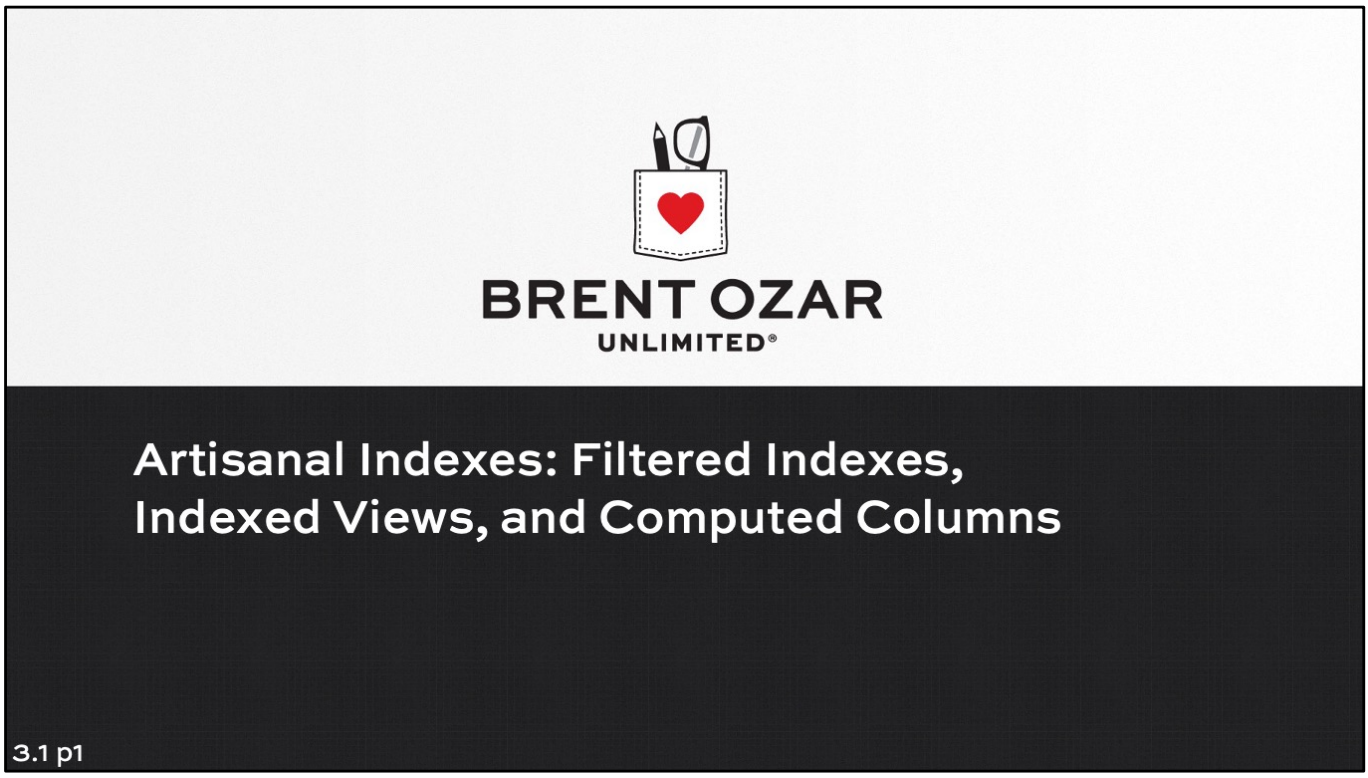


Indexes can benefit from hand-crafting, too

1. App frequently queries a small subset of rows
2. App frequently queries aggregations
3. App frequently queries computations (and the app can't just insert the computed value)

3.1 p3

A big gotcha

Some of these artisanal indexes have a huge gotcha: they won't work with clients who are using different "SET" options in their connect string

- Can't use it for reads
- Writes will fail

This can break your application

```
Msg 1934, Level 16, State 1, Line 1
INSERT failed because the following SET options have incorrect settings:
```

3.1 p4

SET options that impact results

SET options	Required value
ANSI_NULLS	ON
ANSI_PADDING	ON
ANSI_WARNINGS	ON
ARITHABORT	ON
CONCAT_NULL_YIELDS_NULL	ON
NUMERIC_ROUNDABORT	OFF
QUOTED_IDENTIFIER	ON

https://technet.microsoft.com/en-us/library/ms175088

3.1 p5

To catch sessions like this:

```
SELECT *
FROM sys.dm_exec_sessions
WHERE is_user_process = 1 AND
(ansi_nulls = 0
OR ansi_padding = 0
OR ansi_warnings = 0
OR arithabort = 0
OR concat_null_yields_null = 0
OR quoted_identifier = 0)
```

3.1 p6

Curse you, SQL Agent

	session_id	login_time	host_name	program_name	host_process_id	client_version	client_interface_name
1	52	2017-01-27 06:00:43.930	SQL2016A	SQLAgent - Email Logger	2452	7	ODBC
2	53	2017-01-27 06:00:43.930	SQL2016A	SQLAgent - Generic Refresher	2452	7	ODBC
3	54	2017-01-27 06:01:30.117	SQL2016A	Microsoft SQL Server Management Studio	3524	7	.Net SqlClient Data Provide
4	55	2017-01-27 06:01:30.677	SQL2016A	Microsoft SQL Server Management Studio	3524	7	.Net SqlClient Data Provide
5	57	2017-01-27 06:06:26.097	SQL2016A	SQLServerCEIP	1444	7	.Net SqlClient Data Provide

3.1 p7

Don’t let this stop you

Just test before you implement these indexes

- Validate application activity

Hey, that’s not so bad, is it?

