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D1/03. Oracle RDBMS

School on the Database Infrastructure for the CMS Phase 2 Upgrade

Outline

- DBMS overview
    - Types, RDBMS, ACID, History
- Oracle RDBMS
    - History, Documentation
    - Elements, Architecture
- Features and hands-on
    - Transactions
    - Privileges
    - Indexes and performance
    - Catalog Views
    - PL/SQL and stored subprograms

DBMS

- Database Management System (DBMS)
  - software for creating and managing databases
  - makes it possible for end users to create, read, update and delete data in a database
  - an interface between the database and end users or application programs
  - ensures that data is consistently organized and remains easily accessible
  - Major elements
    - Kernel code - manages memory and storage for the DBMS
    - Repository of metadata - aka data dictionary
    - Query language - enables applications to access the data
- Types
  - Usually follows Database Model type (see D1/01 presentation)
  - Hierarchical, Star, Object-Oriented, NoSQL, ...
  - Relational database management system (RDBMS)
  - Specific types, like In-memory, Data warehouse, cloud-based, ...

Database

Database

Database
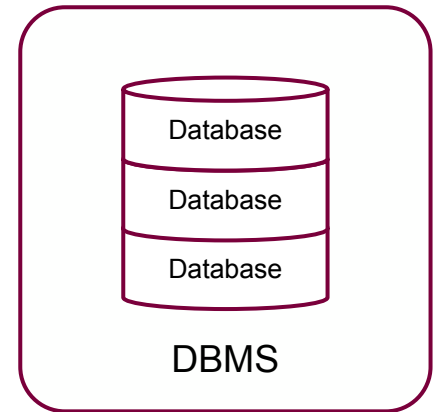
DBMS

Relational DBMS

- Basis - Relational model
- RDBMS distinguishes between the following types of operations
  - Logical operations
    - Application specifies what content is required
  - Physical operations
    - RDBMS determines how things should be done and carries out the operation
    - stores and retrieves data so that physical operations are transparent to applications
- Object-Relational DBMS that implements object-oriented features
  - user-defined types, inheritance, and polymorphism
  - It makes possible to store complex business models in a relational database

ACID Principles

- Atomic
  - <u>transaction</u> symbolizes a unit of work performed (multiple statements)
  - atomic transaction is an indivisible and irreducible series of database operations
  - all or nothing!
- Consistency
  - transaction must change affected data only in <u>allowed ways</u>
  - valid according to all defined rules (constraints, cascades, triggers, and any combination)
- Isolation
  - <u>concurrent execution</u> of transactions (isolation of transactions with locks)
  - concurrency control mechanism like 2-phase locking (2PL)
- Durability
  - committed transaction <u>remains</u> committed even in the case of a system failure

Short DBMS history

- late 60's (pioneers)
  - network (CODASYL) & hierarchical (IMS) DBMS
  - physical data structures reflected in DML (no data independence)
- 1970 (E.F.Codd's paper)
  - the most influential paper in DB research
  - physical and logical data layer separation
- mid 1970's (relational pioneers)
  - 2 functional prototypes: Ingres (UCB) & System R (IBM San Jose)
- early 1980's (commercialization of relational systems)
  - Oracle by Ellison
  - IBM DB2
  - Relational Technology Inc based on Ingres (https://www.openhub.net/p/ingres)
  - others...

Oracle Corporation

- Software Development Laboratories
  - Started by Larry Ellison with two friends in 1977
- Relational Software, Inc
  - Changed the name in 1979
  - First commercially available SQL-based RDBMS: Oracle v2 in 1979
- Oracle Systems Corporation
  - Changed the name in 1982
  - To align itself more closely with its flagship product Oracle Database
  - Initial public offering in 1986
- Oracle Corporation
  - Name change in 1995

