Session No. DM131
New Optimizer and Query Execution Options in Adaptive Server Enterprise 12.0

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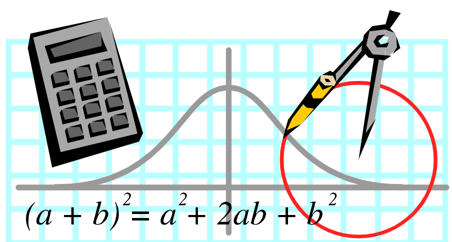
ASE 12.0 Changes

- » Parallel and Serial Sort/Merge Joins
- » Smart Transformation of WHERE Clause Predicates
- » Improved Selectivity Estimation for LIKE Predicates
- » Join transitive closure
- » New Outer Join Syntax and Logic
- » Abstract Query Plans
- » Support for up to 50 tables in a join clause
- » Execute Immediate



From Query Text to Query Results

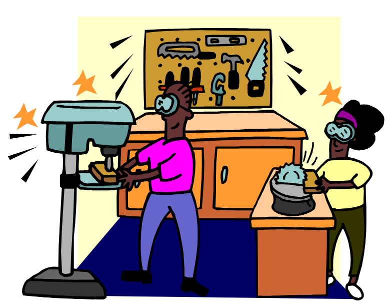
Query Text

- Pre-optimization
  - Join Transitive Closure
  - ANSI Compliant Outer Joins
  - Predicate Transformation
- Optimization
  - Improved costing of "%XXX" like clauses
  - Abstract Query Plans
- Query Execution
  - Sort-Merge Joins
  - 50 table limit
  - Execute Immediate

Query Results

Work in progress

- In ASE 11.9.x the optimizer was re-written:
  - sysstatistics and systabstats replaced distribution pages and provided a much greater level of detail on data distribution across the table
- In the next release of ASE, the replacement for the query execution engine will be fully implemented
- ASE 12.0 contains:
  - first phase of the replacement of the query execution engine - providing new query execution possibilities
  - increased intelligence in pre-optimization processing of queries



What do the icon’s mean??

- New method of calculating costs in when generating the query plan
  - Typically due to additional information being made available from pre-optimization processing of the query

- Performance enhancement
  - Due to new query execution options that process the data more efficiently

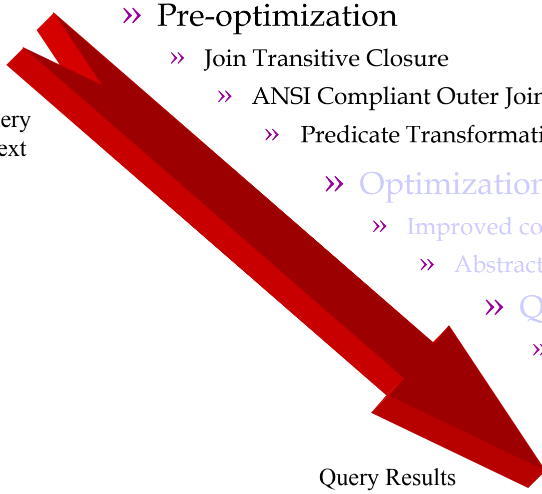
- New query execution functionality
  - New methods of Query Execution to provide increased efficiency in the way that data is accessed and reduce the number of I/O’s that are required

Does it all go faster?

- Whilst many of the changes have been implemented for performance reasons, some provide new functionality that could not be supported before
- Other changes made to ensure that Partner products are fully supported
- Some of the changes, when used, add to the time taken to optimize queries (maybe significantly). These are cases where Abstract Query Plans may provide additional benefits
- Intention is that nothing that is currently implemented should go slower

From Query Text to Query Results

Query Text



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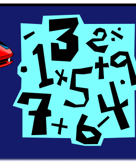
Query Results

Join Transitive Closure

- Provide the optimizer with additional join paths and, hopefully, faster plans.
- Example:
  - *select A.a from A, B, C*
    where A.a = B.b and B.b = C.c
  - Adds "and A.a = C.c" to query
  - Adds join orders BAC, BCA, ACB, CAB
- A new join order may be the cheapest
- SARG transitive closure added in ASE 11.5
  - and guess what - it is still there!!!!