Just make sure you include validating that WRITES can occur as part of the testing

3.1 p8

Normal index creation

```
CREATE NONCLUSTERED INDEX IX_DisplayName
ON dbo.Users(DisplayName);
```

3.1 p10

Filtered index

```
CREATE NONCLUSTERED INDEX IX_DisplayName
ON dbo.Users(DisplayName)
WHERE IsEmployee = 0;
```

3.1 p11

Setting up the Users table

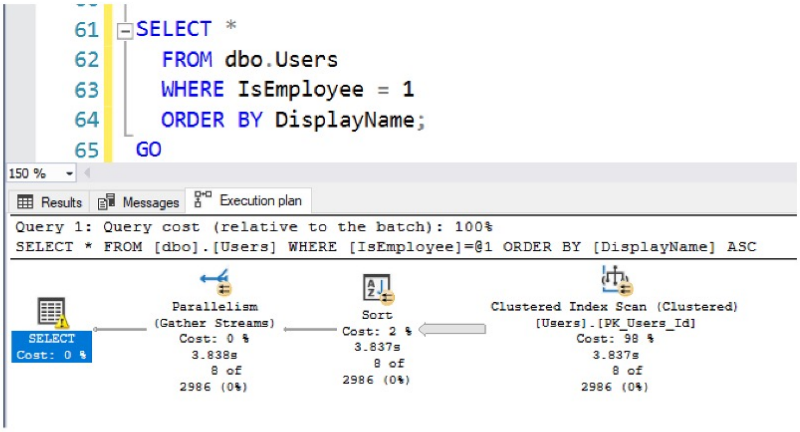
```
ALTER TABLE dbo.Users
    ADD IsEmployee BIT NOT NULL DEFAULT 0;
GO

/* Populate some of the employees: */
UPDATE dbo.Users
    SET IsEmployee = 1
    WHERE Id IN (1, 2, 3, 4, 13249, 23354, 115866, 130213, 146719);
GO
```

3.1 p12

Say we have an Employees page

When we filter for IsEmployee = 1, Clippy's quiet.

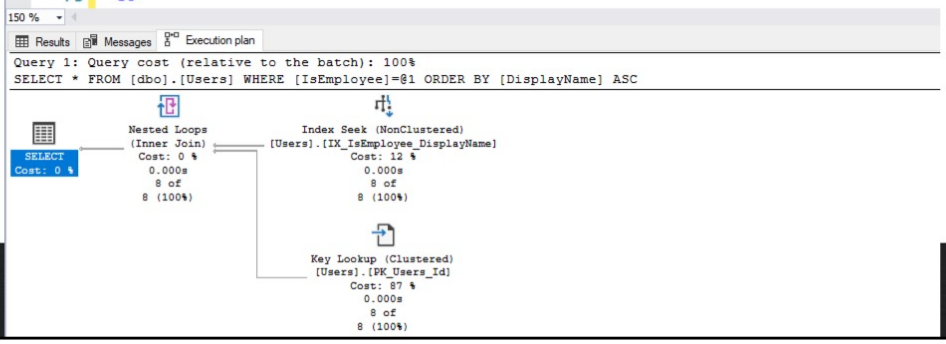


3.1 p13

But it will use a hand-crafted index

Unfiltered, like Mom's Camels

```
67  CREATE INDEX IX_IsEmployee_DisplayName ON dbo.Users(IsEmployee, DisplayName);
68  GO
69  SELECT *
70    FROM dbo.Users
71    WHERE IsEmployee = 1
72    ORDER BY DisplayName;
73  GO
```



3.1 p14

But it's big.

It has all the millions of rows, and takes up space.

When we insert/update/delete, the index changes.

Can we just index the IsEmployee = 1 people?

```
76  sp_BlitzIndex @TableName = 'Users';
77  GO
```

50 %

Results | Messages

	Details: db_schema.table.index(indexid)	Definition: [Property] ColumnName {datatype maxbytes}	Size	S
1	Database [StackOverflow] as of 2020-01-27 08:04 ...	http://FirstResponderKit.org	NULL	F
2	dbo.Users.PK_Users_Id (1)	[CX] [PK] [1 KEY] Id {int 4}	8,917,507 rows; 1.1GB; 1.2MB LOB; 0.0MB Row Ove...	
3	dbo.Users.IX_IsEmployee_DisplayName (3)	[2 KEYS] IsEmployee {bit 1}, DisplayName {nvarchar ...	8,917,507 rows; 305.3MB	[

3.1 p15

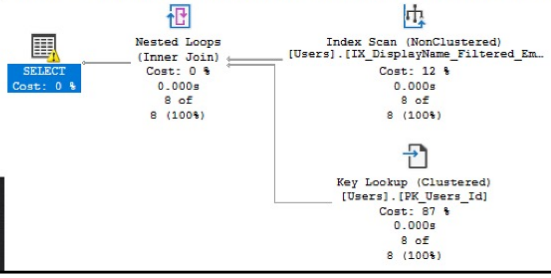
Drop the old, add a filtered

```
79  DropIndexes;
80  GO
81  CREATE INDEX IX_DisplayName_Filtered_Employees ON dbo.Users(DisplayName)
82    WHERE IsEmployee = 1;
83  GO
84  SELECT *
85    FROM dbo.Users
86    WHERE IsEmployee = 1
87    ORDER BY DisplayName;
88  GO
```

150 %

Results | Messages | Execution plan

```
Query 1: Query cost (relative to the batch): 100%
SELECT * FROM [dbo].[Users] WHERE [IsEmployee]=@1 ORDER BY [DisplayName] ASC
```



3.1 p16

And it's tiny: just 8 rows!

```
91  sp_BlitzIndex @TableName = 'Users';
92  GO
```

150 %

Results | Messages

	Details: db_schema.table.index(indexid)	Definition: [Property] ColumnName {datatype maxbytes}	Size
1	Database [StackOverflow] as of 2020-01-27 08:06 ...	http://FirstResponderKit.org	NULL
2	dbo.Users.IX_DisplayName_Filtered_Employees (2)	[1 KEY] DisplayName {nvarchar 80} [FILTER] ([IsEmployee]=(1))	8 rows; 0.1MB
3	dbo.Users.PK_Users_Id (1)	[CX] [PK] [1 KEY] Id {int 4}	8,917,507 rows; 1.1GB; 1.2MB LOB; 0.0MB Row Ove...

