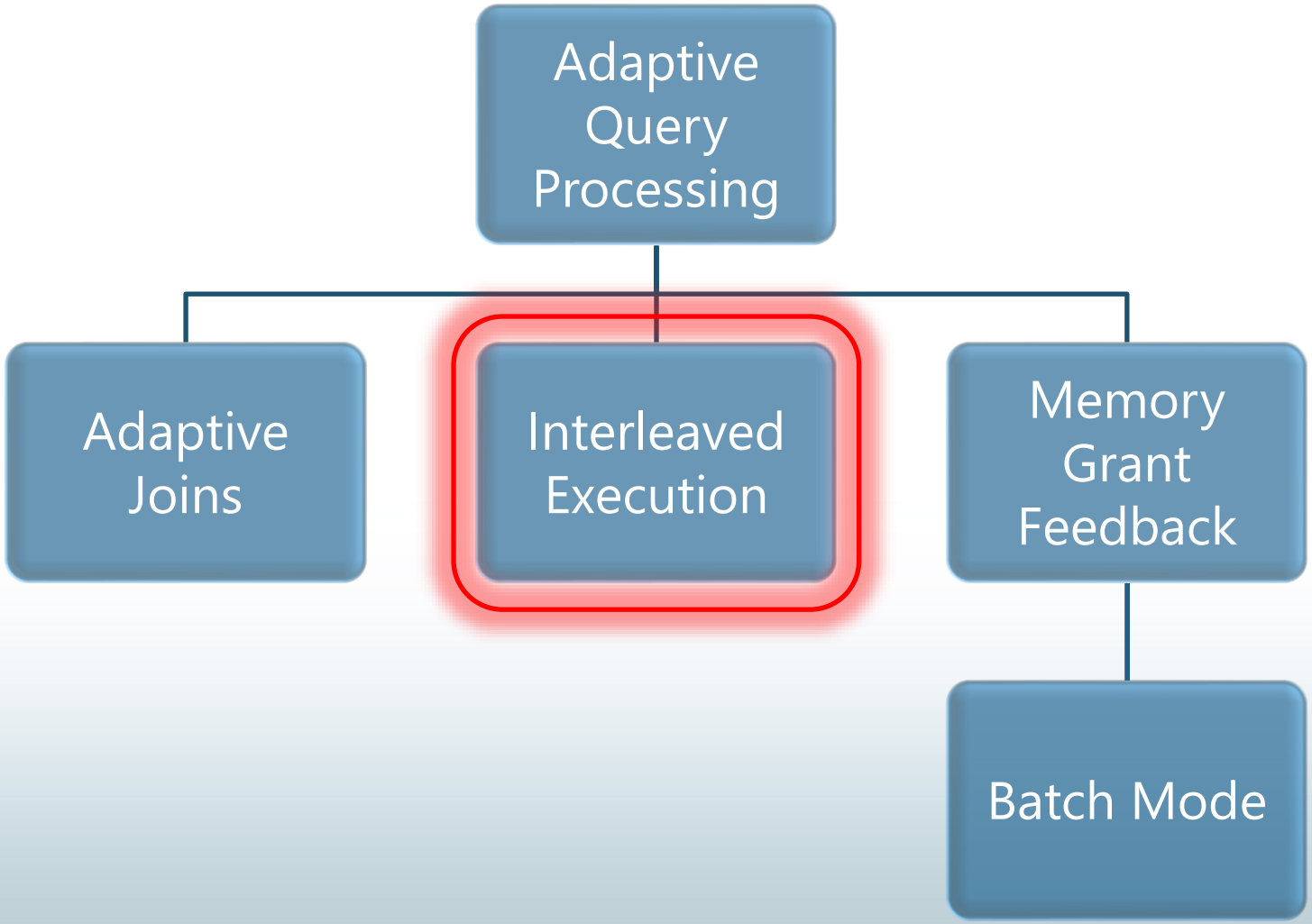



**Adaptive Join**

Chooses dynamically between hash join and nested loops.

| | |
|---|---|
| **Physical Operation** | Adaptive Join |
| **Logical Operation** | Inner Join |
| **Actual Join Type** | NestedLoops |
| **Actual Execution Mode** | Batch |
| **Adaptive Threshold Rows** | 29.1967 |
| **Is Adaptive** | True |
| **Estimated Execution Mode** | Batch |
| **Estimated Join Type** | HashMatch |
| **Actual Number of Rows for All Executions** | 8 |

# Interleaved Execution (2017)




Previously, when a Multi-Statement Table-Valued Function was executed, it used a fixed row estimate of 100 rows.

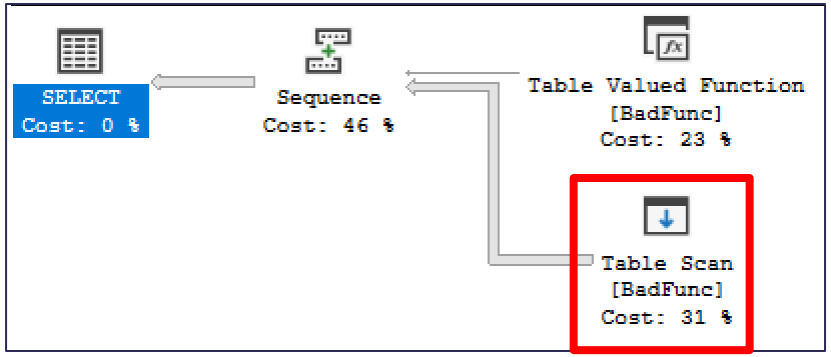
Now execution is paused so a better cardinality estimate can be captured.

# Interleaved Execution (2017)

Interleaved Execution

Compatibility Level 120/130

| Physical Operation | Table Scan |
|---|---|
| Logical Operation | Table Scan |
| Actual Execution Mode | Row |
| Estimated Execution Mode | Row |
| Storage | RowStore |
| Number of Rows Read | 12345 |
| Actual Number of Rows | 12345 |
| Actual Number of Batches | 0 |
| Estimated Operator Cost | 0.003392 (92%) |
| Estimated I/O Cost | 0.003125 |
| Estimated CPU Cost | 0.000267 |
| Estimated Subtree Cost | 0.003392 |
| Number of Executions | 1 |
| Estimated Number of Executions | 1 |
| Estimated Number of Rows to be Read | 100 |
| Estimated Number of Rows | 100 |
| Estimated Row Size | 67 B |
| Actual Rebinds | 0 |
| Actual Rewinds | 0 |
| Ordered | False |
| Node ID | 2 |

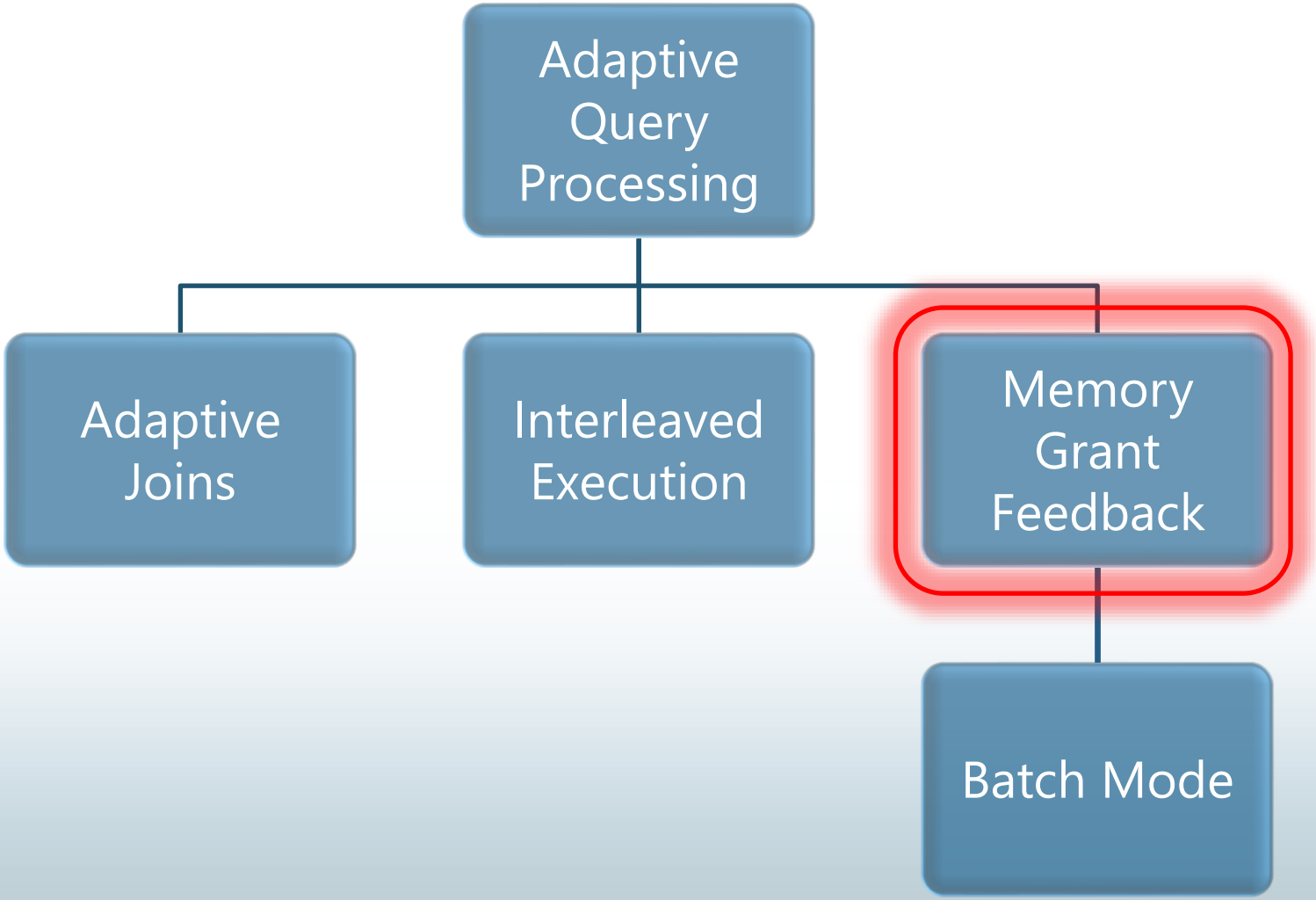



During optimization if SQL Server encounter a read-only multi-statement table-valued function (MSTVF), it will pause optimization, execute the applicable subtree, capture accurate cardinality estimates, and then resume optimization for downstream operations.

