SQL Server Internal Storage Management

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Agenda

- SQL Server Space Allocation
- Indexes and Fragmentation
- Native SQL Server commands
- Quest Central® for Databases - SQL Server

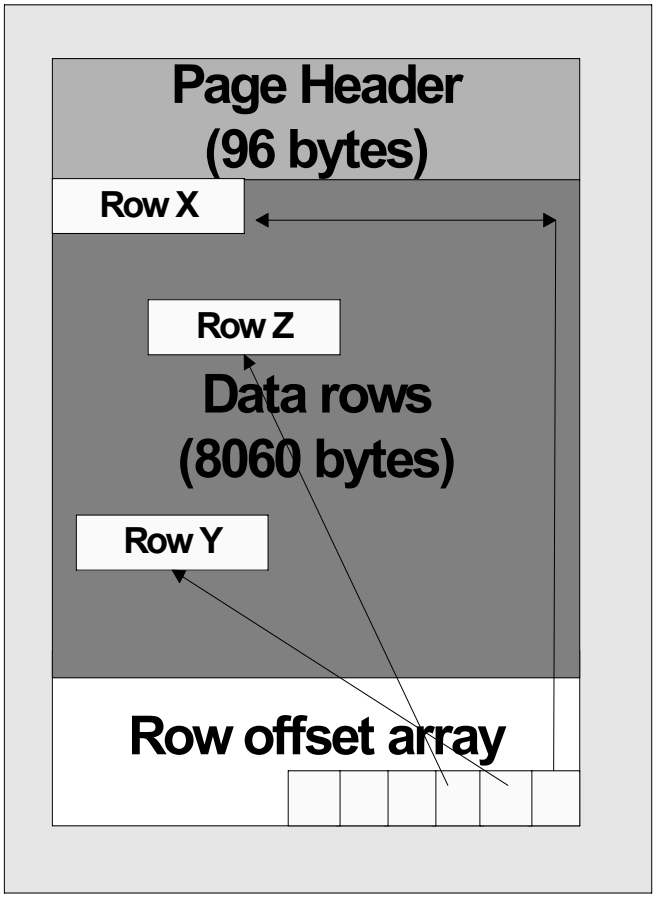
Allocation Hierarchy

- Datafiles
  - Datafiles are allocated to a database
- Extents
  - The unit of measurement used to allocate and de-allocate space to objects
- Pages
  - An Extent is made up of logical grouping of a smaller unit called a *Page*

Pages

- A page is the smallest unit that SQL Server uses for storing data
- A page is 8k bytes in size (8192 bytes)
- There are 128 pages in 1MB
- SQL Server stores allocation information in certain page types

Pages


Page Header
(96 bytes)
Row X
Row Z
Data rows
(8060 bytes)
Row Y
Row offset array

DBCC PAGE

```
PAGE: (1:90)
------------

BUFFER:
-------

BUF @0x00E0E680
---------------
bpage = 0x19AF4000       bhash = 0x00000000       bpageno = (1:90)
bdbid = 6                breferences = 1          bstat = 0x209
bspin = 0                bnext = 0x00000000

PAGE HEADER:
------------

Page @0x19AF4000
----------------
m_pageId = (1:90)        m_headerVersion = 1      m_type = 2
m_typeFlagBits = 0x0     m_level = 0              m_flagBits = 0x2
m_objId = 3              m_indexId = 2            m_prevPage = (1:76)
m_nextPage = (1:368)     pminlen = 9              m_slotCnt = 117
m_freeCnt = 3794         m_freeData = 7720        m_reservedCnt = 0
m_lsn = (23:347:12)      m_xactReserved = 0       m_xdesId = (0:0)
m_ghostRecCnt = 0        m_tornBits = 293015309

Allocation Status
-----------------
GAM (1:2) = ALLOCATED     SGAM (1:3) = NOT ALLOCATED
PFS (1:1) = 0x60 MIXED_EXT ALLOCATED   0_PCT_FULL   DIFF (1:6) =
CHANGED
ML (1:7) = NOT MIN_LOGGED

DATA:
-----

Slot 0, Offset 0x60
-------------------
Record Type = INDEX_RECORD
Record Attributes =  VARIABLE_COLUMNS
19AF4060:  020f2126  02000007  23000100  72005000 &!.....#.P.r
19AF4070:  64006f00  63007500  4e007400  6d006100 .o.d.u.c.t.N.a.m
19AF4080:    006500                        .e.

Slot 1, Offset 0x84
-------------------
Record Type = INDEX_RECORD
```

DBCC PAGE

- Undocumented DBCC command
  - DBCC TRACEON(3604)
  - Go
  - DBCC PAGE(Northwind , 1, 90, 1)
  - GO
- Additional information
  - DBCC TRACEON(2520)
  - GO
  - DBCC HELP(PAGE)
  - Go

DBCC PAGE Parameters

Parameter	Description
dbid / dbname	Database ID / Database name
filenum	Datafile number that contains the page
pagenum	The page number within the file. The page number could be obtained by using another undocumented DBCC command: DBCC EXTENTINFO(DB_Name, table_Name, Index_name).
printopt	0ptional parameter and can accept any of the following:: Default – Returns the buffer header and the page header 1: Returns the buffer and page headers, each row separately, and the row offset table 2: Returns the buffer and page headers, whole page and the offset table 3: Returns the buffer and page headers, each row separately, and the row offset table. Each row and its column values listed separately