Not only does it take less space, but it also doesn't have to be maintained for rows that don't match the filter.

3.1 p17

Who it's for

Very selective column where only 5% of rows match

Queue table:

- ProcessedDate column defaults to null, set to a valid date after row is processed
- Queries ask for WHERE ProcessedDate IS NULL
- Only a few rows need to be processed, but you want to find them quickly
- You never query the rest of the rows by date

3.1 p18

Filtered index limitations

SQL Server 2008+, all editions

Filter can only contain string literals:

- No functions
- Frustrating with “ascending date” type columns

Statistics automatically update at the same rate as the base table (~ 20% of rows updated)

3.1 p19

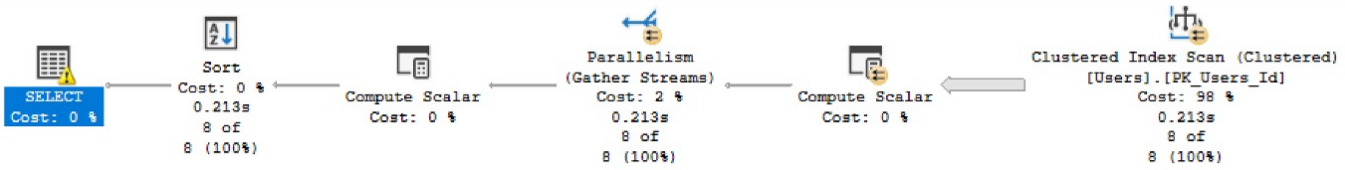
Parameterized queries don't use 'em

```
96  CREATE OR ALTER PROC dbo.usp_SearchUsers @IsEmployee BIT AS
97  SELECT *
98    FROM dbo.Users
99    WHERE IsEmployee = @IsEmployee
100   ORDER BY DisplayName;
101 GO
102 EXEC usp_SearchUsers @IsEmployee = 1;
103 GO
```

150 %

Results | Messages | Execution plan

```
Query 1: Query cost (relative to the batch): 100%
SELECT * FROM dbo.Users WHERE IsEmployee = @IsEmployee ORDER BY DisplayName
```

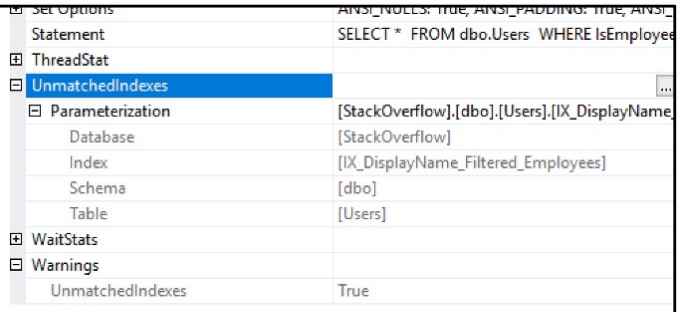


Hidden warning

SQL Server has to build a plan that's safe and reusable for everyone.

This same proc could be called for @IsEmployee = 0.

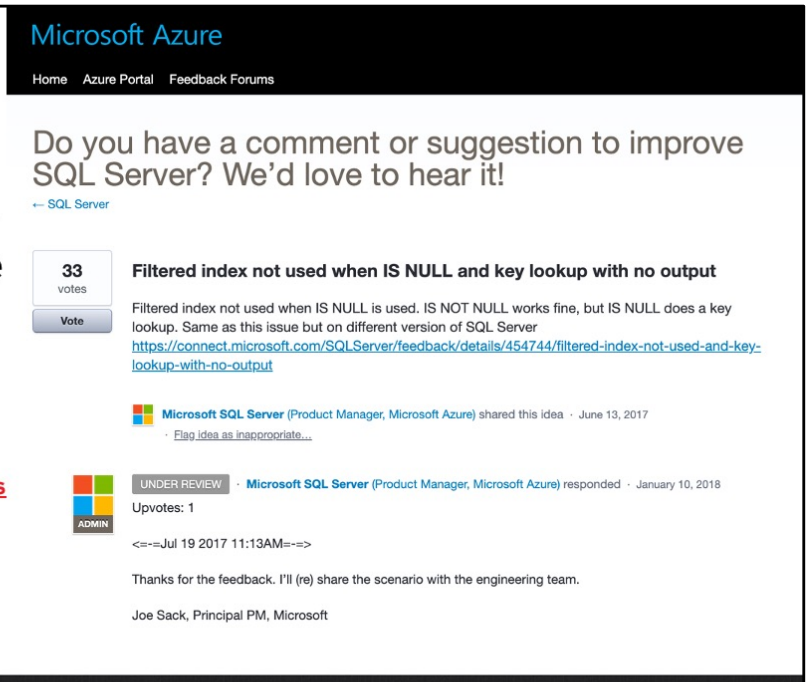
If you really want filtered index usage, you may have to hard-code the filter into the query itself, too.