Join Transitive Closure



- Join Transitive Closure is not considered for:
  - Non-equi-joins (A.a > B.b)
  - Joins that include expressions (A.a = B.b + 1)
  - Joins under an OR expression
  - Outer Joins (A.a =* B.b)
  - Joins in subqueries
  - Joins used for view check or referential check constraints
  - Joins between different type columns (eg, int = smallint)

ANSI Joins

- The Pre-ASE 12.0 outer join syntax (*=, =*) does not have clearly defined semantics
- ANSI SQL92 specifies a new join syntax with clearly defined semantics
- ASE 12.0 implements ANSI joins such that ALL outer joins (even those expressed in TSQL) have clearly defined semantics

Example - Inner Joins

- TSQL Inner Join
  - ```
    SELECT  title, price FROM
      titles, salesdetail
    WHERE
      titles.title_id =
        salesdetail.title_id
    AND
      titles.price > 22.0
    ```
- ANSI Inner Join
  - ```
    SELECT  title, price FROM
      titles
    INNER JOIN salesdetail
    ON
      titles.title_id =
        salesdetail.title_id
    AND
      titles.price > 22.0
    ```


Example - Outer Joins

- TSQL Outer Join
  - ```
    SELECT  title, price FROM
      titles, salesdetail
    WHERE
      titles.title_id *=
        salesdetail.title_id
    AND
      titles.price > 22.0
    ```
- ANSI Outer Join
  - ```
    SELECT  title, price FROM
      titles LEFT OUTER JOIN
      salesdetail
    ON
      titles.title_id =
        salesdetail.title_id
    WHERE
      titles.price > 22.0
    ```

ANSI Join Terminology

- Left and right outer joins
  - In a left join, the outer table and inner table are the left and right tables, respectively
    - The outer table and inner table are also referred to as the row-preserving and null-supplying tables, respectively
  - In a right join, the outer table and inner table are the right and left tables, respectively
- In both of the following, T2 is the inner table
  - T1 left join T2
  - T2 right join T1

Nested Joins

- The left or right member of an ANSI join can be another ANSI join
  - Order of evaluation is determined by the position of ON clause
    - *select * from tname left join taddress*
      ON tname.empid = taddress.empid
      left join temployee
      ON taddress.deptid = temployee.deptid
    - *select * from tname left join taddress left join temployee*
      ON taddress.deptid = temployee.deptid
      ON tname.empid = taddress.empid
  - Parentheses only improve readability - they do not affect the order the join statements are evaluated in
    - *select * from (tname left join taddress*
      ON tname.empid = taddress.empid)
      left join temployee
      ON taddress.deptid = temployee.deptid

Name Scoping Rules

- The ON clause condition can reference columns from:
  - Table references directly introduced in the joined table itself
  - Table references that are contained in the ANSI join
  - Tables introduced in outer query blocks (i.e. - the ANSI outer join appears in a subquery).
- The ON clause condition cannot reference:
  - Tables introduced in a containing outer join
  - Comma separated tables or joined tables in the from-list
- Example - the following is not allowed:
  - *select * from (titles left join titleauthor*
    *on titles.title_id=**roysched.title_id**)*
    left join roysched
    on titleauthor.title_id=roysched.title_id
    where titles.title_id != "PS7777"

Ambiguous TSQL Outer Joins

(Continued)

- In ASE 12.0, TSQL outer joins are converted to ANSI joins
- For example, the TSQL query:
  - *select * from T1, T2, T3*
    *where T1.id *= T2.id*
    and (T1.id = T3.id)
    and (T2.empno = 100 or T3.dept = 6)
- is transformed internally to:
  - *select * from T1 left join T2*
    on T1.id = T2.id, T3
    where T1.id = T3.id
    and (T2.empno = 100 or T3.dept=6)
  - Query has same possible join orders as in pre-ASE12.0, but the OR clause will always be evaluated with WHERE clause
    - In ASE 12.0, an inner table can evaluate both ON and WHERE clause predicates

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Views & Outer Joins

- Prior to 12.0, views containing outer joins and views referenced in outer join queries might not be merged.
  - Example:
    - *create view VOJ1 as*
select o.c1, i.b1 from t3 o, t2 i
*where o.c1 *= i.b1*
*select * from t4, VOJ1*
where t4.d1 = VOJ1.c1
and (VOJ1.b1 = 77 or VOJ1.b1 IS NULL)
- In 12.0, these types of queries can now be merged.
  - Better Performance
    - More join orders and indexing strategies possible.