Compatibility Level 140 or higher

| Physical Operation | Table Scan |
|---|---|
| Logical Operation | Table Scan |
| Actual Execution Mode | Row |
| Estimated Execution Mode | Row |
| Storage | RowStore |
| Number of Rows Read | 12345 |
| Actual Number of Rows | 12345 |
| Actual Number of Batches | 0 |
| Estimated Operator Cost | 0.0168615 (31%) |
| Estimated I/O Cost | 0.003125 |
| Estimated CPU Cost | 0.0137365 |
| Estimated Subtree Cost | 0.0168615 |
| Number of Executions | 1 |
| Estimated Number of Executions | 1 |
| Estimated Number of Rows to be Read | 12345 |
| Estimated Number of Rows | 12345 |
| Estimated Row Size | 67 B |
| Actual Rebinds | 0 |
| Actual Rewinds | 0 |
| Ordered | False |
| Node ID | 2 |

# Batch Mode Memory Grant Feedback (2017)



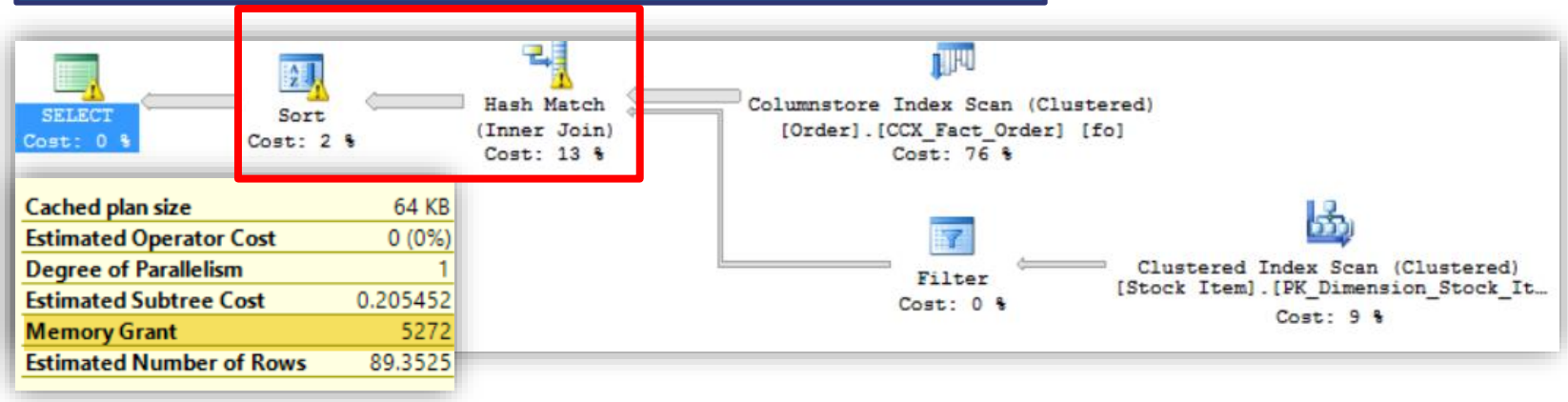

When compiling an execution plan, the query engine estimates how much memory is needed to store rows during join and sort operations.

Too much memory allocation may impact performance of other operations. Not enough will cause a spill over to disk.

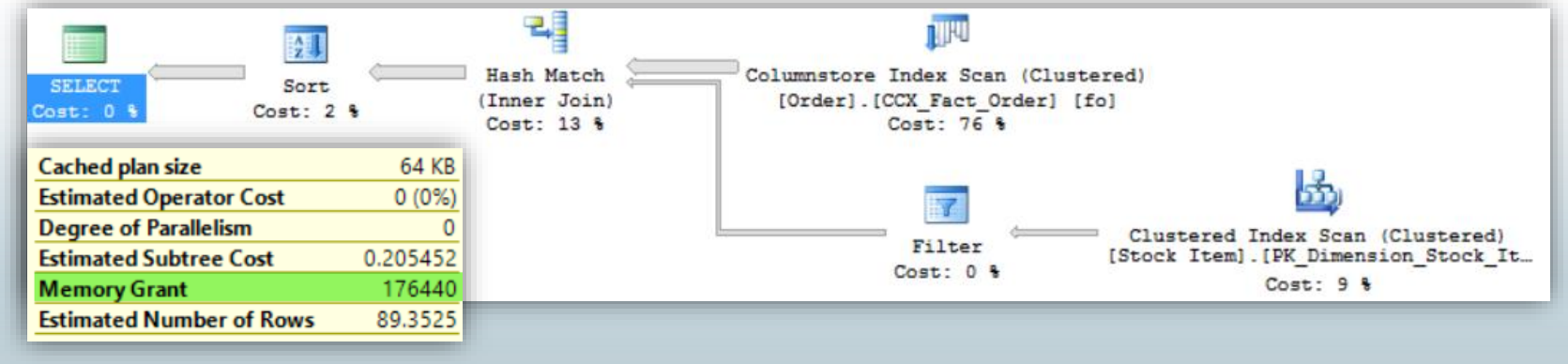
This feature recalculates memory on first execution and updates the cached plan.

# Batch Mode Memory Grant Feedback (2017)

First Execution (Spills detected; feedback generated)

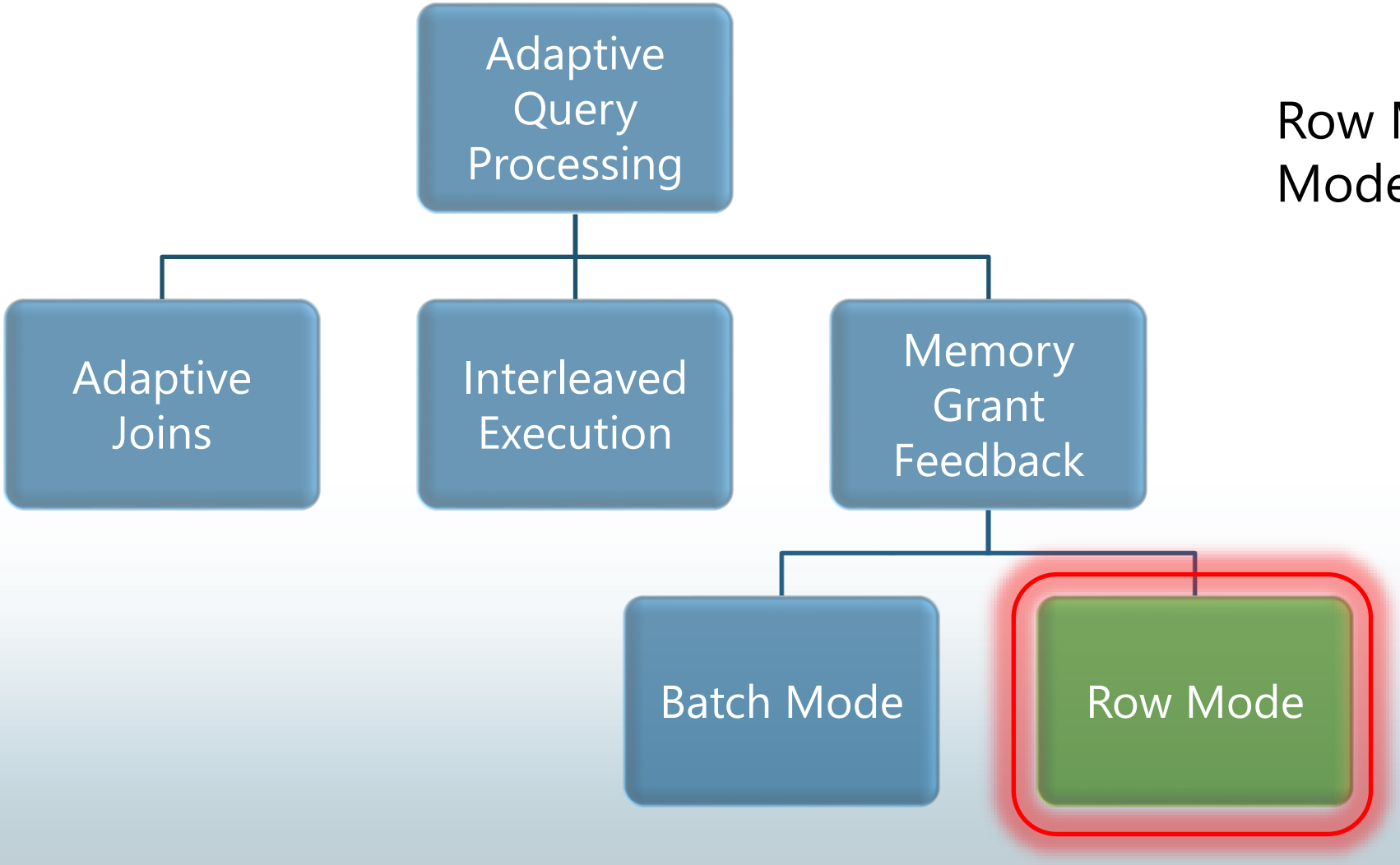



Second Execution (Memory grant adjusted)




Memory Grant Feedback (Batch Mode)

# Row Mode Memory Grant Feedback (2019)




Row Mode is just like Batch Mode, but different.

# Row Mode Memory Grant Feedback (2019)

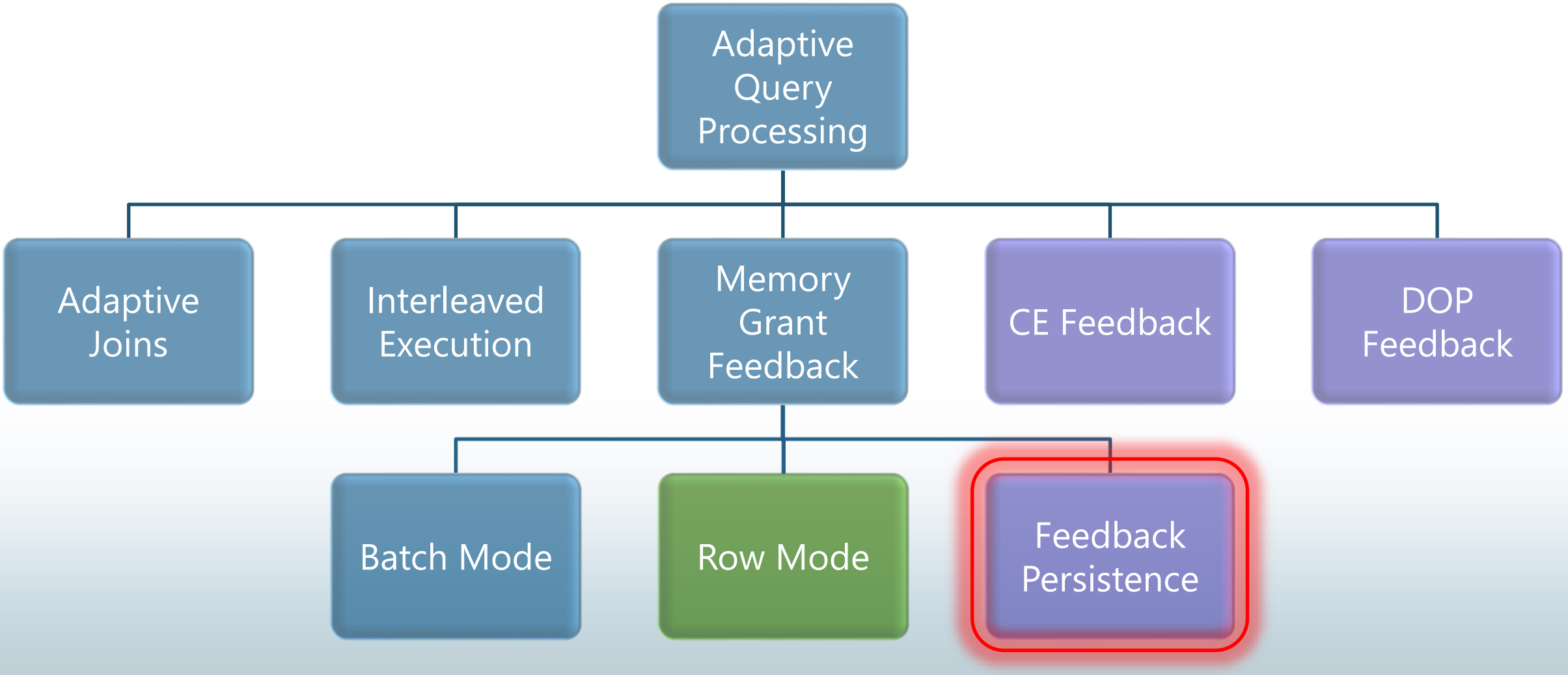
Expands on the batch mode memory grant feedback feature by also adjusting memory grant sizes for row mode operators.

| MemoryGrantInfo | |
|---|---|
| DesiredMemory | 13992 |
| GrantedMemory | 13992 |
| GrantWaitTime | 0 |
| IsMemoryGrantFeedbackAdjusted | YesStable |
| LastRequestedMemory | 13992 |
| MaxQueryMemory | 1497128 |
| MaxUsedMemory | 3744 |

Memory Grant Feedback (Row Mode)

Two new query plan attributes will be shown for actual post-execution plans.

