SQL Server Execution Plan Primer

Iowa Code Camp
17 Jun 2023

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Welcome to Iowa Code Camp!

- Enjoy these two days of learning
- Be sure to visit and thank the sponsors
- Be sure to thank the organizer and volunteers
- Take time to NETWORK with others. That's what this is really all about!
- Act professionally and treat others with respect (like this was a work environment)

Agenda

- Why do we care about execution plans?
- What are the inputs to the optimizer?
- How does the optimizer generate a plan?
- What types of plans are there?
- What operators do we see in execution plans?
- What are some useful ways to execute a plan?

Why Care about Execution Plans?

- SQL is a declarative language
  - We are telling the server WHAT we want, not how to answer the question
- The execution plan tells us HOW SQL Server is resolving the query
- Can be very useful to identify performance issues

Why Care about Execution Plans?

- Execution plans provide front-line insight into decisions made by the optimizer
  - Order in which tables are accessed
  - What indexes are used
  - How much data is expected
  - “Hidden” internal operations

Inputs to Optimization

- The query text
- Physical specs of system (memory, cores, etc.)
- SET options in effect
- Cardinality estimates
- DB properties of referenced objects (data types, nullability, check constraints, foreign keys, uniqueness, etc.)
- Plan cache (optimizer bypass)

Items that are NOT optimizer inputs

- Has the data already been loaded into memory?
  - Cold cache is assumed
- Type of I/O subsystem
  - Spinning disk vs. SSD

Cardinality Estimation

- How many rows will this part of the query generate?
- SQL Server will always generate an estimate
- May be based on statistics or just a guess (heuristics)
- Two primary versions of estimator
  - SQL Server 7
  - Server Server 2014
    - (But each later version of SQL has its own CE)
- Version used based on compatibility level, DB settings, trace flags, query hints

Statistics

- SomeTable has 1,000,000 rows
- There is an index on SomeColumn
- How many rows will the query generate?

```
select ID, SomeColumn, Description
from dbo.SomeTable
where SomeColumn = 123456;
```

Selectivity

- It depends on how selective SomeColumn is
- Maybe every row has 123456
  - Low selectivity
- Or maybe every row is unique
  - High selectivity
- Or somewhere in-between

Selectivity

- A high-level measure of selectivity is “density”

