

DATABASE MANAGEMENT SYSTEMS-ASSIGNMENT QUESTIONS

NAME: NAVULURI ANJALI

RG NO: 192324137

DEPT: AI-DS

1. ER Diagram Question:

Traffic Flow Management System (TFMS)

Scenario

You are tasked with designing an Entity-Relationship (ER) diagram for a Traffic Flow Management System (TFMS) used in a city to optimize traffic routes, manage intersections, and control traffic signals. The TFMS aims to enhance transportation efficiency by utilizing real-time data from sensors and historical traffic patterns.

ER diagram for the Traffic Flow Management System (TFMS):

Entities and Attributes

Roads

- RoadID (PK)
- RoadName
- Length (in meters)
- SpeedLimit (in km/h)

Intersections

- IntersectionID (PK)
- IntersectionName
- Latitude
- Longitude

Traffic Signals

- SignalID (PK)
- IntersectionID (FK referencing Intersections)

- SignalStatus (Green, Yellow, Red)
- Timer (countdown to next change)

Traffic Data

- TrafficDataID (PK)
- RoadID (FK referencing Roads)
- Timestamp
- Speed (average speed on the road)
- Congestion Level (degree of traffic congestion)

Relationships

A road can have multiple intersections (one-to-many): Roads -> Intersections

Cardinality: 1: N

Optionality: Mandatory (a road must have at least one intersection)

An intersection can have multiple roads (many-to-many): Intersections -> Roads

Cardinality: M: N

Optionality: Mandatory (an intersection must have at least one road)

An intersection can have one traffic signal (one-to-one): Intersections -> Traffic Signals

Cardinality: 1:1

Optionality: Optional (an intersection may not have a traffic signal)

A traffic signal is associated with one intersection (one-to-one): Traffic Signals -> Intersections

Cardinality: 1:1

Optionality: Mandatory (a traffic signal must be associated with an intersection)

A road can have multiple traffic data points (one-to-many): Roads -> Traffic Data

Cardinality: 1: N

Optionality: Mandatory (a road must have at least one traffic data point)

Normalization Considerations

To ensure the ER diagram adheres to normalization principles, we can apply the following rules:

First Normal Form (1NF): Each table cell must contain a single value. This is already satisfied in the ER diagram.

Second Normal Form (2NF): Each non-key attribute in a table must depend on the entire primary key. This is satisfied since each attribute in each entity depends on the primary key of that entity.

Third Normal Form (3NF): If a table is in 2NF, and a non-key attribute depends on another non-key attribute, then it should be moved to a separate table. This is not applicable in this ER diagram since there are no transitive dependencies.

+-----+

| Roads |

+-----+

| RoadID (PK) |

| RoadName |

| Length |

| SpeedLimit |

+-----+

|

| 1: N

v

+-----+

| Intersections |

+-----+

| IntersectionID |

| IntersectionName|

| Latitude |

| Longitude |

+-----+

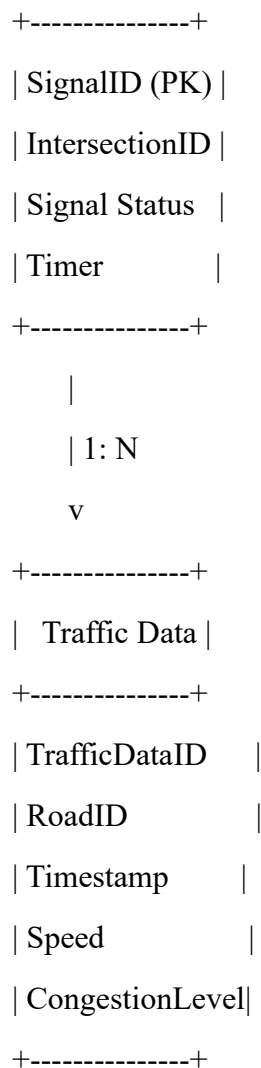
|

| 1:1

v

+-----+

| Traffic Signals|



The relationships between the entities are represented by the lines connecting them:

- A road can have multiple intersections (one-to-many): Roads -> Intersections
- An intersection can have multiple roads (many-to-many): Intersections -> Roads
- An intersection can have one traffic signal (one-to-one): Intersections -> Traffic Signals
- A traffic signal is associated with one intersection (one-to-one): Traffic Signals -> Intersections
- A road can have multiple traffic data points (one-to-many): Roads -> Traffic Data

Here is a key to the notation used:

- (PK) indicates a primary key

- 1: N indicates a one-to-many relationship
- 1:1 indicates a one-to-one relationship
- M: N indicates a many-to-many relationship
- indicates a mandatory relationship (i.e., a relationship that must exist)
- indicates an optional relationship (i.e., a relationship that may or may not exist)

2.