WHERE Bugs = 1

You usually need the filtered column in the index somewhere (either keys or includes) or else:

https://feedback.azure.com/forums/908035-sql-server/suggestions/32896348-filtered-index-not-used-when-is-null-and-key-looku



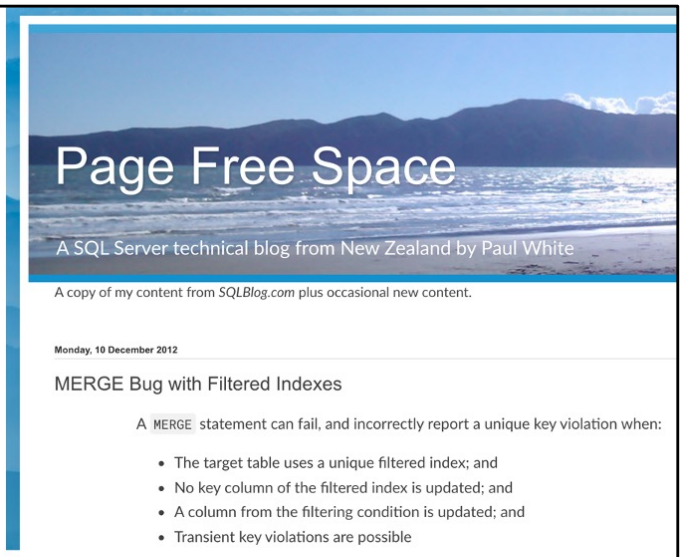
3.1 p22

WHERE Bugs = 1

https://www.sql.kiwi/2012/12/merge-bug-with-filtered-indexes.html

Closed as won't-fix, still present in SQL Server 2019

MERGE has many more issues, though



3.1 p23

Use Caution with SQL Server's MERGE Statement

By: Aaron Bertrand | Updated: 2018-07-24 | Comments (25) | Related: 1 | 2 | 3 | 4 | 5 | 6 | More > T-SQL

Problem

SQL Server 2008 introduced the MERGE statement, which promised to be a simpler way to combine insert/update/delete statements, such as those used during ETL (extract, transform and load) operations. However, MERGE originally shipped with several "wrong results" and other bugs - some of which have been addressed, and some of which continue to exist in current versions. People also tend to make some leaps of faith regarding atomicity - they don't realize that the single statement actually performs different operations separately, and thus can suffer from issues due to concurrency and race conditions just like separate statements can.

Solution

I have been recommending that - for now - people stick to their tried and true methods of separate statements. Here are the major reasons:

Bugs with the SQL Server Merge Statement

It can be quite difficult to validate and guarantee that you are immune from any of the bugs that still exist. A few Connect items that you should be aware of, that are either still active, closed as "Won't Fix"/"By Design", or have only been fixed in specific versions (often requiring a cumulative update or on-demand hotfix):

Connect issue	Current / last known status
#773895 : MERGE Incorrectly Reports Unique Key Violations	Won't Fix
#771336 : Indexed view is not updated on data changes in base table	Fixed only in 2012+
#766165 : MERGE evaluates filtered index per row, not post operation, which causes filtered index violation	Won't Fix
#723696 : Basic MERGE upsert causing deadlocks	By Design
#713699 : A system assertion check has failed ("cxrowset.cpp":1528)	Won't Fix
#699055 : MERGE query plans allow FK and CHECK constraint violations	Active

Connect issue	Current / last known status
#773895 : MERGE Incorrectly Reports Unique Key Violations	Won't Fix
#771336 : Indexed view is not updated on data changes in base table	Fixed only in 2012+
#766165 : MERGE evaluates filtered index per row, not post operation, which causes filtered index violation	Won't Fix
#723696 : Basic MERGE upsert causing deadlocks	By Design
#713699 : A system assertion check has failed ("cxrowset.cpp":1528)	Won't Fix
#699055 : MERGE query plans allow FK and CHECK constraint violations	Active
#685800 : Parameterized DELETE and MERGE Allow Foreign Key Constraint Violations	Won't Fix
#654746 : merge in SQL2008 SP2 still suffers from "Attempting to set a non-NULL-able column's value to NULL"	Active
#635778 : NOT MATCHED and MATCHED parts of a SQL MERGE statement are not optimized	Won't Fix
#633132 : MERGE INTO WITH FILTERED SOURCE does not work properly	Won't Fix
#596086 : MERGE statement bug when INSERT/DELETE used and filtered index	Won't Fix
#583719 : MERGE statement treats non-nullable computed columns incorrectly in some scenarios	Won't Fix
#581548 : SQL2008 R2 Merge statement with only table variables fails	Fixed only in 2012+
#539084 : Search condition on a non-key column and an ORDER BY in source derived table breaks MERGE completely	Won't Fix
#357419 : MERGE statement bypasses Referential Integrity	Fixed only in 2012+
Merge statement fails when running db in Simple recovery model (2016)	Fixed only with trace flag 692
MERGE statement assertion error when database is in simple recovery model (2017)	Fixed only with trace flag 692
MERGE and INSERT with COLUMNSTORE index creates crash dump	Unacknowledged
Support MERGE INTO target for memory optimized tables	Under Review
MERGE fails with a duplicate key error when using DELETE and INSERT actions	Under Review
CDC logging wrong operation type for a MERGE statement, when Unique index is present	Under Review
Query optimizer cannot make plan for merge statement	Under Review
Poor error message with MERGE when source/target appear in impossible places	Won't Fix
MERGE statement provokes deadlocking due to incorrect locking behavior	Under Review
Merge statement Delete does not update indexed view in all cases	Under Review
EXCEPTION_ACCESS_VIOLATION When referencing the "deleted" table from an OUTPUT statement during MERGE	Under Review
Fulltext index not updating after changing text column via MERGE statement on a partitioned table	Under Review
MERGE on not matched by source UPDATE ignores variable declaration	Under Review
"A severe error occurred on the current command." with MERGE and OUTPUT	Fixed only in 2014+

Okay. Here's the situation.

