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新一代面向数据仓库索引技术概览

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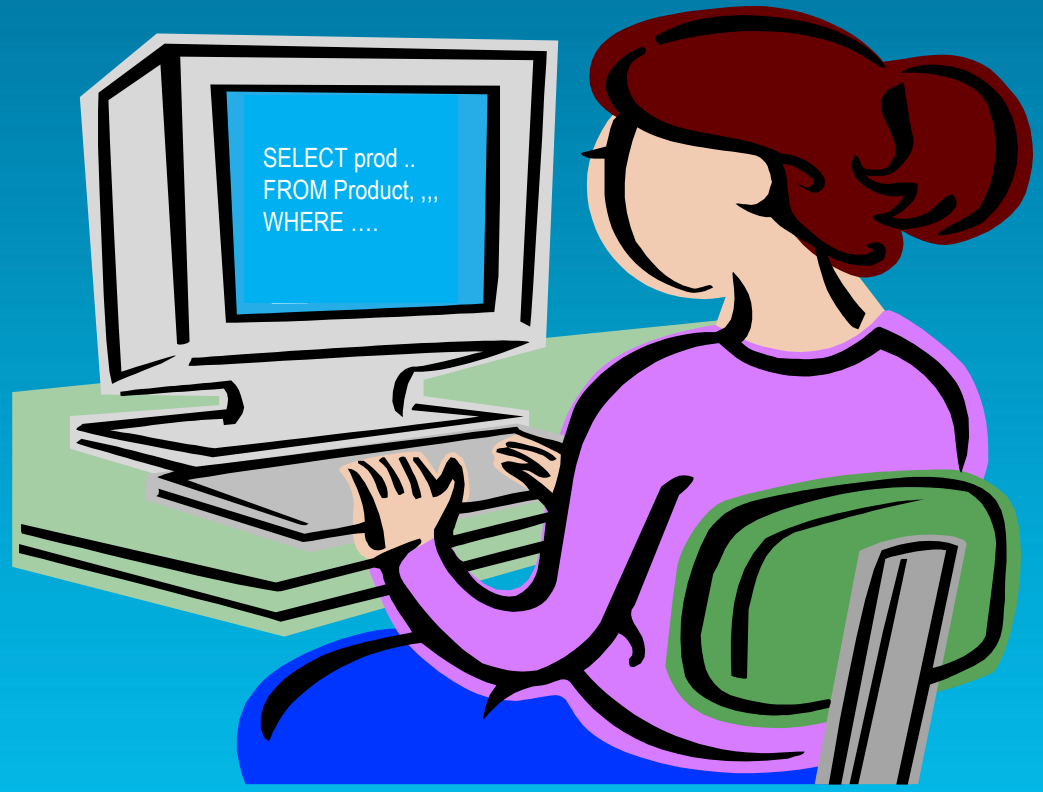
Alice, Today

Alice, Today

Alice, Today



Alice, Today

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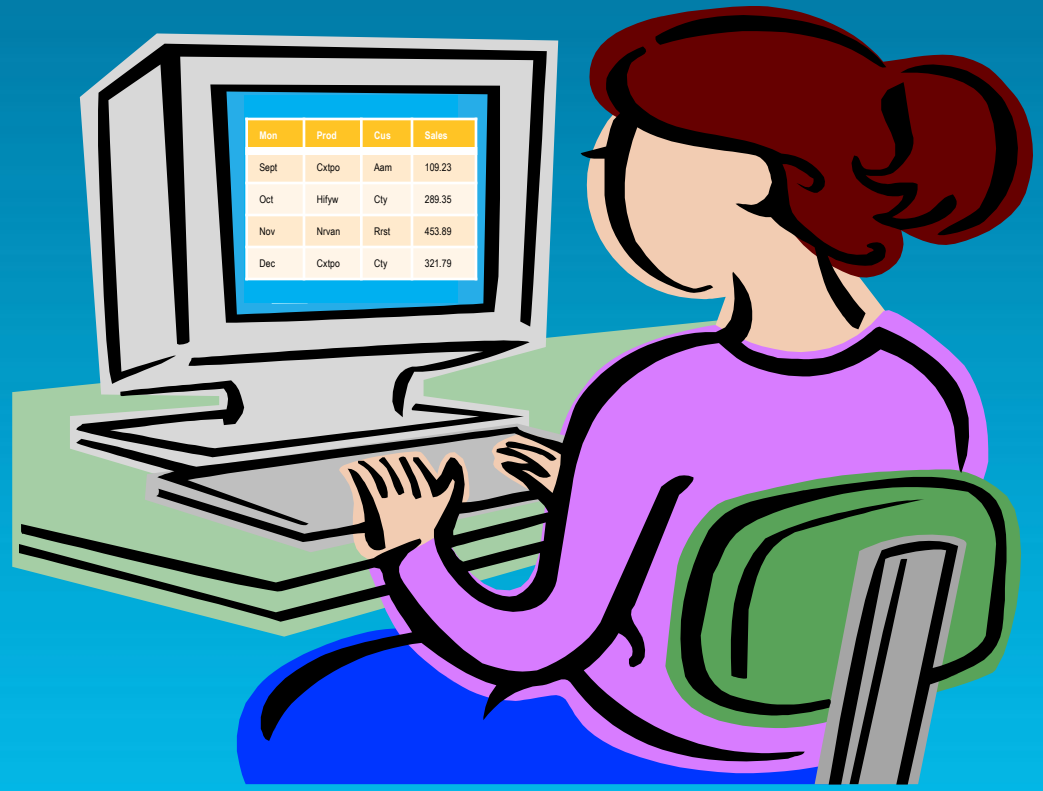
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Alice, Today


