From Zero to Hero: SQL Server Performance Made Easier

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SQL Server Tiger Team

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8+ years at Microsoft

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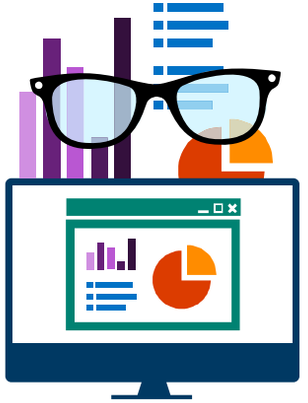
Session Objectives And Takeaways

SQL Server Tiger Team



Show new diagnostics improvements for SQL Server engine

Show new diagnostic tools built into SQL Server for performance scenarios

Learn how to use the new diagnostics to troubleshoot common performance issues

Show of hands

When was the last time you dealt with a **query** performance issue?

SQL Server Tiger Team

Query Performance Troubleshooting Fundamentals

Why does a query slow down?

- Excessive resource consumption
- Poor indexing strategy
- Lack of useful statistics
- Lack of useful partitioning
- Consequence of blocked queries
- Incorrect server configurations

Context for Slow-Running Query Analysis

- Is the performance problem related to a component other than queries?
  - **For example, is the problem slow network performance?**
  - **Are there any other components that might be causing or contributing to performance degradation?**
- If the performance issue is related to queries, which query or set of queries is involved?
- Was the query optimized with useful statistics?
- Are suitable indexes available?
- Are there any data or index hot spots?
- If you have a large volume of data, do you need to partition it?
- Is the Query Optimizer provided with the best opportunity to optimize a complex query?

Performance Dashboard in SSMS

No extra downloads!
No new schema to deploy!
Long standing request by CSS and customers

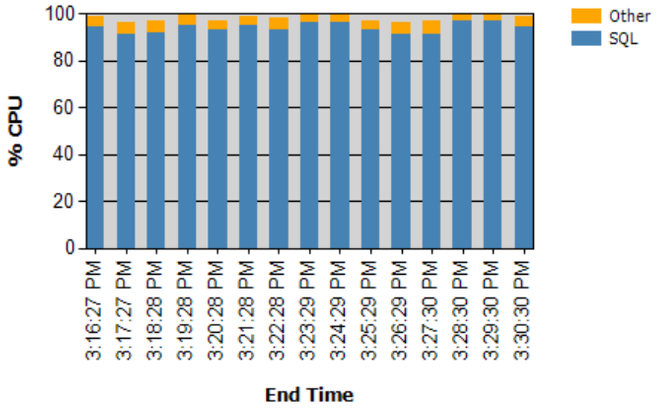
Microsoft SQL Server Performance Dashboard

Report Local Time: 5/31/2017 3:31:04 PM

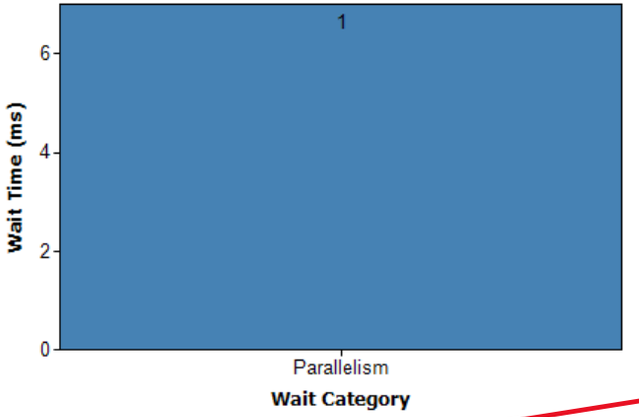
[redacted] (13.0.4422.0 - Enterprise Edition (64-bit))

Overall performance may be degraded because the system shows signs of being CPU-bound.This SQL Server instance is consuming the majority of the CPU. Click on any of the SQL data points in the chart below to investigate further.

System CPU Utilization



Current Waiting Requests



Current Activity

	User Requests	User Sessions
Count	27	32
Elapsed Time (ms)	4573004	741818
CPU Time (ms)	2043203(44.68%)	101108(13.63%)
Wait Time (ms)	2529801(55.32%)	640710(86.37%)
Cache Hit Ratio	100.000%	98.313%

Historical Information

Waits — IO Statistics
Latches
Expensive Queries
By CPU — By Duration
By Logical Reads — By Physical Reads
By Logical Writes — By CLR Time