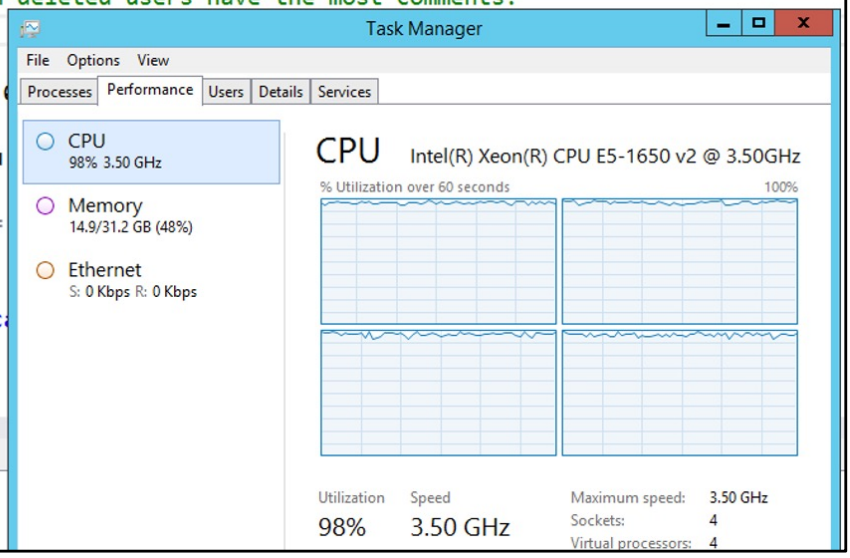
```
/*
Say we need to quickly find which non-deleted users have the most comments:
*/
ALTER TABLE dbo.Comments
  ADD IsDeleted BIT NOT NULL DEFAULT 0;
GO
SELECT TOP 100 u.Id, u.DisplayName, u.Location, u.AboutMe, SUM(1) AS CommentCount
  FROM dbo.Users u
  INNER JOIN dbo.Comments c ON u.Id = c.UserId
  WHERE u.IsDeleted = 0
    AND c.IsDeleted = 0
  GROUP BY u.Id, u.DisplayName, u.Location, u.AboutMe
  ORDER BY SUM(1) DESC;
GO
```

3.1 p27

A lot of comments, so this sucks.

```
/*
Say we need to quickly find which non-deleted users have the most comments:
*/
ALTER TABLE dbo.Comments
  ADD IsDeleted BIT NOT NULL DEFAULT (
GO
SELECT TOP 100 u.Id, u.DisplayName, u
  FROM dbo.Users u
  INNER JOIN dbo.Comments c ON u.Id =
  WHERE u.IsDeleted = 0
    AND c.IsDeleted = 0
  GROUP BY u.Id, u.DisplayName, u.Loca
  ORDER BY SUM(1) DESC;
GO
```

Messages



The plan does suggest an index.

And it's one of the worst indexes you could design.

It keys on Comments.IsDeleted, which is all zeroes.

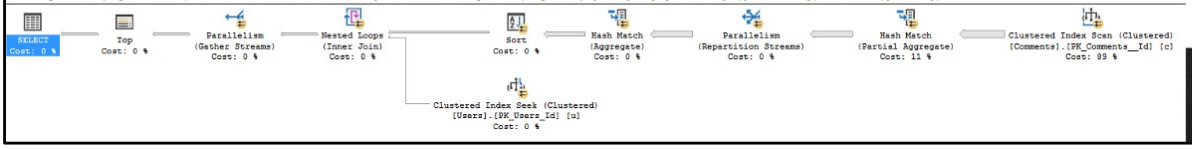
Then it just INCLUDES UserId without even sorting it!

```
148 SELECT TOP 100 u.Id, u.DisplayName, u.Location, u.AboutMe, SUM(1) AS CommentCount
149   FROM dbo.Users u
150   INNER JOIN dbo.Comments c ON u.Id = c.UserId
151   WHERE u.IsDeleted = 0
152     AND c.IsDeleted = 0
153   GROUP BY u.Id, u.DisplayName, u.Location, u.AboutMe
154   ORDER BY SUM(1) DESC;
155 GO
```

150 %

Messages | Execution plan

```
Query 1: Query cost (relative to the batch): 100%
SELECT TOP 100 u.Id, u.DisplayName, u.Location, u.AboutMe, SUM(1) AS CommentCount FROM dbo.Users u INNER JOIN dbo.Comments c ON u.Id = c.UserId WHERE u.IsDeleted = 0 AND c.IsDeleted
Missing Index (Impact 85.74): CREATE NONCLUSTERED INDEX [<Name of Missing Index, sysname,>] ON [dbo].[Comments] ([IsDeleted]) INCLUDE ([UserId])
```

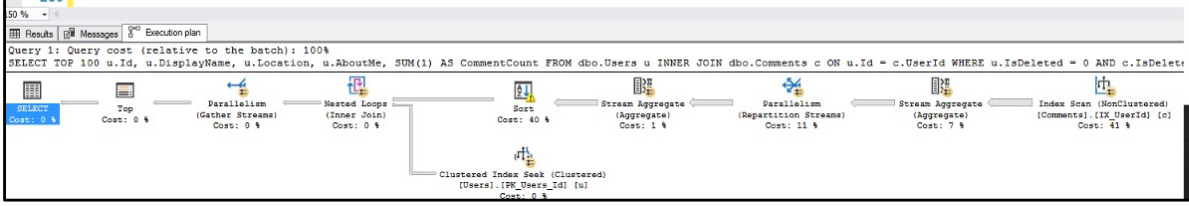


We could do better manually, but...