Extents

- Uniform Extent
  - All pages belong to the same object
- Mixed Extent
  - Pages could belong to multiple objects

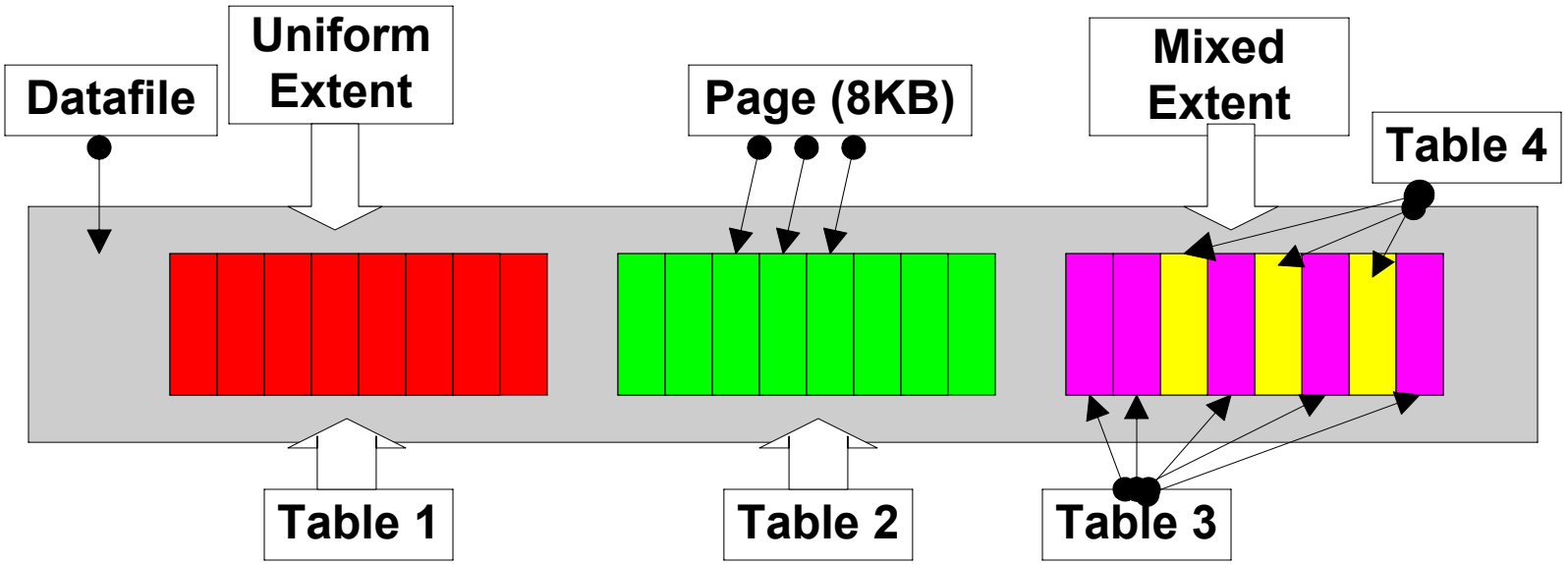
Datafiles and Filegroups

- Datafiles – Operating System files that map the database
- Filegroups – A file group is a logical grouping of datafiles.

RAID

- RAID solutions are usually the best choice for SQL Server
  - RAID-1 (Mirroring)
  - RAID-5 (Striping with parity)

Datafile, Pages and Extents



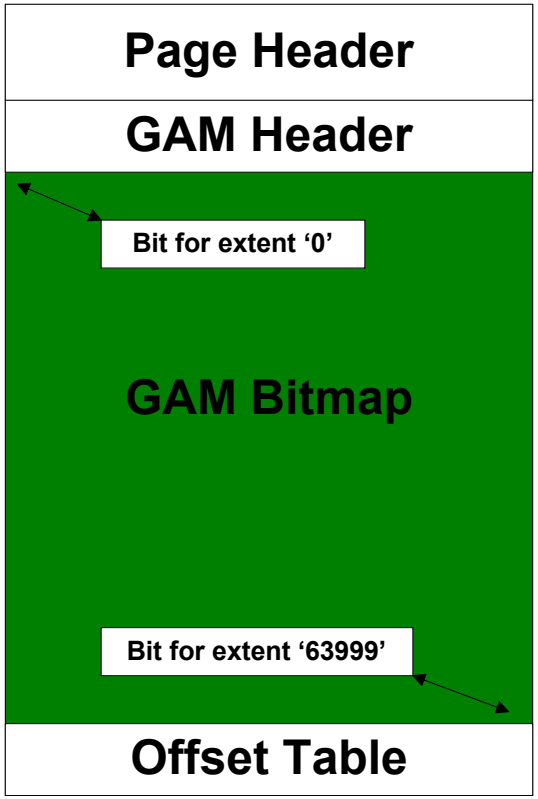
Allocation Management

- SQL Server uses bitmaps to manage allocation information
- Bit per Extent:
  - Global Allocation Map (GAM)
  - Shared Global Allocation Map (SGAM)
  - Index Allocation Map (IAM)
- Byte per page:
  - Page Free Space (PFS)

Global Allocation Map Pages (GAM)

- A GAM page reports whether an extent is free or allocated
- Each GAM page contains information up to 64,000 extents
  - 4GB of data
- GAM pages reside on Page 2 of each data file

GAM Pages


Page Header
GAM Header
Bit for extent '0'
GAM Bitmap
Bit for extent '63999'
Offset Table