Predicate Transformation

- Significant performance improvement in queries with limited access paths (i.e. very few possible SARGS/Joins/OR's that can be used to qualify rows in a table)
- Additional optimization achieved by generating new search paths based on
  - join conditions
  - search clauses
  - optimizable OR clauses
- Full cartesian joins are avoided for some of the complex queries.

Example

» Example query:

- » *select * from lineitem, part*
  where (p_partkey = l_partkey and l_quantity >= 10)
  or (p_partkey = l_partkey and l_quantity <= 20)

» Above query is transformed to the following:

- » *select * from lineitem, part*
  where ((p_partkey = l_partkey and l_quantity >= 10)
  or (p_partkey = l_partkey and l_quantity <= 20))
  and (p_partkey = l_partkey)
  and (l_quantity >= 10 or l_quantity <= 20)

Predicate Transformation Internals

» New processing phase introduced in the compiler

- » just before the start of the optimizer
- » in the 'decision' module

» The main driver routine performs the following:

- » identifies whether a set of disjuncts(*) (minimum 2) are present at the top level of a query or part of a single AND statement
- » for each set of disjuncts(*), the predicates within it are classified into join, search and OR clauses
- » data structures are set up to point to the relevant predicates which are later factored out
  - » (*) disjuncts - clauses on either side of an OR statement

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Predicate Transformation Internals

- New conjuncts(*) are created by suitable transformation of the collected predicates
- These conjuncts (*) are then added at the top level to the original search_condition
- Compilation is suppressed for
  - any new conjunct(*), added by predicate factoring and transformation, which does not get selected as an access path (by optimizer)
    - (*) conjuncts - clauses separated by AND statements, typically SARG and Join clauses

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LIKE

- Change to costing for LIKE clauses that are not migrated into SARG's
- Provides better row estimates, resulting in better query plans.
- Example
  - *select … from part, partsupp, lineitem*
    where l_partkey = p_partkey
    and l_partkey = ps_partkey
    and p_title = '%Topographic%'

Better Selectivity Estimates For Like Clauses

- New scheme to improve selectivity and qualifying row estimate
  - The LIKE string is compared with histogram cell boundaries
  - For every match, weight of the cell is added to selectivity estimates
  - If there are matches
    - The total of selectivity estimates * the number of rows in the table = estimated qualifying rows
  - If there are no matches
    - Estimated as 1 / # of cells in the histogram
  - This also applies queries with LIKE clauses of the type
    - like "_abc", or like "[ ]abc"

Abstract Query Plans

- What could go wrong with the Optimizer?
  - Statistics may not apply to the data that is now in the table
  - The query plan used for a stored procedure may not be applicable to the query at hand
  - The buffer cache model and the actual buffer cache usage at run time could differ
  - These issues are caused by:
    - Modeling for a different data skew
    - Modeling for a different usage skew
    - Data distribution unknown at development time, e.g.:
      - Densities
      - Magic numbers
      - What average for the density

Can Better Be Worse Than Good?

- What happens to the installed base when the optimizer is enhanced?
  - Most find it better
  - Some find it worse…
- One solution to all these problems would be to implement rules based optimization. However:
  - Rule based decisions could be sub-optimal as they require the developer to have a knowledge of the eventual data layout
  - Developers very often have very little knowledge of how to write efficient query plans
  - The overhead on development of using Rules Based Optimization is massive
  - The assumed heuristics are not always right

Curing Unexpected Behavior

- What are the options for improving the optimizer and getting rid of unexpected behavior?
  - Implementing a better and more dynamic cost model
  - Implementing some form of extremely flexible rules based optimization
  - Allowing good query plans to be captured and re-used

Abstract Query Plans

- An abstract query plan is a persistent, human readable description of a query plan, that's associated to a SQL statement
- It is not syntactically part of the statement
- The description language is a relational algebra
- Possible to specify only a partial plan, where the optimizer completes the plan generation
- Stored in a system catalog *sysqueryplans*
- Persistent across:
  - connections
  - Server versions (i.e. upgrades)

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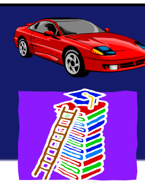
Where will AQP's be used?