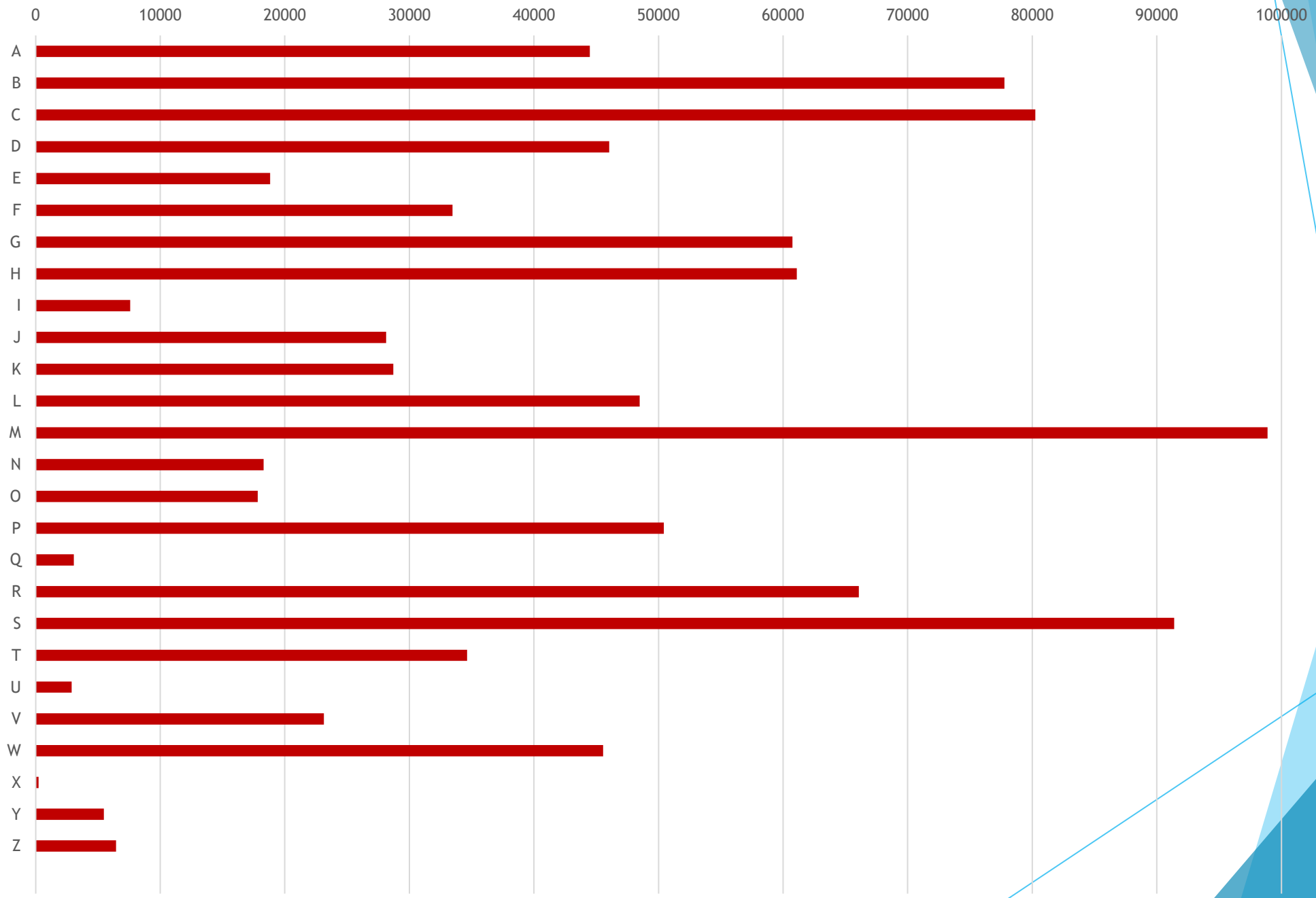
$$\frac{1}{\text{Number of distinct values}}$$

- If every row is 123456
  - Density = 1
- If every row is unique
  - Density = 0.000001 (1/1,000,000)

Let’s get more specific

```
select c.ID, c.FirstName, c.LastName, c.State
from dbo.Customer c
where c.LastName like ‘B%';
```

```
select c.ID, c.FirstName, c.LastName, c.State
from dbo.Customer c
where c.LastName like ‘Q%';
```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Y
Z

An equality query

```
select c.ID, c.FirstName, c.LastName, c.State
from dbo.Customer c
where c.LastName = 'Baker';
```

Name	Updated	Rows	Rows Sampled	Steps
idx_PersonSample__LastName	Feb 1 2019 10:25AM	1000000	1000000	200

All density	Average Length	Columns
4.892512E-06	13.34736	LastName
1E-06	17.34736	LastName, ID

RANGE_HI_KEY	RANGE_ROWS	EQ_ROWS	DISTINCT_RANGE_ROWS	AVG_RANGE_ROWS
Ayala	5736	572	1711	3.352426
Baker	4287	1193	1198	3.578464
Barnes	5963	597	1655	3.603021
Barrett	1633	327	204	8.004902

- Baker = 1193 rows

RANGE_HI_KEY	RANGE_ROWS	EQ_ROWS	DISTINCT_RANGE_ROWS	AVG_RANGE_ROWS
Ayala	5736	572	1711	3.352426
Baker	4287	1193	1198	3.578464
Barnes	5963	597	1655	3.603021
Barrett	1633	327	204	8.004902

- How about this one?

```
select c.ID, c.FirstName, c.LastName, c.State
from dbo.Customer c
where c.LastName = 'Baldwin';
```

- Between Baker & Barnes: average key has 3.603 rows
- Estimate is 3.603 rows (actual is 210 rows)
- But `'Banjo'` will also be estimated as 3.603 rows (actual = 1)

Statistics: Key Points

- Based on contents of the index at **some past time**
- Maximum of 200 steps
- Becomes a key input to the cardinality estimator
- Update frequency based on how many rows in the table have been modified
  - Through SQL 2014: 20% of rows
  - After SQL 2016: Default is more aggressive updating
  - DBA jobs to update (Ola Hallengren maintenance solution)