Shared Global Allocation Map pages (SGAM)

- SGAM pages record which extents are currently used as mixed extents and have at least one unused page
- Each GAM page contains information up to 64,000 extents, which is 4GB of data
- SGAM pages reside on Page 3 of each data file

GAM and SGAM Pages

Current Status of an Extent	GAM bit setting	SGAM bit setting
Free Extent	1	0
Uniform extent or a Mixed Extent that is full	0	0
Mixed extent that has free pages	0	1

Index Allocation Map Page (IAM)

- IAM pages keep track of extents that are allocated to an object
- IAM pages for an object are chained
- IAM pages are not distributed in fixed intervals
- Each IAM page manages up to 4GB of allocation information for an object

Page Free Space (PFS)

- PFS byte map
  - 1byte for each page
  - Keeps track of free space in a page
  - Every PFS page covers 8088 pages
  - 1st page in the datafile

  - Space Usage:
    - Page is empty
    - 1-50% full
    - 51-80% full
    - 81-95% full
    - 96-100% full

Indexes

- B-Tree organization
  - Root nodes
  - Leaf nodes
  - Intermediate nodes
- Clustered index
  - One Clustered index per table
  - Leaf level becomes the data pages
- Non-clustered index
  - 249 non-clustered indexes

Fill Factor

- Fill Factor controls the percentage of free space in the leaf pages of an index when it is created or rebuilt
  - It has direct impact on Split Pages
  - It is a percentage from 0% to 100%

Pad Index

- Pad Index controls the percentage of free space in the interior pages of an index
  - Only available when creating unique index with the fill factor percentage specified
  - Uses the percentage that is specified for the fill factor

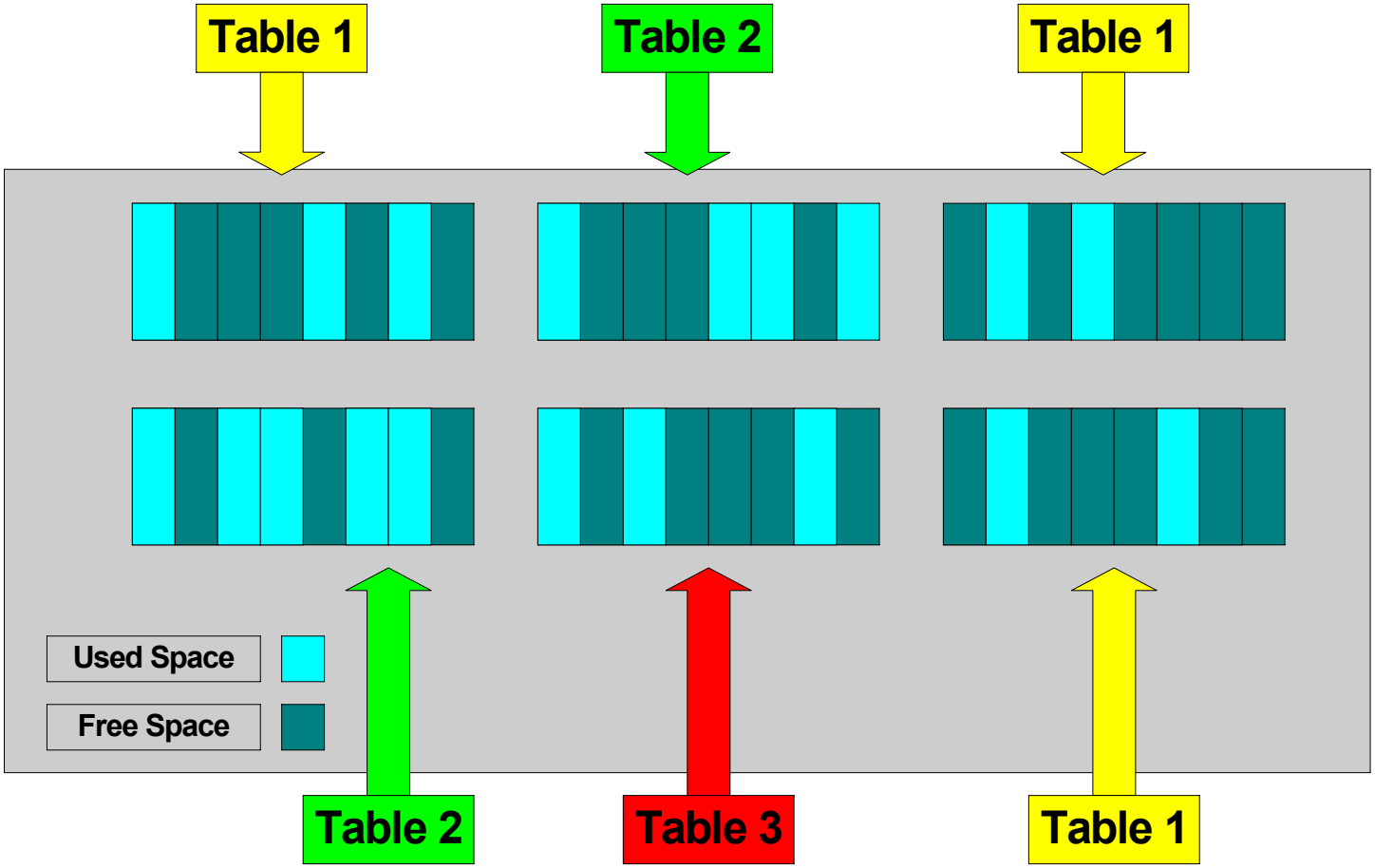
Fragmentation

- Fragmentation is a condition in which an index contains pages that are out of order
  - Becomes a performance problem for indexes with more than 1000 pages
  - Fragmentation does not effect heaps or queries whose data pages reside in the SQL Server's data cache