Oracle Database Milestones

- Oracle V2 (1979) RSI introduced Oracle V2 (Version 2) as the first commercially available SQL-based RDBMS, a landmark event in the history of relational databases
- Oracle Version 3 (1983), was the first relational database to run on mainframes, minicomputers, and PCs. The database was written in C, enabling the database to be ported to multiple platforms
- Version 4 through Version 6 added enhancements to concurrency control, data distribution, and scalability
- Oracle7 (1992) introduced PL/SQL stored procedures and triggers
- Oracle8 (1997) object-relational database, supporting many new data types and partitioning of large tables
- Oracle8i (1999) provided native support for internet protocols and server-side support for Java
- Oracle9i (2001) multiple instances to access a single database simultaneously (RAC) and Oracle XML DB
- Oracle Database 10g (2003) introduced grid computing for virtualization of computing resources
- Oracle Database 11g (2007) automation improvements
- Oracle Database 12c (2013) was designed for the Cloud, In-Memory column store, and support for JSON
- Oracle Database Release 18c (2018) further integration of RESTful services like RDF, PGQL
- Oracle Database Release 19c (2019) enhancement of RESTful like REST Enabled SQL Support
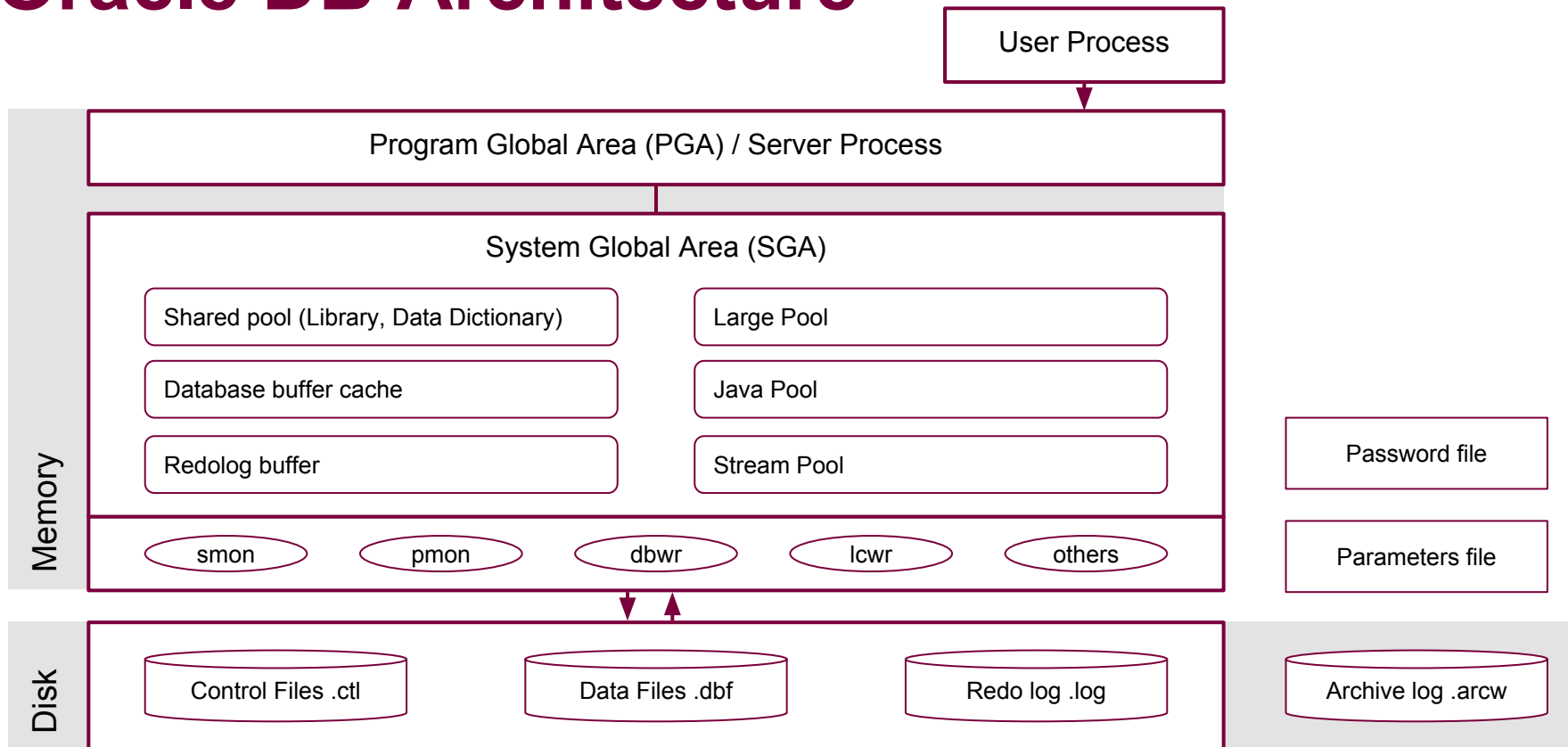
Oracle Documentation