# Feedback Persistence (2022)



# Feedback Persistence and Percentile (2022)

**Problem**: Cache Eviction

- Feedback is not persisted if the plan is evicted from cache or failover
- Record of how to adjust memory is lost and must re-learn

**Solution**: Persist the feedback

- Persist the memory grant feedback in the Query Store

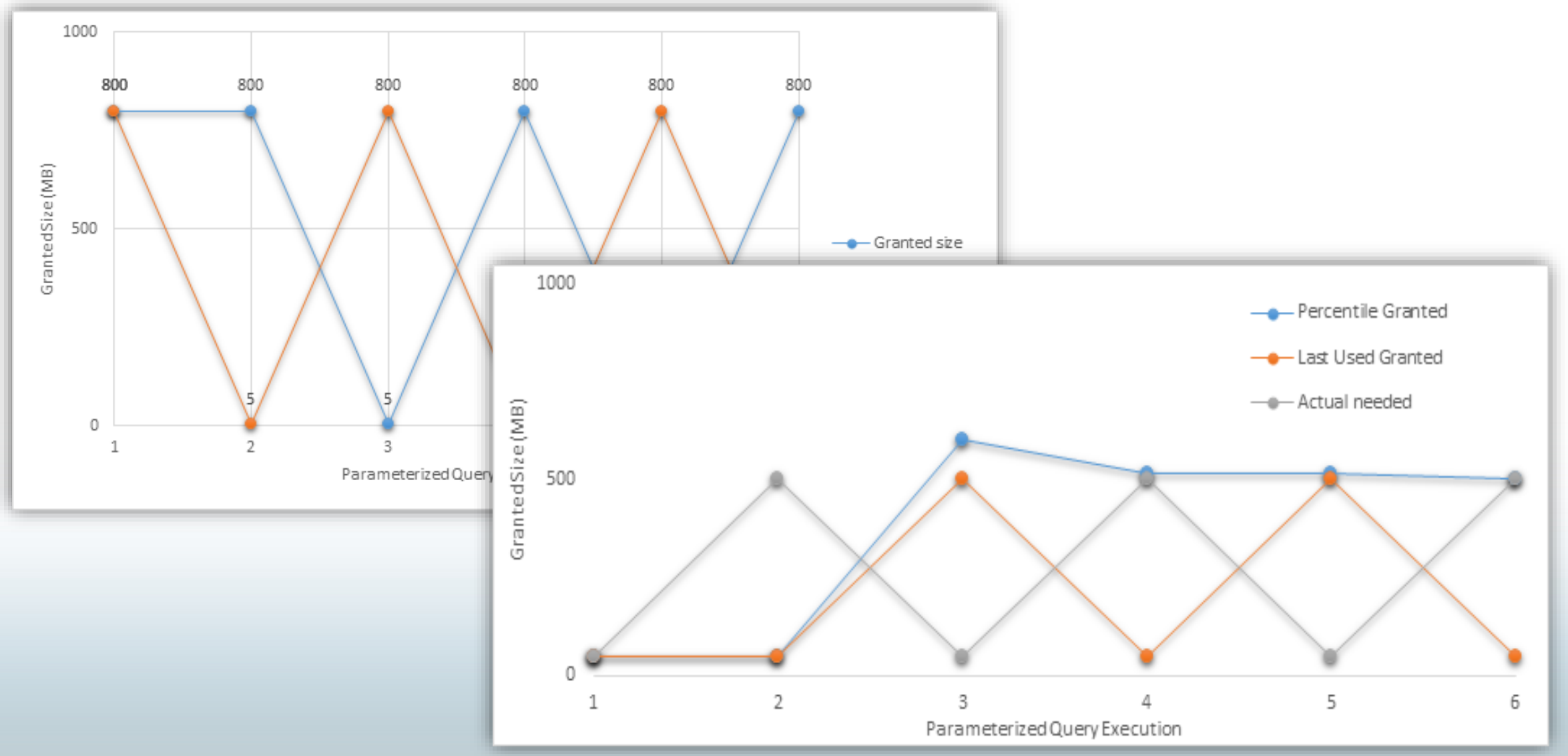
**Problem**: Oscillating Feedback

- Memory grants adjusted based on last feedback
- Parameter Sensitive Plans could change feedback

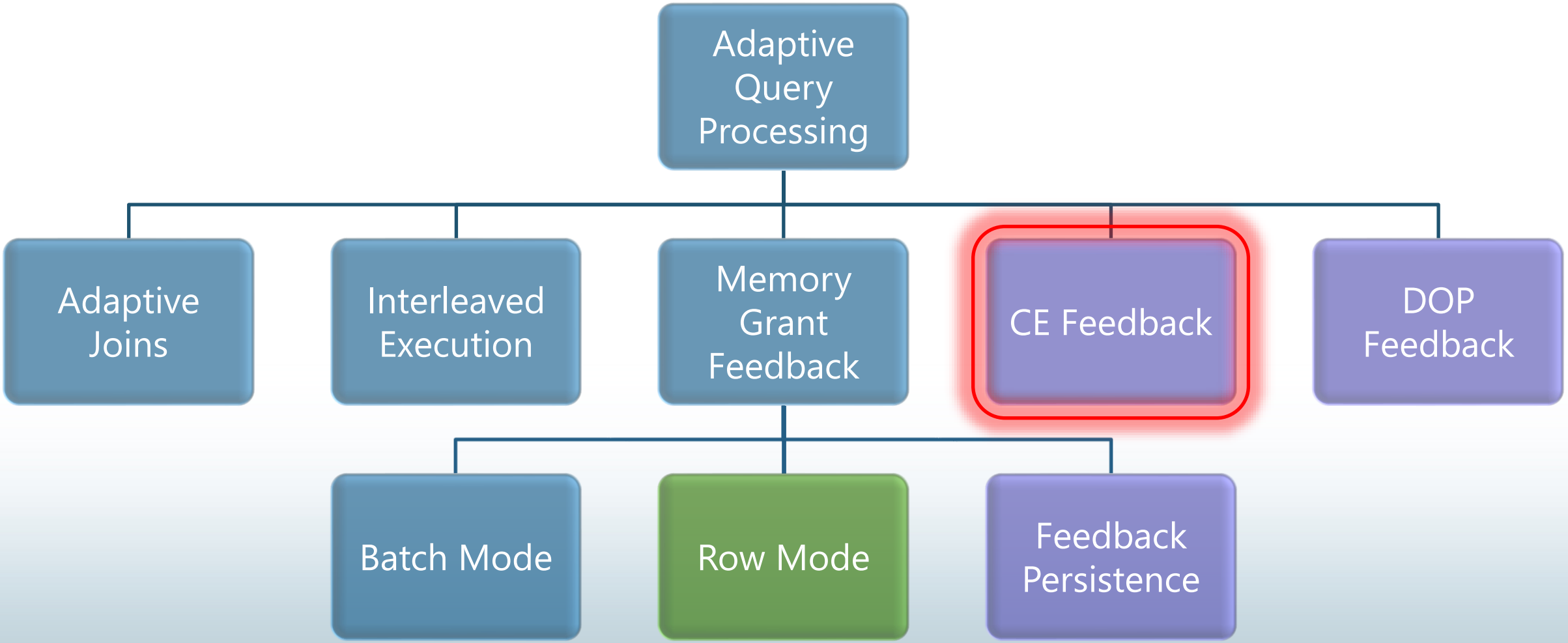
**Solution**: Percentile-based calculation

- Smooths the grant size values based on execution usage history

# Feedback Persistence and Percentile (2022)



# Cardinality Estimator Feedback (2022)



# Cardinality Estimator Feedback (2022)

## Cardinality Estimation Today

- CE determines the estimated number of rows for a query plan
- CE models are based on statistics and assumptions about the distribution of data
- Learn more about CE models and assumptions https://aka.ms/sqlCE

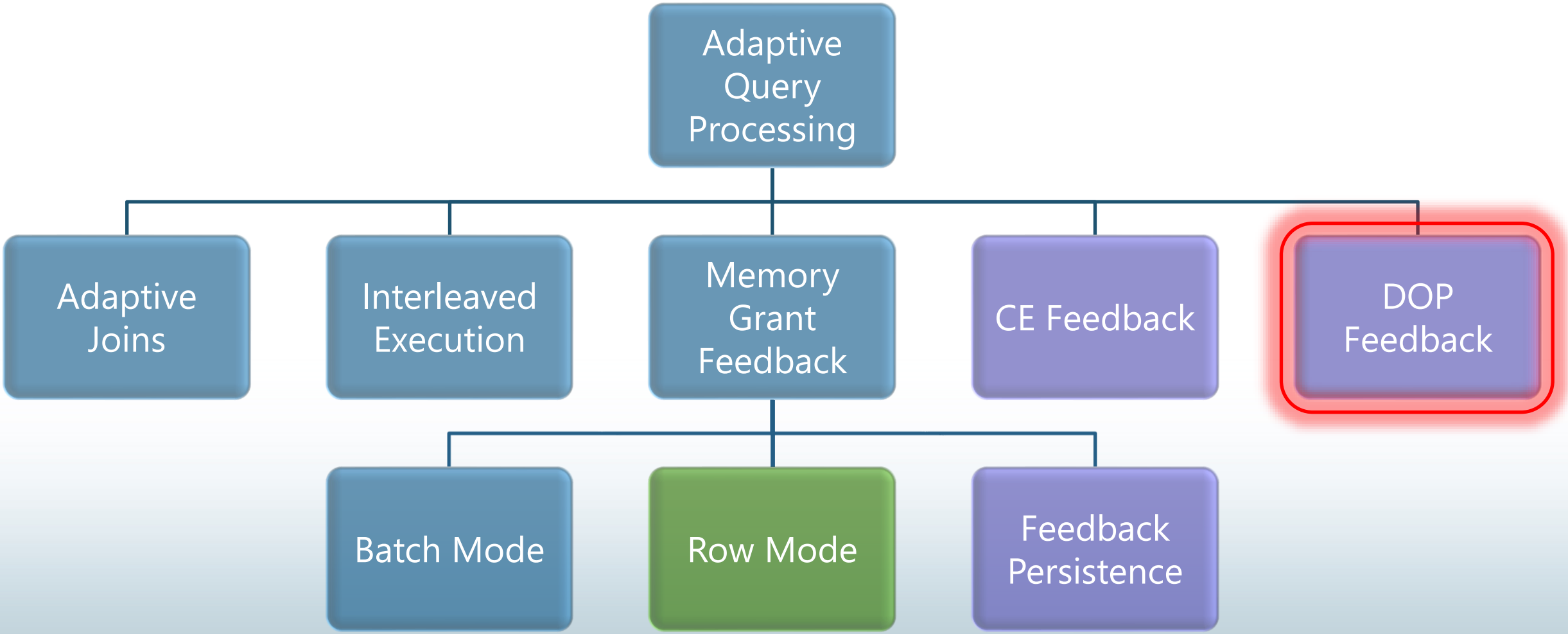
## **Problem**: Incorrect Assumptions for Cardinality Estimates

- The cardinality estimator sometimes makes incorrect assumptions
- Poor assumptions leads to poor query plans.
- One CE models doesn't fit all scenarios

## **Solution**: Learn from historical CE model assumptions

- CE Feedback will evaluate accuracy for repeated queries
- If assumption looks incorrect, test a different CE model assumption and verify if it helps
- If a CE model assumption does help, it will replace the current plan in cache.