Miscellaneous Information

Active Traces	1
Active Xevent Sessions	4
Databases	16
Missing Indexes	11

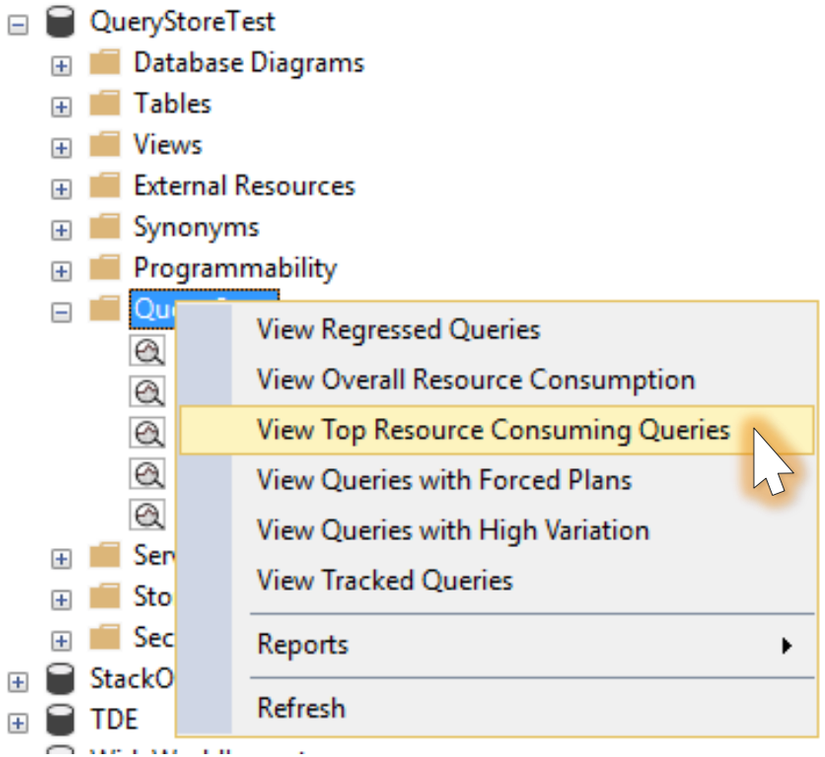
Categorized Wait stats page

New categorized Latches page

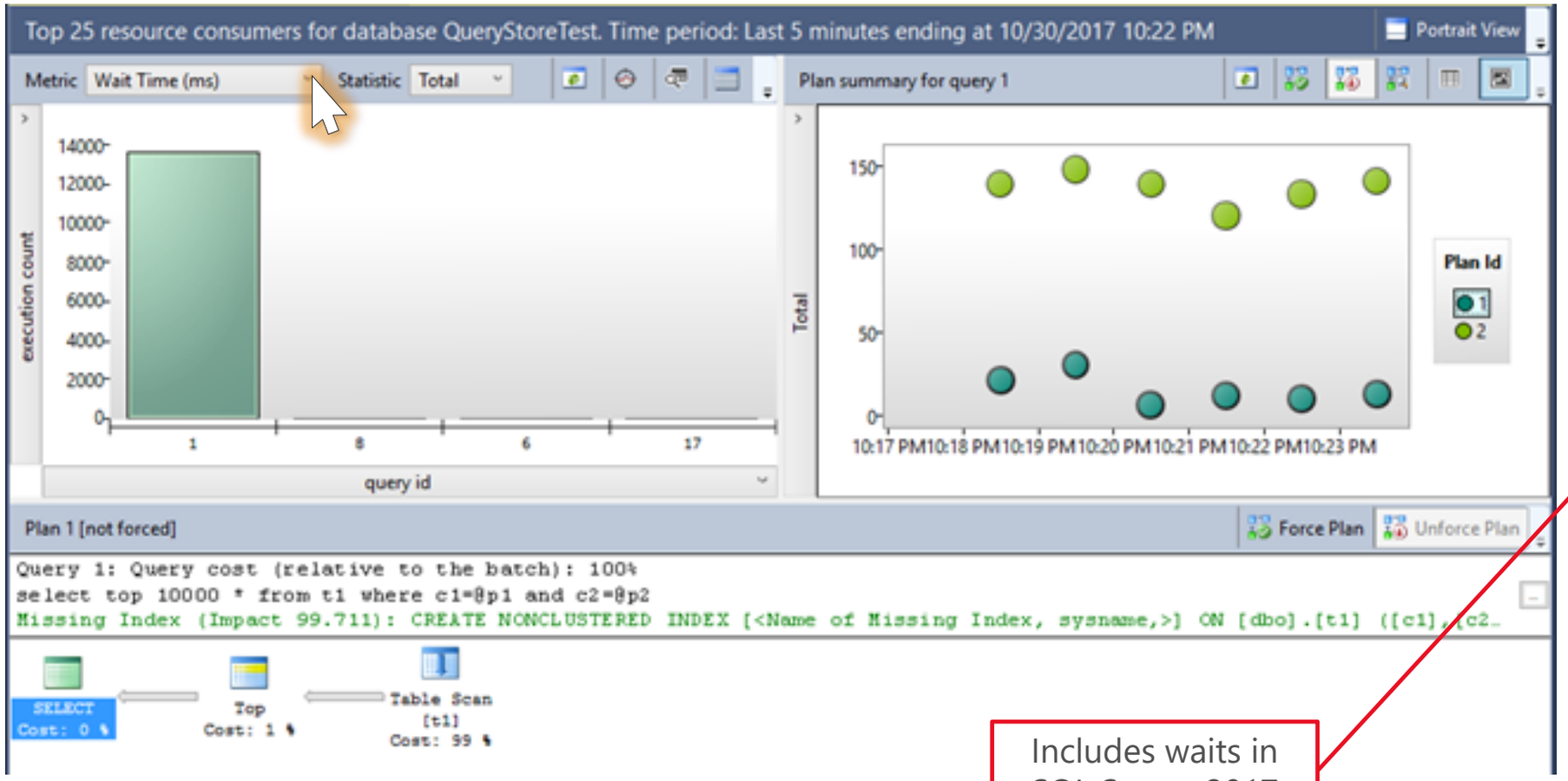
Scoring added to Missing Index Report

Query Store

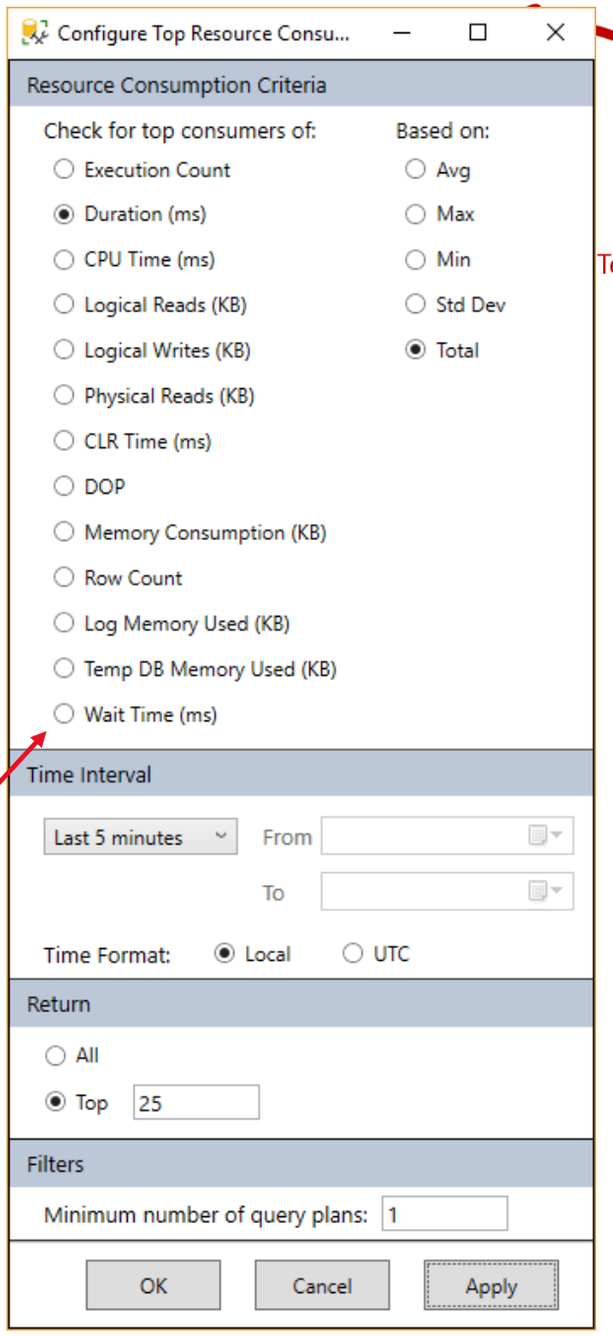
Comprehensive query-performance information when you need it most!



Query Store



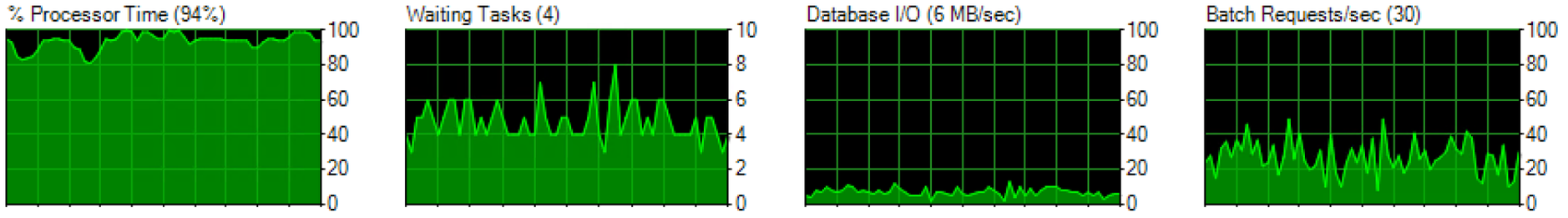
Includes waits in SQL Server 2017



Team

And yes. Activity Monitor

Overview



Processes

Resource Waits

Data File I/O

Recent Expensive Queries

Active Expensive Queries

Query	Ses...	CPU (ms...	Database	Elapsed ...	Physical ...	Writes	Logical ...	Row Co...	Allocate...
SELECT e.[BusinessEntityID], p.[Title], ...	53	67440	AdventureW...	139490	0	250	3540276	0	115520
SELECT e.[BusinessEntityID], p.[Title], ...	54	19952	AdventureW...	21127	0	245	1160914	0	115520
SELECT e.[BusinessEntityID], p.[Title], ...	55	59409	AdventureW...	173721	0	250	3128131	0	115520
SELECT e.[BusinessEntityID], p.[Title], ...	56	43750	AdventureW...	133006	0	246	2348542	0	115520
SELECT ProductID, Total = SUM(LineTotal)FR...	57	3	AdventureW...	3	0	0	75	0	1072
SELECT [SalesOrderDetailID] ,[OrderQty] ...	58	1104	AdventureW...	11836	0	0	10	0	264
SELECT e.[BusinessEntityID], p.[Title], ...	59	87290	AdventureW...	173110	0	251	4556573	0	115520
SELECT e.[BusinessEntityID], p.[Title], ...	63	54900	AdventureW...	59061	0	248	3066894	0	115520
SELECT [SalesOrderDetailID] ,[OrderQty] ...	64	992	AdventureW...	11615	0	0	10	0	264
SELECT e.[BusinessEntityID], p.[Title] ...	65	55181	AdventureW...	169077	0	249	2913449	0	115520

Once I find the slow-running query, how do I analyze it?

Query plans: a map to the execution context

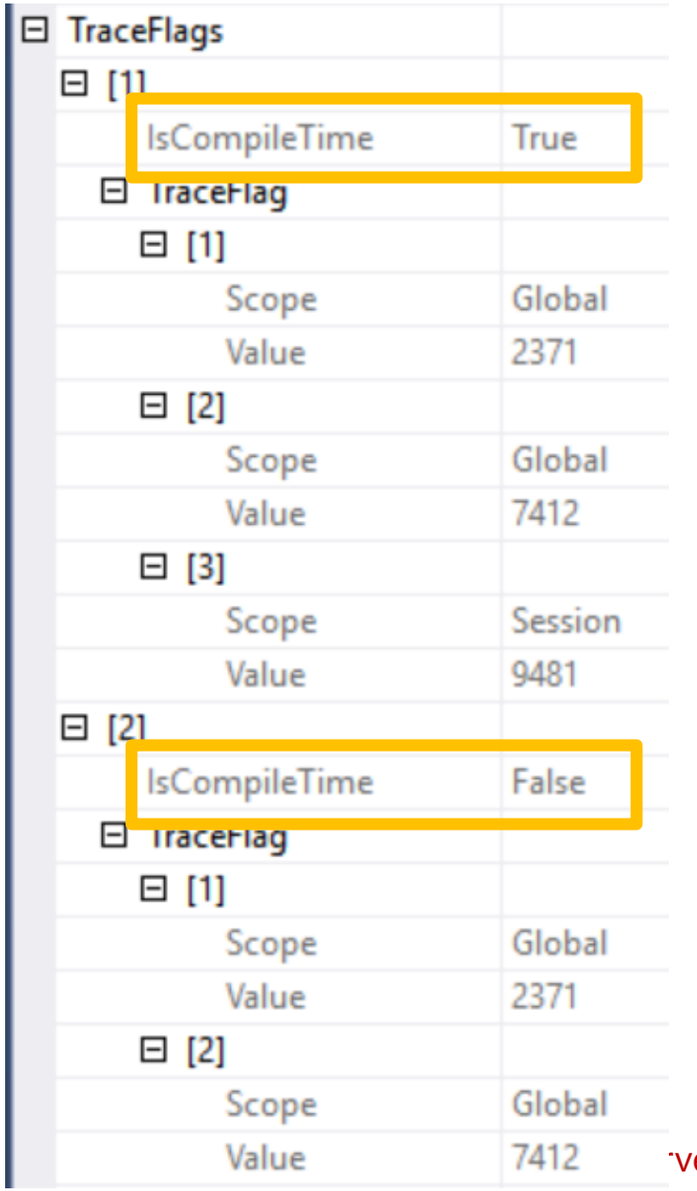
- How data is accessed
- How data is joined
- Sequence of operations
- Use of temporary worktables and sorts
- Estimated rowcounts, iterations, and costs from each step
- Actual rowcounts and iterations
- How data is aggregated
- Use of parallelism
- Query execution warnings
- Query execution stats
- Hardware/Resource stats

Getting all context info in Showplan: Trace Flags

Shows list of active trace flags:

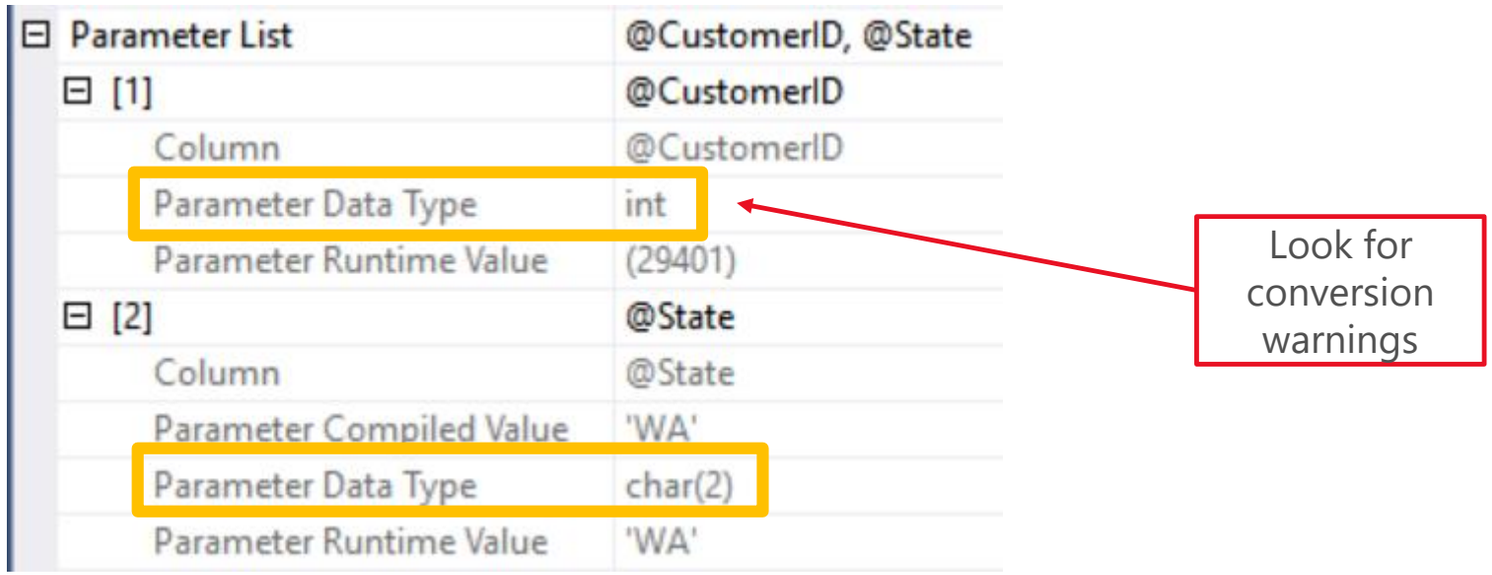
- Query
- Session
- Global

Useful to understand if active Trace execution context



Getting all context info in Showplan: Param Data Types

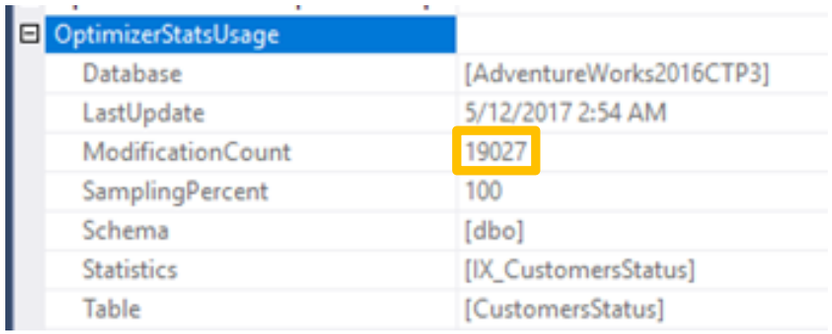
Easier detection of type conversion issues

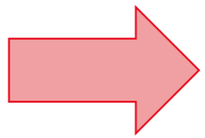


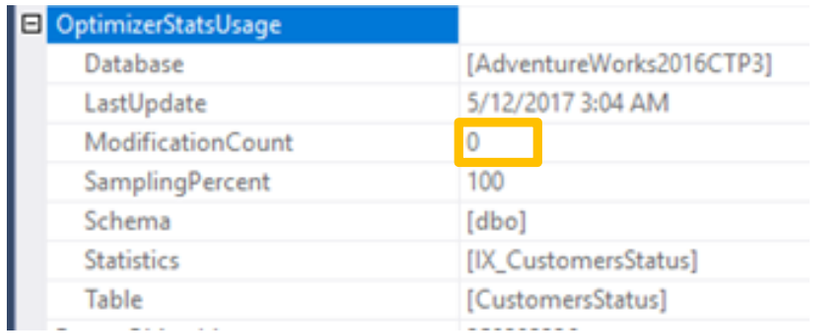
Getting all context info in Showplan: Statistics

Identify which statistics were used by the Query Optimizer for a given compilation.

Gain actionable insight to where estimations came from.







Getting all context info in Showplan: Times

Persisting information on elapsed and CPU times

QueryTimeStats	
CpuTime	89
ElapsedTime	274

QueryTimeStats	
CpuTime	91903
ElapsedTime	92330

Is all the elapsed time spent on CPU? Look for waits

And Scalar UDF elapsed and CPU times

QueryTimeStats	
CpuTime	628
ElapsedTime	1174
UdfCpuTime	443
UdfElapsedTime	445

How much elapsed time is spent on UDF?

Getting all context info in Showplan: Waits

Shows top 10 waits from sys.dm_exec_session_wait_stats

Correlate waits with overall query times

QueryTimeStats	
CpuTime	1045
ElapsedTime	3010

Misc	
Cached plan size	160 KB
CardinalityEstimationModelV	130
CompileCPU	11
CompileMemory	728
CompileTime	136
DatabaseContextSettingsId	3
Degree of Parallelism	12
Estimated Number of Rows	121308
Estimated Operator Cost	0 (0%)
Estimated Subtree Cost	4.48002
Memory Grant	80448
MemoryGrantInfo	
Optimization Level	FULL

WaitStats	
[1]	
WaitCount	98
WaitTimeMs	3
WaitType	LATCH_SH
[2]	
WaitCount	50
WaitTimeMs	761
WaitType	PAGEIOLATCH_SH
[3]	
WaitCount	67
WaitTimeMs	1942
WaitType	LATCH_EX
[4]	
WaitCount	129
WaitTimeMs	2509
WaitType	ASYNC_NETWORK_IO
[5]	
WaitCount	2220
WaitTimeMs	30622
WaitType	CXPACKET

Note: Parallelism waits available in SQL Server 2017 CU3 and 2016 SP2

Getting all context info in Showplan: memory

Showplan extended to include grant usage per thread and iterator

Memory Grant	783288
MemoryGrantInfo	
DesiredMemory	28592000
GrantedMemory	783288
GrantWaitTime	0
MaxUsedMemory	0
RequestedMemory	783288
RequiredMemory	4064
SerialDesiredMemory	28588448
SerialRequiredMemory	512

Is the used memory close to granted?
Is the memory above granted?
Look for warnings

Also in sys.dm_exec_query_stats

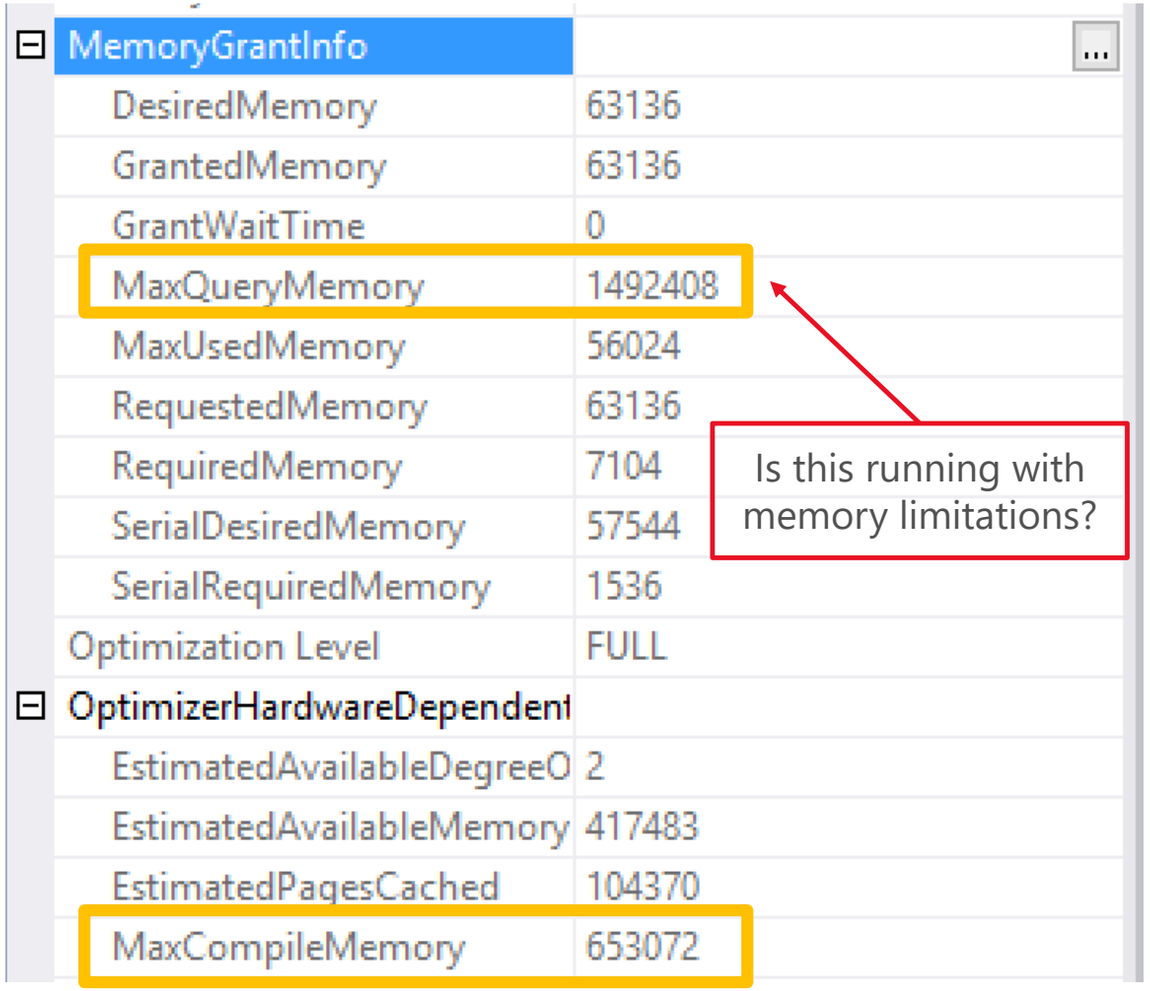
total_grant_kb	last_grant_kb	min_grant_kb	max_grant_kb	total_used_grant_kb	last_used_grant_kb
783288	783288	783288	783288	0	0

min_used_grant_kb	max_used_grant_kb	total_ideal_grant_kb	last_ideal_grant_kb	min_ideal_grant_kb	max_ideal_grant_kb
0	0	28592000	28592000	28592000	28592000