Question 1: Top 3 Departments with Highest Average Salary

Task:

1. Write a SQL query to find the top 3 departments with the highest average salary of employees. Ensure departments with no employees show an average salary of NULL.

SQL Query

```
WITH department_salaries AS (
    SELECT
        d.DepartmentID,
        d.DepartmentName,
        AVG (e. Salary) AS AvgSalary
    FROM
        Departments d
    LEFT JOIN
        Employees e ON d. DepartmentID = e. DepartmentID
    GROUP BY
        d.DepartmentID, d. DepartmentName
)
SELECT
```

```
DepartmentID,  
DepartmentName,  
AvgSalary  
FROM  
department_salaries  
ORDER BY  
AvgSalary DESC  
LIMIT 3;
```

Explanation:

This SQL query finds the top 3 departments with the highest average salary of employees. It does this by:

- Joining the **Departments** table with the **Employees** table on the **DepartmentID** column
- Calculating the average salary for each department using the **AVG** function
- Including departments with no employees in the result set, with a **NULL** value for average salary
- Sorting the result set in descending order by average salary
- Returning only the top 3 departments with the highest average salary

Question 2: Retrieving Hierarchical Category Paths

Task:

1. **Write a SQL query using recursive Common Table Expressions (CTE) to retrieve all categories along with their full hierarchical path (e.g., Category > Subcategory > Sub-subcategory).**

SQL Query

```
WITH RECURSIVE category_hierarchy AS (  
-- Anchor query: Select top-level categories
```

```
SELECT
    CategoryID,
    CategoryName,
    CAST (CategoryName AS VARCHAR(MAX)) AS HierarchicalPath,
    0 AS Level
```

```
FROM
```

```
    Categories
```

```
WHERE
```

```
    ParentCategoryID IS NULL
```

```
UNION ALL
```

```
-- Recursive query: Select child categories
```

```
SELECT
```

```
    c.CategoryID,
```

```
    c.CategoryName,
```

```
    ch.HierarchicalPath + '>' + c.CategoryName,
```

```
    ch. Level + 1
```

```
FROM
```

```
    Categories c
```

```
INNER JOIN
```

```
    category_hierarchy ch ON c. ParentCategoryID = ch. CategoryID
```

```
)
```

```
SELECT
```

```
    CategoryID,
```

```
    CategoryName,
```

```
    HierarchicalPath
```

FROM

category_hierarchy

ORDER BY

HierarchicalPath;

Explanation of Recursive CTE

This SQL query uses a recursive Common Table Expression (CTE) to retrieve all categories along with their full hierarchical path. Here's what it does:

- It starts with the top-level categories (categories with no parent)
- Then, it recursively adds child categories to the result set, building the hierarchical path by concatenating the parent category's path with the child category's name
- The query continues to add child categories until it reaches the lowest level of the hierarchy
- Finally, it returns the category ID, category name, and the full hierarchical path for each category

Question 3: Total Distinct Customers by Month

Task:

1. **Design a SQL query to find the total number of distinct customers who made a purchase in each month of the current year. Ensure months with no customer activity show a count of 0.**

SQL Query

WITH Months AS (

SELECT

DATENAME (MONTH, DATEFROMPARTS (YEAR (GETDATE ()), m, 1)) AS
MonthName

FROM

(VALUES (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12)) AS Months(m)

),

CustomerPurchases AS (


```

SELECT

    DATENAME (MONTH, o. OrderDate) AS MonthName,

    COUNT (DISTINCT c. CustomerID) AS CustomerCount

FROM

    Customers c

INNER JOIN

    Orders o ON c. CustomerID = o. CustomerID

WHERE

    YEAR (o. OrderDate) = YEAR (GETDATE ())

GROUP BY

    DATENAME (MONTH, o. OrderDate)
)

SELECT

    m.MonthName,

    COALESCE (cp. CustomerCount, 0) AS CustomerCount

FROM

    Months m

LEFT JOIN CustomerPurchases cp ON m. MonthName = cp. MonthName

ORDER BY

    m.MonthName;

```

Explanation of the Query

- **Months CTE:** The first CTE, **Months**, generates a list of all 12 months of the year using a derived table with **VALUES** clause. The **DATENAME** function is used to get the month name from the month number.
- **Customer Purchases CTE:** The second CTE, **Customer Purchases**, retrieves the number of distinct customers who made a purchase in each month of the current year.