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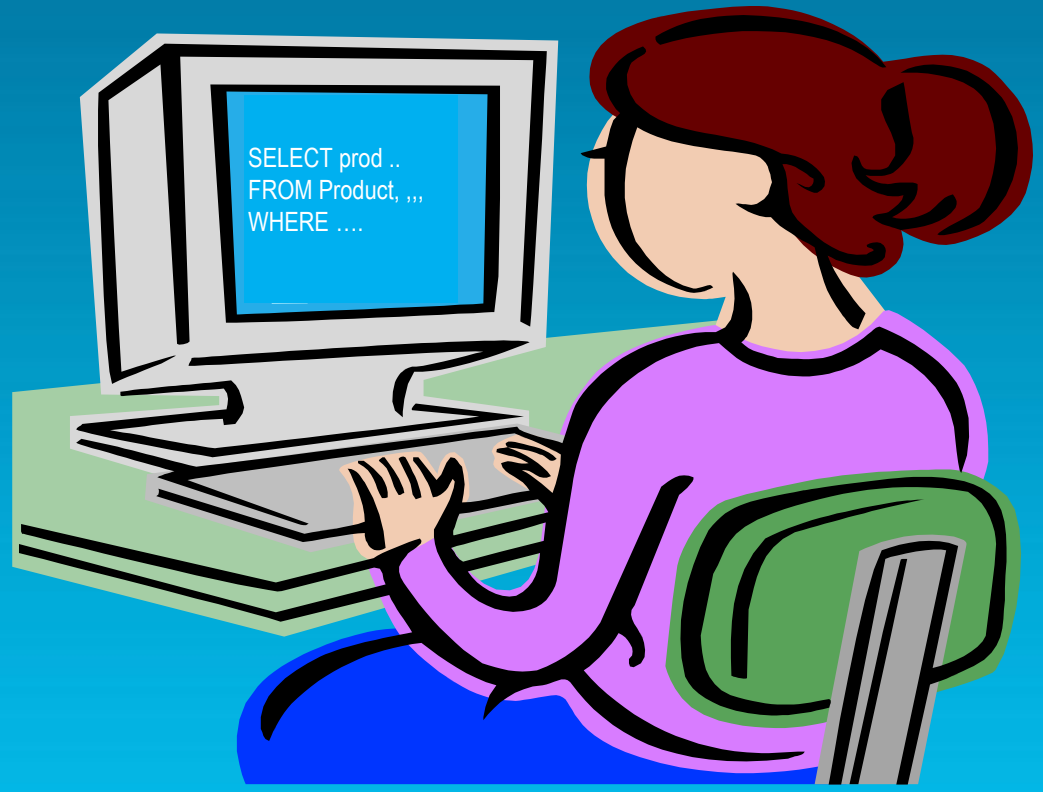
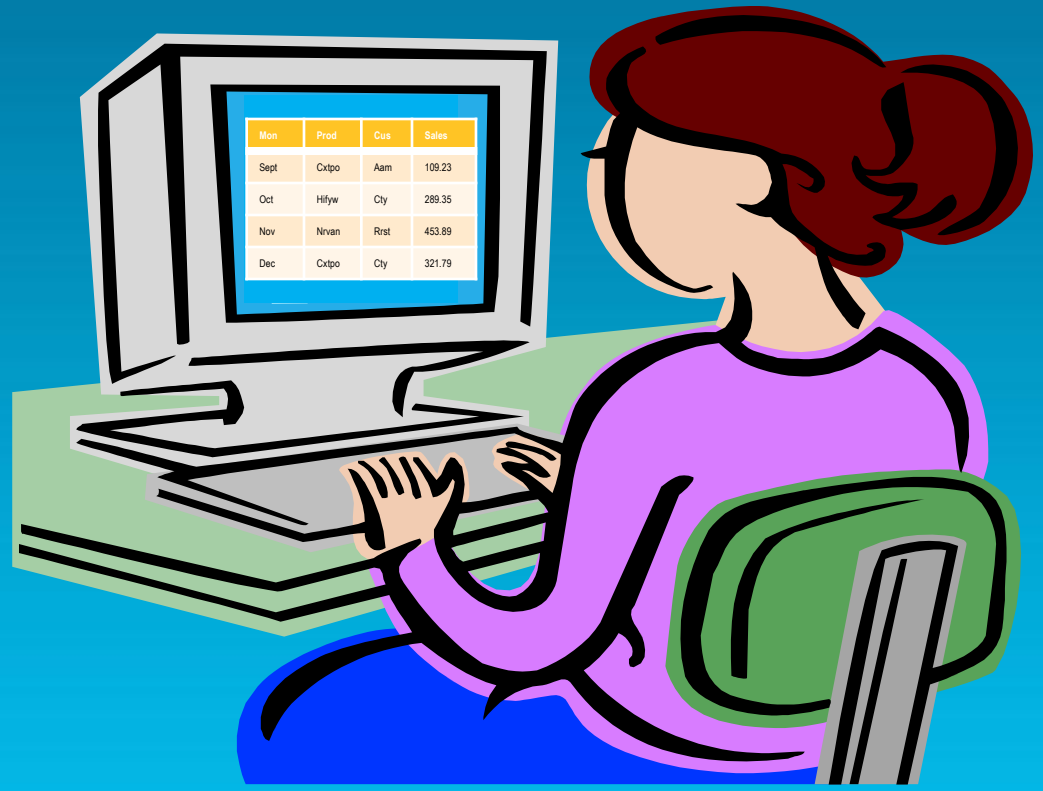
Alice, Tomorrow