Getting all context info in Showplan: RG info

List attributes of Resource Governor Settings

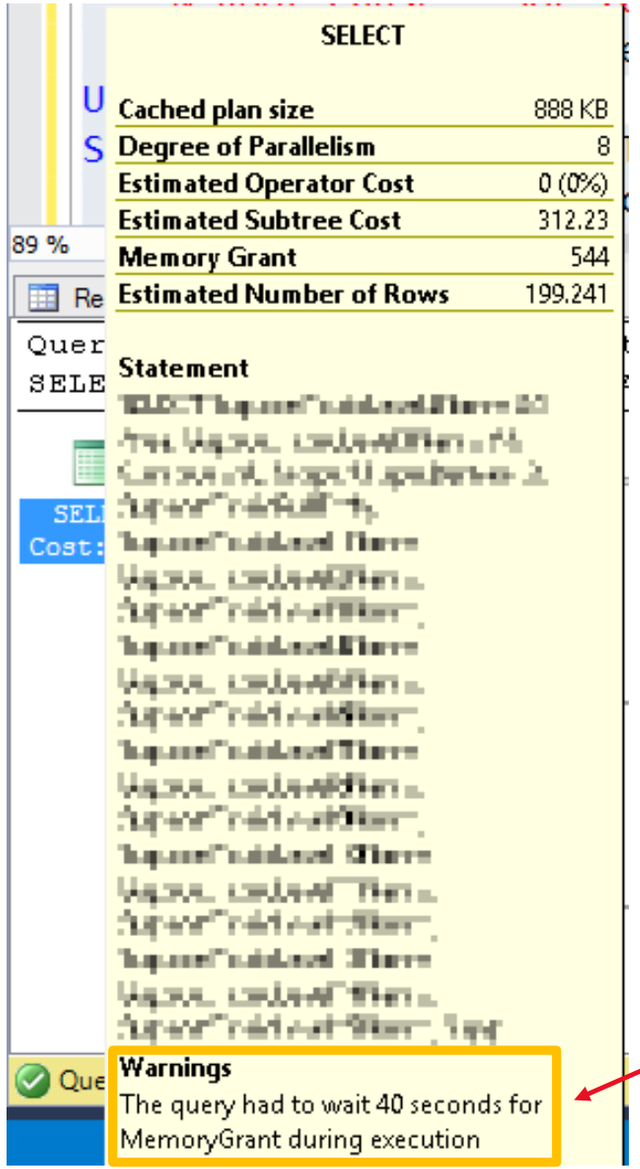
- MaxCompileMemory for maximum query optimizer memory in KB during compile under RG.
- MaxQueryMemory for maximum query memory grant under RG MAX_MEMORY_PERCENT hint.



Analyzing query plan properties

Notice the warnings

Warning: Memory Grant Wait



Occurs when a T-SQL statement or stored procedure waits more than one second for a memory grant or when the initial attempt to get memory fails.

Been there since SQL Server 2012

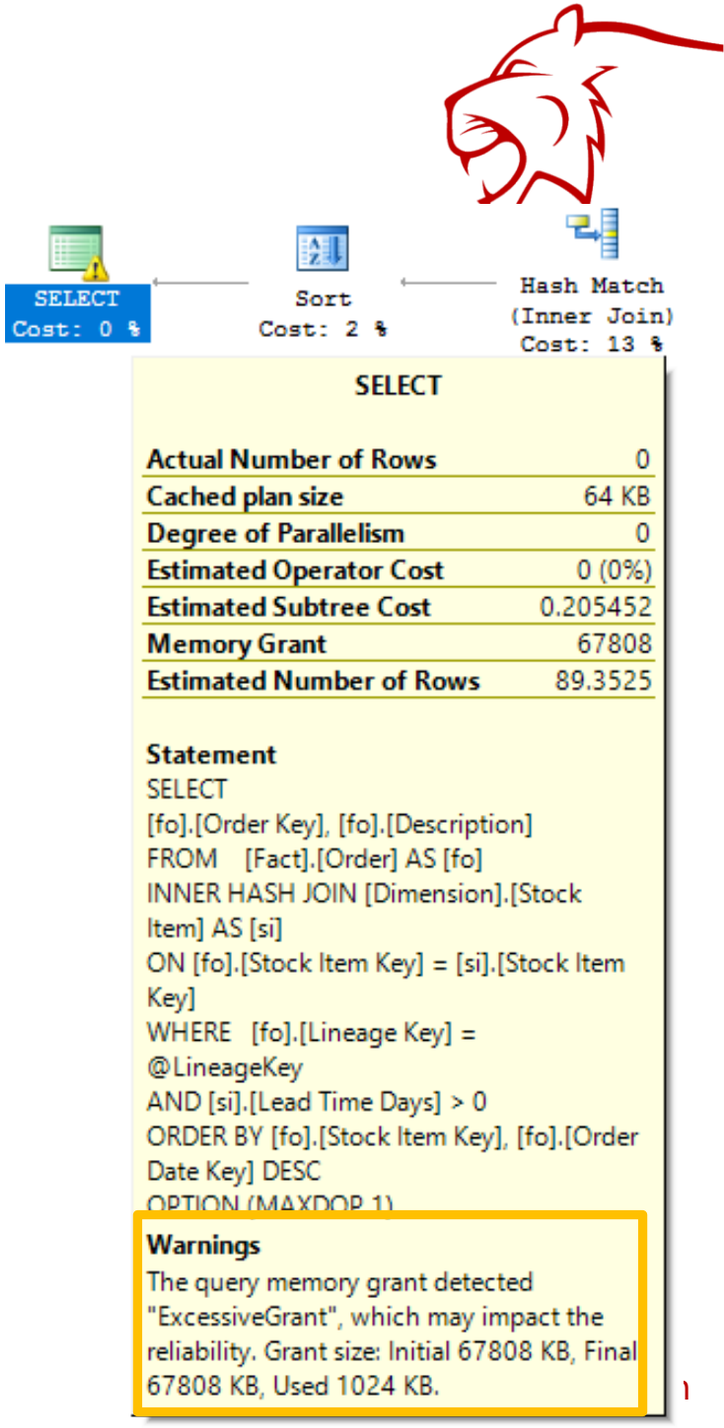
RESOURCE_SEMAPHORE waits may indicate excessive number of concurrent queries, or excessive memory request amounts

Warning: Memory Grant

3 conditions:

- **Excessive Grant**: when max used memory is too small compared to the granted memory. This scenario can cause blocking and less efficient usage when large grants exist and a fraction of that memory was used.