Types of Execution Plans

- Text
- XML
- Graphical

```
select c.State, sum(od.Quantity * od.UnitPrice) as
   OrderAmount
from dbo.OrderHeader oh
join dbo.OrderDetail od on od.OrderId = oh.OrderId
join dbo.Customer c on c.CustomerID =
oh.CustomerId
where od.ProductId >= 760 and od.ProductId <= 792
group by c.State;
```

Types of Execution Plans – Text (Deprecated)

```
set showplan_text on; (less detail)
set showplan_all on;  (more detail)
```

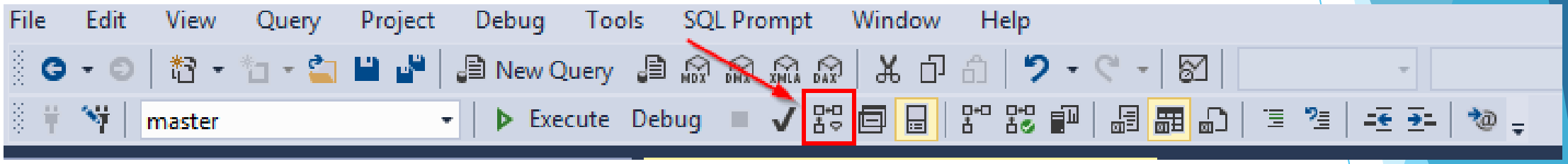
```
StmtText
------------------------------------------------------------------------------------------
  |--Hash Match(Aggregate, HASH:([c].[State]), RESIDUAL:([CorpDB].[dbo].[Customer].[State] as [c].[St
       |--Merge Join(Inner Join, MERGE:([c].[CustomerID])=([oh].[CustomerId]), RESIDUAL:([CorpDB].[dbo
            |--Clustered Index Scan(OBJECT:([CorpDB].[dbo].[Customer].[PK__Customer__A4AE64B8B53AF27A]
            |--Sort(ORDER BY:([oh].[CustomerId] ASC))
                 |--Merge Join(Inner Join, MERGE:([oh].[OrderId])=([od].[OrderId]), RESIDUAL:([CorpDB]
                      |--Clustered Index Scan(OBJECT:([CorpDB].[dbo].[OrderHeader].[PK__OrderHea__C390
                      |--Sort(ORDER BY:([od].[OrderId] ASC))
                           |--Compute Scalar(DEFINE:([Expr1004]=CONVERT_IMPLICIT(money,[CorpDB].[dbo].
                                |--Clustered Index Scan(OBJECT:([CorpDB].[dbo].[OrderDetail].[PK__Orde
```

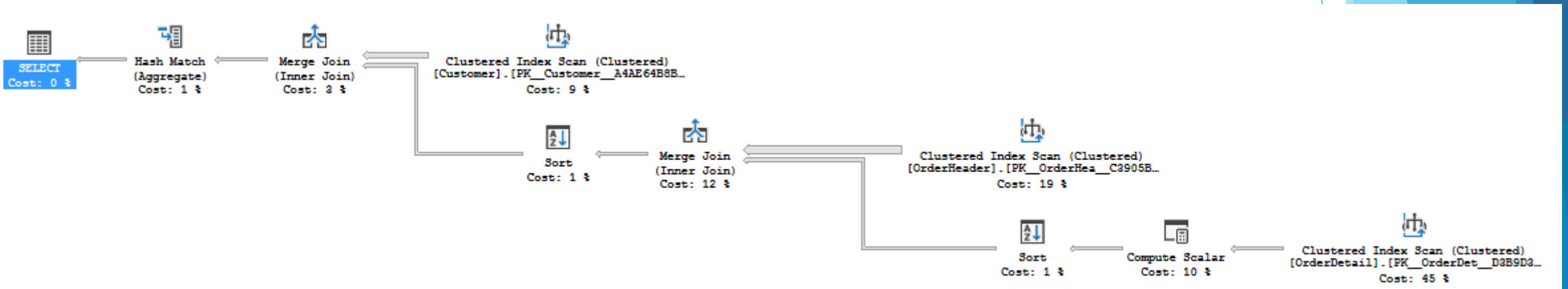
Types of Execution Plans - XML

```
set showplan_xml on;
```