Alice, Tomorrow



Alice, Tomorrow



Alice, Tomorrow

Alice, Tomorrow

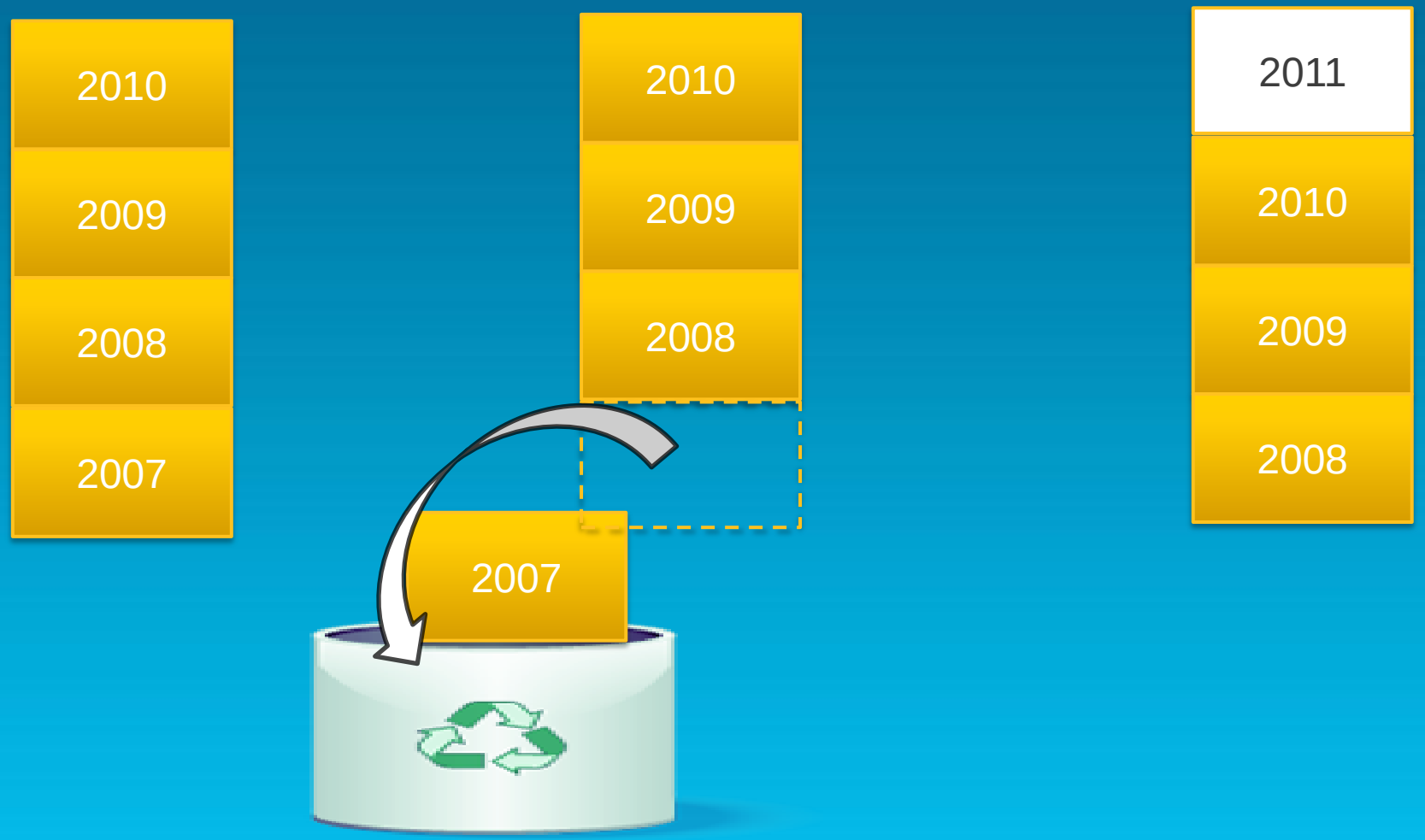
Project Apollo

- Accelerates data warehouse queries
  - New columnstore index
  - Improved query execution
- Makes SQL Server more interactive
- Easy to use
- Reduces TCO

Data warehouse workload

- Read-mostly
  - Load large amounts of data
  - Append new data incrementally
  - Rarely update existing data
  - Often retain data for given time (e.g. 1, 3, 7 yrs)
    - Sliding window data management

Sliding window



Data warehouse schemas and queries

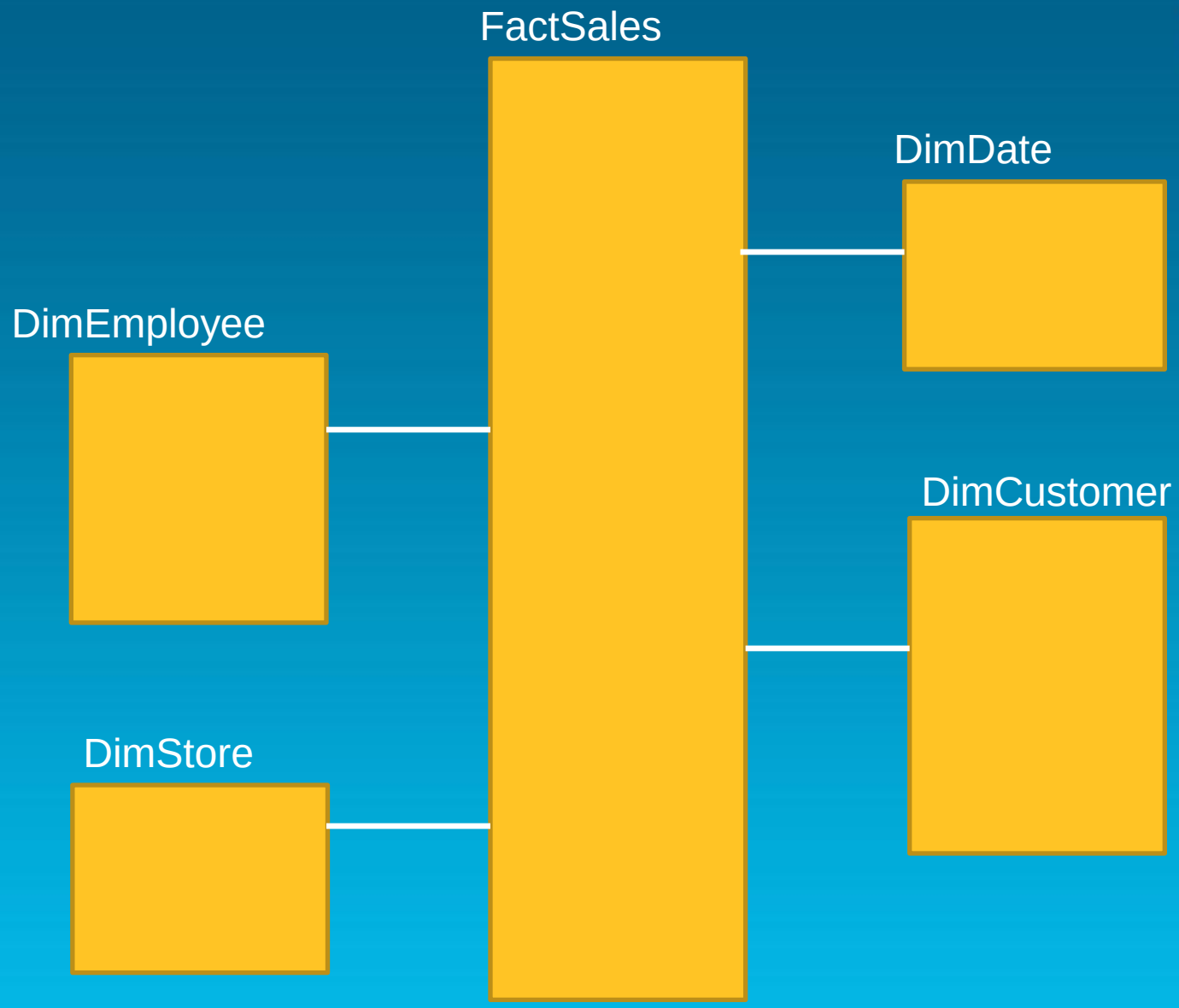
- Star schema
  - Fact tables ← put columnstore indexes here
  - Dimension tables
- Star joins
- Most queries aggregate data

Star schema

FactSales(CustomerKey int,
ProductKey int,
EmployeeKey int,
StoreKey int,
OrderDateKey int,
SalesAmount money)

DimCustomer(CustomerKey int,
FirstName nvarchar(50),
LastName nvarchar(50),
Birthdate date,
EmailAddress nvarchar(50))