We can create a filtered index on UserId just for non-deleted comments.

However, we're still gonna have to scan the whole thing and run totals.

```
161 SELECT TOP 100 u.Id, u.DisplayName, u.Location, u.AboutMe, SUM(1) AS CommentCount
162   FROM dbo.Users u
163   INNER JOIN dbo.Comments c ON u.Id = c.UserId
164   WHERE u.IsDeleted = 0
165     AND c.IsDeleted = 0
166   GROUP BY u.Id, u.DisplayName, u.Location, u.AboutMe
167   ORDER BY SUM(1) DESC;
168 GO
169
```



The query is much faster now.

It's way better than it was, finishing in seconds.

It's only doing 81K logical reads, which is good.

However, it's going parallel and burning multiple cores to do all this totaling every time it runs, and that never gets cached.

```
(100 rows affected)
Table 'Comments'. Scan count 5, logical reads 80694, physi
Table 'Users'. Scan count 0, logical reads 488, physical r
Table 'Worktable'. Scan count 0, logical reads 0, physical
Table 'Worktable'. Scan count 0, logical reads 0, physical

(1 row affected)

 SQL Server Execution Times:
   CPU time = 9844 ms,  elapsed time = 5727 ms.
```

3.1 p31

Enter the indexed view, also known as a materialized view.

Normally we think of views as syntax shortcuts.

Indexed views are good for:

- Pre-baking CPU-intensive aggregations
- Pre-baking joins (which isn't usually a big deal, except at scale)

3.1 p32

Creating the view and the clustered index

```
CREATE OR ALTER VIEW dbo.vwCommentsByUser WITH SCHEMABINDING AS
    SELECT UserId,
        SUM(1) AS CommentCount,
        COUNT_BIG(*) AS MeanOldSQLServerMakesMeDoThis
    FROM dbo.Comments
    WHERE IsDeleted = 0
    GROUP BY UserId;
GO
CREATE UNIQUE CLUSTERED INDEX CL_UserId ON dbo.vwCommentsByUser(UserId);
GO
```

3.1 p33

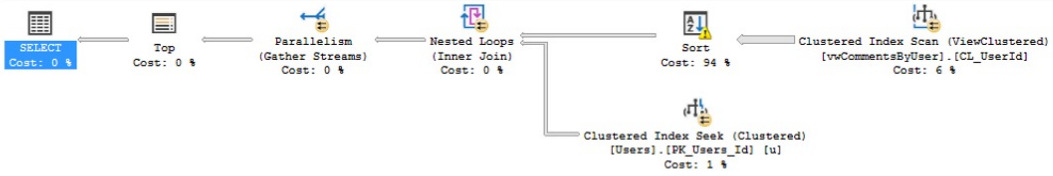
Rerun your query with no changes

```
185 SELECT TOP 100 u.Id, u.DisplayName, u.Location, u.AboutMe, SUM(1) AS CommentCount
186   FROM dbo.Users u
187   INNER JOIN dbo.Comments c ON u.Id = c.UserId
188   WHERE u.IsDeleted = 0
189     AND c.IsDeleted = 0
190   GROUP BY u.Id, u.DisplayName, u.Location, u.AboutMe
191   ORDER BY SUM(1) DESC;
192 GO
193
```

150 %

Results | Messages | Execution plan

Query 1: Query cost (relative to the batch): 100%
SELECT TOP 100 u.Id, u.DisplayName, u.Location, u.AboutMe, SUM(1) AS CommentCount FROM dbo.Users u INNER JOIN dbo.Comment



3.1 p34

Reads and CPU time drop, too

```
(100 rows affected)
Table 'Users'. Scan count 0, logical reads 481, physical rea
Table 'Worktable'. Scan count 0, logical reads 0, physical r
Table 'vwCommentsByUser'. Scan count 5, logical reads 5346,
Table 'Worktable'. Scan count 0, logical reads 0, physical r

(1 row affected)

 SQL Server Execution Times:
   CPU time = 1250 ms,  elapsed time = 474 ms.
```

3.1 p35

THIS ALMOST NEVER WORKS.

SQL Server Enterprise Edition is supposed to auto-match your query to the newly created indexed view, without changing your query.

In reality, this almost never works, and you have to:

- Change your query to point to the view
- Use the WITH (NOEXPAND) hint on your query to force SQL Server to use not just the view, but the index on the view
- Do a little dance to the indexed view gods

3.1 p36

Indexed view fine print

View must be created with schemabinding
- References only tables in the same database
- No outer joins, self joins, or subqueries
- No OVER clause (or ranking/windowing functions)
- No OUTER or CROSS APPLY

If you're grouping (most common use)
- The view must contain a COUNT_BIG column
- No HAVING
- No MIN, MAX, TOP, or ORDER BY

The clustered index on the view must be unique

Lots more rules – Books Online has a full list:
- BrentOzar.com/go/viewrules

3.1 p37

Indexed view limitations

"Why isn't SQL using my indexed view?" ← asks everyone who tries this feature

There's an Enterprise Edition feature to match queries with the view automatically

- Watch your query plans closely– it may not use the view as often as you want
- Even in EE, you may often need to reference the view by name and add a NOEXPAND hint

Every indexed view (and nonclustered index you add to an indexed view) adds overhead:

- More writes for each insert/update/delete
- More to check for corruption

3.1 p38

Indexed views have overhead.