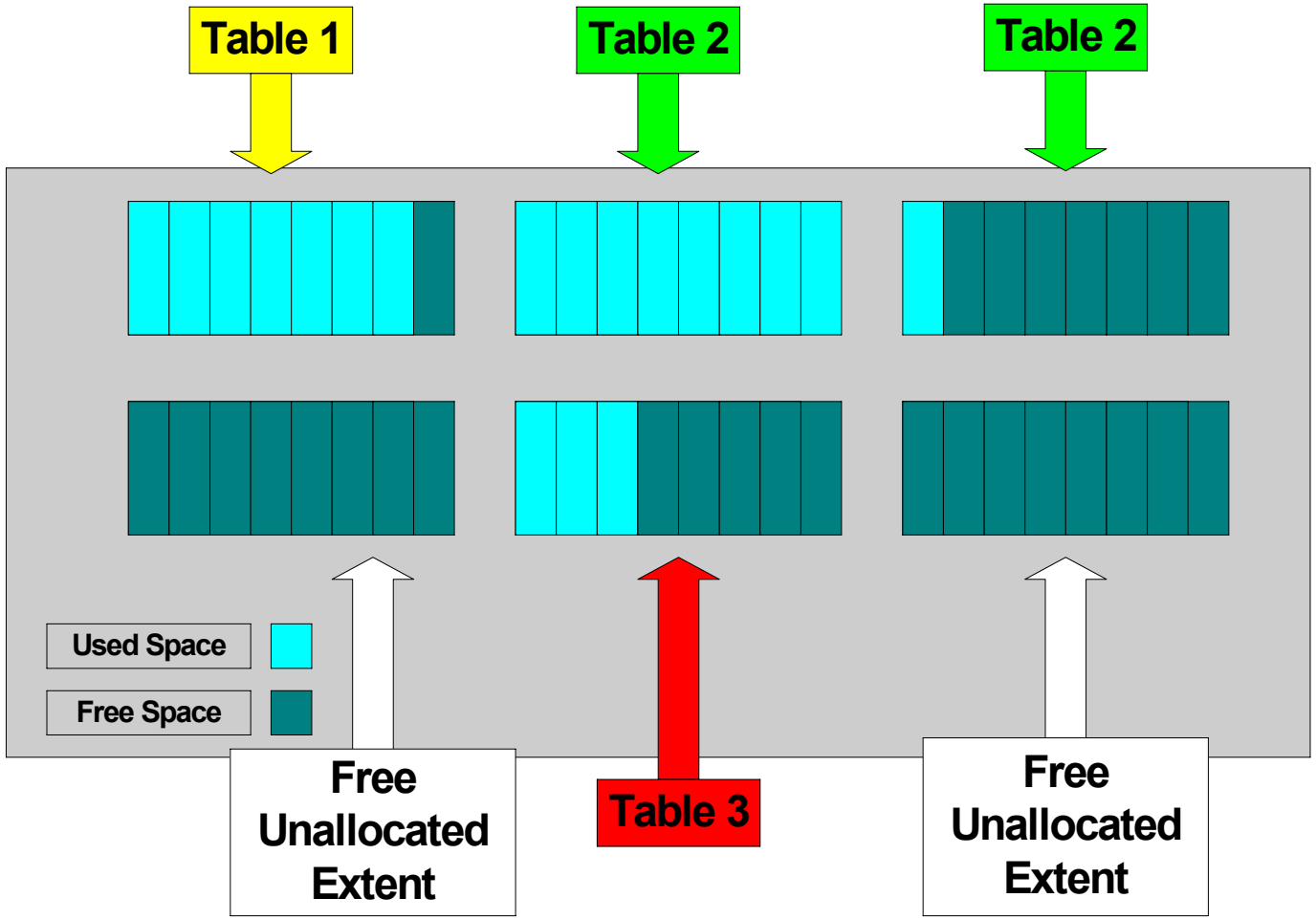
Scan Density

- Scan Density is the contiguity or closeness of the extents allocated to an object
  - High extent switches = low scan density

Fragmented Database



Defragmented Database



Native Tools

- DBCC SHOWCONTIG
- DBCC DBREINDEX
- DBCC INDEXDEFRAG

DBCC SHOWCONTIG

DBCC SHOWCONTIG scanning 'Customers' table...
Table: 'Customers' (2073058421); index ID: 1, database ID: 6
TABLE level scan performed.
- Pages Scanned.....: 35
- Extents Scanned.....: 8
- Extent Switches.....: 29
- Avg. Pages per Extent.....: 4.4
- Scan Density [Best Count:Actual Count].....: 16.67% [5:30]
- Logical Scan Fragmentation .....: 48.57%
- Extent Scan Fragmentation .....: 50.00%
- Avg. Bytes Free per Page.....: 2554.6
- Avg. Page Density (full).....: 68.44%