DimProduct …



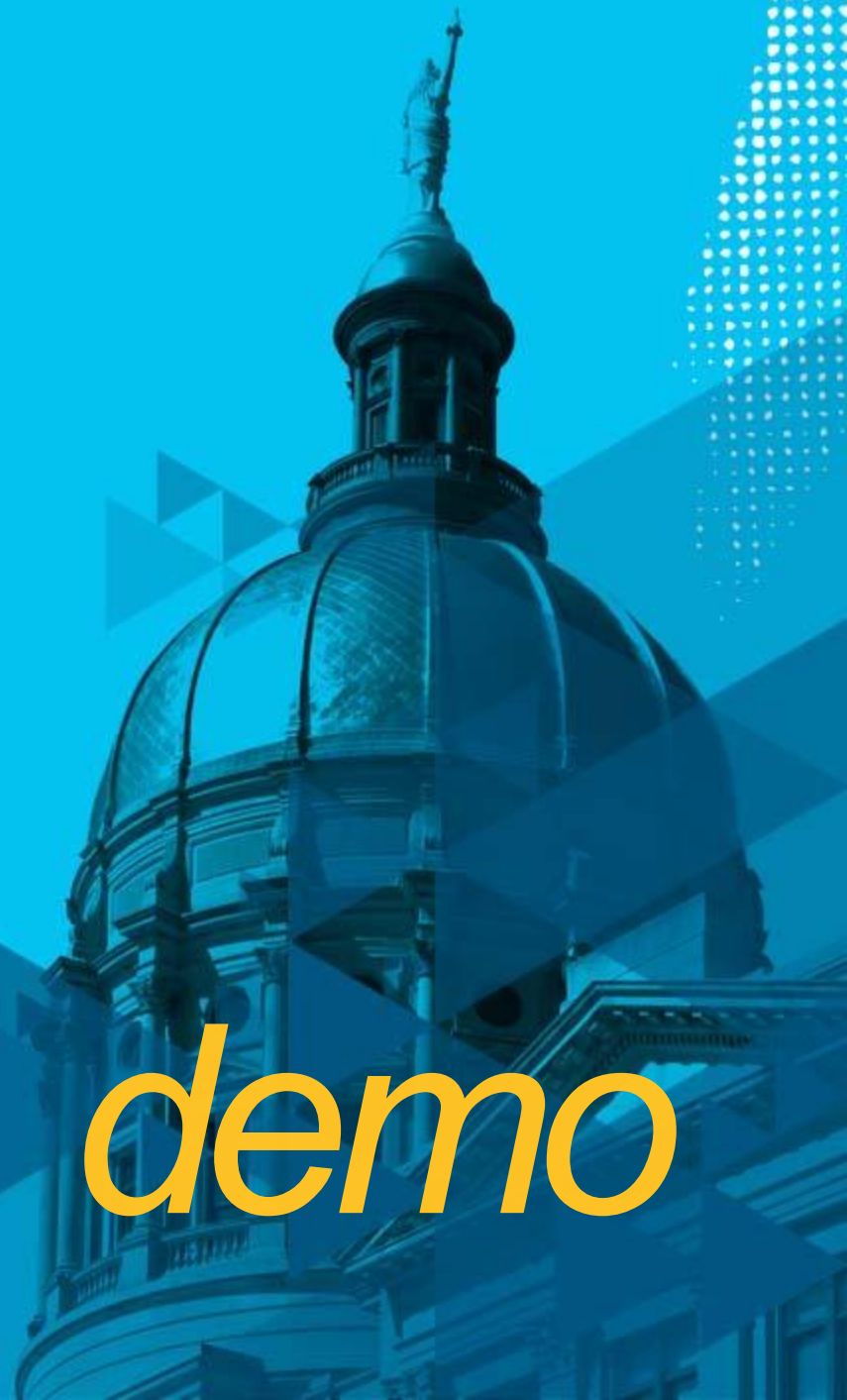
Star join query

```
SELECT TOP 10 p.ModelName, p.EnglishDescription,
      SUM(f.SalesAmount) as SalesAmount
FROM FactResellerSalesPart f, DimProduct p, DimEmployee e
WHERE f.ProductKey=p.ProductKey
      AND e.EmployeeKey=f.EmployeeKey
      AND f.OrderDateKey >= 20030601
      AND p.ProductLine = 'M' -- Mountain
      AND p.ModelName LIKE '%Frame%'
      AND e.SalesTerritoryKey = 1
GROUP BY p.ModelName, p.EnglishDescription
ORDER BY SUM(f.SalesAmount) desc;
```

“Typical” data warehouse queries

- Process large amounts of data
- Reporting queries
- Often slow (minutes to hours)
- DBAs spend considerable effort
  - Designing indexes, tuning queries
  - Building summary tables, indexed views, OLAP cubes

Query Acceleration With Columnstore Indexes

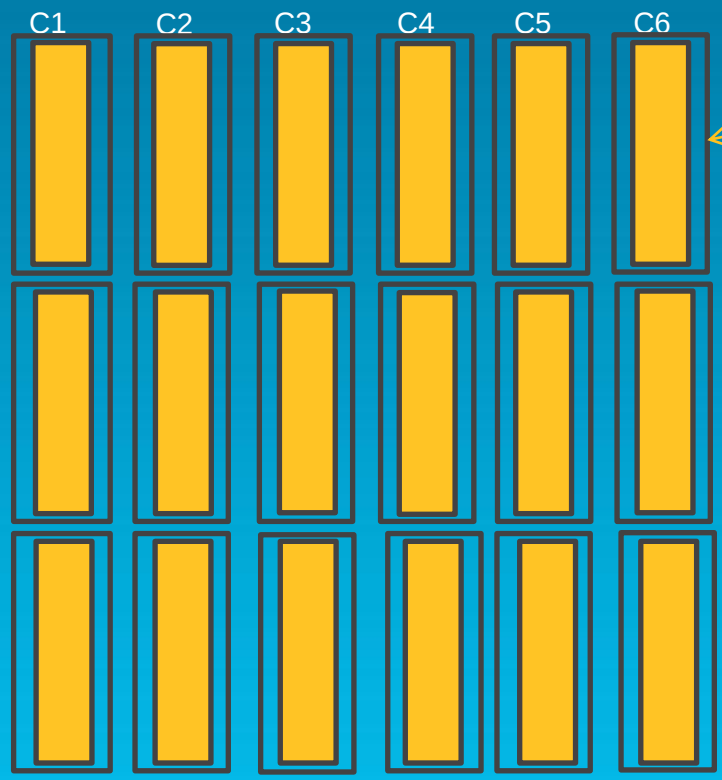


demo

Columnar storage structure

Row store:

Column store:

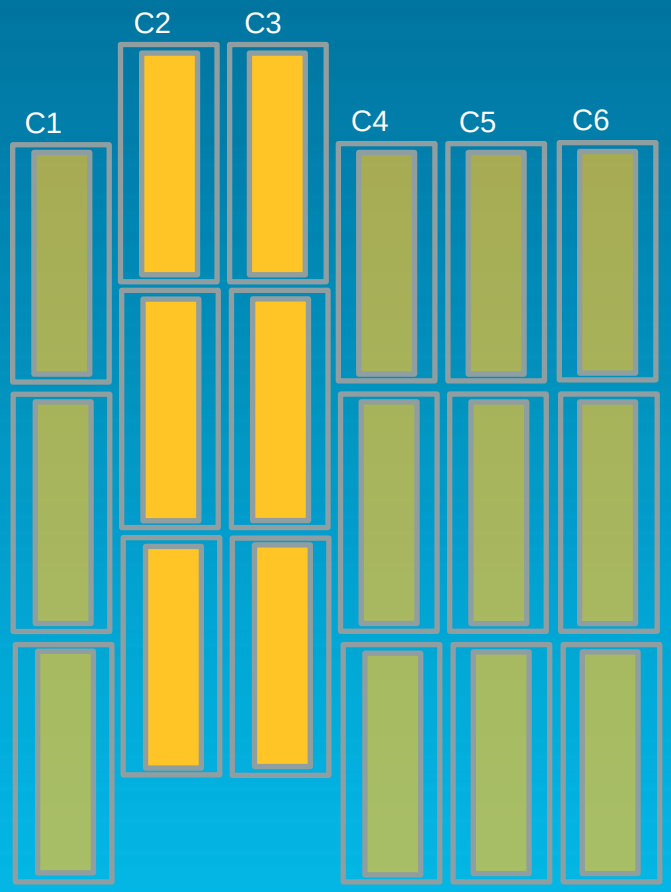


Pages

Uses VertiPaq compression

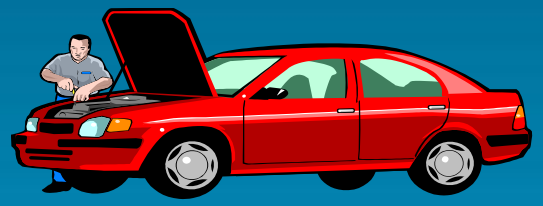
Reduced I/O using columnstore indexes

SELECT region, sum (sales) …



- Fetches only needed columns from disk
- Columns are compressed
- Less IO
- Better buffer hit rates

Advanced query execution technology



- Batch mode execution of some operations
  - Processes rows in batches
  - Groups of batch operations in query plan
- Efficient data representation
- Highly efficient algorithms
- Better parallelism

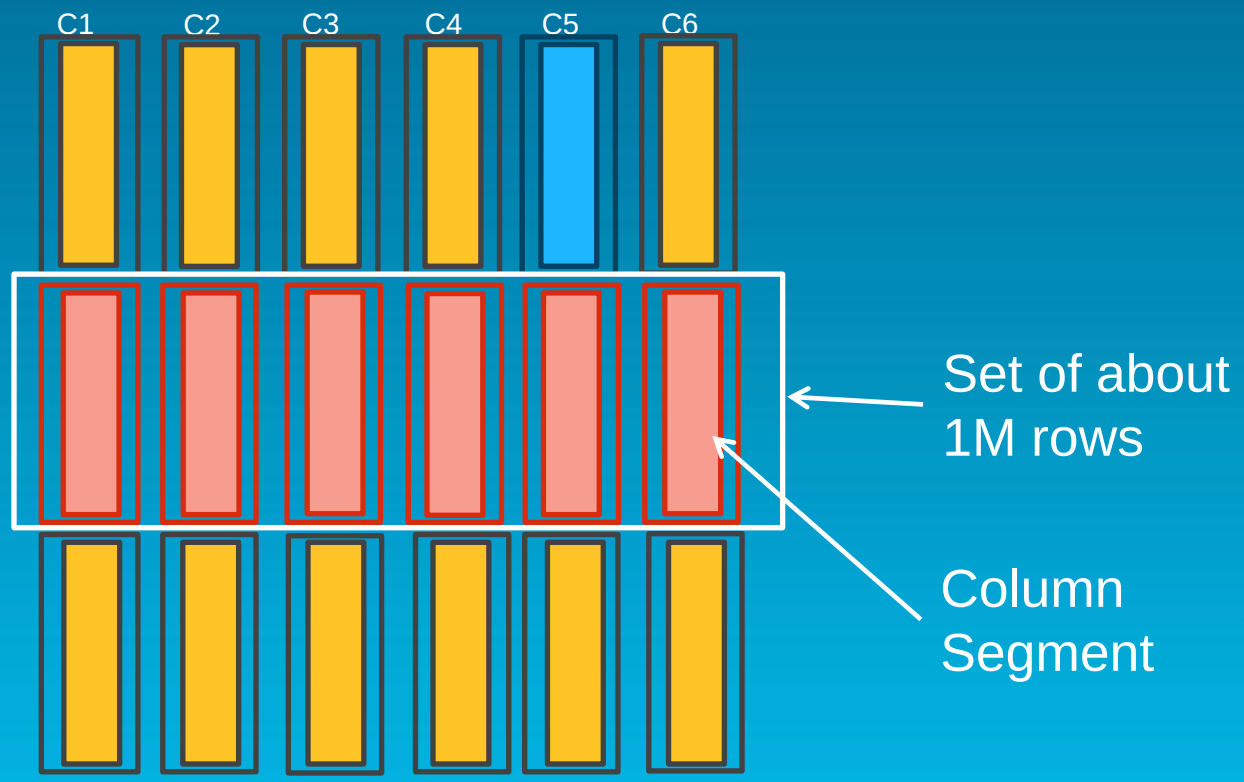
Batch Mode: Performance Gains

- Depends on query, data characteristics, etc.
  - Limited by how much of query plan uses columnstore & batch processing; may achieve 100x speed up
- 1 TB version of TPC-DS DB 32 proc, 256 GB RAM

```
SELECT w_city, w_state, d_year, SUM(cs_sales_price) AS cs_sales_price
FROM warehouse, catalog_sales, date_dim
WHERE w_warehouse_sk = cs_warehouse_sk and cs_sold_date_sk = d_date_sk
     and w_state = 'SD' and d_year = 2002
GROUP BY w_city, w_state, d_year
ORDER BY d_year, w_state, w_city;
```

	Cold Buffer Pool		Warm Buffer Pool	
	CPU	**Elapsed**	**CPU**	**Elapsed**
Row store	259 s	20 s	206 s	3.1 s
Columnstore + batch	19.8 s	0.8 s	16.3 s	0.3 s
Speedup	13 X	25 X	13 X	10 X

Column segments



- Column segment contains values from one column for a set of about 1M rows
- Column segments are compressed
- Each column segment stored in separate LOB
- Column segment is unit of transfer from disk

Constraints on use with other indexes & partitioning

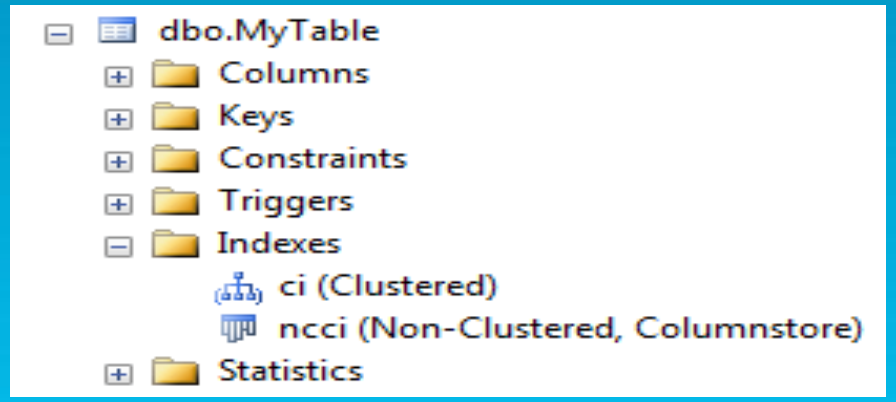
- Base table must be clustered B-tree or heap
- Columnstore index:
  - nonclustered
  - one per table
  - must be partition-aligned
  - not allowed on indexed view
  - can’t be a filtered index