# Degree of Parallelism Feedback (2022)



# Degree of Parallelism Feedback (2022)

## Parallelism Today

- Parallelism is often beneficial for querying large amounts of data, but transactional queries could suffer when time spent coordinating threads outweighs the advantages of using a parallel plan

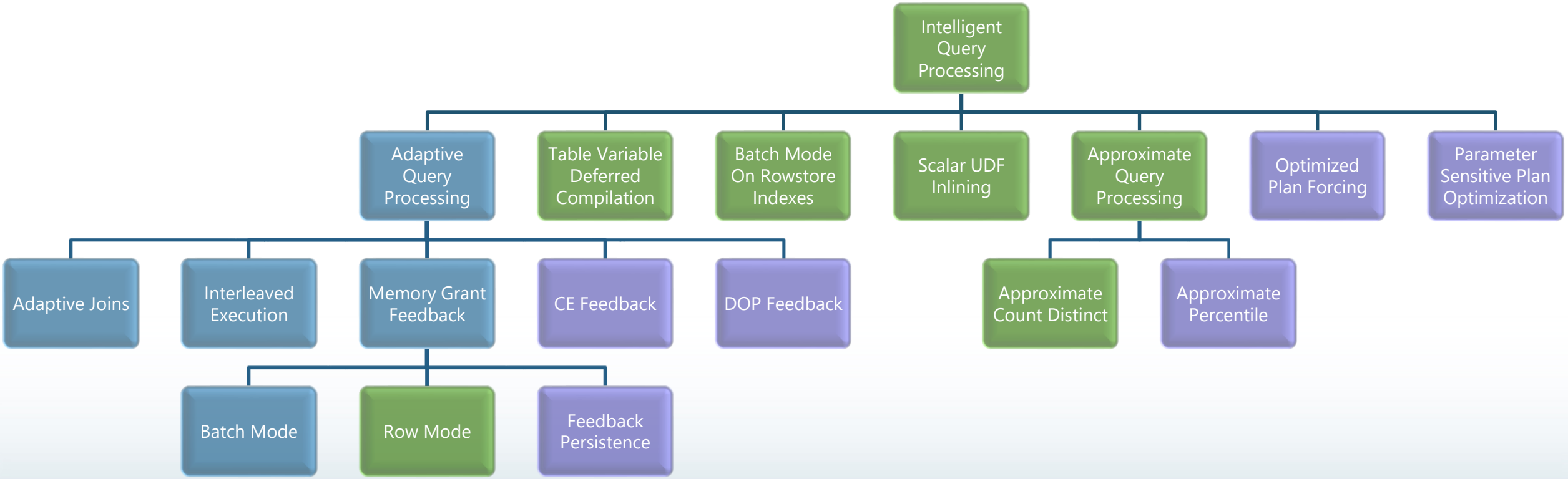
## Current Settings

- Before SQL Server 2019, default value for MAXDOP = 0
- With SQL Server 2019, default is calculated at setup based on available processors
- Azure SQL Database the default MAXDOP is 8

## DOP Feedback

- DOP Feedback will **identify** parallelism inefficiencies for repeating queries, based on CPU time, elapsed time, and waits
- If parallelism usage is inefficient, the DOP will be **lowered** for next execution (min DOP = 2) and then **verify** if it helps
- Only verified feedback is persisted (Query Store).
  - If next execution regresses, back to last good known DOP

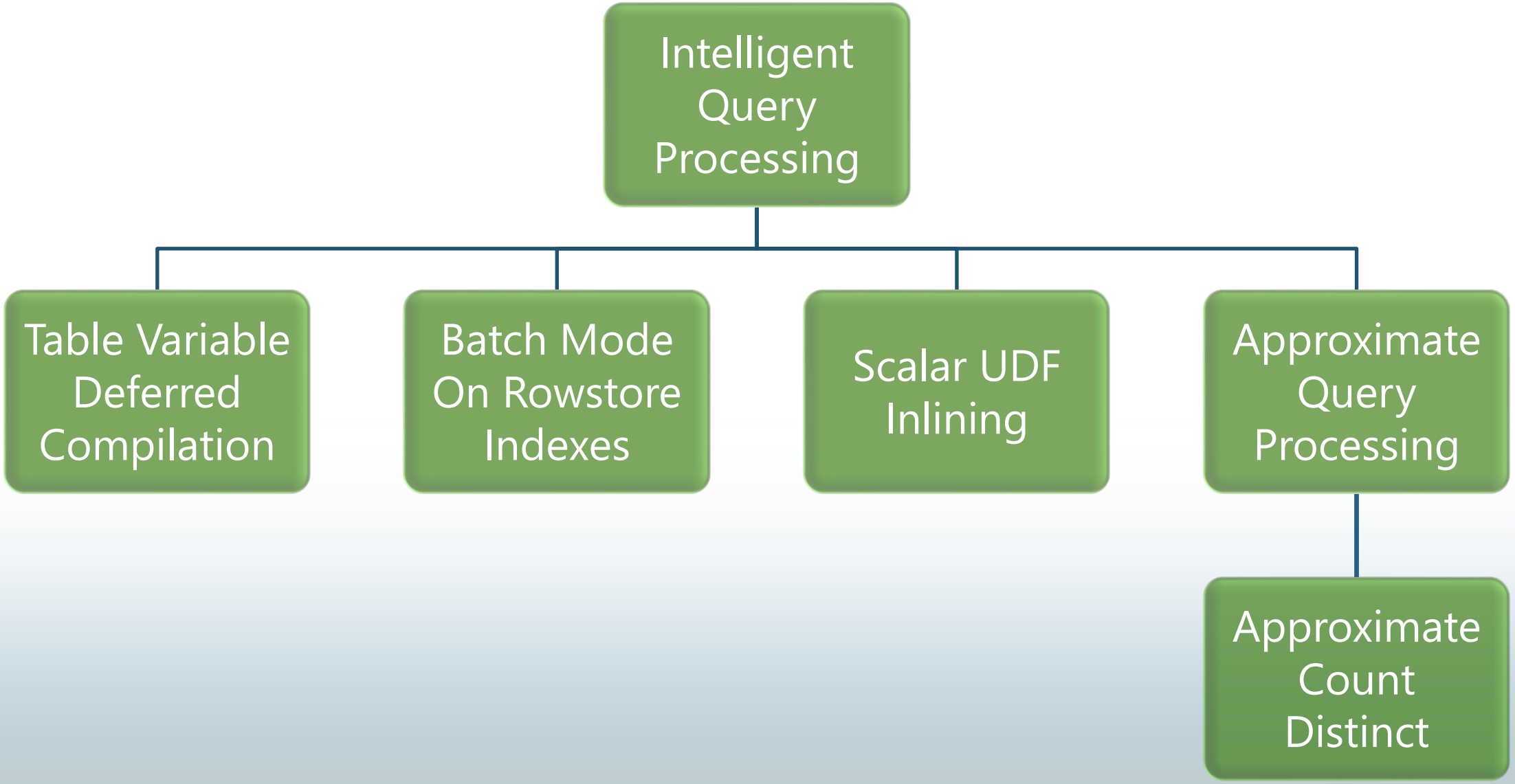
# Intelligent Query Processing Feature Family