Types of Execution Plans - Graphical

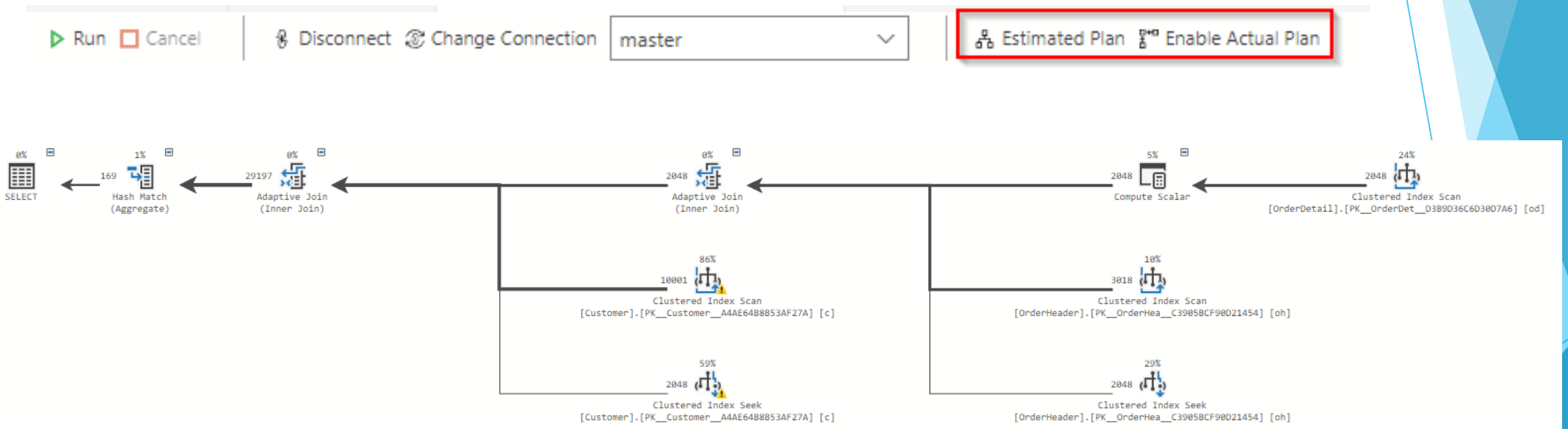
- Display Estimated Execution Plan (Ctrl-L)