Creating the columnstore index

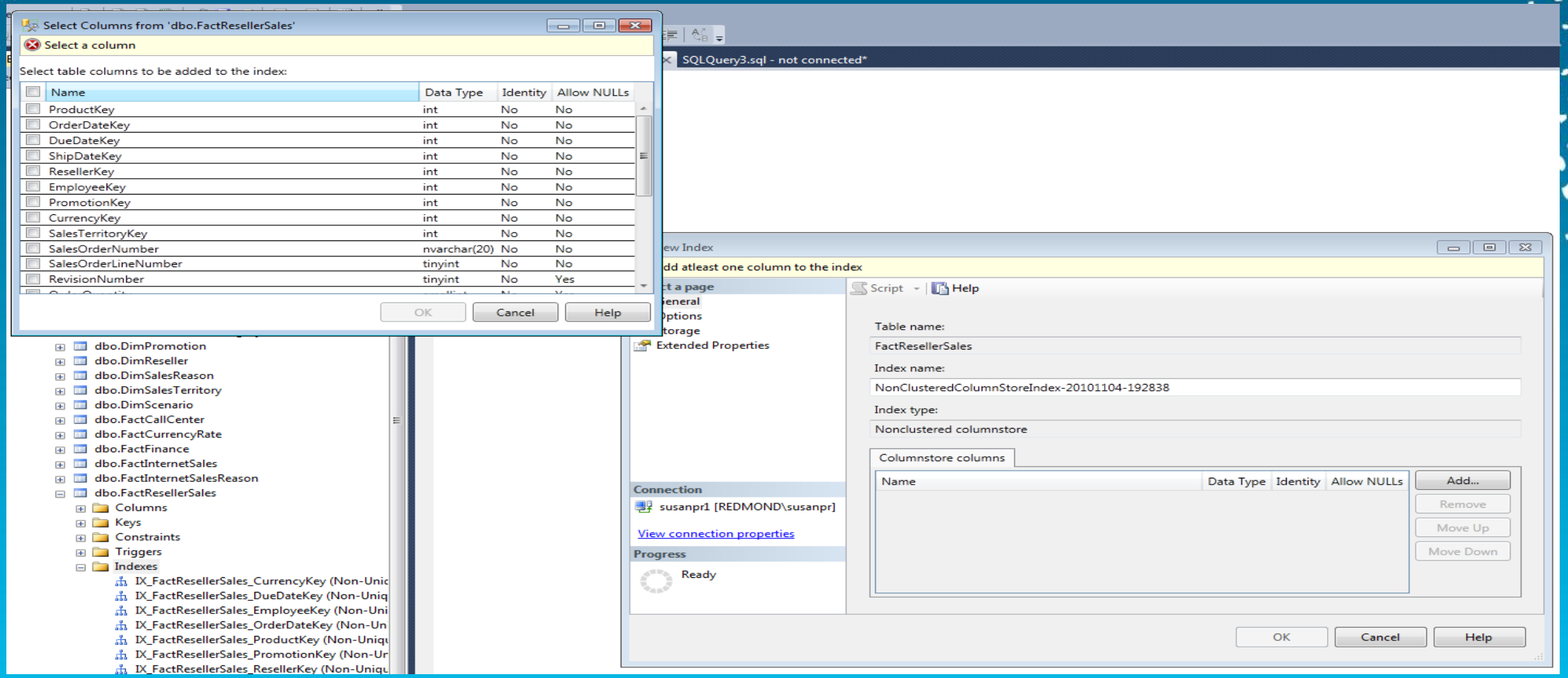
- Create the table
- Load data into the table
- Create a non-clustered columnstore index on all, or some, columns

```
CREATE NONCLUSTERED COLUMNSTORE INDEX ncci ON myTable(OrderDate, ProductID,
SaleAmount)
```

Object Explorer



Index dialog makes index creation easy



Query optimization with columnstores

- Cost-based
- Optimizer chooses index
- Optimizer chooses batch mode operators

Using hints with columnstore indexes

- use the columnstore index

```
select distinct (SalesTerritoryKey)
from dbo.FactResellerSales with (index (ncci))
```

- use a different index

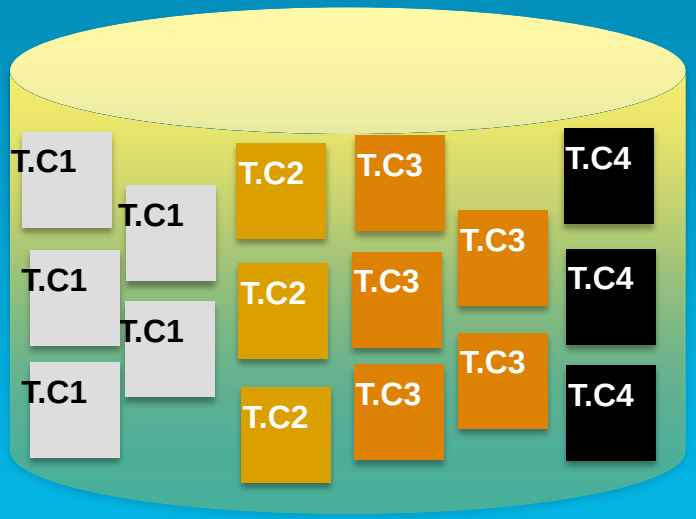
```
select distinct (SalesTerritoryKey)
from dbo.FactResellerSales with (index (ci))
```

- ignore columnstore

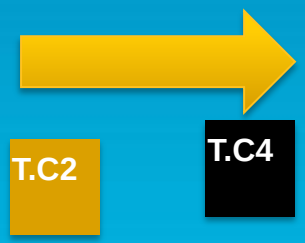
```
select distinct (SalesTerritoryKey)
from dbo.FactResellerSales
option(ignore_nonclustered_columnstore_index)
```