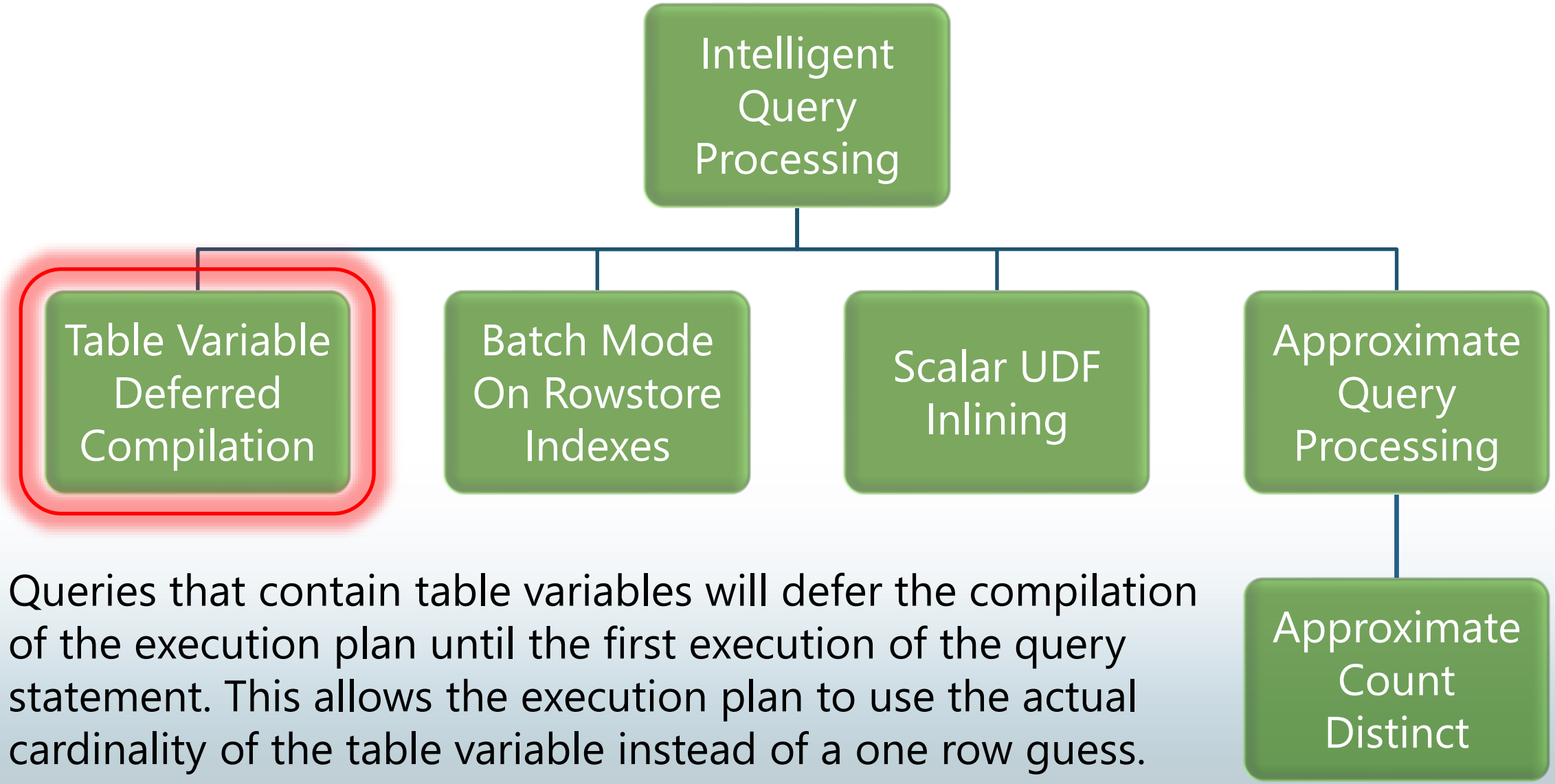

Azure SQL Database

2017 | 2019 | 2022

# Intelligent Query Processing (2019)

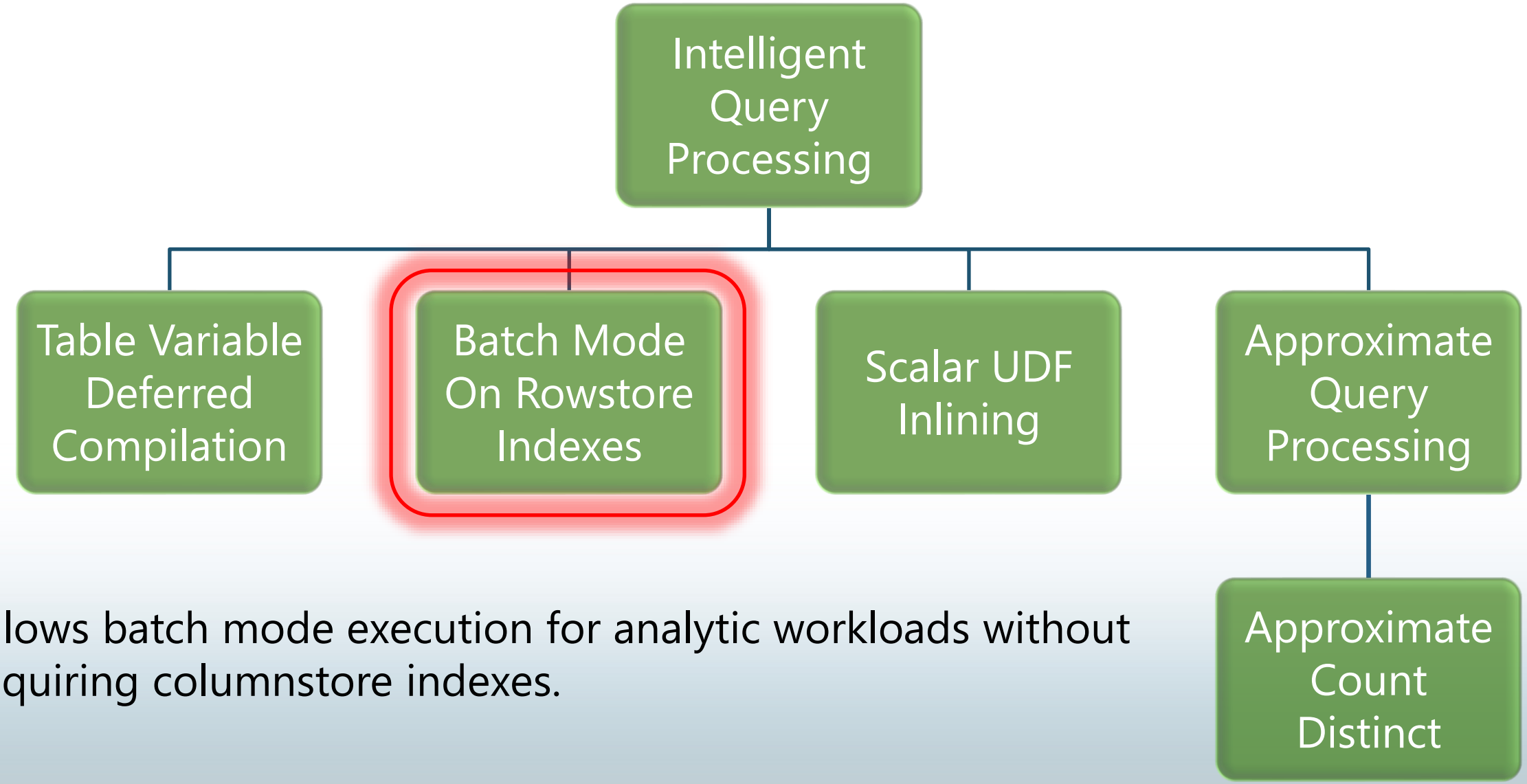


# Table Variable Deferred Compilation



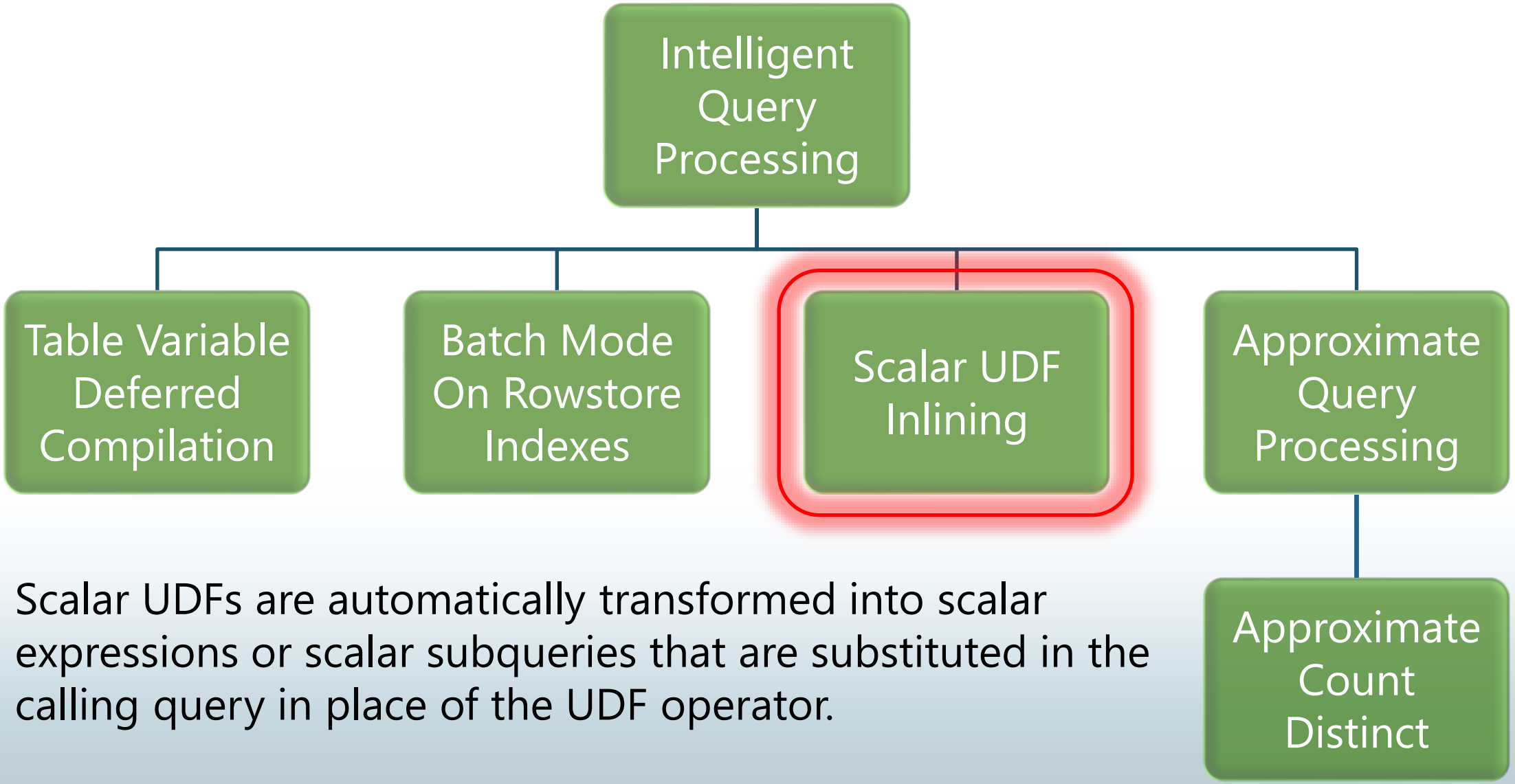

Queries that contain table variables will defer the compilation of the execution plan until the first execution of the query statement. This allows the execution plan to use the actual cardinality of the table variable instead of a one row guess.

# Batch Mode on Rowstore Indexes



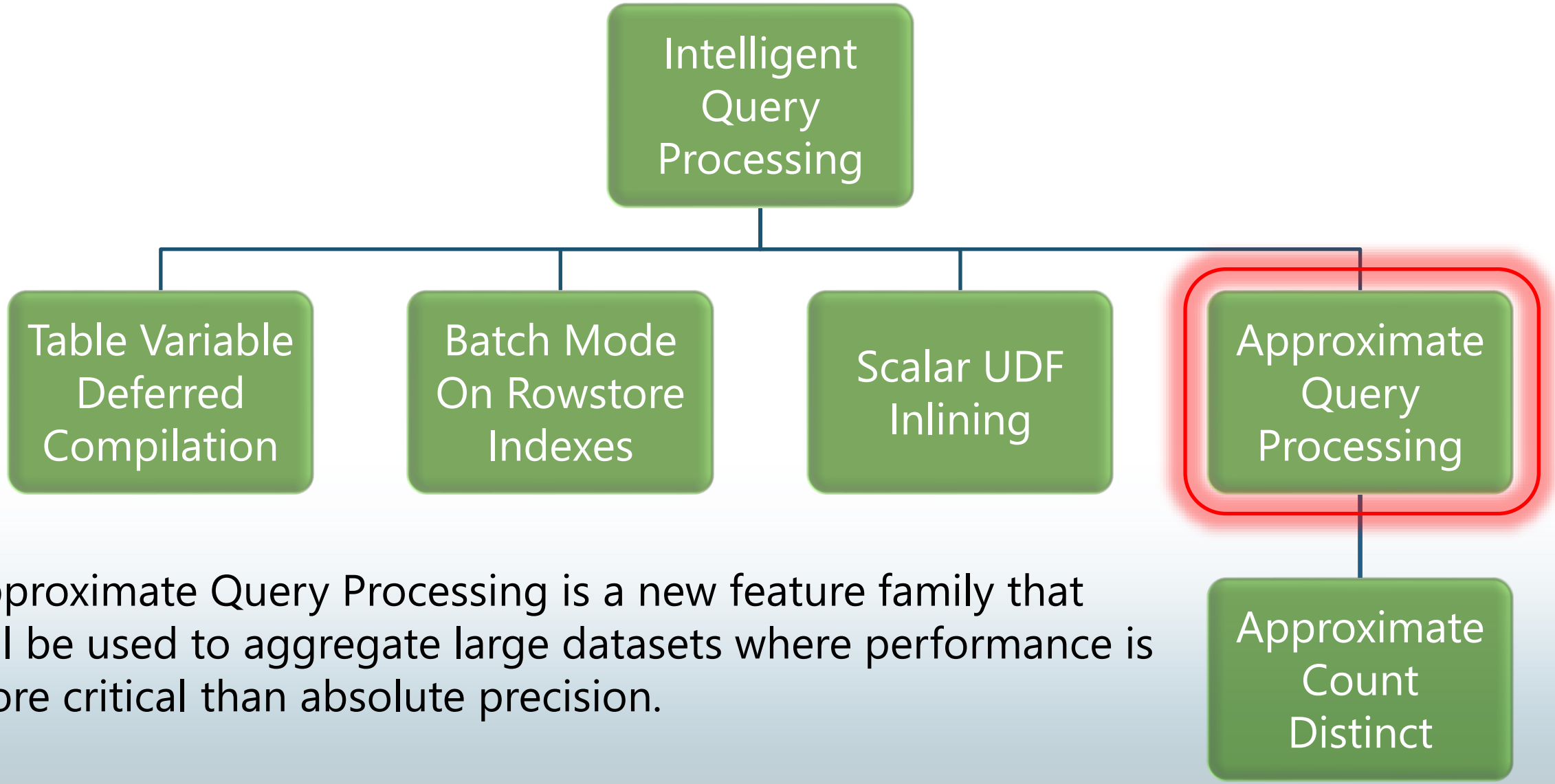

Allows batch mode execution for analytic workloads without requiring columnstore indexes.