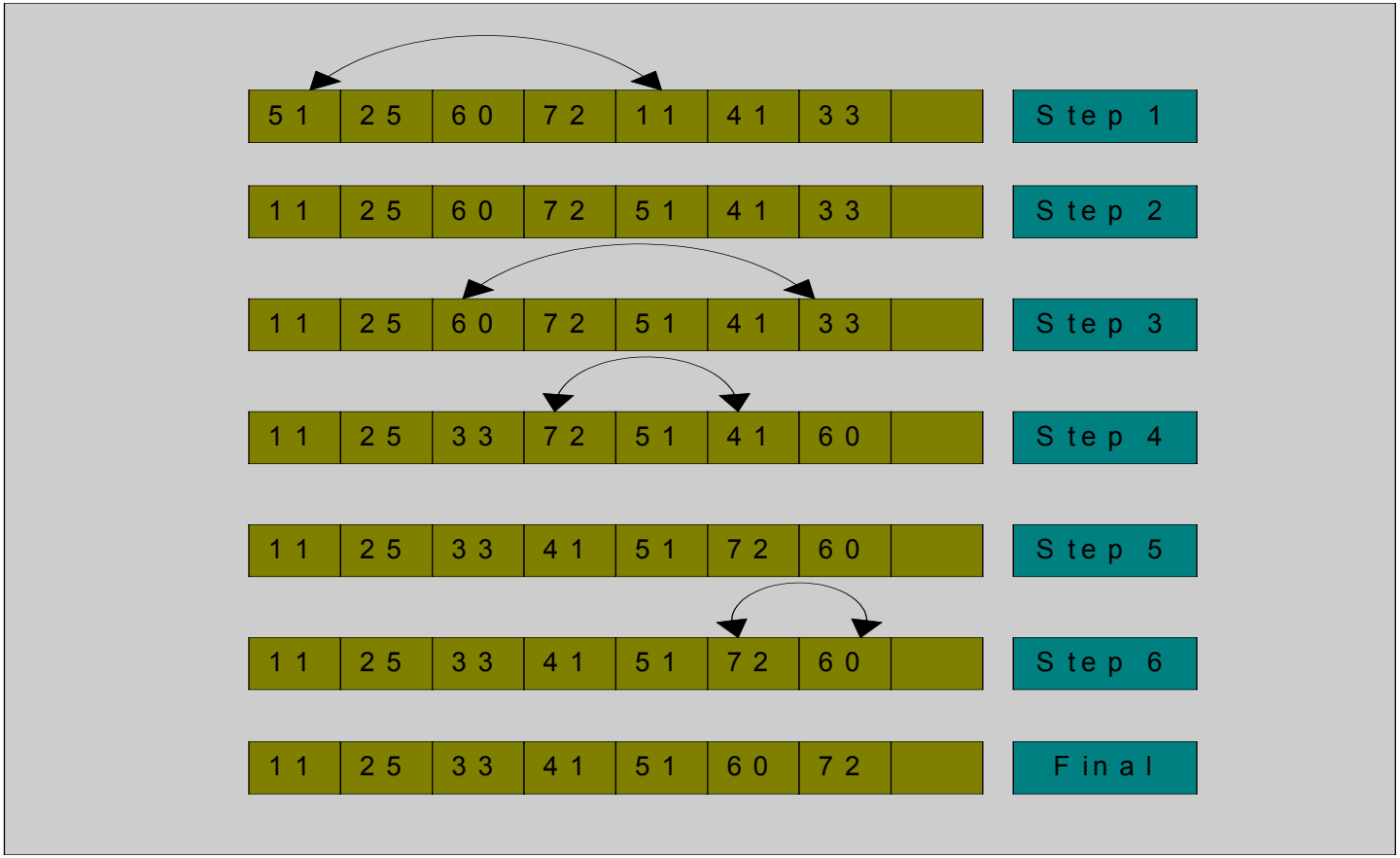
DBCC DBREINDEX

- Rebuild indexes dynamically
- Off-line operation
- Automatic update statistics

DBCC INDEXDEFRAG

- On-line operation
- Reorder physical pages to match the logical pages
- Does not update statistics