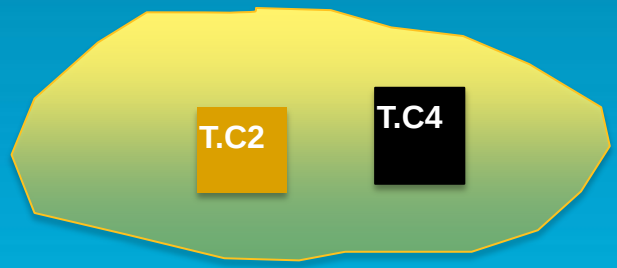
Memory management

- Memory management is automatic
- Columnstore persisted on disk
- Needed columns fetched into memory
- Column segments flow between disk and memory

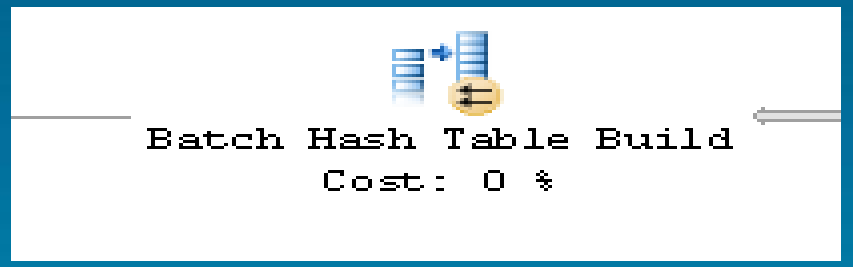


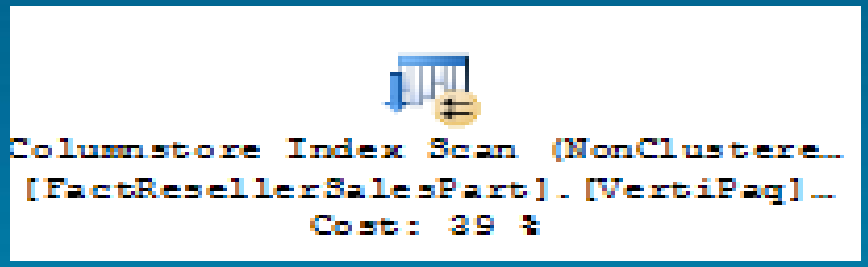

```
SELECT C2, SUM(C4)
FROM T
GROUP BY C2;
```