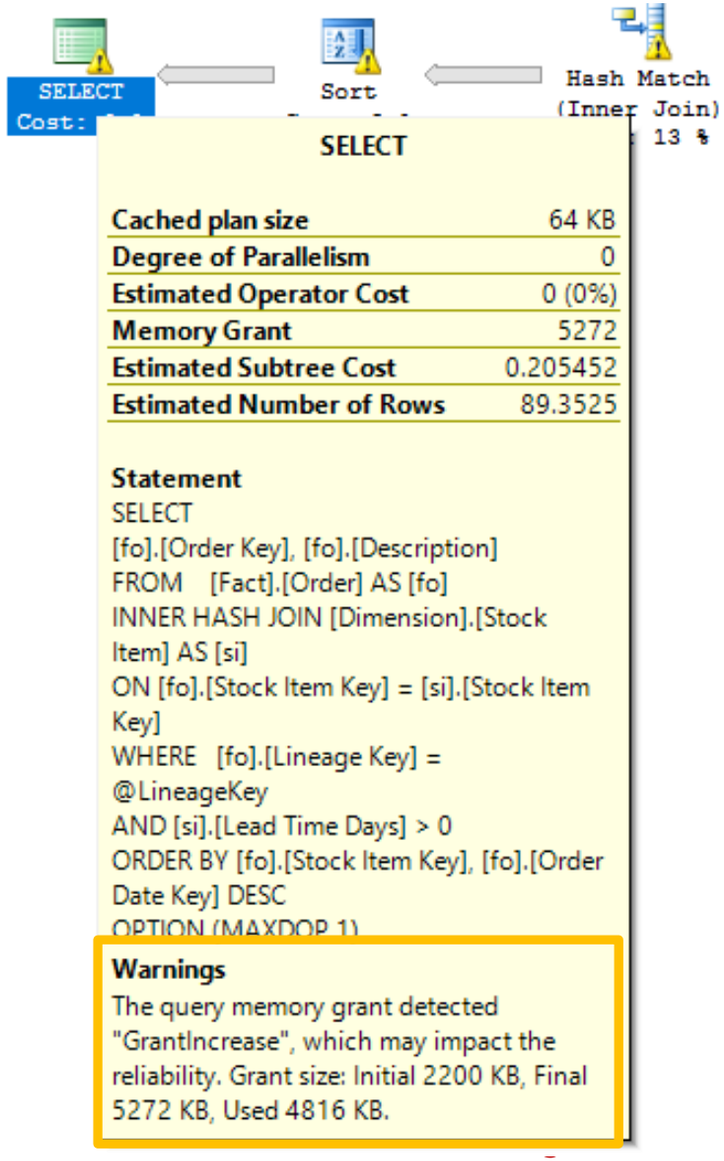
KB
3172997



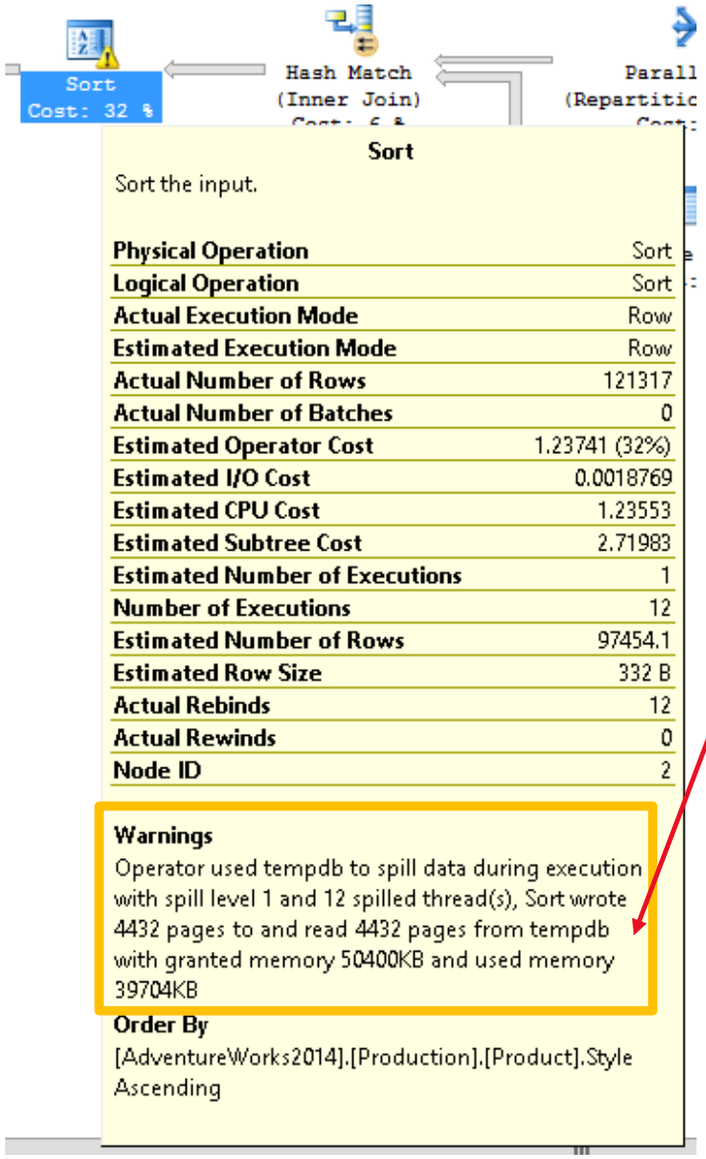
Warning: Memory Grant

3 conditions:

- **Excessive Grant**: when max used memory is too small compared to the granted memory. This scenario can cause blocking and less efficient usage when large grants exist and a fraction of that memory was used.
- **Grant Increase**: when the dynamic grant starts to increase too much, based on the ratio between the max used memory and initial request memory. This scenario can cause server instability and unpredictable workload performance.
- **Used More Than Granted**: when the max used memory exceeds the granted memory. This scenario can cause OOM conditions on the server.

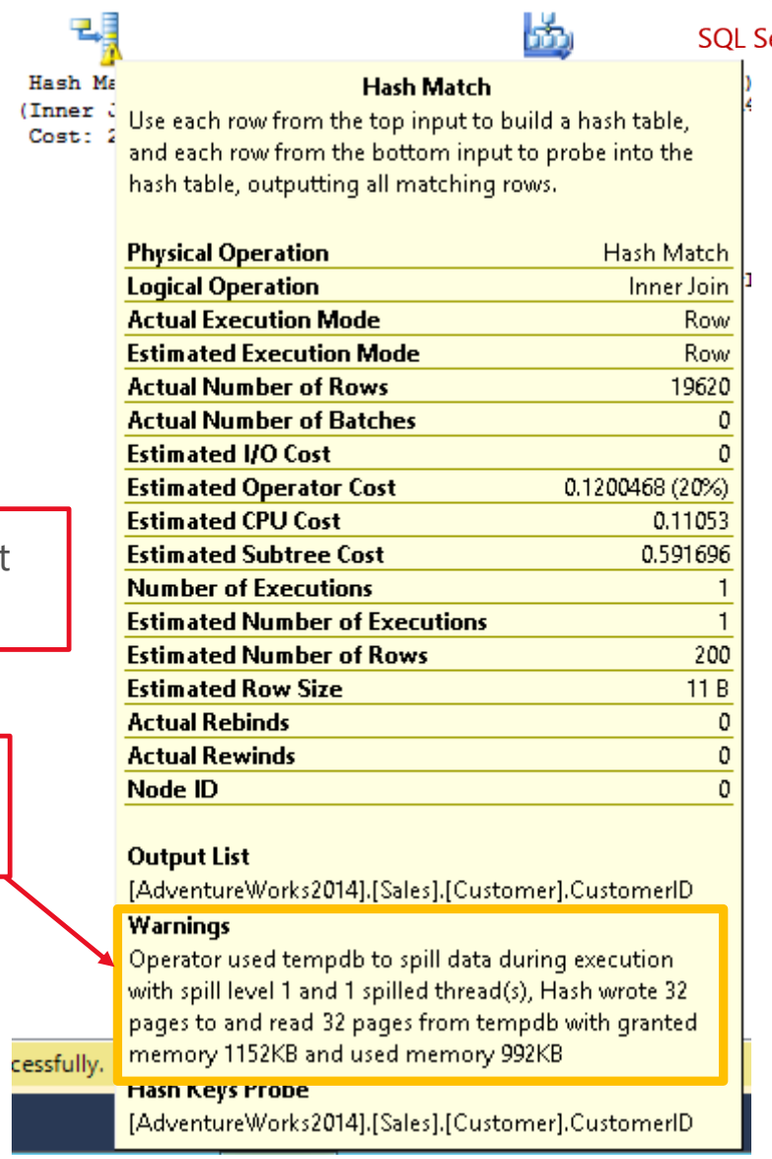


Warning: Spills



Is this spill relevant to go after? Does it consume too many resources?

And this one? What if this executes dozens of times per minute?



SQL Server Tiger Team

Analyzing query plan properties

Looking at per-operator runtime stats

Insights into every query plan node

Properties

Clustered Index Scan (Clustered)

Misc	
Actual Execution Mode	Row
Actual I/O Statistics	
Actual Lob Logical Reads	0
Actual Lob Physical Reads	0
Actual Lob Read Aheads	0
Actual Logical Reads	1345
Actual Physical Reads	3
Actual Read Aheads	1376
Actual Scans	5
Actual Number of Batches	0
Actual Number of Rows	121317
Thread 0	0
Thread 1	40604
Thread 2	17684
Thread 3	27027
Thread 4	36002
Actual Rebinds	0
Actual Rewinds	0
Actual Time Statistics	
Actual Elapsed CPU Time (ms)	74
Actual Elapsed Time (ms)	456

SET STATISTICS IO not needed

SET STATISTICS TIME not needed

Predicate Pushdown

- Query specifies a predicate that can be used to filter rows.
- That filter can be evaluated on top of a table or **index scan/range** operation – predicate is pushed down to Storage Engine.
  - Almost always SQL Server will do this, even if your predicate doesn't filter all rows.
- Any remaining parts of the predicate are known as "residual" and must be evaluated for each row output by the scan or range operation – usually using a **Filter** operator.

Searching without pushdown


```
SELECT [ProductID]
FROM [Sales].[SalesOrderDetail]
WHERE [ModifiedDate] BETWEEN '2011-01-01' AND '2012-01-01'
AND [OrderQty] >= 10
```

Sales.SalesOrderDetail

ModifiedDate	ProductID	Store		lesAmount
2010-12-31	106	01		30
2011-01-07	103	04		17
2011-01-07	109	04	7	
2011-02-12	103	03	5	
2011-03-08	106	05	7	25
2011-04-16	106	02	10	40
2011-07-20	102	02	12	50
2011-10-21	106	03	16	55
2011-12-15	103	03	20	55
(...)	(...)	(...)	(...)	(...)
2012-01-01	109	01	11	16
2012-01-11	102	05	5	10

Actual Rows

Filter

Range Scan

Result Set

ModifiedDate	ProductID	StoreID	OrderQty	SalesAmount
2011-04-16	106	02	10	40
2011-07-20	102	02	12	
2011-10-21	106	03	16	
2011-12-15	103	03	20	
(...)	(...)	(...)	(...)	(...)
2012-01-01	109	01	11	16

Searching with pushdown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SELECT [ProductID]
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```

Sales.SalesOrderDetail

ModifiedDate	ProductID	StoreID	OrderQty	SalesAmount
2010-12-31	106	01	12	30
2011-01-07			1	17
2011-01-07			7	20
2011-02-12	1(	03	5	40
2011-03-08	10	05	7	25
2011-04-16	106	02	10	40
2011-07-20	102	02	12	50
2011-10-21	106	03	16	55
2011-12-15	103	03	20	55
(...)	(...)	(...)	(...)	(...)
2012-01-01	109	01	11	16
2012-01-11	102	05	5	10

Range Scan

Actual Rows

Result Set

ModifiedDate	ProductID	StoreID	OrderQty	SalesAmount
2011-04-16	106	02	10	40
2011-07-20	102	02	12	50
2011-10-21	106	03	16	55
2011-12-15	103	03	20	55
(...)	(...)	(...)	(...)	(...)
2012-01-01	109	01	11	16

Predicate Pushdown as seen in Showplan


```
SELECT * FROM [Production].[TransactionHistory]
WHERE [ProductID] = 870 AND [Quantity] > 10
```

Key Stats

- *Actual Rows in result set = 39*
- *Actual Rows Read = 113443*

Clustered Index Scan (Clustered)

Scanning a clustered index, entirely or only a range.

Physical Operation	Clustered Index Scan
Logical Operation	Clustered Index Scan
Actual Execution Mode	Row
Estimated Execution Mode	Row
Storage	RowStore
Actual Number of Rows	39
Actual Number of Batches	0
Estimated Operator Cost	0.651523 (88%)
Estimated I/O Cost	0.589051
Estimated CPU Cost	0.0624722
Estimated Subtree Cost	0.651523
Number of Executions	4
Estimated Number of Executions	1
Estimated Number of Rows	1500.73
Estimated Row Size	54 B
Actual Rebinds	0
Actual Rewinds	0
Ordered	False
Node ID	1

SQL 2014

Clustered Index Scan (Clustered)

Scanning a clustered index, entirely or only a range.