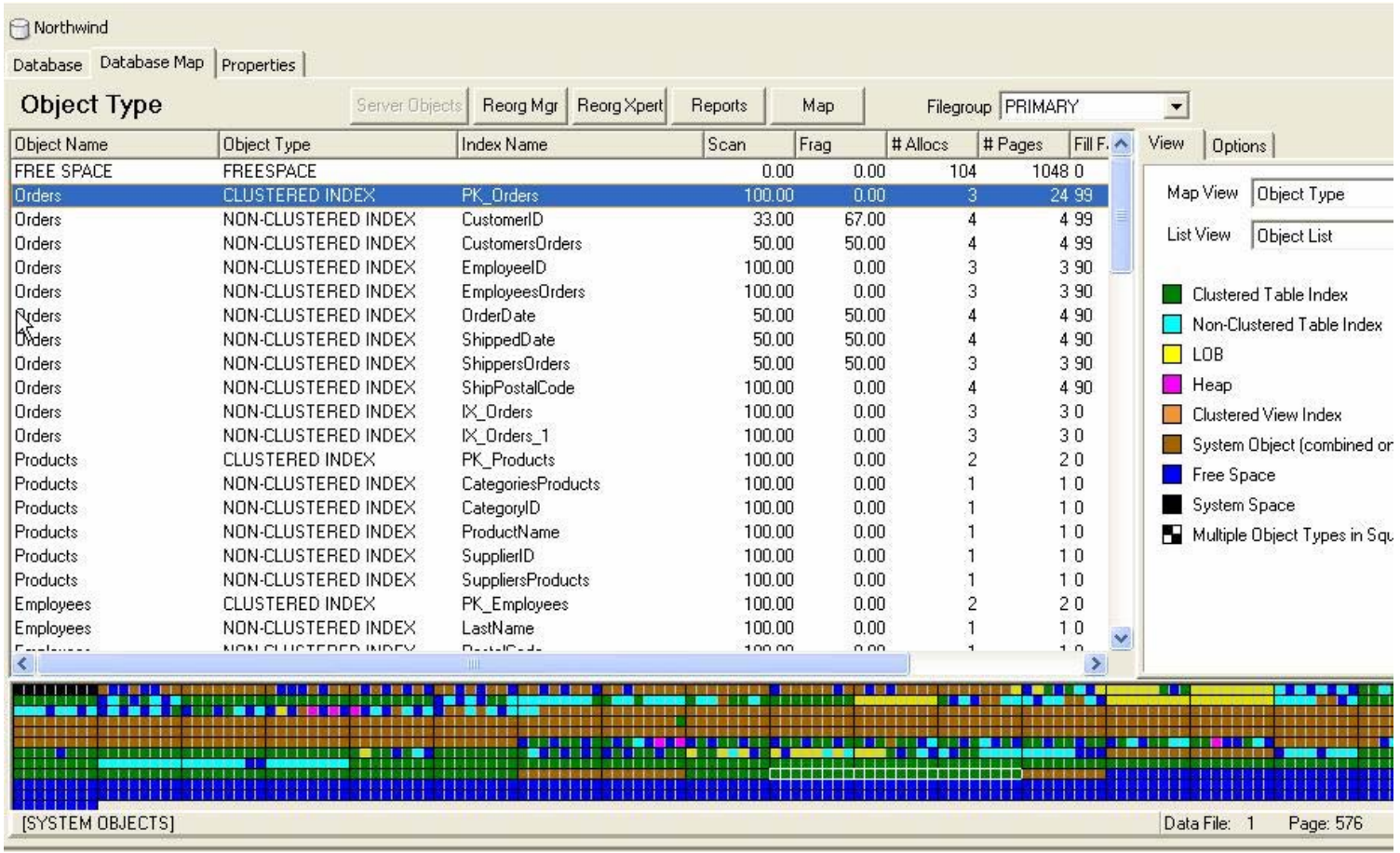
DBCC INDEXDEFRAG



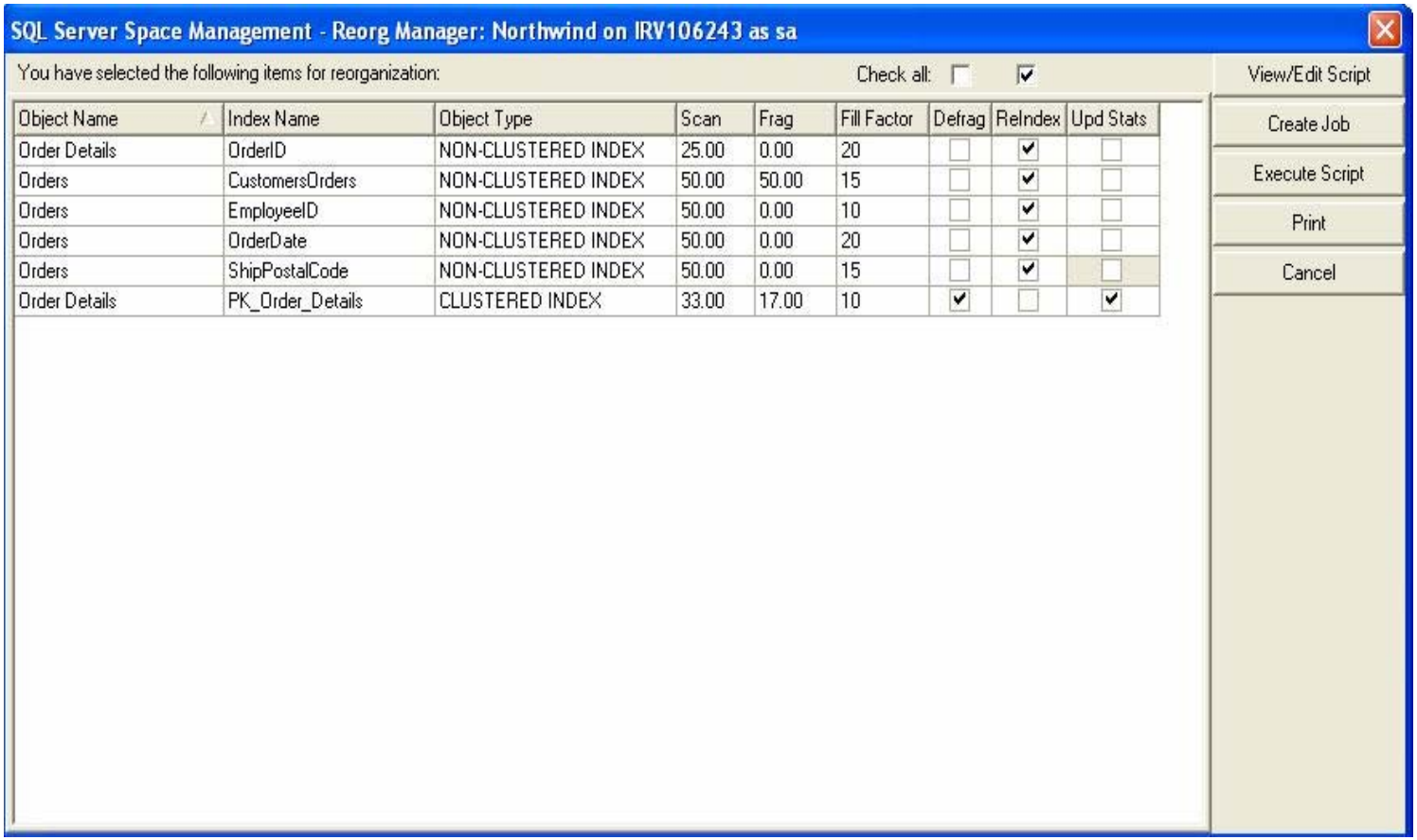
Quest Central® for Databases - SQL Server