# Scalar User-Defined Function Inlining



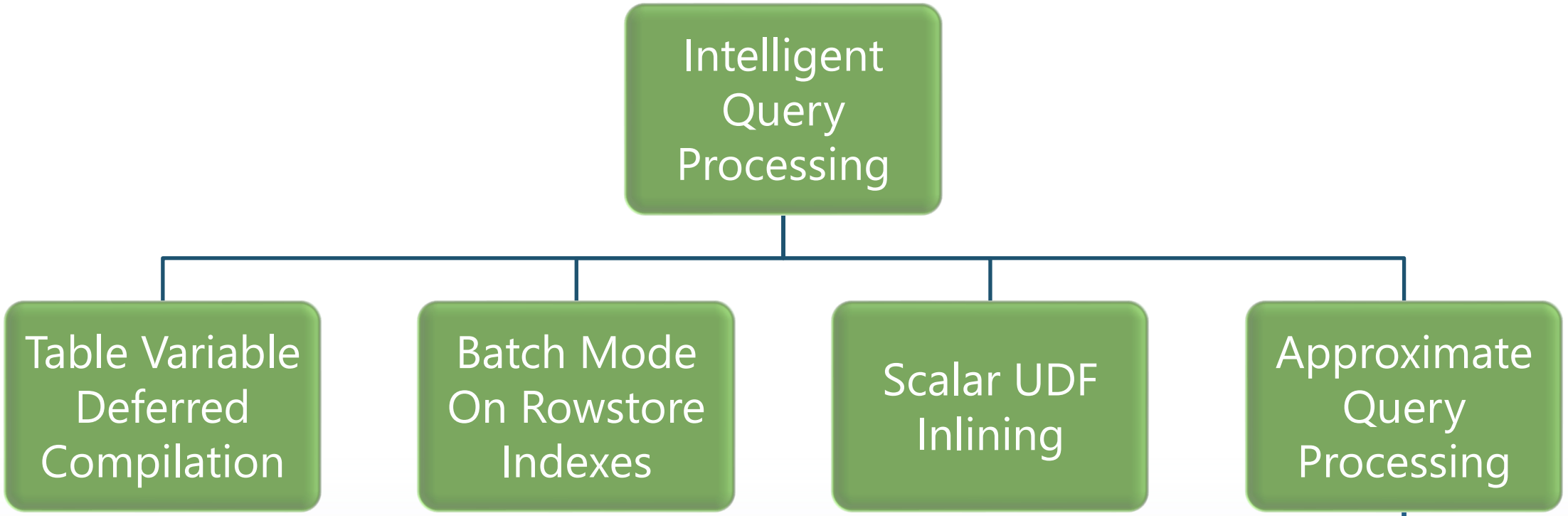

Scalar UDFs are automatically transformed into scalar expressions or scalar subqueries that are substituted in the calling query in place of the UDF operator.

# Approximate Query Processing




Approximate Query Processing is a new feature family that will be used to aggregate large datasets where performance is more critical than absolute precision.

# Approximate Count Distinct (2019)




A new aggregate function APPROX_COUNT_DISTINCT that returns the approximate number of unique non-null values in a group.

# Approximate Count Distinct

It returns the approximate number of unique non-null values in a group.

It is designed to provide aggregations across large data sets where responsiveness is more critical than absolute precision.

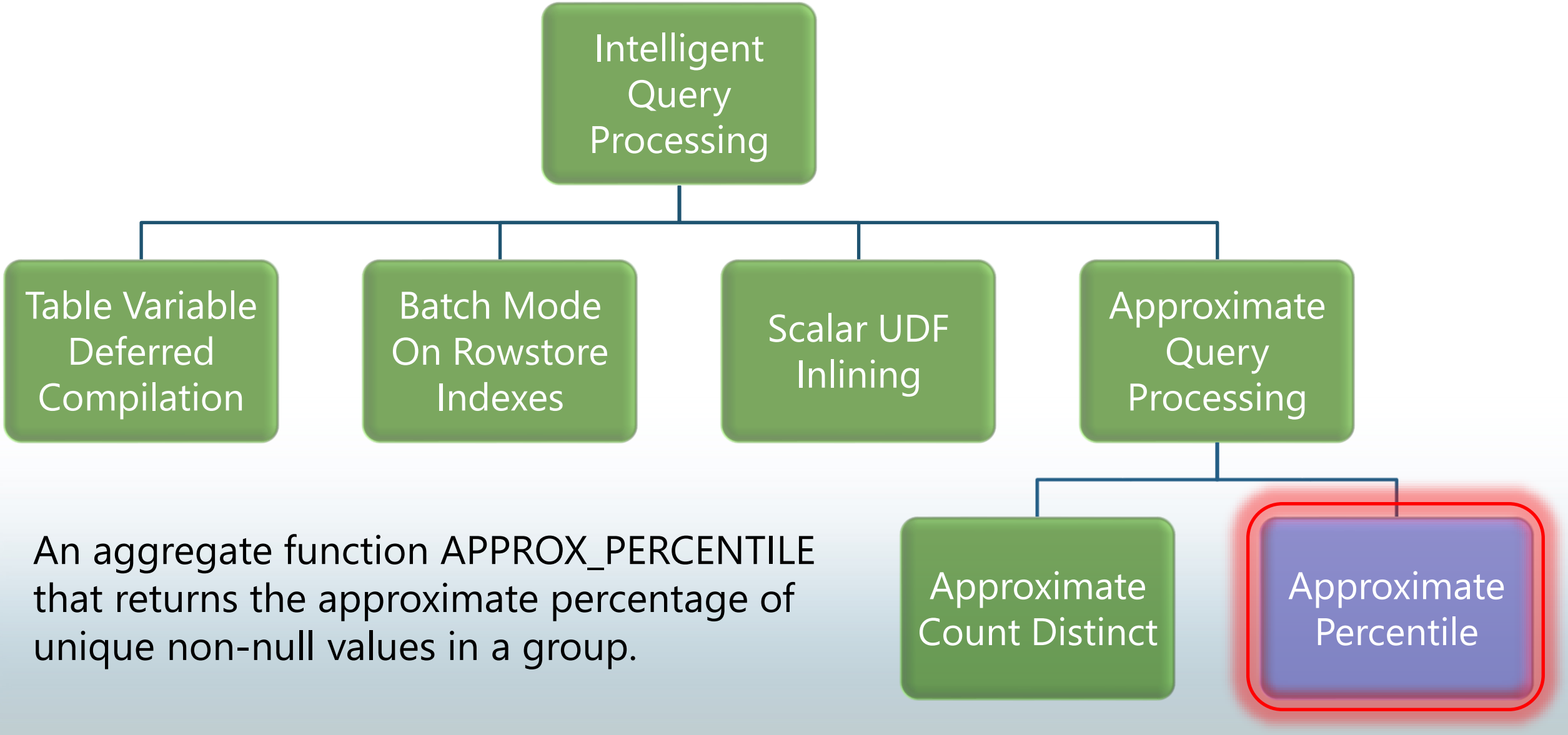
Guarantees up to a 2% error rate within a 97% probability.

Requires less memory than an exhaustive COUNT DISTINCT operation so it is less likely to spill memory to disk compared to COUNT DISTINCT.

Approximate Count Distinct

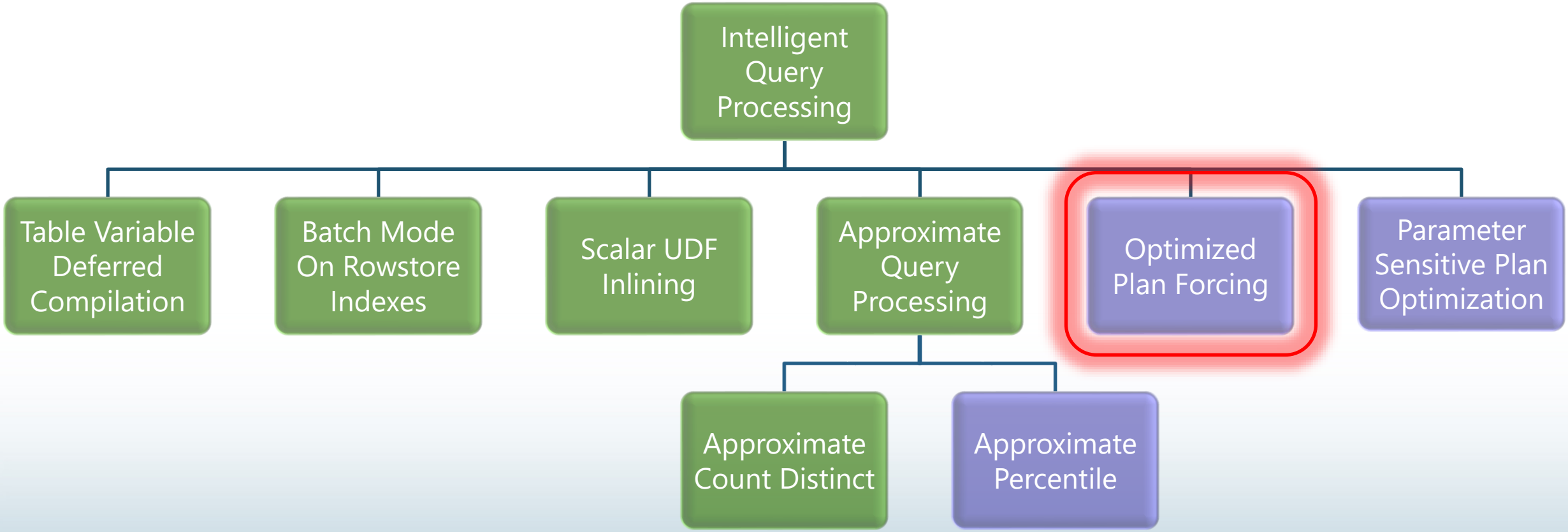
```
SELECT APPROX_COUNT_DISTINCT(O_OrderKey) AS Approx_Distinct_OrderKey
FROM dbo.Orders;
```

# Approximate Percentile (2022)




An aggregate function APPROX_PERCENTILE that returns the approximate percentage of unique non-null values in a group.