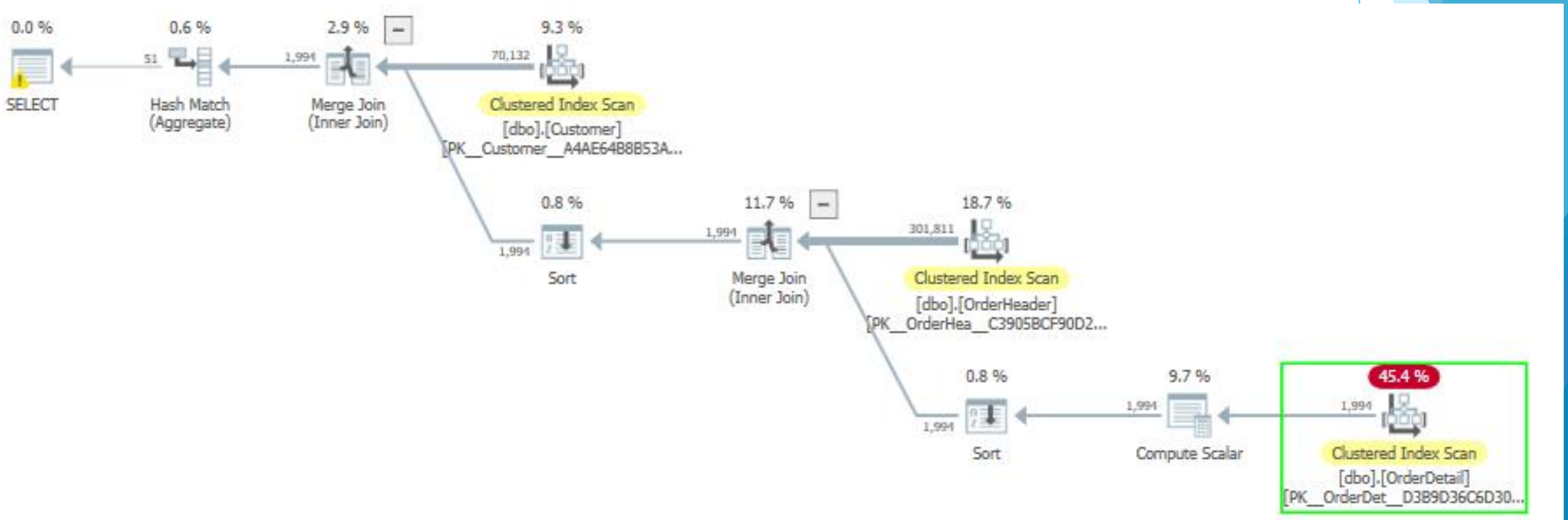
Types of Execution Plans - Graphical

- Azure Data Studio



Types of Execution Plans - Graphical

- Alternate way to view graphical plans (SentryOne Plan Explorer)



Types of Execution Plans – Estimated vs Actual

- Estimated execution plans
  - Query is not executed
  - Best guess of plan that would actually be used
  - In some cases cannot be generated
- Actual execution plans
  - Query is executed
  - Some chance it may differ from estimated plan
  - Includes runtime statistics (actual rows)

Actual Execution Plans

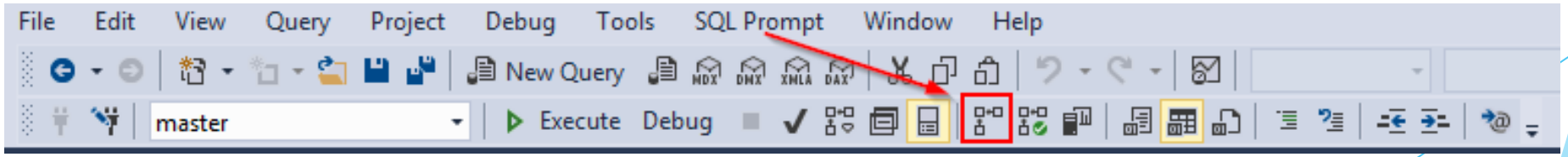
- Actual plan - text

```
set statistics profile on;
```

- Actual plan - XML

```
set statistics xml on;
```

- Actual plan - Graphical
  - Include Actual Execution Plan (Ctrl-M)