- Application providers don't want to include vendor specific syntax in their queries
- In general, users don't want to modify a production application to solve an upgrade optimizer problem
- Still, it's possible to include them if so desired
  - Example:
    - *select c1 from t1 where c2 = 0*
      plan '(I_scan () t1)'

How are the plans created?

- Abstract query plans are captured and reused:
  - *set plan dump 'new_plans_group' on*
  - *set plan load 'new_plans_group'*
- When the capture mode is enabled, all queries are stored, together with their generated abstract query plan, in SYSQUERYPLANS
- Abstract query plan administration commands are available, allowing to create, delete or modify individual plans and groups

What Do Abstract Plans Look Like?



- Full plan examples:
  - *select * from t1 where c=0* *(i_scan c_index t1)*
    - Instructs the optimizer to
      - perform an index scan on table *t1* using the *c_index* index.
  - *select * from t1, t2 where t1.c = t2.c and t1.c = 0* *(nl_g_join (i_scan i1 t1) (i_scan i2 t2))*
    - Instructs the optimizer to:
      - perform a nested loop join with table t1 outer to t2
      - perform an index scan on table t1 using the i1 index
      - perform an index scan on table t2 using the i2 index

What Do Abstract Plans Look Like?
(Continued)

- Partial plan examples:
  - *select * from t1 where c=0* *(i_scan t1)*
    - Instructs the optimizer to
      - perform an index scan on t1.
  - *select * from t1, t2 where t1.c = t2.c and t1.c = 0* *(t_scan t2)*
  - Instructs the optimizer to
    - access t2 via a table scan.
  - *select c11 from t1, t2 where t1.c12 = t2.c21* *(prop t1 (parallel 1))*
  - Instructs the optimizer not to access t1 in parallel.

From Query Text to Query Results

- » Pre-optimization
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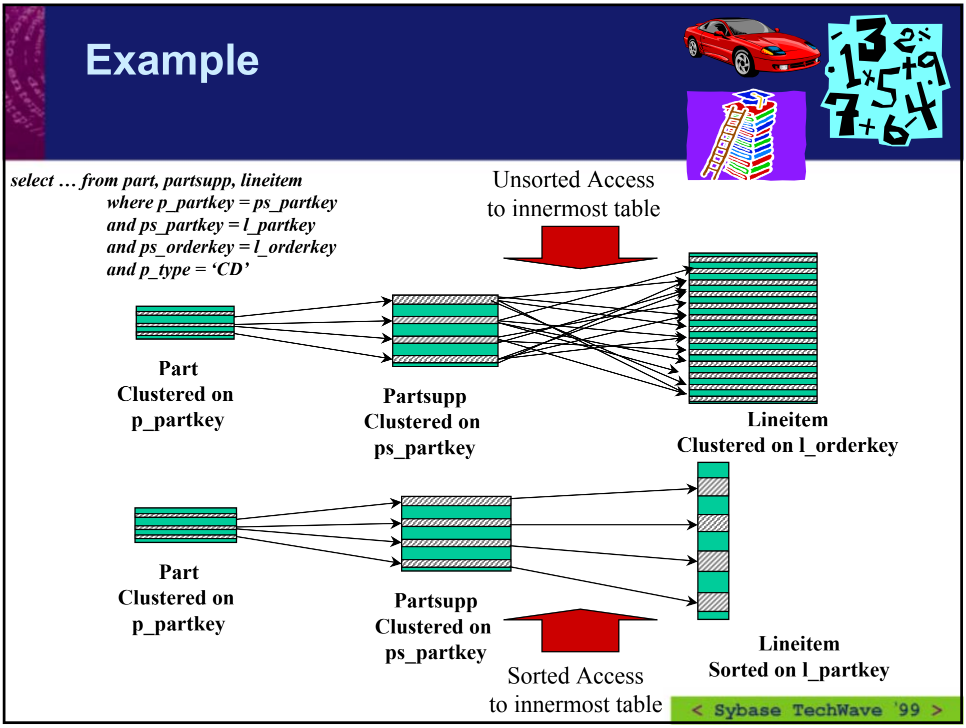
    - » ANSI Compliant Outer Joins
      - » Predicate Transformation
- » Optimization
  - » Improved costing of "%XXX" like clauses
    - » Abstract Query Plans
- » Query Execution
  - » Sort-Merge Joins
    - » 50 table limit
      - » Execute Immediate

Why sort-merge joins ?