Physical Operation	Clustered Index Scan
Logical Operation	Clustered Index Scan
Actual Execution Mode	Row
Estimated Execution Mode	Row
Storage	RowStore
Number of Rows Read	113443
Actual Number of Rows	39
Actual Number of Batches	0
Estimated I/O Cost	0.589051
Estimated Operator Cost	0.620287 (92%)
Estimated Subtree Cost	0.620287
Estimated CPU Cost	0.0312361
Number of Executions	8
Estimated Number of Executions	1
Estimated Number of Rows	1500.73
Estimated Row Size	54 B
Actual Rebinds	0
Actual Rewinds	0
Ordered	False
Node ID	1

SQL 2016

Clustered Index Scan (Clustered)

Scanning a clustered index, entirely or only a range.

Physical Operation	Clustered Index Scan
Logical Operation	Clustered Index Scan
Actual Execution Mode	Row
Estimated Execution Mode	Row
Storage	RowStore
Number of Rows Read	113443
Actual Number of Rows	39
Actual Number of Batches	0
Estimated I/O Cost	0.589792
Estimated Operator Cost	0.621028 (92%)
Estimated CPU Cost	0.0312361
Estimated Subtree Cost	0.621028
Number of Executions	8
Estimated Number of Executions	1
Estimated Number of Rows	1500.73
Estimated Number of Rows to be Read	113443
Estimated Row Size	54 B
Actual Rebinds	0
Actual Rewinds	0
Ordered	False
Node ID	1

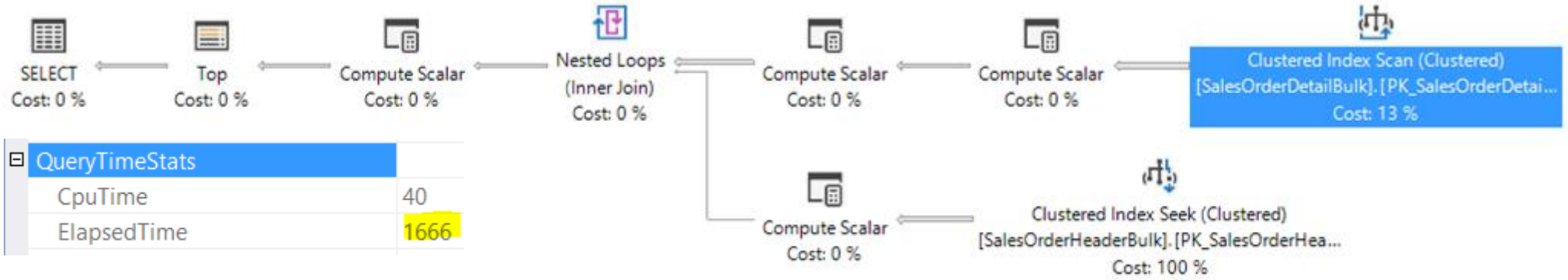
SQL 2016 SP1

Optimizer Row Goal

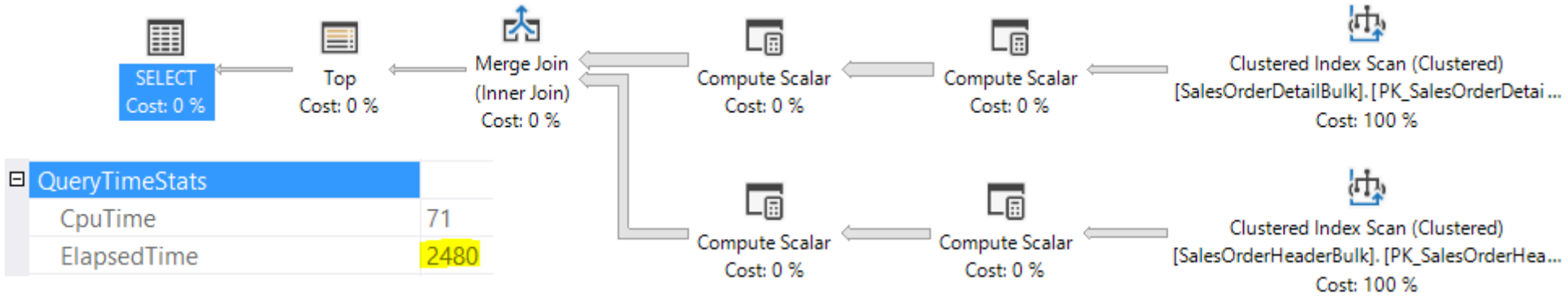
- Query specifies a target number of rows (a.k.a. row goal) that may be expected at runtime.
- How? When query uses a **TOP**, **IN** or **EXISTS** clause, the **FAST** query hint, or a **SET ROWCOUNT** statement – that row goal is used as part of the query optimization process.
- If the row goal plan is applied, the *estimated number of rows* is reduced.
  - Optimizer assumes that a smaller number of rows will have to be processed, in order to reach the row goal.

Optimizer row goal – the good case

```
SELECT TOP (100) * FROM Sales.SalesOrderHeaderBulk AS s
INNER JOIN Sales.SalesOrderDetailBulk AS d ON s.SalesOrderID = d.SalesOrderID
WHERE s.TotalDue > 1000 OPTION (RECOMPILE);
```

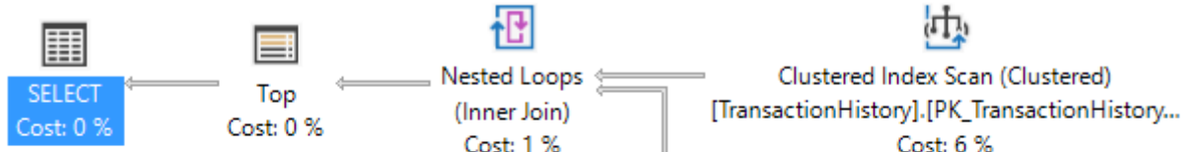



```
SELECT TOP (100) * FROM Sales.SalesOrderHeaderBulk AS s
INNER JOIN Sales.SalesOrderDetailBulk AS d ON s.SalesOrderID = d.SalesOrderID
WHERE s.TotalDue > 1000 OPTION (RECOMPILE, USE HINT('DISABLE_OPTIMIZER_ROWGOAL'));
```



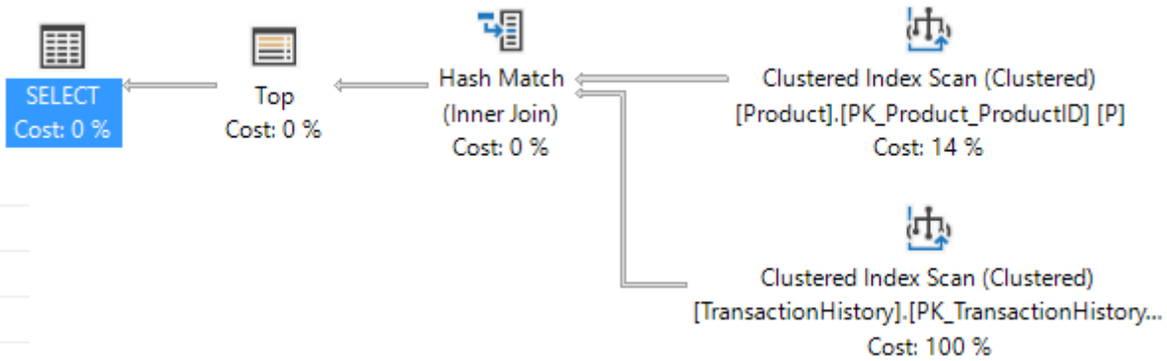
Optimizer row goal – the "bad" case

```
SELECT TOP 250 * FROM Production.TransactionHistory H
INNER JOIN Production.Product P ON  H.ProductID = P.ProductID
OPTION (RECOMPILE)
```



QueryTimeStats	
CpuTime	7
ElapsedTime	165

```
SELECT TOP 250 * FROM Production.TransactionHistory H
INNER JOIN Production.Product P ON  H.ProductID = P.ProductID
OPTION (RECOMPILE, USE HINT('DISABLE_OPTIMIZER_ROWGOAL'));
```



QueryTimeStats	
CpuTime	6
ElapsedTime	18

Discoverability of Optimizer row goal

Clustered Index Scan (Clustered)

Misc	
Actual Execution Mode	Row
Actual I/O Statistics	
Actual Number of Batches	0
Actual Number of Rows	250
Actual Rebinds	0
Actual Rewinds	0
Actual Time Statistics	
Defined Values	[AdventureWorks2016
Description	Scanning a clustered i
Estimated CPU Cost	0.124944
Estimated Execution Mode	Row
Estimated I/O Cost	0.589792
Estimated Number of Executions	1
Estimated Number of Rows	250
Estimated Number of Rows to be R	113443
Estimated Operator Cost	0.0048447 (6%)
Estimated Rebinds	0
Estimated Rewinds	0
Estimated Row Size	54 B
Estimated Subtree Cost	0.0048447
EstimateRowsWithoutRowGoal	113443
Forced Index	False
ForceScan	False
Logical Operation	Clustered Index Scan
Node ID	2
NoExpandHint	False
Number of Executions	1
Number of Rows Read	250

Diff *Estimated rows* vs *Estimated rows without Row Goal*?

Diff *Estimated number of rows to be Read* and *Number of rows read*?