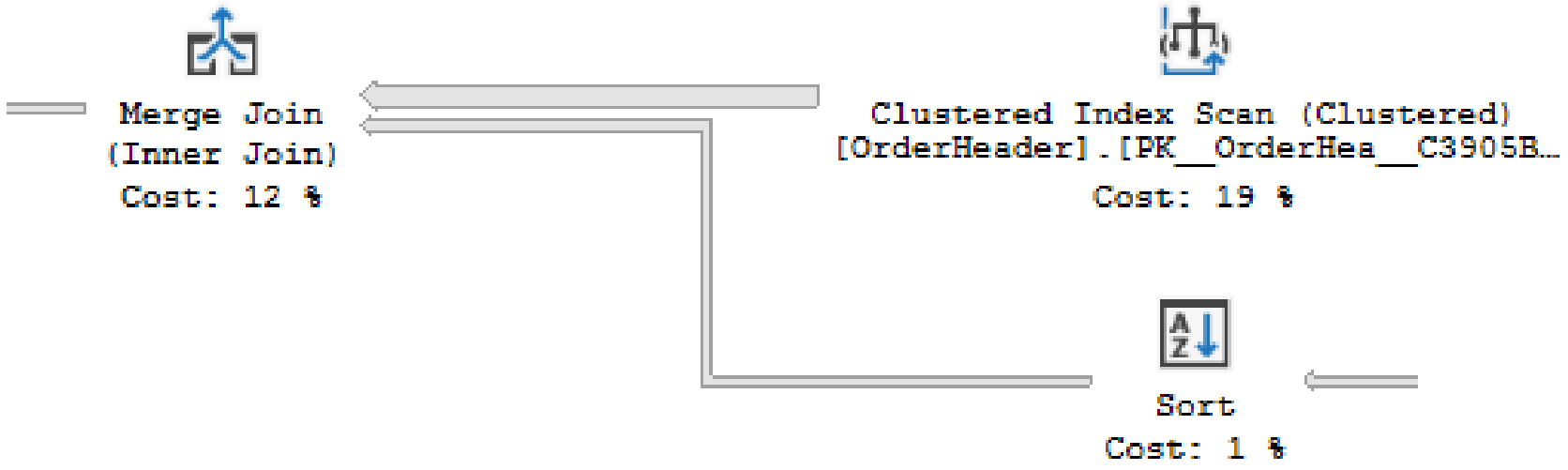


Two Types of Tables

- Heaps
  - Not organized in any particular way
  - No index structure on top of data
  - Can still have nonclustered indexes
- Clustered Index
  - Data is stored in key order
  - Has a B-tree structure on top of the data
  - Can also have nonclustered indexes

The Execution Plan

- Consist of operators and connectors
- Connector (flow of data)
  - Width indicates number of rows
- Plans are frequently read right-to-left, top-to-bottom



Operators

- About 70 operators possible; most are infrequently seen
- Responsible to respond for a request for the next row
- Common operators
  - Data Access (scans, seeks, lookups)
  - Joins (merge, nested loops, hash)
  - Other (sorts, aggregations, spools, etc.)

Full list of operators

Operators – Data Access

- Scan – Read entire contents of object
- Does not necessarily return all rows read
- May result from non-SARGable predicates
- Myth: scans are evil

Clustered Index Scan

Index Scan

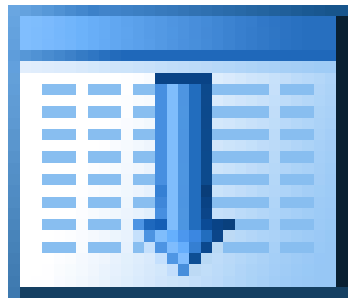
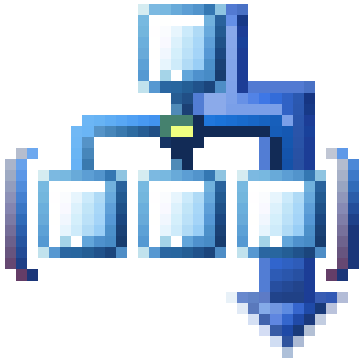


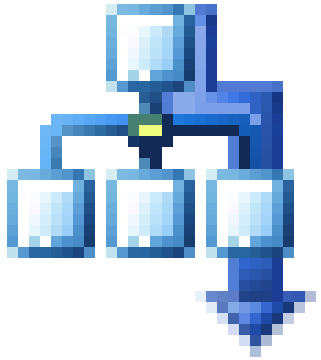
Table Scan

Operators – Data Access

- Seek – Uses index structure to find key values
  - Can be a point lookup or involve a partial scan
- Cannot seek into a heap
- Myth: seeks are always good



Clustered Index Seek



Index Seek

Scans vs. Seeks

- SQL will tend to favor scans if the number of rows expected is large enough that cost for a (sequential) scan is less than the cost of random I/O for seeks
  - “Tipping point”
- Cardinality errors can cause the “wrong” access type to be used

Operators – Data Access

- Lookup – Retrieve additional columns from table
  - Used when non-clustered index does not have all the columns needed to resolve query (not covering)
- Useful when number of lookups is small

Key Lookup

RID Lookup

Operators – Joins

- Three main join algorithms
  - Merge Join
  - Nested Loop Join
  - Hash Join
- (Also adaptive join, hybrid nested loop and hash)

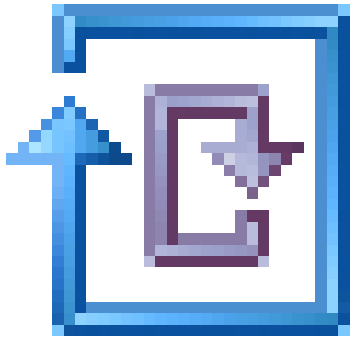
Operators – Merge Join

- Requires both tables to be sorted on join columns
  - May introduce intermediate sort operation
  - But sorts are expensive
- Useful when data is already naturally sorted by join columns