- » Ordered joins provide clustered access to joining rows; result in less logical and physical I/Os.
- » Can exploit indexes that pre-order rows on joining columns.
- » Sort Merge Join Algorithm - Often Better Performance for DW/DSS Queries Than Nested Loop Join of ASE Today


Example
select … from part, partsupp, lineitem
where p_partkey = ps_partkey
and ps_partkey = l_partkey
and ps_orderkey = l_orderkey
and p_type = 'CD'
Unsorted Access
to innermost table
Part
Clustered on
p_partkey
Partsupp
Clustered on
ps_partkey
Lineitem
Clustered on l_orderkey
Part
Clustered on
p_partkey
Partsupp
Clustered on
ps_partkey
Sorted Access
to innermost table
Lineitem
Sorted on l_partkey
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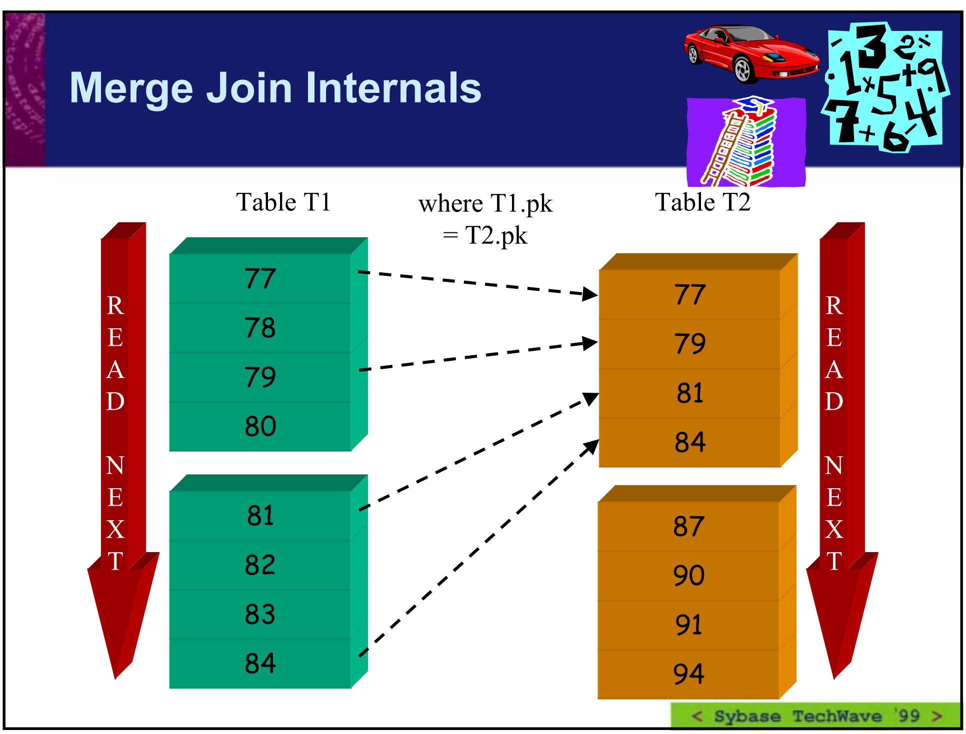
Merge Join Internals
Table T1
where T1.pk
= T2.pk
Table T2
READ NEXT
77
78
79
80
81
82
83
84
77
79
81
84
87
90
91
94
READ NEXT
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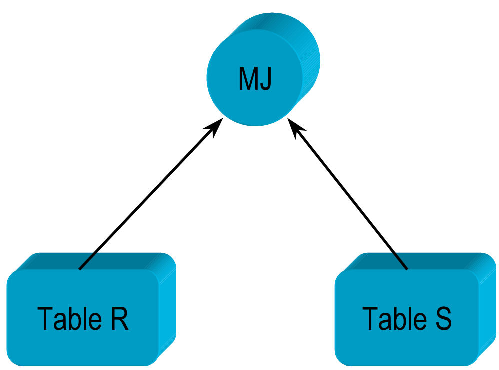
Merge Joins in ASE 12.0