- Help Center
  - https://docs.oracle.com/en/
- Oracle Database
  - https://docs.oracle.com/en/database/oracle/oracle-database/index.html
- SQLPlus
  - https://docs.oracle.com/en/database/oracle/oracle-database/19/sqpqr/index.html#SQPQR101
- SQL Reference
  - https://docs.oracle.com/en/database/oracle/oracle-database/19/sqlrf/index.html
- SQL Developer
  - https://docs.oracle.com/en/database/oracle/sql-developer/

Major Oracle Database Elements

- Database
  - collection of physical operating system files on disk
    - not logical concept as in other DBMS
- Instance
  - collection of processes and listeners which is mounted on a database system
  - instance can only mount to one database
    - DB2 can have many databases under it
  - a database can have more than one instance
  - an instance belongs to a database (or further can think it as an instance is a database)
- Schema/User
  - schema the set of objects (tables, indexes, views, etc) that belong to a user
  - in Oracle, a user can be considered the same as a schema
    - when a user is created, a schema with the same name will also be created
  - database instance can have multiple users/schemas

Oracle DB Architecture

User Process

Memory

Program Global Area (PGA) / Server Process

System Global Area (SGA)

Shared pool (Library, Data Dictionary)	Large Pool
Database buffer cache	Java Pool
Redolog buffer	Stream Pool

smon   pmon   dbwr   lcwr   others

Password file

Parameters file

Disk

Control Files .ctl   Data Files .dbf   Redo log .log

Archive log .arcw

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Oracle Namespaces

- Names must be from 1 to 30 bytes long (with some exceptions)
  - SCHEMA.TABLE.COLUMN - each element is 30 bytes long max
- Schema objects that share one namespace
  - Tables, Views, Sequences, Private synonyms, Stand-alone procedures, Stand-alone stored functions, Packages, Materialized views, User-defined types
- Schema objects that has its own namespace
  - Indexes, Constraints, Clusters, Database triggers, Private database links, Dimensions

DATABASE NAMESPACE

SCHEMA NAMESPACE

Tables, Views, Sequences, Private Synonyms, Standalone Procedures and Functions, Views , Types, ...

Indexes

Constraints

Users, Roles, Public Synonyms

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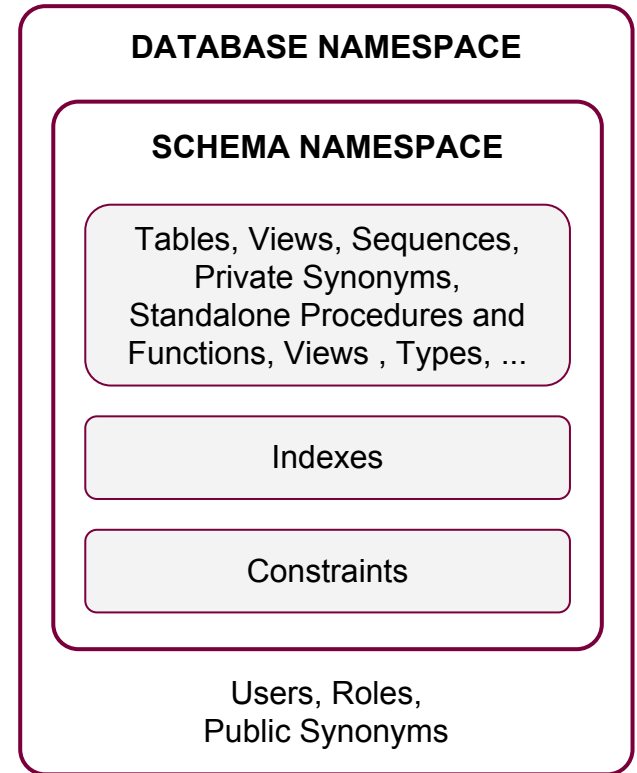
Transactions

- Transaction
    - logical atomic unit of work that contains one or more SQL statements
    - either all committed (applied to the database) or all rolled back (undone from the database)
- Workflow
    - Transaction begins
        - when the first executable SQL statement is encountered
    - Transaction ends
        - User issues a COMMIT or ROLLBACK statement
        - User runs a DDL statement such as CREATE, DROP, RENAME, or ALTER
            - all DML statements are being committed beforehand
        - user disconnects from Oracle (transaction is committed)
        - user process terminates abnormally (transaction is rolled back)
    - Next executable SQL statement automatically starts next transaction