It joins the **Customers** and **Orders** tables, filters the orders by the current year, and groups the results by month.

- **LEFT JOIN:** The main query uses a **LEFT JOIN** to combine the **Months** CTE with the **Customer Purchases** CTE. This ensures that all months are included in the result set, even if there are no customer purchases in a particular month.
- **COALESCE:** The **COALESCE** function is used to replace **NULL** values in the **Customer Count** column with 0. This handles the case where there are no customer purchases in a month, ensuring that the result set shows a count of 0 for that month.
- **ORDER BY:** Finally, the result set is sorted by month name to ensure that the months are in the correct order.

Question 4: Finding Closest Locations

Task:

1. Write a SQL query to find the closest 5 locations to a given point specified by latitude and longitude. Use spatial functions or advanced mathematical calculations for proximity.

SQL Query

WITH ClosestLocations AS (

SELECT

l.LocationID,

l.LocationName,

l.Latitude,

l.Longitude,

(

3959 * ACOS (

COS(RADIANS(@lat)) * COS (RADIANS (l. Latitude)) *

COS (RADIANS (l. Longitude) - RADIANS(@lon)) +

SIN(RADIANS(@lat)) * SIN (RADIANS (l. Latitude))

```

    )
    ) AS Distance
FROM
    Locations l
)
SELECT
    LocationID,
    LocationName,
    Latitude,
    Longitude,
    Distance
FROM
    ClosestLocations
ORDER BY
    Distance
LIMIT 5;

```

Explanation of the Mathematical Approach

The query uses the Haversine formula, a well-known algorithm for calculating the distance between two points on a sphere (such as the Earth) given their longitudes and latitudes. The formula is implemented using a combination of trigonometric functions and mathematical operations.

Here's a breakdown of the formula:

- **3959** is the average radius of the Earth in miles.
- **ACOS** calculates the inverse cosine of the angle between the two points.
- **COS(RADIANS(@lat))** and **COS (RADIANS (l. Latitude))** calculate the cosine of the latitude angles.

- **COS (RADIANS (l. Longitude) - RADIANS(@lon))** calculates the cosine of the longitude difference.
- **SIN(RADIANS(@lat))** and **SIN (RADIANS (l. Latitude))** calculate the sine of the latitude angles.
- The formula combines these values to calculate the distance between the two points.

Question 5: Optimizing Query for Orders Table

Task:

1. Write a SQL query to retrieve orders placed in the last 7 days from a large Orders table, sorted by order date in descending order.

SQL Query

SELECT

- o. OrderID,
- o. OrderDate,
- o. CustomerID,
- o. TotalAmount

FROM

Orders o

WHERE

- o. OrderDate >= DATEADD (DAY, -7, CONVERT (DATE, GETDATE ()))

ORDER BY

- o. OrderDate DESC;

Discussion of Strategies Used to Optimize the Query

- **Indexing:** Creating an index on the **Order Date** column can significantly improve query performance. This is because the query filters on this column, and an index can help the database quickly locate the relevant rows.

- **Date arithmetic:** Instead of using a function like **DATEDIFF** to calculate the date range, I used the **DATEADD** function to subtract 7 days from the current date. This allows the database to use an index on the **Order Date** column.
- **Convert to date:** By converting the **GETDATE ()** function to a **DATE** data type, I ensured that the database can use an index on the **Order Date** column. This is because the **GETDATE ()** function returns a **DATETIME** value, which may not be compatible with the **DATE** data type of the **Order Date** column.
- **Avoid using functions in the WHERE clause:** By rewriting the query to use a date range instead of a function like **DATEDIFF**, I avoided the need for the database to evaluate the function for each row. This can improve performance, especially for large tables.
- **Optimized sorting:** By sorting the results in descending order by **Order Date**, I ensured that the database can use an index on this column to optimize the sorting operation.

3.

PL/SQL Questions

Question 1: Handling Division Operation

Task:

1. Write a PL/SQL block to perform a division operation where the divisor is obtained from user input. Handle the **ZERO_DIVIDE** exception gracefully with an appropriate error message.