» The type of Merge Join selected depends on the join keys and available indexes
  - » Merge Joins in ASE 12.0 are broken into four distinct types:
    - » Full Merge Join
    - » Left Merge Join
    - » Right Merge Join
    - » Sort Merge Join
  - » There are actually eight Merge Joins possibilities since each one of the above Merge Join types can also be done in parallel

Full Merge Join

One step process

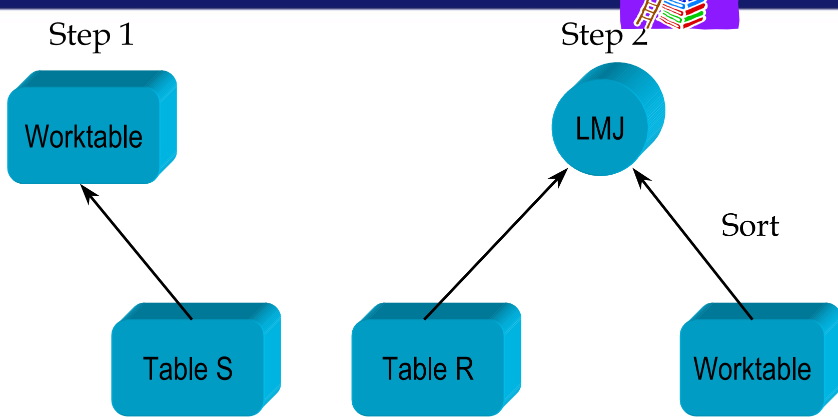


Scan the indexes on the join keys for both tables and merge the results

Full Merge Join

» Both tables to be joined have useful indexes on the join keys
- » No sorting is needed
- » The tables can be easily merged by following the indexes
  - » The index guarantees that the data can be accessed in a sorted manner by following the index leaf
- » Full Merge Joins are only possible for the outermost pair of tables in the join order
  - » Thus, if the join order is {R,S,T,U}, only R and S can be joined via a Full Merge Join

Left Merge Join



Create and populate the worktable

Sort the worktable and merge with the outer (left) table

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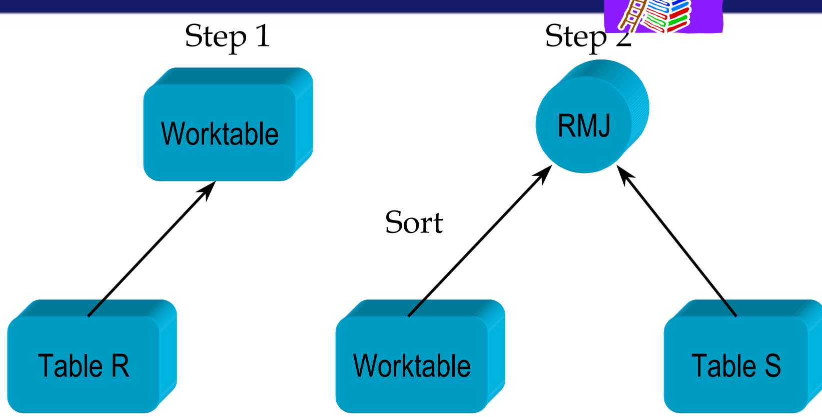
Left Merge Join

- The table the Optimizer has chosen to be the inner does not have a useful index on the join column
  - The inner (right) table must be first sorted into a worktable
  - A useful index with the necessary ordering from the left (outer) side is used to perform the merge join
  - Left Merge Joins are only possible for the outermost pair of tables in the join order
    - Thus, if the join order is {R,S,T,U}, only R and S can be joined via a Left Merge Join