Bert Wagner video with animation of merge join

Operators – Nested Loop Join

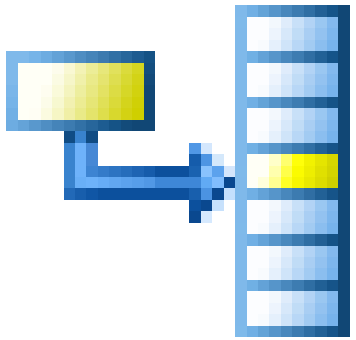
- Compare each row in top input with each row in bottom input
- Bottom input may be static or may change depending on value of top row
- Useful when top input is small and bottom input is efficient to search



Bert Wagner video with animation of loop join

Operators – Hash Join

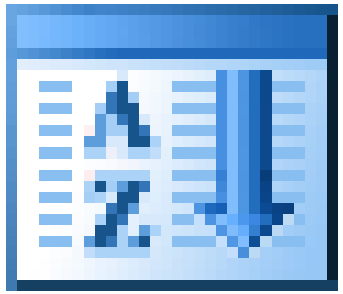
- Each top row is hashed by join columns and bucketized
- Each bottom is hashed, looked up in hash table
- Useful when both inputs are large and unsorted



Bert Wagner video with animation of loop join

Operators – Sort

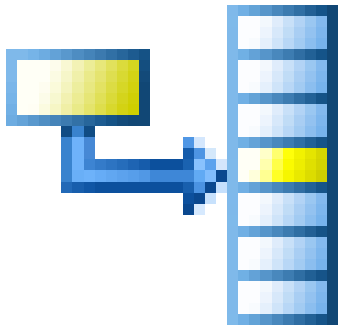
- Tends to be a very expensive operation
- Highly dependent on cardinality estimate
  - Drive memory grant
- Watch for spills to tempdb
- Is the sort really needed?



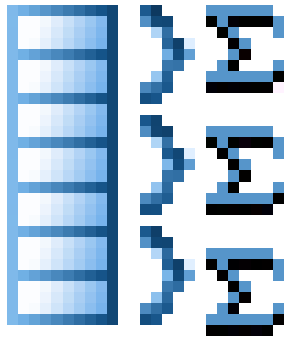
Sort

Operators – Aggregation

- Calculate SUM, COUNT, AVG, MIN, MAX, etc.
- Hash aggregate builds hash table to find common rows (based on grouping columns)
- Stream aggregate input must be sorted, watches for changes in grouping columns



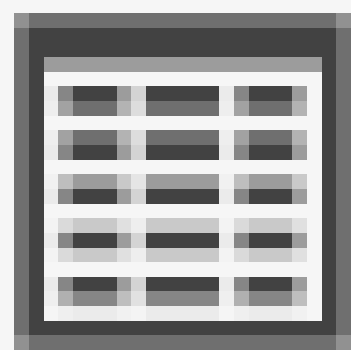
Hash Aggregate



Stream Aggregate

Operators – SELECT

- (Or INSERT, DELETE, UPDATE, MERGE)
- Left-most pseudo-operator
- Contains properties of the execution plan as a whole



SELECT

Operators

- And many, many more operators
  - Various Insert, Update, Delete, Merge operators
    - Clustered idx, non-clustered idx, heap
  - Compute Scalar, Constant Scan
  - Spools (Eager vs. Lazy)
  - Parallelism
    - Distribute Streams, Repartition Streams, Gather Streams
  - Etc.