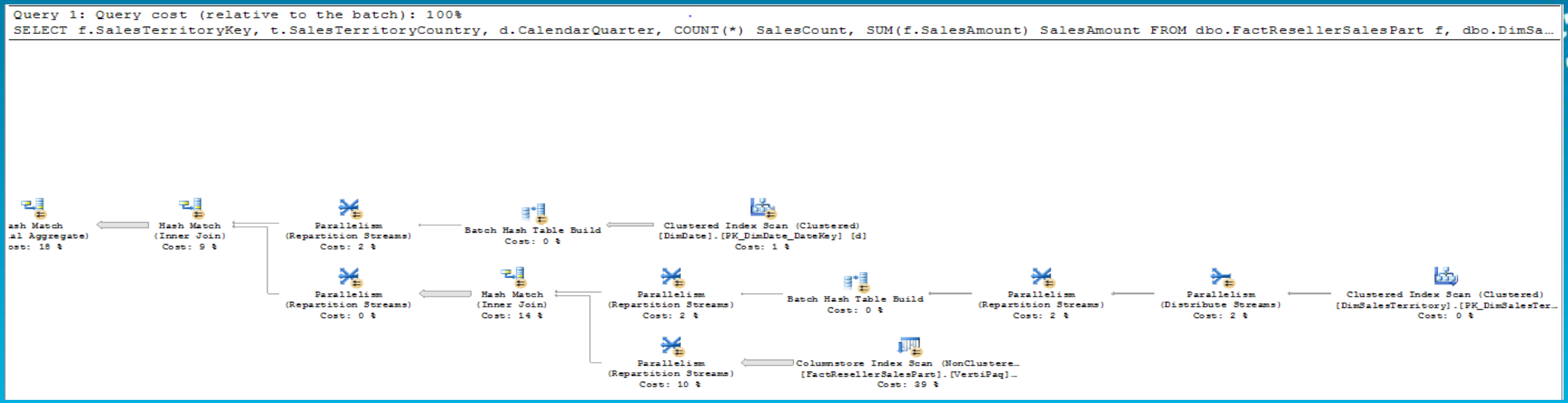


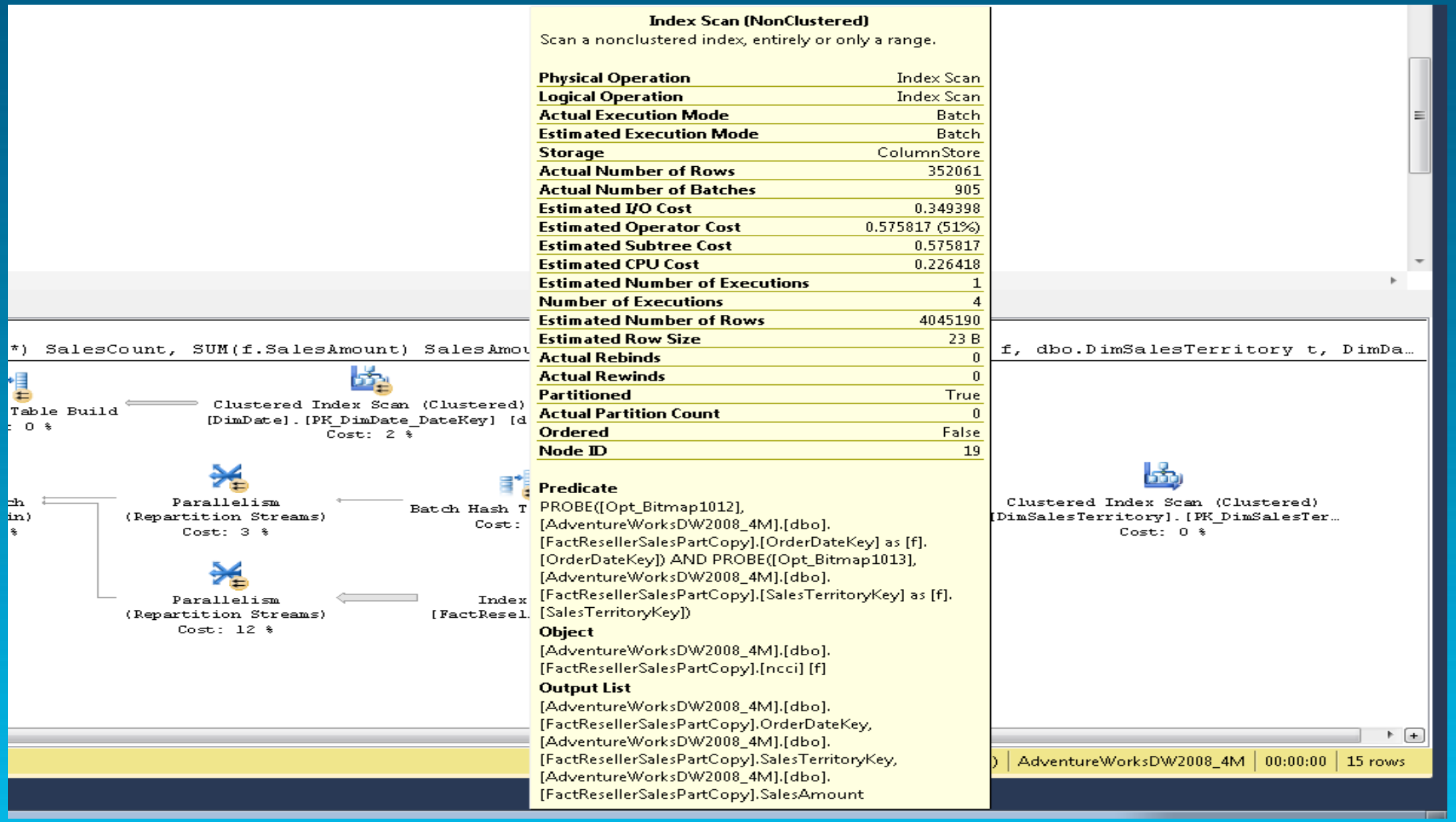


New showplan elements for columnstores and batch processing








Index Scan (NonClustered)
Scan a nonclustered index, entirely or only a range.
Physical Operation Index Scan
Logical Operation Index Scan
Actual Execution Mode Batch
Estimated Execution Mode Batch
Storage ColumnStore
Actual Number of Rows 352061
Actual Number of Batches 905
Estimated I/O Cost 0.349398
Estimated Operator Cost 0.575817 (51%)
Estimated Subtree Cost 0.575817
Estimated CPU Cost 0.226418
Estimated Number of Executions 1
Number of Executions 4
Estimated Number of Rows 4045190
Estimated Row Size 23 B
Actual Rebinds 0
Actual Rewinds 0
Partitioned True
Actual Partition Count 0
Ordered False
Node ID 19
Predicate
PROBE([Opt_Bitmap1012], [AdventureWorksDW2008_4M].[dbo].[FactResellerSalesPartCopy].[OrderDateKey] as [f].[OrderDateKey]) AND PROBE([Opt_Bitmap1013], [AdventureWorksDW2008_4M].[dbo].[FactResellerSalesPartCopy].[SalesTerritoryKey] as [f].[SalesTerritoryKey])
Object
[AdventureWorksDW2008_4M].[dbo].[FactResellerSalesPartCopy].[ncci] [f]
Output List
[AdventureWorksDW2008_4M].[dbo].[FactResellerSalesPartCopy].OrderDateKey, [AdventureWorksDW2008_4M].[dbo].[FactResellerSalesPartCopy].SalesTerritoryKey, [AdventureWorksDW2008_4M].[dbo].[FactResellerSalesPartCopy].SalesAmount
*) SalesCount, SUM(f.SalesAmount) SalesAmou
f, dbo.DimSalesTerritory t, DimDa…
Table Build
: 0 %
Clustered Index Scan (Clustered)
[DimDate].[PK_DimDate_DateKey] [d
Cost: 2 %
Parallelism
(Repartition Streams)
Cost: 3 %
Batch Hash T
Cost:
Parallelism
(Repartition Streams)
Cost: 12 %
Index
[FactResel
Clustered Index Scan (Clustered)
[DimSalesTerritory].[PK_DimSalesTer…
Cost: 0 %
AdventureWorksDW2008_4M
00:00:00
15 rows

Columnstore index catalog tables

```
select name, object_id, index_id, type_desc, number_of_segments from sys.column_store_index_stats;
```

100 %

Results | Messages

	name	object_id	index_id	type_desc	number_of_segments
1	VertiPaq	114099447	6	NONCLUSTERED COLUMNSTORE	4250

```
select hobt_id, column_id, segment_id, row_count, on_disk_size from sys.column_store_segments;
```

100 %

Results | Messages

	hobt_id	column_id	segment_id	row_count	on_disk_size
1	72057594103922688	1	0	1048576	1141968
2	72057594103922688	1	1	1048576	1135464
3	72057594103922688	1	2	1048576	1143176

```
select hobt_id, column_id, dictionary_id, on_disk_size from sys.column_store_dictionaries;
```

100 %

Results | Messages

	hobt_id	column_id	dictionary_id	on_disk_size
1	72057594103922688	1	0	9720
2	72057594103922688	2	0	1204
3	72057594103922688	3	0	1336

Columnstore indexes: interoperability with the rest of SQL Server

- Most things “just work” with columnstore indexes
  - Backup and restore
  - Mirroring
  - Log shipping
  - SSMS
  - Administration, tools

Data type restrictions

- Unsupported types
  - decimal > 18 digits
  - Binary
  - BLOB
  - (n)varchar(max)
  - Uniqueidentifier
  - Date/time types > 8 bytes
  - CLR

Query performance restrictions

- Outer joins
- Unions
- Consider modifying queries to hit “sweet spot”
  - Inner joins
  - Star joins
  - Aggregation

Loading new data into a columnstore index

- Columnstore makes table read-only
- Partition switching allowed
- INSERT, UPDATE, DELETE, and MERGE not allowed
- Two recommended methods for loading data
- Disable, update, rebuild
- Partition switching

Adding data to a table with a columnstore index

- Method 1: Disable the columnstore index
- Disable (or drop) the index
  - ALTER INDEX my_index ON MyTable DISABLE
- Update the table
- Rebuild the columnstore index
  - ALTER INDEX my_index ON MyTable REBUILD

Adding data to a table with a columnstore index

- Method 2: Use Partitioning
- Load new data into a staging table
- Build a columnstore index
  - CREATE NONCLUSTERED COLUMNSTORE INDEX my_index ON StagingT(OrderDate, ProductID, SaleAmount)
- Split empty partition
- Switch the partition into the table
  - ALTER TABLE StagingT SWITCH TO T PARTITION 5

Advanced near-real-time append

- Partitioned table with columnstore index
- Keep copy of data from latest partition in separate row-store table S
- While(True) {
  - Append new data to S for desired period (say 15 minutes)
  - Columnstore index S
  - Swap S with newest partition
  - Drop columnstore index on S
  - Insert rows in S to “catch up” S to current time
  - }

When to build a columnstore index

- Read-mostly workload
- Most updates are appending new data
- Workflow permits partitioning or index drop/rebuild
  - Typically a nightly load window
- Queries often scan & aggregate lots of data

What tables to columnstore index

- Large fact tables
- (Maybe) very large dimension tables

When not to build a columnstore index

- Frequent updates
- Partition switching or rebuilding index doesn’t fit workflow
- Frequent small look up queries
  - B-tree indexes may give better performance
- Your workload does not benefit

Summary: Apollo in a nutshell

Columnstore technology

+

Advanced query processing

Astonishing speedup for DW queries

Thank you!

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