Oracle Transactions hands-on (1)

- Open two sqlplus sessions, same user/account → (1) and (2)
- (1) Create a table with primary key

```
CREATE TABLE TTEST (ID number primary key);
```

- (1) Insert a couple of records

```
INSERT INTO TTEST VALUES (1);

INSERT INTO TTEST VALUES (2);
```

- (1) Check records exist in the same session?

```
SELECT * FROM TTEST;
```

- (2) Check if records exist in another session?
- (1) Commit transaction

```
COMMIT;
```

- (2) Check if records exist in second session

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Oracle Transactions hands-on (2)

- (1) Insert a record

```
INSERT INTO TTEST VALUES (3);
```

- (2) Insert the same record here too!
- (1) Commit transaction

```
COMMIT;
```

- (1) Insert a record

```
INSERT INTO TTEST VALUES (3);
```

- (2) Insert the same record here too!
- (1) Rollback transaction

```
ROLLBACK;
```

Privileges

- Authorization model
  - Every object has an <u>owner</u> = schema = user
  - privileges control if a user can <u>access and/or modify</u> an object owned by <u>another</u> user
  - privileges are <u>granted or revoked</u> by
    - instance administrator, a user with the ADMIN privilege
    - owner of the object
- Accounts = Object owners
  - Administrative accounts SYS, SYSTEM
  - Schema accounts = users
- Roles
  - groupings of privileges that you can use to create different levels of database access
  - all users of the database have the <u>PUBLIC</u> role
  - DBA, SYSDBA, SYSOPER are administrative roles

Oracle Privileges hands-on

- Try to access your colleagues table

```
SELECT * FROM CMS_{LAST_NAME}.PARTS;
```

- Grant read access to PUBLIC role

```
GRANT SELECT ON PARTS TO PUBLIC;
```

- Try to select from colleagues table again?

Oracle Privileges hands-on

- Grant modification of data to fellow students

```
GRANT SELECT, INSERT, UPDATE ON TTEST TO CMS_DBSCHOOL_STUDENT;
```

- Try to insert, update data records in colleagues' table.
- Try to DELETE records there. Does it work?

- Revoke modification permission

```
REVOKE INSERT, UPDATE ON TTEST FROM CMS_DBSCHOOL_STUDENT;
```

Indexes

- Index
  - schema object that contains an entry for each value that appears in the indexed column(s)
  - provides direct, fast access to rows
  - Index types in Oracle
    - Normal indexes (B-tree)
    - Bitmap indexes (rowids associated with a key value as a bitmap)
    - Partitioned indexes
    - Function-based indexes (based on expressions), Domain indexes (application-specific)
- CREATE INDEX statement
  - creates an index on one or more columns of a table

```
CREATE INDEX parts_name_idx ON parts (name);
```

SQL Query Execution

- <u>Parser</u> checks syntax and semantic analysis
- <u>Optimizer</u> determines the most efficient way of producing the result of the query by either
    - costing methods - cost-based optimizer (CBO)
    - internal rules - rule-based optimizer (RBO)
- <u>Row Source Generator</u> outputs the execution plan for the SQL statement based on the plan
- <u>SQL Execution Engine</u> executes plan and then produces the results of the query
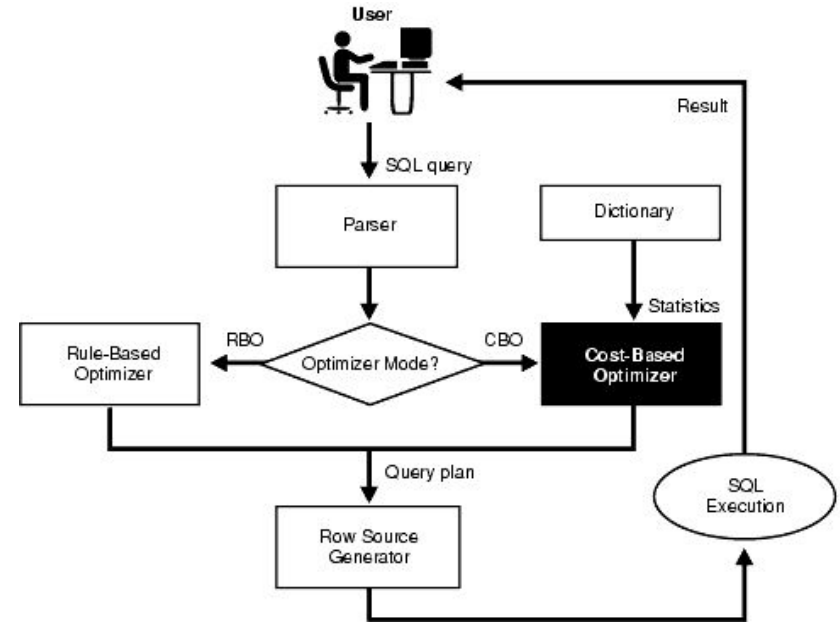
SQL Optimization Hints