Just like regular nonclustered indexes, they slow down DUI operations.

If the view spans multiple tables, then data modification causes serializable range locks, too:

https://www.brentozar.com/archive/2018/09/locks-taken-during-indexed-view-modifications/

3.1 p39

Indexed view corruption

This is the worst kind of corruption:
you can still query it, but it returns null when there's really valid data

To detect the corruption, you have to run DBCC CHECKDB with EXTENDED_LOGICAL_CHECKS for compatibility level 110 and higher

One clue that you might be at risk: if there's not an obvious set of columns that makes a unique clustering key, such as a set of GROUP BY columns, the view might be at risk

Read more in Paul White's post:
http://sqlperformance.com/2015/04/sql-indexes/an-indexed-view-bug-with-scalar-aggregates

3.1 p41

Say we have a legacy app.

It doesn't trust the contents of the data.

It LTRIM/RTRIMs everything.

We can't change the code.

```
200 SELECT *
201   FROM dbo.Users
202   WHERE LTRIM(RTRIM(DisplayName)) = 'Brent Ozar';
203 GO
204
205 /* Will it use an index on DisplayName? */
206 CREATE INDEX IX_DisplayName ON dbo.Users(DisplayName);
207 GO
```

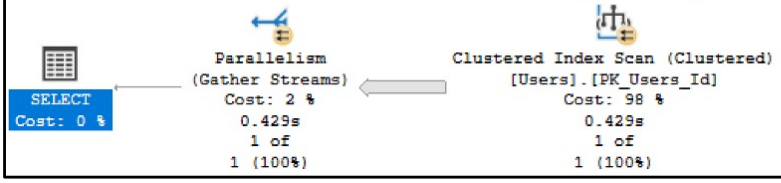
Diabolical.

```
200  SELECT *
201    FROM dbo.Users
202    WHERE LTRIM(RTRIM(DisplayName)) = 'Brent Ozar';
203  GO
204
205  /* Will it use an index on DisplayName? */
206  CREATE INDEX IX_DisplayName ON dbo.Users(DisplayName);
207  GO
```

150 %

Results | Messages | Execution plan

```
Query 1: Query cost (relative to the batch): 100%
SELECT * FROM dbo.Users WHERE LTRIM(RTRIM(DisplayName)) = 'Brent Ozar'
```

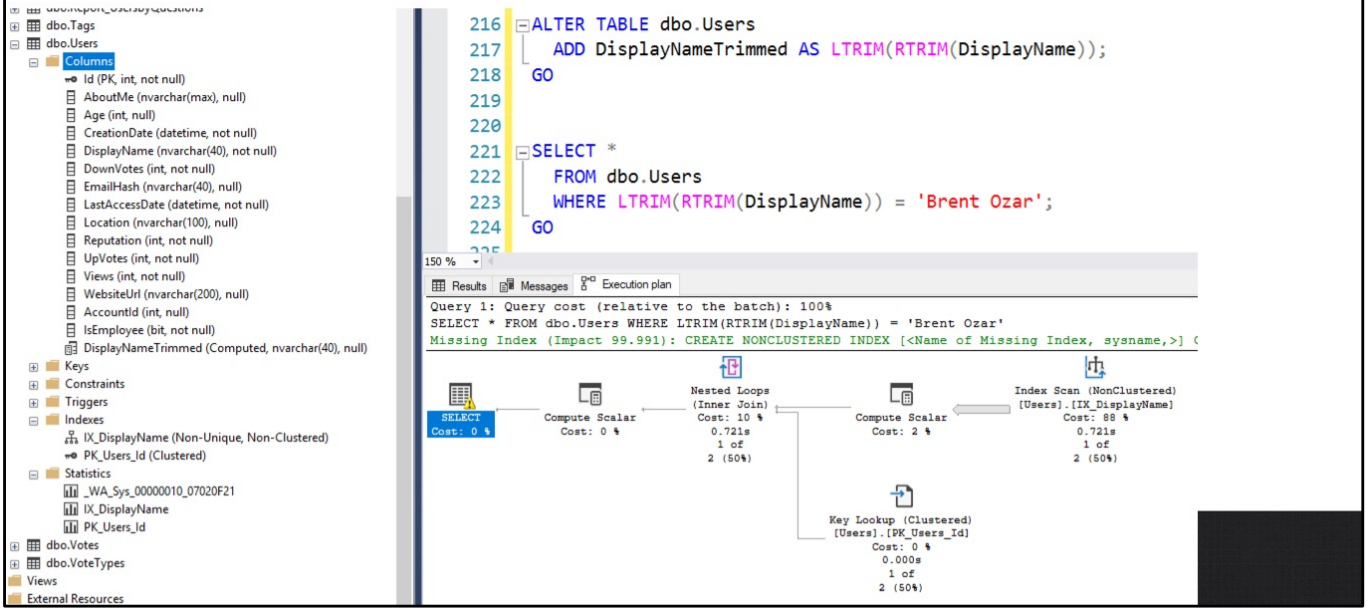


The 3 problems

1. Our estimates may be way off
2. We're ignoring nonclustered indexes
3. We're not getting index seeks

3.1 p45

Step 1: add a computed column.



There's a lot to take in here.

This really does add a new column to the table.

I did NOT persist it for a bunch of reasons:

- It's a metadata-only change
- It finishes nearly instantly with low blocking
- Doesn't need to rewrite all of the 8KB pages, so no big logging problems either
- I didn't *need* to persist it:
  suddenly the query scans the index!