PL/SQL Query

DECLARE

dividend NUMBER: = 10;

divisor NUMBER;

result NUMBER;

```

BEGIN

divisor: = &enter_divisor; -- obtain divisor from user input

BEGIN

    result: = dividend / divisor;

    DBMS_OUTPUT.PUT_LINE ('Result: ' || result);

EXCEPTION

WHEN ZERO_DIVIDE THEN

    DBMS_OUTPUT.PUT_LINE ('Error: Division by zero');

END;

END;

```

Explanation of error handling strategies implemented:

The code uses a nested BEGIN-END block to catch the specific exception obtained from a division operation. The divisor is obtained from user input, and the division operation is performed inside the inner BEGIN-END block. If a division by zero exception is raised, the EXCEPTION block immediately follows the division operation and catches the ZERO_DIVIDE exception. Inside the EXCEPTION block, an error message is displayed indicating that a division by zero has occurred. This approach ensures that the program does not terminate abruptly due to the exception, but instead handles it gracefully and provides a meaningful error message to the user.

Question 2: Updating Rows with FORALL

Task:

- 1. Use the FORALL statement to update multiple rows in the Employees table based on arrays of employee IDs and salary increments.**

PL/SQL Query

```

DECLARE

TYPE emp_id_array IS VARRAY (10) OF NUMBER;

```

```
TYPE salary_inc_array IS VARRAY (10) OF NUMBER;
```

```
emp_ids emp_id_array := emp_id_array (101, 102, 103, 104, 105);
```

```
salary_incs salary_inc_array := salary_inc_array (1000, 2000, 3000, 4000, 5000);
```

```
BEGIN
```

```
FORALL i IN 1.emp_ids. COUNT
```

```
    UPDATE Employees
```

```
        SET salary = salary + salary_incs(i)
```

```
        WHERE employee_id = emp_ids(i);
```

```
COMMIT;
```

```
END;
```

Description of how FORALL improves performance for bulk updates:

The FORALL statement is a bulk DML (Data Manipulation Language) statement that allows you to execute a single DML statement multiple times, with each iteration using a different set of values from an array. In this example, we use two arrays, emp_ids and salary_incs, to store the employee IDs and corresponding salary increments.

1. **Reduced number of SQL statements:** Instead of executing multiple individual UPDATE statements, one for each employee, the FORALL statement executes a single UPDATE statement that updates multiple rows in a single operation.
2. **Improved performance:** By reducing the number of SQL statements, the FORALL statement minimizes the overhead of parsing, binding, and executing individual statements.
3. **Enhanced concurrency:** FORALL statements can take advantage of Oracle's parallel processing capabilities, allowing multiple updates to be executed concurrently, further improving performance.
4. **Error handling:** If an error occurs during the execution of the FORALL statement, Oracle rolls back the entire operation, ensuring data consistency and integrity.

Question 3: Implementing Nested Table Procedure

Task:

1. **Implement a PL/SQL procedure that accepts a department ID as input, retrieves employees belonging to the department, stores them in a nested table type, and returns this collection as an output parameter.**

PL/SQL Query

```
CREATE OR REPLACE TYPE employee_type AS OBJECT (  
    employee_id NUMBER,  
    first_name VARCHAR2(20),  
    last_name VARCHAR2(20)  
);  
  
CREATE OR REPLACE TYPE employee_collection AS TABLE OF employee_type;  
  
CREATE OR REPLACE PROCEDURE get_department_employees(  
    p_department_id IN NUMBER,  
    p_employees OUT employee_collection  
) AS  
  
BEGIN  
  
    SELECT employee_type (e. employee_id, e. first_name, e. last_name)  
    BULK COLLECT INTO p_employees  
    FROM Employees e  
    WHERE e. department_id = p_department_id;  
  
END get_department_employees;
```

Explanation of how nested tables are utilized and returned as output:

1. **Nested Table Type:** We define a nested table type **employee_collection** as a table of **employee_type** objects. This allows us to store a collection of employee records.
2. **Procedure Definition:** The **get_department_employees** procedure takes two parameters: **p_department_id** (input) and **p_employees** (output). The output parameter **p_employees** is of type **employee_collection**.
3. **BULK COLLECT INTO:** Inside the procedure, we use the **BULK COLLECT INTO** statement to retrieve the employees belonging to the specified department and store them in the **p_employees** collection. This statement allows us to fetch multiple rows into a single collection.
4. **Returning the Collection:** The **p_employees** collection is returned as an output parameter, which can be accessed by the calling program.