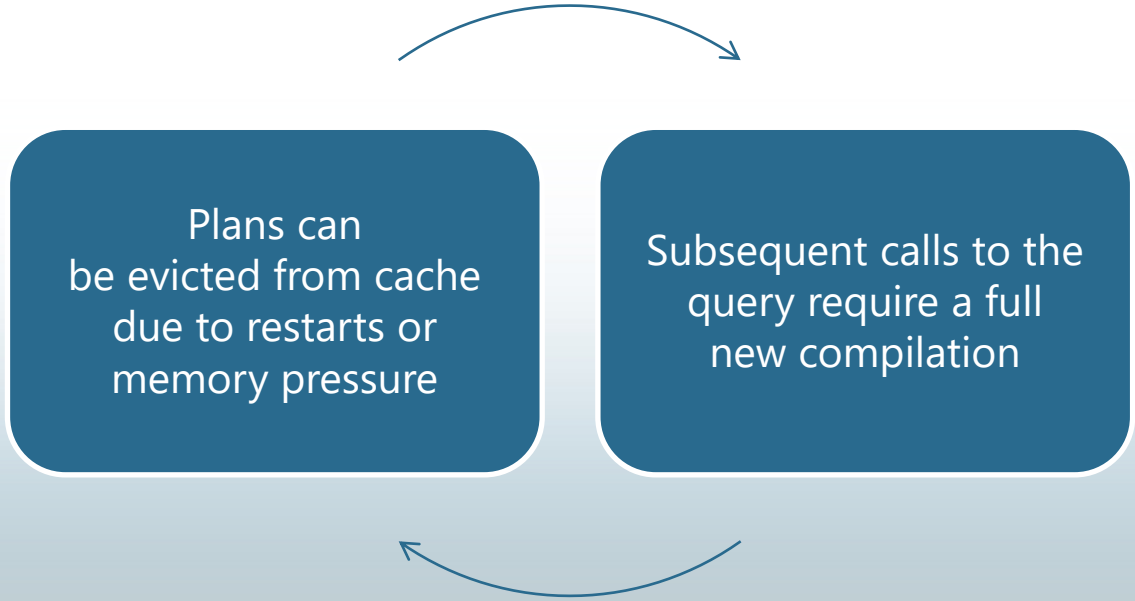
# Optimized Plan Forcing (2022)



# Optimized Plan Forcing (2022)

## Query Compilation Today

- Query optimization and compilation is a multi-phased process of quickly generating a “good-enough” query execution plan
- Query execution time includes compilation. Can be time and resource consuming
- To reduce compilation overhead for repeating queries, SQL caches query plans for re-use

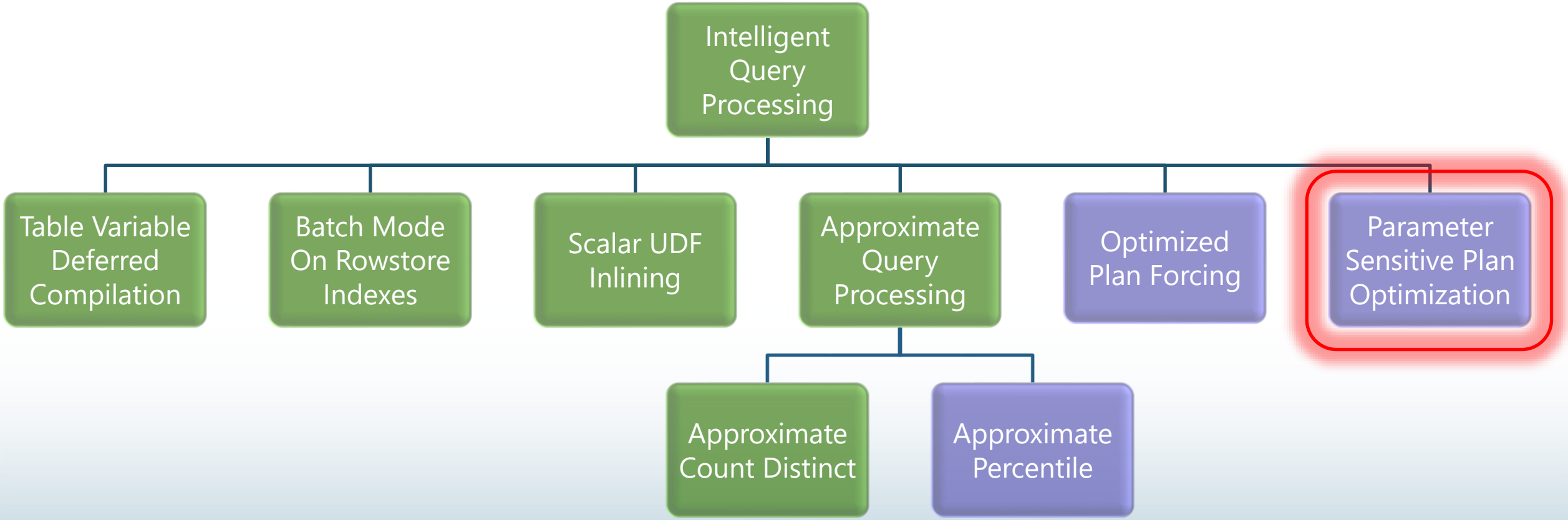


# Optimized Plan Forcing (2022)

## Query Compilation Replay

- Stores a *compilation replay script* (CRS) that persists key compilation steps in Query Store (not user visible)
- Version 1 targets previously forced plans through Query Store and Automatic Plan Correction
- Uses those previously-recorded CRS to quickly reproduce and cache the original forced plan **at a fraction of the original compilation cost**
- Compatible with Query Store hints and secondary replica support

# Parameter Sensitive Plan Optimization (2022)



# Parameter Sensitive Plans (2022)

## Parameter Sensitive Plans Today

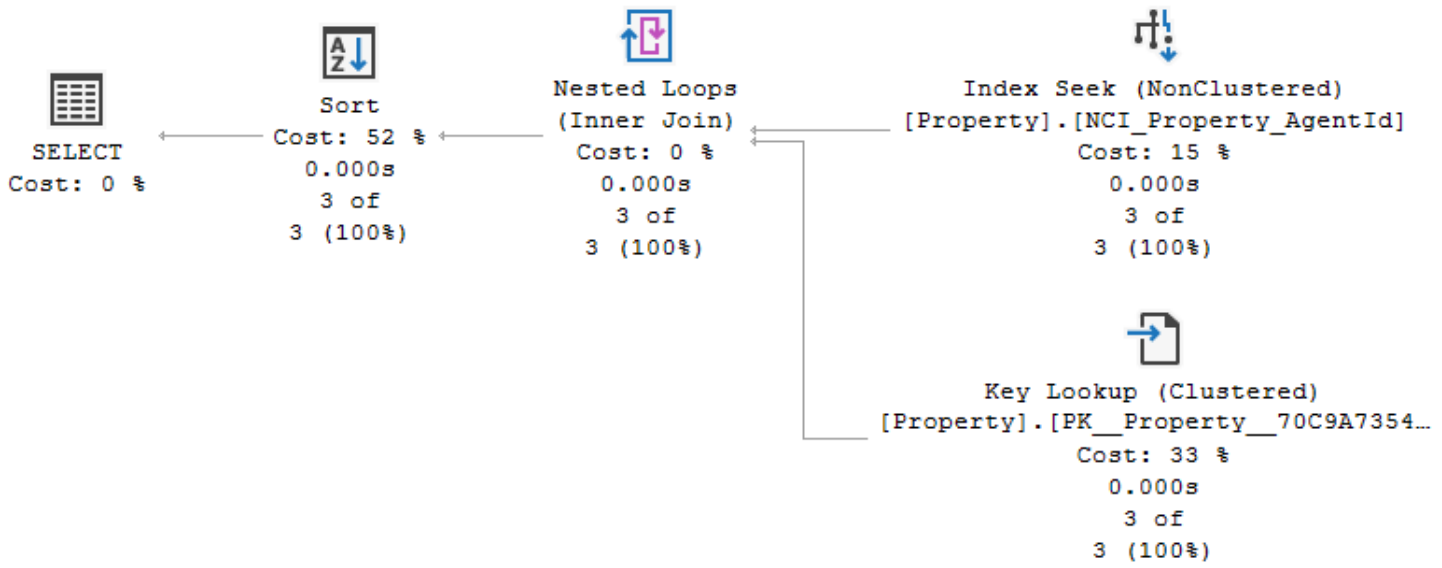
- Parameter-sniffing problem refers to a scenario where a **single** cached plan for a parameterized query is **not optimal for all** possible input parameter values
- If plan is not representative of most executions, you have a perceived "bad plan"

## Current Workarounds

- RECOMPILE
- OPTION (OPTIMIZE FOR…)
- OPTION (OPTIMIZE FOR UNKNOWN)
- Disable parameter sniffing entirely
- KEEPFIXEDPLAN
- Force a known plan
- Nested procedures
- Dynamic string execution

# PSP today (Example of Real Estate agent's portfolio)

New compile on Agent 4

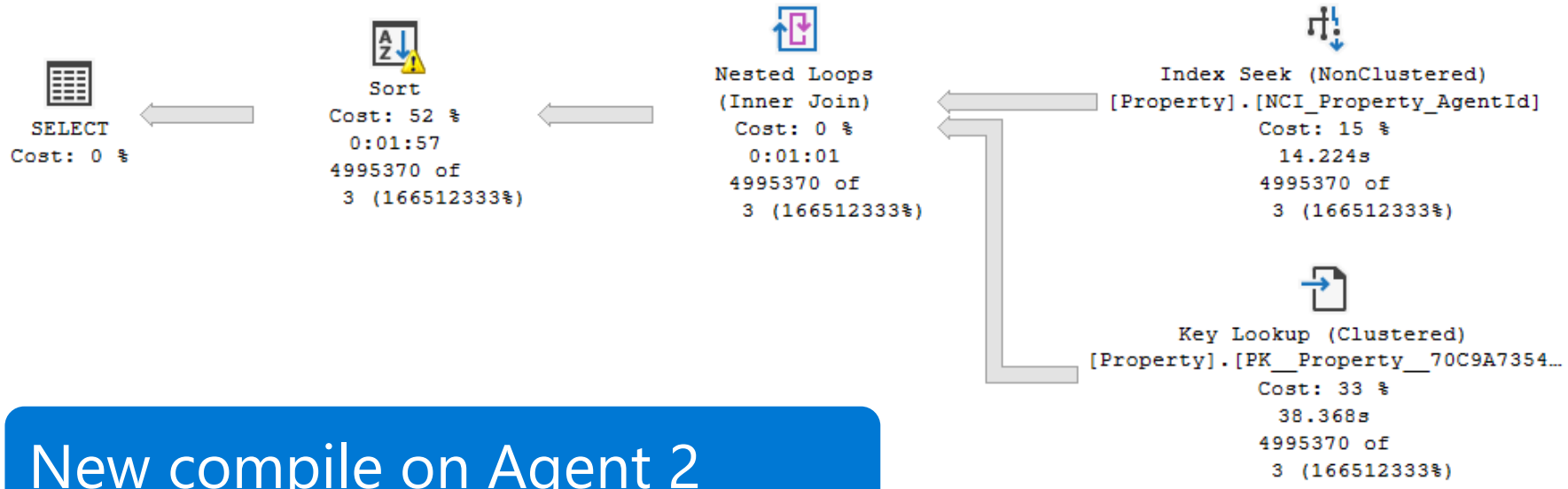



| QueryTimeStats | |
|---|---|
| CpuTime | 0 |
| ElapsedTime | 0 |

This example was borrowed from Pedro Lopes @SQLPedro

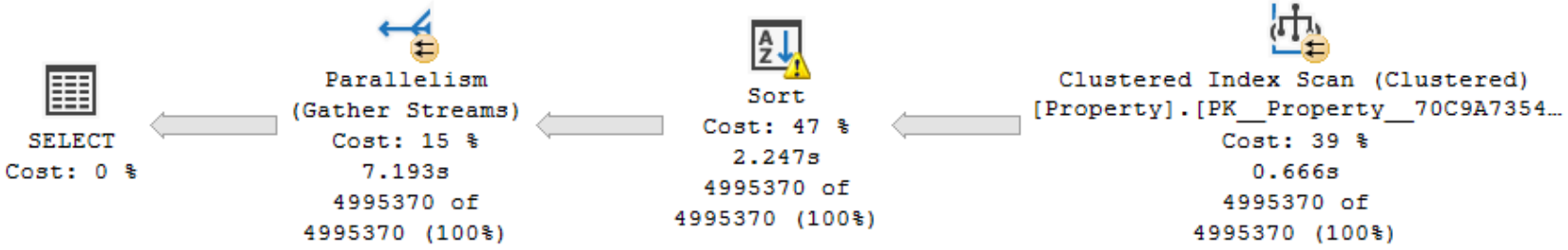
# PSP today (Example of Real Estate agent's portfolio)