1. Index all the predicates in `JOIN, WHERE, ORDER BY` and `GROUP BY` clauses
2. Avoid using functions in predicates as index is not used if there is a function on the column

    `SELECT * FROM TABLE1 WHERE UPPER(COL1)='ABC'`

3. Avoid using wildcard (%) at the beginning of a predicate

    `SELECT * FROM TABLE1 WHERE COL1 LIKE '%ABC'`

4. Avoid unnecessary columns in `SELECT` clause (replace * with columns)
5. Use inner join, instead of outer join if possible
6. `DISTINCT` and `UNION` should be used only if it is necessary
7. CLOB/BLOB columns must be put at the end of the statements
8. Limit `ORDER BY` clause usage
9. Educate yourself
   a. SQL Tuning by Oracle
   b. Techniques for improving the performance of SQL queries by IBM Knowledge Center

Data Dictionary

- Data dictionary views / catalog views (aka Reflection)
  - monitor the state of the database in real time
- View types
  - USER, ALL, DBA show information about schema objects
    - at different levels of privilege
  - V$ show performance-related information
  - _PRIVS views show privilege information for users, roles, and objects
- Reference
  - Lookup "Oracle Catalog Views" in web
  - https://docs.oracle.com/database/121/nav/catalog_views.htm

Catalog Views hands-on

- Use sqlplus alone
- Discover which table columns are indexed?
- Discover index types
- Provide the single results table

- Hint:
  - Search web for "Oracle Catalog Views"
  - Discover USER_IND* catalog view names

PL/SQL

- PL/SQL is a Procedural Language for SQL
  - compiled by the Oracle Database server and stored inside the database
  - both PL/SQL and SQL run within the same server process
- Try to execute this in sqlplus:

```
BEGIN
   FOR i IN 5..20 LOOP
      IF MOD(i,2) = 0 THEN
         INSERT INTO ttest(id) VALUES (i);
      END IF;
   END LOOP;
   COMMIT;
END;
```

PL/SQL stored subprograms

- Stored Procedures and Functions
  - compiled and stored in an Oracle Database, ready to be executed
  - can accept parameters when they are executed
- Packages (specification and optional body)
  - groups logically related PL/SQL types, variables, and subprograms

```
CREATE OR REPLACE FUNCTION ttest_total RETURN number IS
   total number := 0;
BEGIN
   SELECT count(*) into total FROM ttest;
   RETURN total;
END;
/

select ttest_total() from dual;
```

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PL/SQL hands-on

- Create function IS_EVEN
  - accepts NUMBER parameter
  - returns string (varchar2) "EVEN" or "ODD"
- Use the function in SQL to print table for each TTEST row

```
        ID EVEN
------------------
         3 ODD
         1 ODD
         6 EVEN
        20 EVEN
        10 EVEN
        12 EVEN
        14 EVEN
        16 EVEN
        18 EVEN
         4 EVEN
         2 EVEN
         8 EVEN

12 rows selected.
```

Summary

- Most popular DBMS - Relational
  - Based on Relational Model
  - Separation of Logical and Physical layers
  - Oracle Database - one of the leading ones in the market. Since the beginning.
- Oracle Database
  - Database - Files
  - Instance - Service
  - Account/Schema - main objects container / subject of privileges
- Features to consider
  - Catalog Views - database reflection (lookup reference)
  - SQL tuning - huge subject, mind indexes, …
  - PL/SQL - powerful application development tool