“SARG”ability

- Search ARGument ABILITY
- Can the predicate take advantage of an index?
- Usually caused by using column in an expression
- “Negatives” generally non-SARGagble: NOT IN, <>, etc
- Some predicates cannot be made SARGable
- Watch for implicit type casting

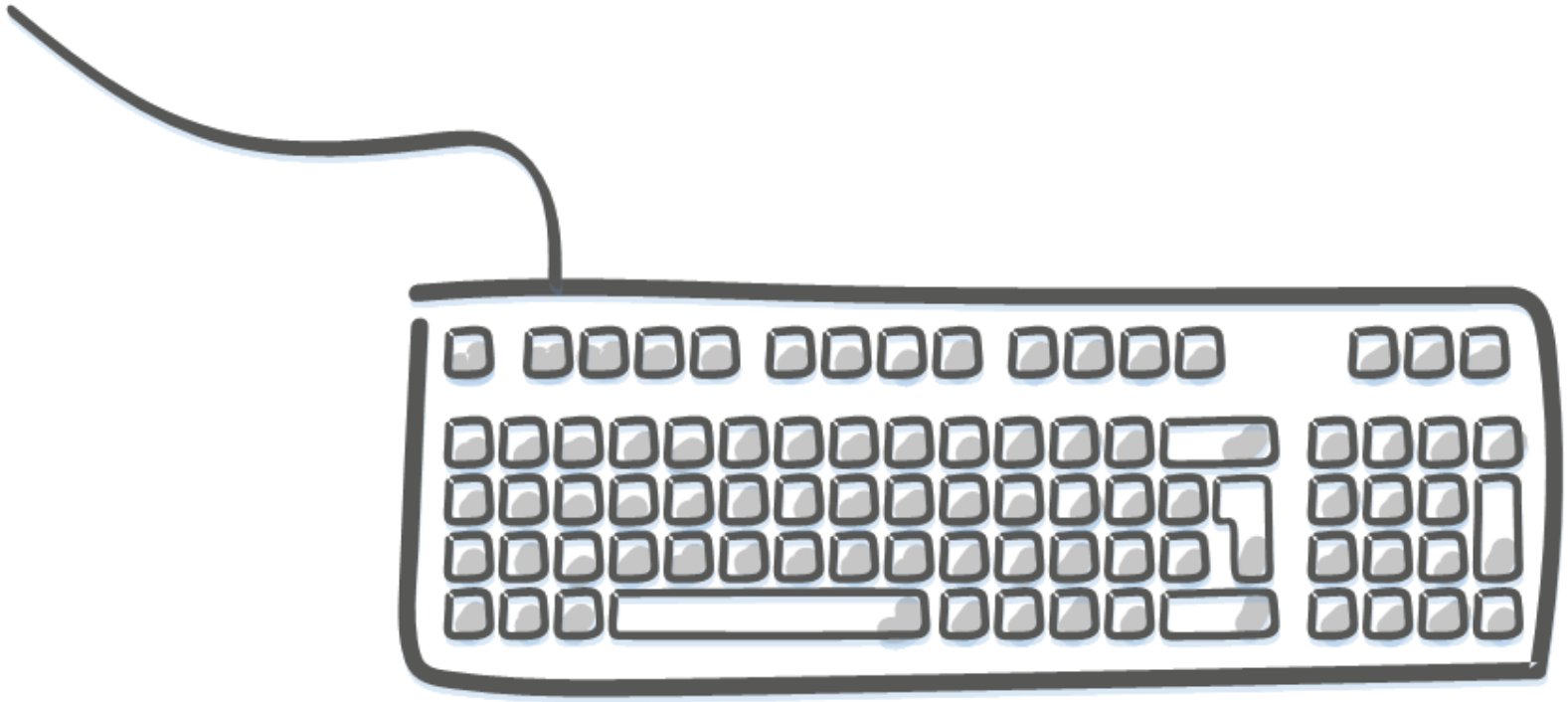
“SARG”ability

- Examples (assume index exists on column)

Not SARGable	SARGable
Value + 1 = 7	Value = 6
LEFT(Name, 2) = ‘Sm’	Name LIKE ‘Sm%’
CAST(OrderDate as date) = @dt	OrderDate >= @dt AND OrderDate < dateadd(day, 1, @dt)
ISNULL(Name, ‘’) = ‘’	(Name IS NULL OR Name = ‘’)
Name LIKE ‘%ohnson’	n/a

Demo

- Execution problem pain points



Resources

- Grant Fritchey, SQL Server Execution Plans, 3rd Edition (free download)
- AdventureWorks2014 (download)

Thank You

- This presentation and supporting materials can be found at www.breannahansen.com/executionplans
  - Slide deck
  - Scripts

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