## Using cached plan for Agent 2




| QueryTimeStats | |
|---|---|
| CpuTime | 88667 |
| ElapsedTime | 214222 |

## New compile on Agent 2




| QueryTimeStats | |
|---|---|
| CpuTime | 46620 |
| ElapsedTime | 105288 |

# PSP Optimization (2022)

Automatically enables multiple, active cached plans for a single parameterized statement

Cached execution plans will accommodate different data sizes based on the customer-provided runtime parameter value(s)

Design considerations

- Too many plans generated could create cache bloat, so limit # of plans in cache
- Overhead of PSP optimization must not outweigh downstream benefit
- Compatible with Query Store plan forcing

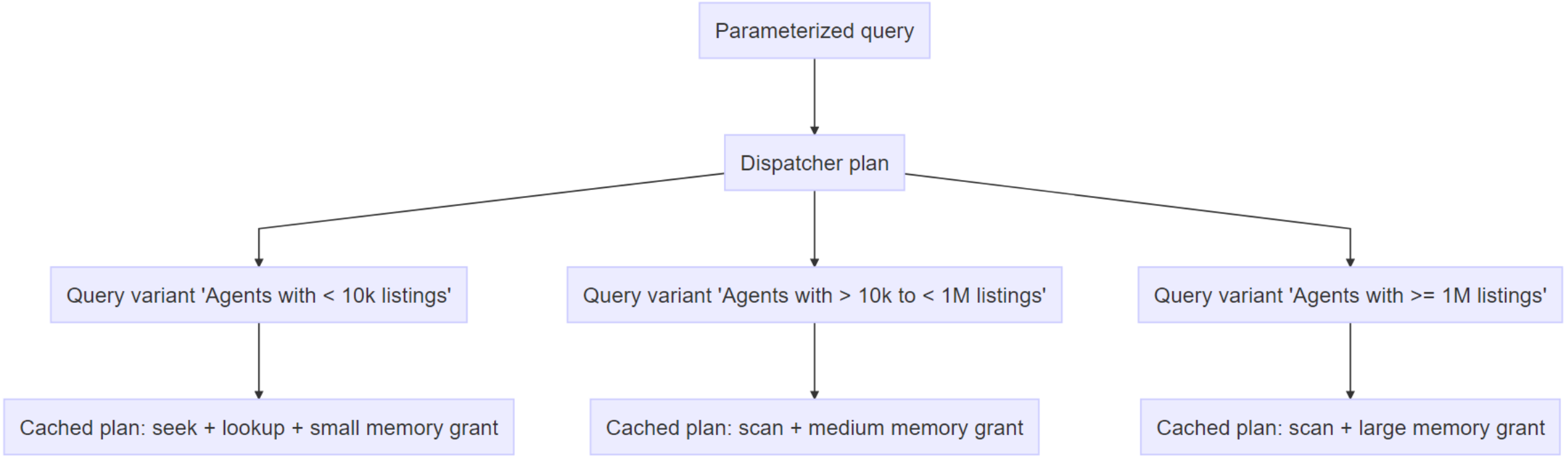
# PSP Predicate Selection (2022)

During initial compilation PSP optimization will evaluate the most "at risk" parameterized predicates (up to three out of all available)

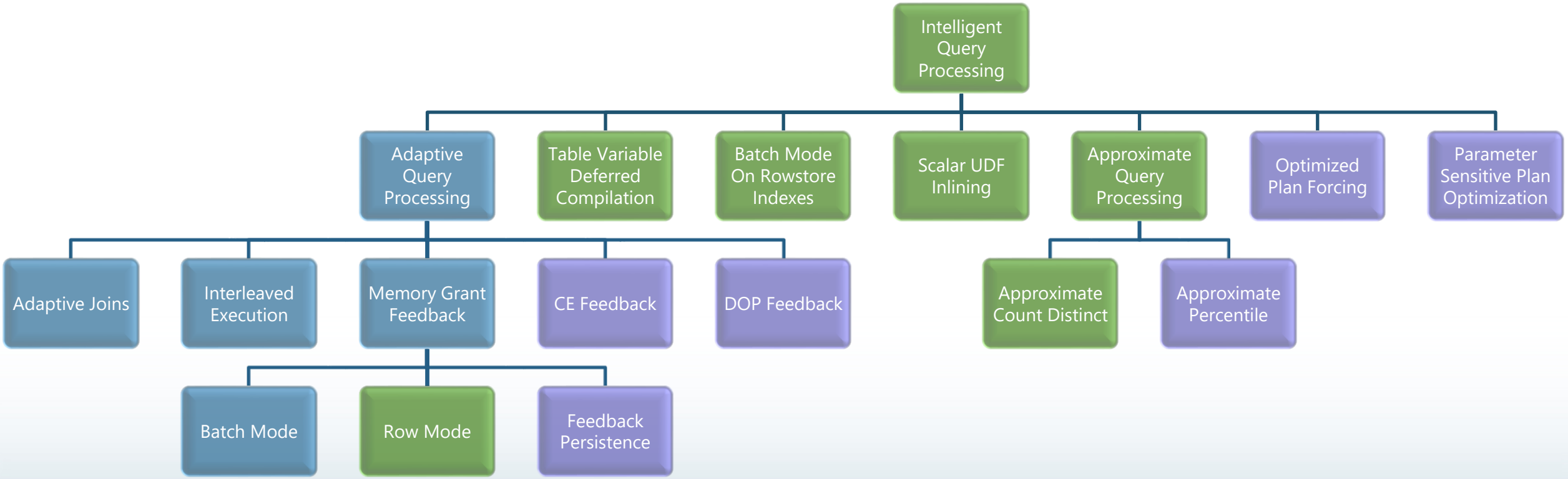
First version is scoped to equality predicates referencing statistics-covered columns; `WHERE AgentId = @AgentId`

Uses the statistics histogram to identify non-uniform distributions

# Boundary Value Selection (Dispatcher Plan)



# Intelligent Query Processing Feature Family




Azure SQL Database

2017 | 2019 | 2022

# Questions?

# Learn more

Learn more about SQL Server 2022

aka.ms/sqlserver2022

Watch a technical deep-dive on SQL Server 2022

aka.ms/sqlserver2022mechanics

Don’t miss out on Data Exposed (Look for SQL Server 2022 – Episode 3)

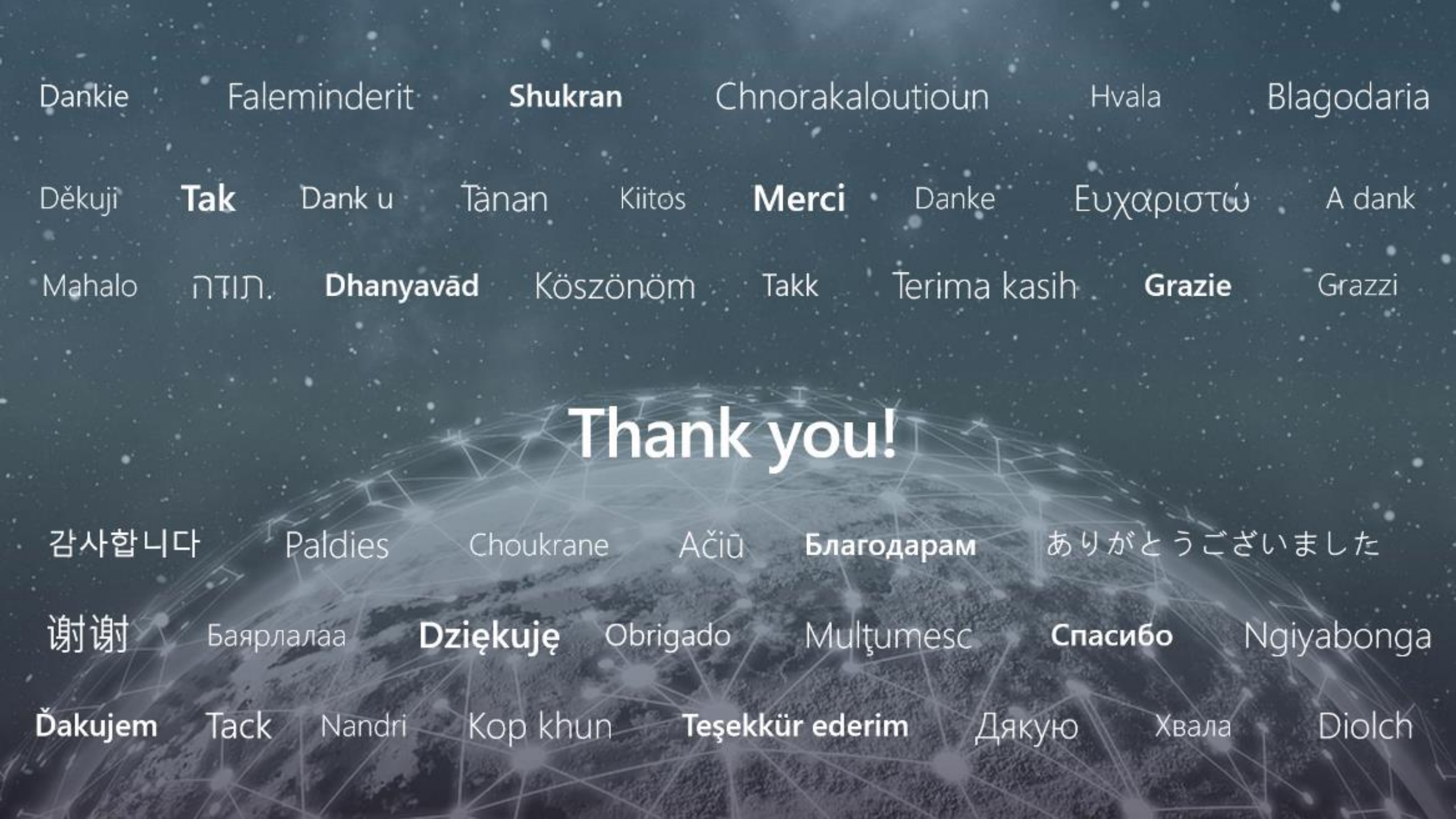
aka.ms/dataexposed

More information on Intelligent Query Processing
(Currently does not have 2022 information.)

aka.ms/IQP

https://aka.ms/IQPDemos

https://aka.ms/SQLCE


Dankie
Faleminderit
Shukran
Chnorakaloutioun
Hvala
Blagodaria
Děkuji
Tak
Dank u
Tänan
Kiitos
Merci
Danke
Ευχαριστώ
A dank
Mahalo
תודה.
Dhanyavād
Köszönöm
Takk
Terima kasih
Grazie
Grazzi
Thank you!
감사합니다
Paldies
Choukrane
Ačiū
Благодарам
ありがとうございました
谢谢
Баярлалаа
Dziękuję
Obrigado
Mulţumesc
Спасибо
Ngiyabonga
Ďakujem
Tack
Nandri
Kop khun
Teşekkür ederim
Дякую
Хвала
Diolch