- Powerful database tools that extend and enhance the abilities of the enterprise SQL Server DBA
  - database administration
  - performance diagnostics
  - load testing
  - database analysis
  - space management
  - database comparison

Database Map

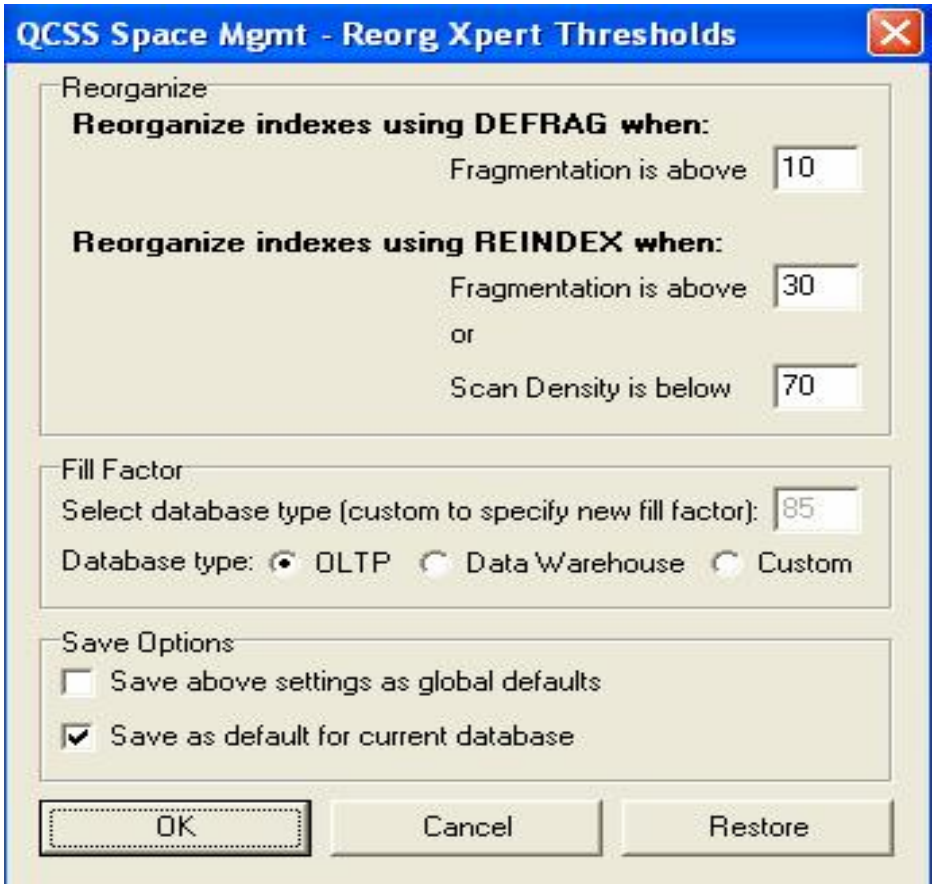


Reorg Manager

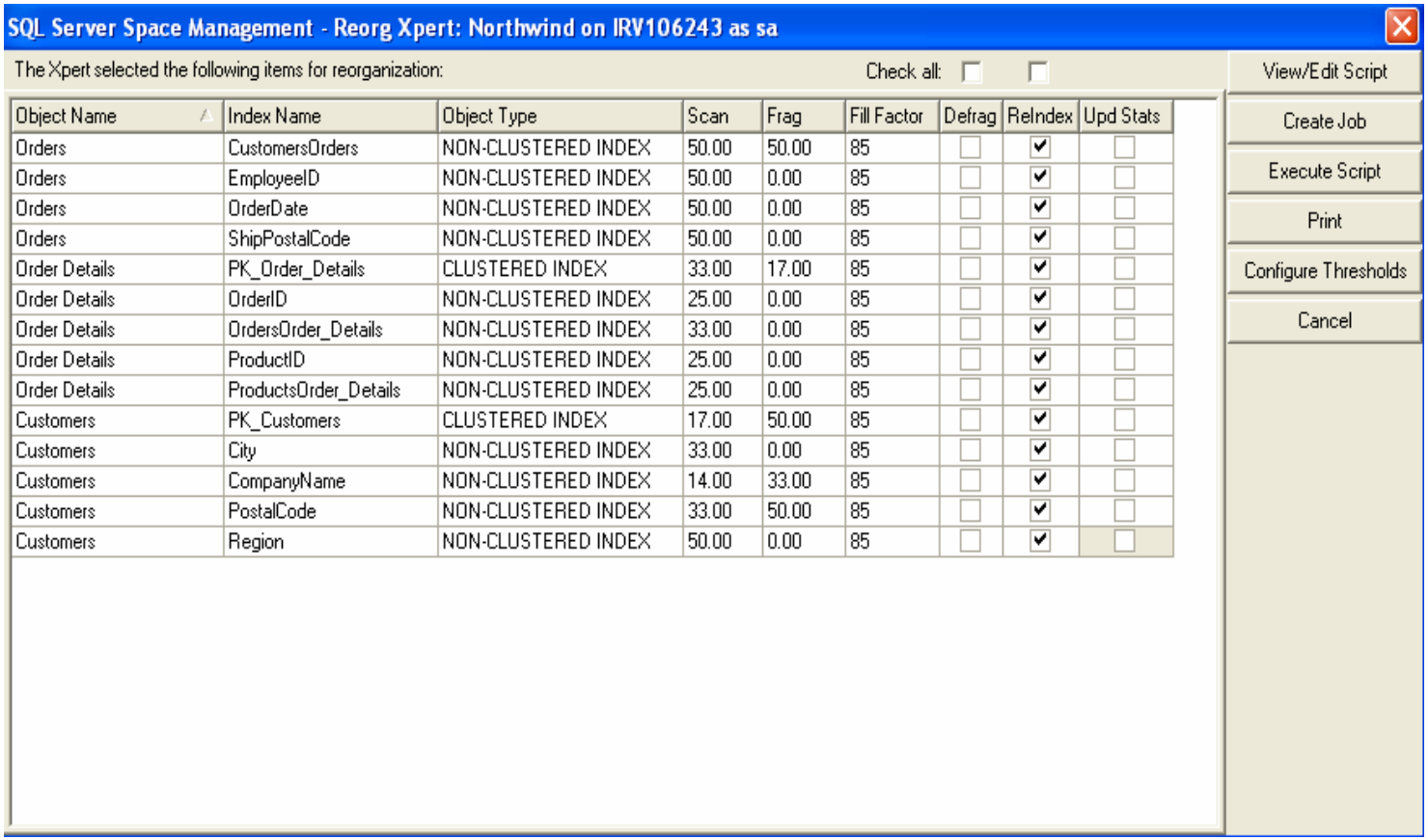


Object Name	Index Name	Object Type	Scan	Frag	Fill Factor	Defrag	ReIndex	Upd Stats
Order Details	OrderID	NON-CLUSTERED INDEX	25.00	0.00	20	☐	☑	☐
Orders	CustomersOrders	NON-CLUSTERED INDEX	50.00	50.00	15	☐	☑	☐
Orders	EmployeeID	NON-CLUSTERED INDEX	50.00	0.00	10	☐	☑	☐
Orders	OrderDate	NON-CLUSTERED INDEX	50.00	0.00	20	☐	☑	☐
Orders	ShipPostalCode	NON-CLUSTERED INDEX	50.00	0.00	15	☐	☑	☐
Order Details	PK_Order_Details	CLUSTERED INDEX	33.00	17.00	10	☑	☐	☑

Reorg Xpert


QCSS Space Mgmt - Reorg Xpert Thresholds
Reorganize
Reorganize indexes using DEFRAG when:
Fragmentation is above
10
Reorganize indexes using REINDEX when:
Fragmentation is above
30
or
Scan Density is below
70
Fill Factor
Select database type (custom to specify new fill factor):
85
Database type:
OLTP
Data Warehouse
Custom
Save Options
Save above settings as global defaults