Right Merge Join



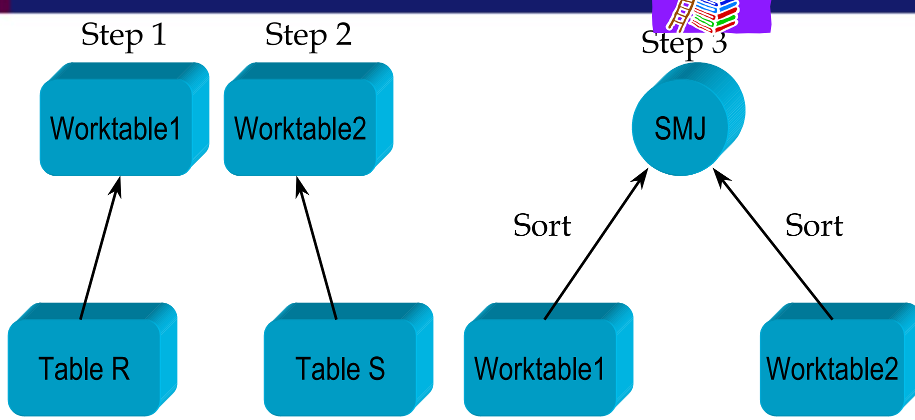
Create and populate the worktable

Sort the worktable and merge with the inner (right) table

Right Merge Join

- The table the Optimizer has chosen to be the outer does not have a useful index on the join column
  - The outer (left) table must be first sorted into a worktable
  - A useful index with the necessary ordering from the right (inner) side is used to perform the merge join

Sort-Merge Join



Create and populate the worktables

Sort the worktables and merge the results

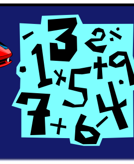
Sort-Merge Join

- Neither table has an index on the join column, or the Optimizer's costing algorithm has determined (based upon its cost calculation) that it is cheaper to "reformat"
  - This involves the base table being read into a worktable which is created with the required indexes
    - This method is chosen for Merge Joins when a useful index is not available
  - The worktable is then sorted
  - Subsequent joins are to the worktable, not the base table
- In the case of a Sort-Merge join, the Optimizer has determined that the base tables must both be sorted into worktables and then merged

Cost Model

- Historically, the costing for join selection set is:
  - # of pgs for retrieval of a row from the inner table * number of qualifying rows in the outer table
- For sort merge join the Logical I/O cost is estimated as below :
  - outer_lio = cost of scanning outer table
  - inner_lio = # duplicates in outer *
    (join selection set + index height) +
    (# unique values in outer * (join selection set))

Restrictions on Sort/Merge Joins


- Merge Join not selected for the following cases
  - Subqueries (not outer query block)
  - Update statements
  - Outer Joins
  - Referential Integrity
  - Remote Tables
  - Cursor statements

50 Table Limit

- Number of user tables in a query has been increased to make it possible for users to run queries with a large number of non-flattened subqueries.
- Increase maximum number of non-RI tables per query
  - from 16 user tables and 12 work tables
  - to 50 user tables and 14 work tables
- Not designed for 50 tables in the “from . . . . “ clause

Are you nesting loops 50 deep?

- In one respect the answer is yes, but this functionality is not designed to be used this way
- Sort-merge will provide major performance improvements if you are
- Short circuiting means that the number of tables actually accessed is reduced in most cases
- Additional tables require configuration of auxiliary scan descriptors
  - previously these were only used for RI
  - now extended to support additional tables when more than 16 are accessed

50 Table Limit

- What did not change?
  - Pre-allocated scan descriptors per process (16 non-RI user, 12 non-RI work, 20 system, 0 RI)
  - Maximum subqueries per query (16)
  - Maximum RI tables per query (192 RI user and 192 RI work)
  - Maximum user tables under all sides of a UNION (256)
  - Default "number of aux scan descriptors" per server (200)
  - Default number of tables considered at a time for 2 to 25 joining tables (4)
    - Note: for 25 - 37 and 38 - 50 tables this number decreases

50 Table Limit

- What else changed?
  - Maximum auxiliary scan descriptors per process increased from 384 to 454 (192 RI user + 192 RI work + 34 non-RI user + 2 non-RI work + 34 system)
  - Default number of tables considered at a time by the optimizer when generating the query plan decreased to 3 for 26 to 37 joining tables, 2 for 38 to 50 joining tables
  - If you use set tablecount to change the number of tables considered, set tablecount 0 will reset it to the above behavior.