3.1 p47

We fixed problem #1 and #2

1. Our estimates may be way off
2. We're ignoring nonclustered indexes
3. We're not getting index seeks

If we want to fix #3, we need an index on the new computed column.

3.1 p48

Index the computed field.

Create a nonclustered index on it:

```
CREATE INDEX IX_DisplayNameTrimmed
  ON dbo.Users(DisplayNameTrimmed);
```

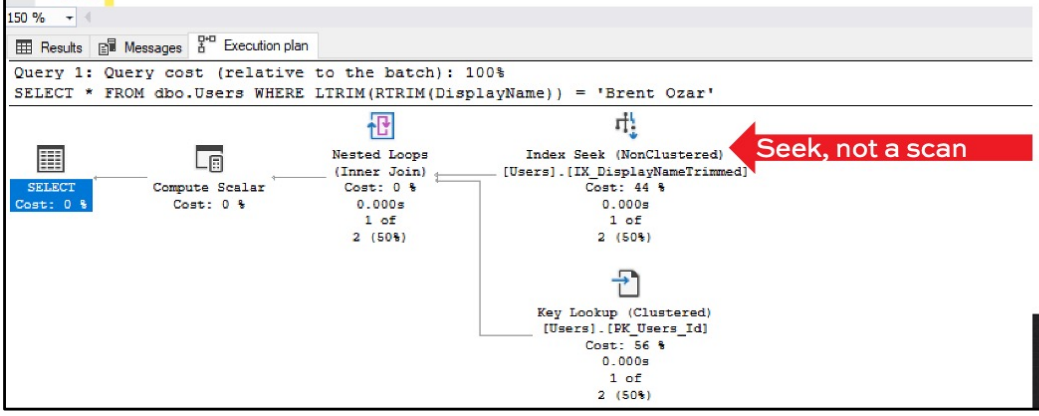
This persists the computed field's data in the index, but not in the clustered index of the table.

This isn't a metadata-only operation: we're actually creating data pages.

3.1 p49

Pardon my French, but voila!

```
227  CREATE INDEX IX_DisplayNameTrimmed ON dbo.Users(DisplayNameTrimmed);
228  GO
229  SELECT *
230    FROM dbo.Users
231    WHERE LTRIM(RTRIM(DisplayName)) = 'Brent Ozar';
232  GO
233
```



Fixing non-sargable queries

	Better estimates	Smaller scans	Index seeks
Add an index on the filtered field	No	Sometimes	No
Add a computed column closely matching the query's filter	Yes	Sometimes	Sometimes
Index the computed column	Yes	Usually	Usually

I can't just say "yes always" because queries are complicated: for example, if you're doing a SELECT * and getting >5% of the rows, you're likely going to end up doing scans to avoid key lookups.

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Here's the magic

Queries can pick up the indexed computed column without directly referring to it by name

- SQL Server matches the computation in the query to the computation in the computed column
- Then it can use the index on it

Computed columns can also generate statistics that improve estimates and get better plans

This allow you to optimize some queries without changing their syntax!

3.1 p52

Indexed computed column perks

Works in Standard Edition

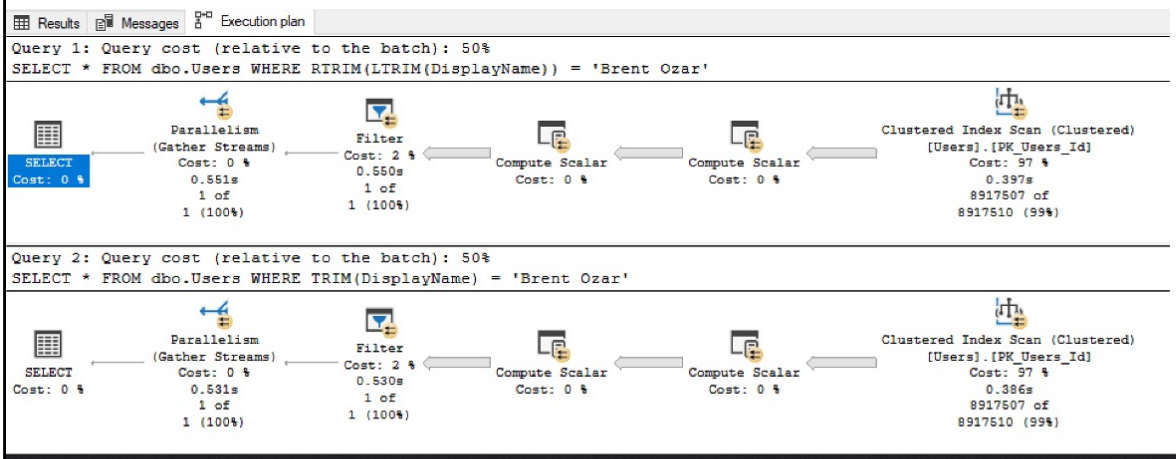
Works in SQL Server 2005+

Can optimize code without requiring code changes in the app

3.1 p53

Drawbacks: it's gotta match

If I change it to RTRIM/LTRIM, or TRIM, no go:



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What we learned

Look for these app symptoms

1. Frequently queries small subset of rows: Filtered Indexes
2. App frequently queries an aggregation on low or moderate write tables: Indexed Views
3. App frequently queries computations, but can't write this computation in the table itself: Indexed Computed Columns

3.1 p56

Don’t overuse these.

90% of the time, you just need plain ol’ clustered & nonclustered indexes.

9% of the time, getting creative with the 5 & 5 guideline is enough.

This is about the 1%.

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