USE HINT('DISABLE_OPTIMIZER_ROWGOAL')

Clustered Index Seek (Clustered)

Misc	
Actual Execution Mode	Row
Actual I/O Statistics	
Actual Number of Batches	0
Actual Number of Rows	250
Actual Rebinds	0
Actual Rewinds	0
Actual Time Statistics	
Defined Values	[AdventureWo
Description	Scanning a pa
Estimated CPU Cost	0.0001581
Estimated Execution Mode	Row
Estimated I/O Cost	0.003125
Estimated Number of Executions	251.00025
Estimated Number of Rows	1
Estimated Number of Rows to be R	1
Estimated Operator Cost	0.0803081 (93
Estimated Rebinds	247.856
Estimated Rewinds	2.14425
Estimated Row Size	229 B
Estimated Subtree Cost	0.0803081
Forced Index	False
ForceScan	False
ForceSeek	False
Logical Operation	Clustered Inde
Node ID	3
NoExpandHint	False
Number of Executions	250
Number of Rows Read	250

See now, and no attribute *Estimated rows without Row Goal*

SQL Server Tiger Team

Faster insights

The middle-of-the-night call

You're on call for supporting the data tier of a mission-critical SQL Server instance

Key business processes are being delayed when ETL is running.

You get a call asking to **mitigate** the issue and then determine the **root cause**.

Defining the problem

Reasonable hypothesis: a long running query.

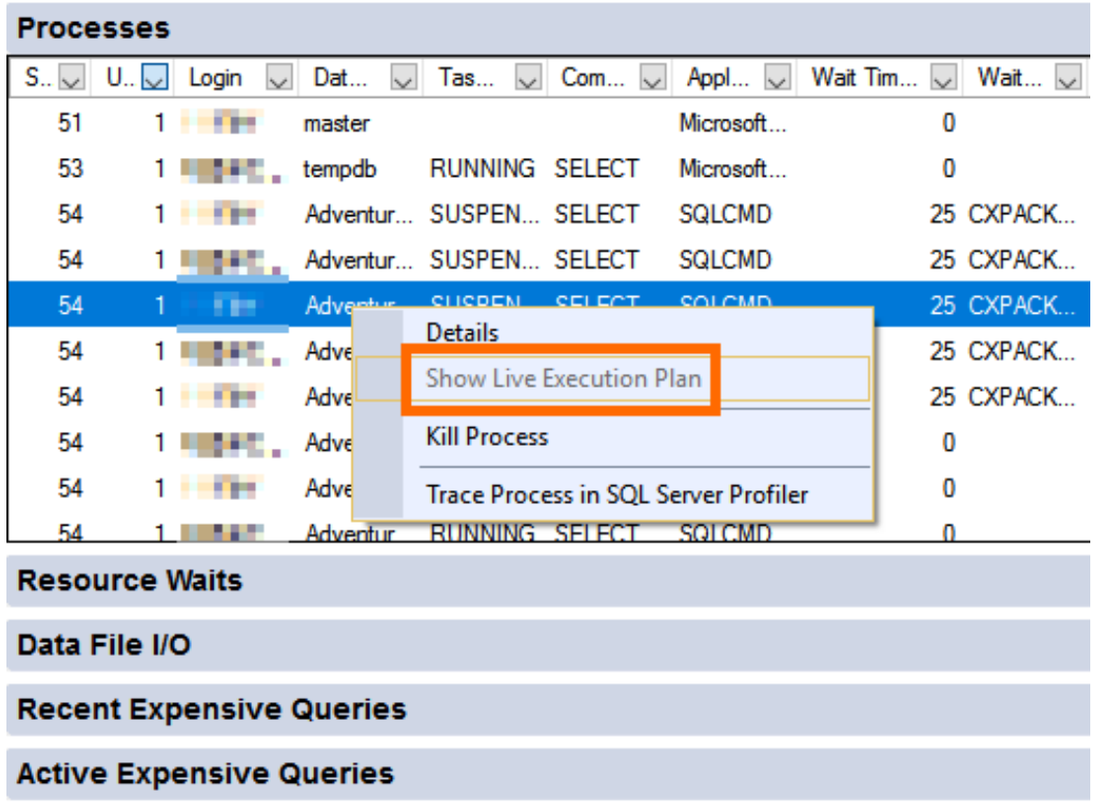
Query completion is a prerequisite for the availability of an actual query plan.

Actual query plans unsuitable for troubleshooting complex performance issues:

- Long running queries
- Queries that run indefinitely and never finish execution.

What if I could do live query troubleshooting?

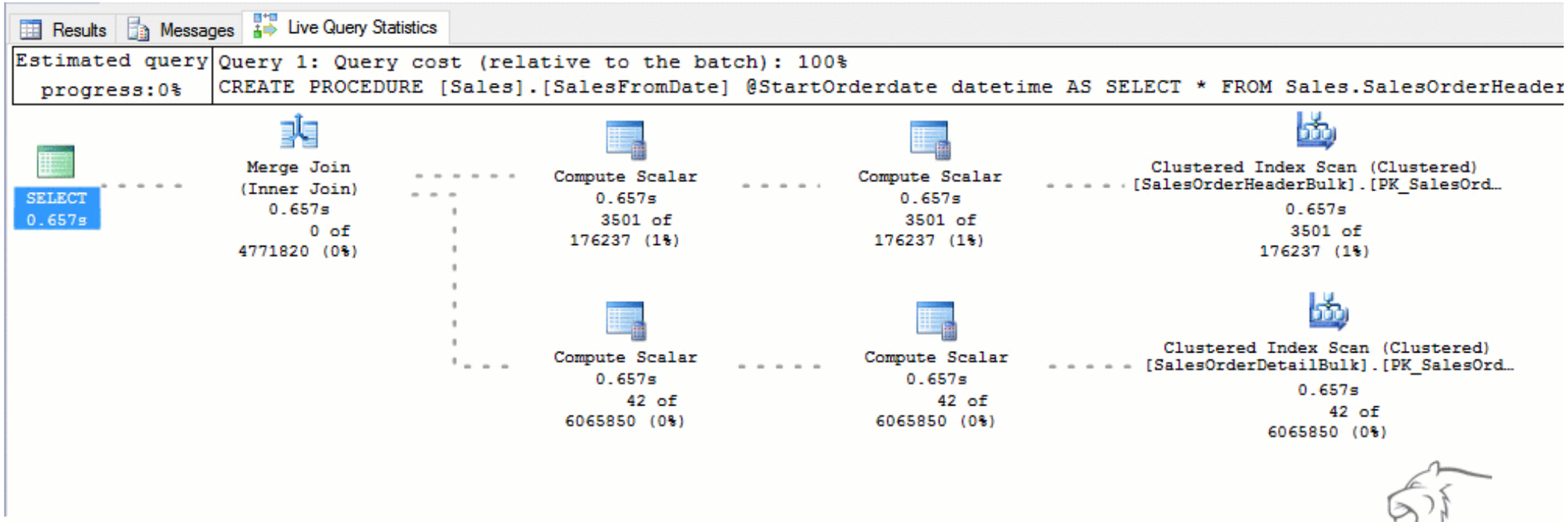
- What we need is live execution plan!
- Now as default behavior:
- To have in-flight query execution statistics, the query execution statistics profile infrastructure must be enabled **on demand**.
- But cost overhead goes up to 75% with TPC-C like workload.
- It makes bad things worse if running all the time.



What if I could do live query troubleshooting?

Can be enabled for a target session:

- Specifying *Include Live Query Statistics* in SSMS.
- SET STATISTICS XML ON
- SET STATISTICS PROFILE ON



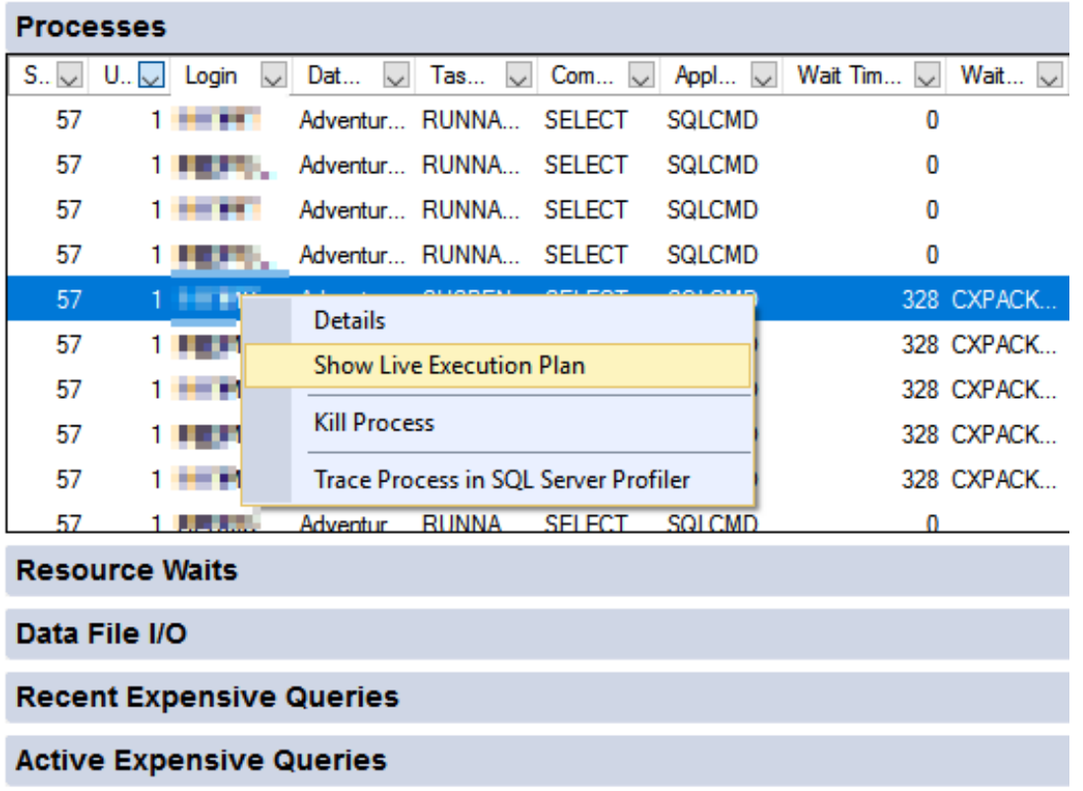
What if I could do live query troubleshooting?