Execute Immediate

- Execute Immediate command is formed by materialising the command string.
- The command string is materialised by concatenating the "string literals" and the values of the variables"
- The variables can be filled at runtime as seen in the examples above.
- Syntax
  - *exec ({str_constant | str_var } [+ {str_constant | str_var }] ...)*

Enables variable syntax if required

- Can be used:
  - inside procedures to query tables and columns specified as arguments to the procedure.
  - in ISQL scripts, where a batch queries tables or columns from the database and then constructs a query on the fly using those table and column names.
- Example
  - ```
    declare @tabname char(100)
    select @tabname = b.authortable
    from books b
    where b.publisher = 'randomhouse'
    exec ( " select authors from " + @tabname )
    ```


Static and Dynamic Context

- Static Context :-
  - The context in which queries outside of execute immediate but within the same batch are executed.
- Dynamic context :-
  - The context in which queries enclosed in an execute immediate command are executed.
    ```

Static and Dynamic Context
(continued)

- Objects created in static scope can be referenced in dynamic scope.
  - *create table tab1*
*exec (“select * from tab1”)*
- Objects created in dynamic scope cannot be referenced in static scope.
  - *exec (“ create table tab1 “)*
*select * from tab1*
- Objects created in dynamic scope can be referenced in subsequent dynamic scope.
  - *exec (“ create table tab1 “)*
*exec (“ select * from tab1 “)*

Security Issues

- Security is paramount, therefore permission checking is
- Example
  - as user1
    - *create proc p1*
@anyquery char(255)
as
<do a pile of stuff>
exec (@anyquery)
go
  - as user2
    - *p1 “ select * from tab1”*
go
- user2 will get an error if user2 does not have

Restrictions

- Only *char* and *varchar* variables can be used in the command string.
- Certain commands are disallowed :-
  - transaction commands (**begin, end, abort**)
  - database connection commands (**use, connect**)
  - **set** commands
  - **dbcc** commands
- Execute immediate is not reentrant.

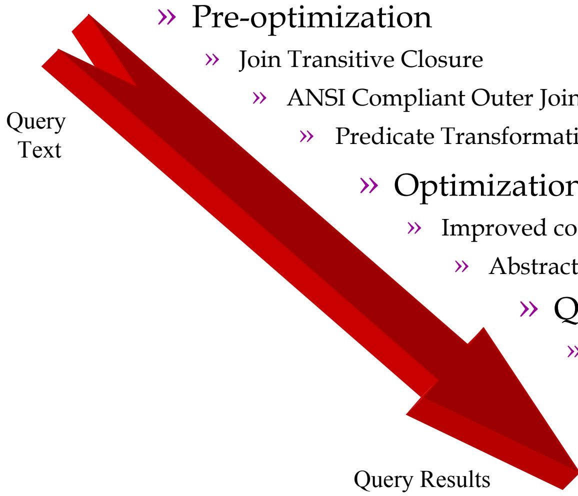
Where/how it cannot be used?

- White spaces are not automatically added into the string formed by concatenation.
  - *exec ("select" + "*" + "from" + "tab1")*
*looks like "select*fromtab1"*
- It does not replace select command :-
  - *insert into t exec (" select * from tab1 ")*
- Within a quoted string, references to variables declared in the static scope are not allowed.
  - *create proc p @tab char(30), @col char(30), @res int*
as
exec ("select @res " + " from " + " @tab ")

Where it cannot be used?
(continued)

- Cursor, Temp table visibility :-
  - In current implementation, cursors, temporary tables and variables are bound to the proc_hdr.
  - Execute Immediate creates a new proc_hdr to execute the commands and destroys the proc_hdr on completion.
  - Cursors, temporary tables are not carried over from the dynamic context to the static context.

From Query Text to Query Results



- Pre-optimization
  - Join Transitive Closure
  - ANSI Compliant Outer Joins
  - Predicate Transformation
- Optimization
  - Improved costing of "%XXX" like clauses
  - Abstract Query Plans
- Query Execution
  - Sort-Merge Joins
  - 50 table limit
  - Execute Immediate

Summary

- Pre-optimisation
  - Intelligent and improved pre-processing of queries provides the optimizer with more options in the production of the optimal query plan
- Optimization
  - Increased use of existing statistics
  - Uncertainty over Query Plan changes when ASE is upgraded or when new implementation performed no longer occurs
- Query Execution
  - New, more efficient, join strategies available
  - Much more complex SQL supported
  - "On the fly" SQL now possible

Session No. DM131 New Optimizer and Query Execution Options in Adaptive Server Enterprise 12.0

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