Save as default for current database
OK
Cancel
Restore

Reorg Xpert



Object Name	Index Name	Object Type	Scan	Frag	Fill Factor	Defrag	ReIndex	Upd Stats
Orders	CustomersOrders	NON-CLUSTERED INDEX	50.00	50.00	85	☐	☑	☐
Orders	EmployeeID	NON-CLUSTERED INDEX	50.00	0.00	85	☐	☑	☐
Orders	OrderDate	NON-CLUSTERED INDEX	50.00	0.00	85	☐	☑	☐
Orders	ShipPostalCode	NON-CLUSTERED INDEX	50.00	0.00	85	☐	☑	☐
Order Details	PK_Order_Details	CLUSTERED INDEX	33.00	17.00	85	☐	☑	☐
Order Details	OrderID	NON-CLUSTERED INDEX	25.00	0.00	85	☐	☑	☐
Order Details	OrdersOrder_Details	NON-CLUSTERED INDEX	33.00	0.00	85	☐	☑	☐
Order Details	ProductID	NON-CLUSTERED INDEX	25.00	0.00	85	☐	☑	☐
Order Details	ProductsOrder_Details	NON-CLUSTERED INDEX	25.00	0.00	85	☐	☑	☐
Customers	PK_Customers	CLUSTERED INDEX	17.00	50.00	85	☐	☑	☐
Customers	City	NON-CLUSTERED INDEX	33.00	0.00	85	☐	☑	☐
Customers	CompanyName	NON-CLUSTERED INDEX	14.00	33.00	85	☐	☑	☐
Customers	PostalCode	NON-CLUSTERED INDEX	33.00	50.00	85	☐	☑	☐
Customers	Region	NON-CLUSTERED INDEX	50.00	0.00	85	☐	☑	☐

Thank you.

Additional Resources:

More information about Quest Central:
http://www.quest.com/quest_central/

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