Can be enabled for a target session:

- Specifying *Include Live Query Statistics* in SSMS.
- SET STATISTICS XML ON
- SET STATISTICS PROFILE ON

Or globally to view the LQS from other sessions (such as from Activity Monitor):

- Enabling *query_post_execution_showplan* extended event.



Query progress – anytime, anywhere

Starting with SQL Server 2016 SP1* we have enabled *lightweight query execution statistics profile infrastructure* to continuously collecting per-operator query execution statistics.

Can be enabled by:

- Using global TF 7412.
- Enabling query_thread_profile extended event.
- When lightweight profiling is on, sys.dm_exec_query_profiles is also populated for all sessions.

This enables usage of LQS feature in SSMS (including Activity Monitor) and of the new DMF sys.dm_exec_query_statistics_xml.

The following still use regular profiling infra:

- SET STATISTICS XML (or Include Actual Plan).
- *query_post_execution_showplan* extended event.

What is the impact of live query troubleshooting?

Query Execution Statistics Profiling Infrastructure tests with TPC-C like workloads

	Overhead percent (up to)	
Infra Type	**no active xEvents**	**Active xEvent query_post_execution_showplan**
Regular	**75.5**	93.17
Lightweight in SQL Server 2014 SP2/2016	3.5	62.02
Lightweight in SQL Server 2016 SP1 and above	**2**	14.3

Demo

Bringing it all together with live troubleshooting

Solution1 - Microsoft SQL Server Management Studio (Administrator)

Quick Launch (Ctrl+Q)

File Edit View Project Debug Tools Window Help

New Query | Generic Debugger | DegreeOfParallelism

Object Explorer

Connect

- Lord-Plagueis (SQL Server 13.0.4452.18 - Lord
- Lord-Tyranus (SQL Server 14.0.3006.16 - Lord-
  - Databases
  - Security
  - Server Objects
  - Replication
  - PolyBase
  - Always On High Availability
  - Management
  - Integration Services Catalogs
  - SQL Server Agent (Agent XPs disabled)
  - XE Profiler

Properties

Ready

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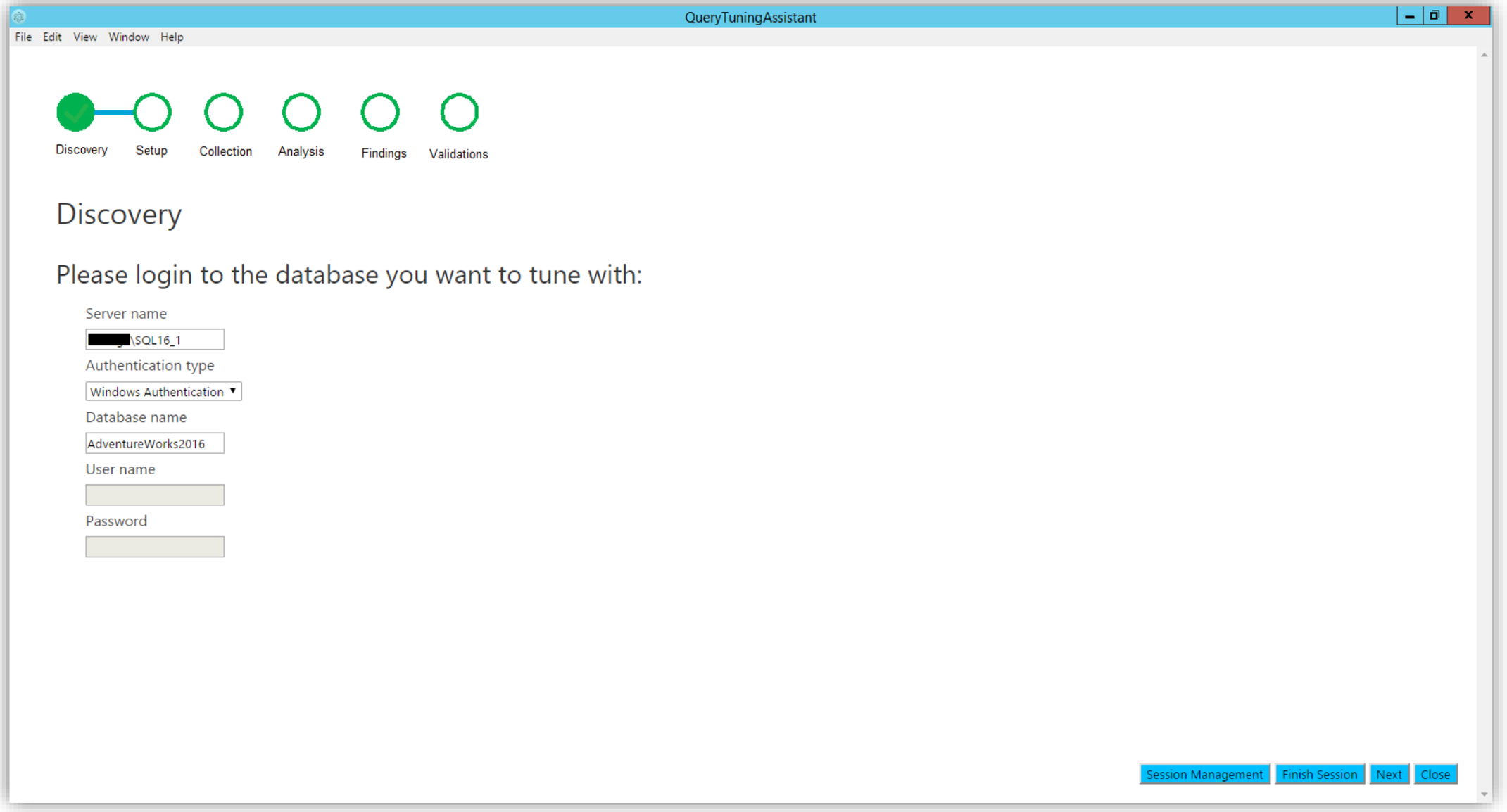
Project TunA

Bob did mention I'd be talking about fish ☺

Query Tuning Assistant



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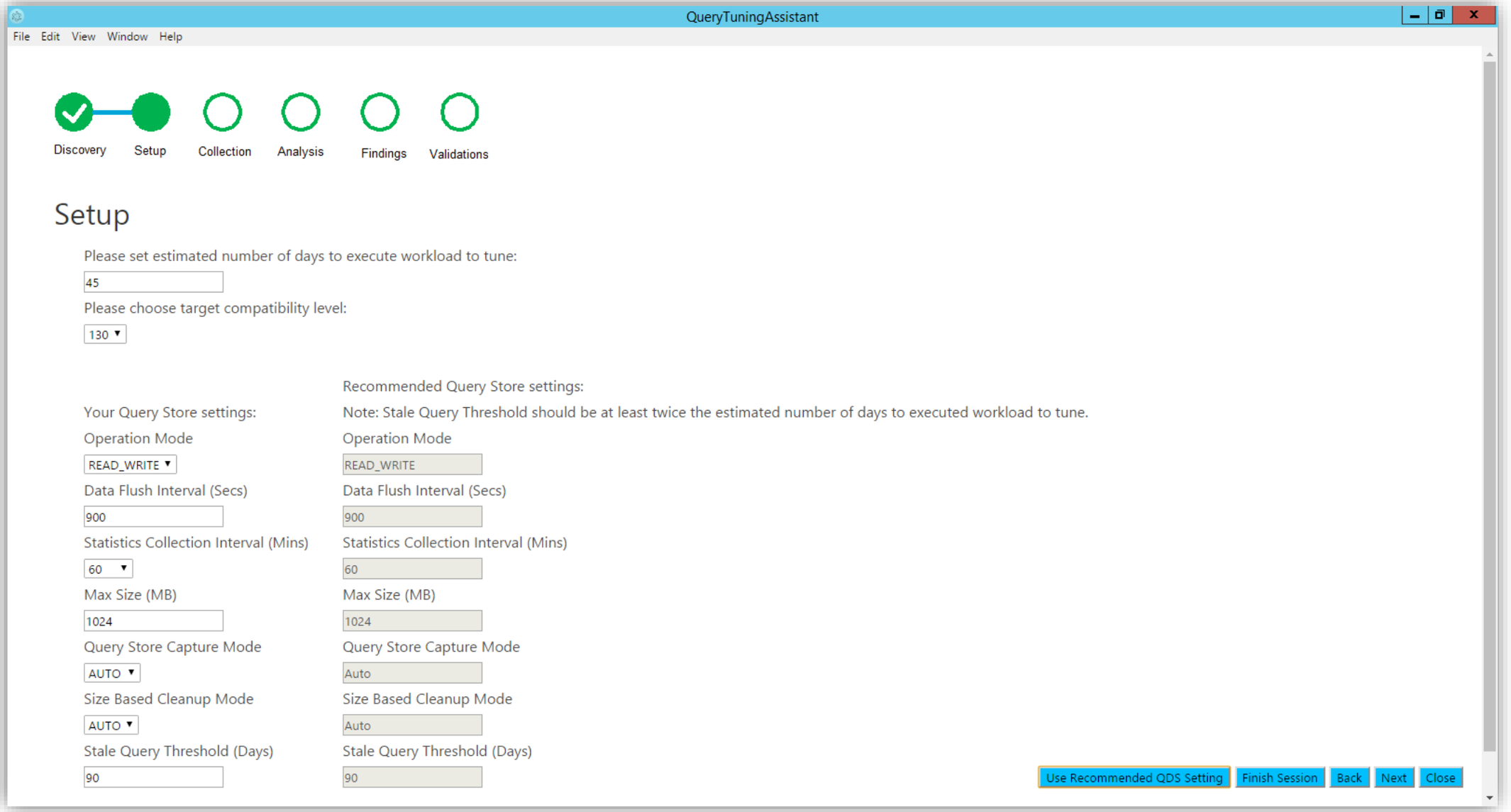
Query Tuning Assistant



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