Question 4: Using Cursor Variables and Dynamic SQL

Task:

1. Write a PL/SQL block demonstrating the use of cursor variables (REF CURSOR) and dynamic SQL. Declare a cursor variable for querying EmployeeID, FirstName, and LastName based on a specified salary threshold.

PL/SQL Query

DECLARE

-- Declare a REF CURSOR type

TYPE ref_cursor IS REF CURSOR;

-- Declare a cursor variable

v_cursor ref_cursor;

-- Declare variables to hold the dynamic SQL statement and its parameters

v_sql_stmt VARCHAR2(200);

v_salary_threshold NUMBER := 50000;

```

-- Declare variables to hold the query results

v_employee_id NUMBER;

v_first_name VARCHAR2(20);

v_last_name VARCHAR2(20);

BEGIN

-- Construct the dynamic SQL statement

v_sql_stmt := 'SELECT employee_id, first_name, last_name FROM Employees WHERE

salary > :salary_threshold';

-- Open the cursor variable with the dynamic SQL statement

OPEN v_cursor FOR v_sql_stmt USING v_salary_threshold;

-- Fetch the query results

LOOP

FETCH v_cursor INTO v_employee_id, v_first_name, v_last_name;

EXIT WHEN v_cursor%NOTFOUND;

-- Process the query results

DBMS_OUTPUT.PUT_LINE ('Employee ID: ' || v_employee_id || ', Name: ' ||

v_first_name || ' ' || v_last_name);

END LOOP;

-- Close the cursor variable

CLOSE v_cursor;

END;

```

Explanation of how dynamic SQL is constructed and executed:

1. Declaring a REF CURSOR type: We declare a REF CURSOR type, which is a pointer to a cursor.
2. Declaring a cursor variable: We declare a cursor variable v_cursor of type REF CURSOR.
3. Constructing the dynamic SQL statement: We construct a dynamic SQL statement as a string, using a placeholder: salary_threshold for the salary threshold parameter.
4. Opening the cursor variable: We open the cursor variable with the dynamic SQL statement, passing the v_salary_threshold parameter as a bind variable.
5. Fetching the query results: We fetch the query results using a LOOP statement, which iterates over the rows returned by the cursor.
6. Processing the query results: We process the query results by printing the employee ID, first name, and last name to the console.
7. Closing the cursor variable: We close the cursor variable to release system resources.

Dynamic SQL is constructed by concatenating strings to form a SQL statement. In this example, we construct a SELECT statement with a WHERE clause that filters employees based on a salary threshold. The: salary_threshold placeholder is replaced with the actual value of v_salary_threshold when the cursor is opened.

Question 5: Designing Pipelined Function for Sales Data

Task:

1. **Design a pipelined PL/SQL function get_sales_data that retrieves sales data for a given month and year. The function should return a table of records containing OrderID, CustomerID, and OrderAmount for orders placed in the specified month and year.**

PL/SQL Query:

```
CREATE OR REPLACE PACKAGE sales_data_pkg AS  
  
TYPE sales_data_rec IS RECORD (  
    order_id NUMBER,
```

```

    customer_id NUMBER,

    order_amount NUMBER

);

TYPE sales_data_tbl IS TABLE OF sales_data_rec;

FUNCTION get_sales_data(p_month IN NUMBER, p_year IN NUMBER)

    RETURN sales_data_tbl PIPELINED;

END sales_data_pkg;

CREATE OR REPLACE PACKAGE BODY sales_data_pkg AS

    FUNCTION get_sales_data(p_month IN NUMBER, p_year IN NUMBER)

        RETURN sales_data_tbl PIPELINED AS

    BEGIN

        FOR cur_rec IN (

            SELECT order_id, customer_id, order_amount

            FROM orders

            WHERE EXTRACT (MONTH FROM order_date) = p_month

            AND EXTRACT (YEAR FROM order_date) = p_year

        ) LOOP

            PIPE ROW (sales_data_rec(cur_rec.order_id, cur_rec.customer_id,
cur_rec.order_amount));

        END LOOP;

        RETURN;

    END get_sales_data;

END sales_data_pkg;

```

Explanation of how pipelined table functions improve data retrieval efficiency:

1. **Pipelined Functions:** A pipelined function is a type of table function that returns a table of records in a pipelined manner, allowing the caller to process the data in a streaming fashion.
2. **Improved Efficiency:** Pipelined table functions improve data retrieval efficiency in several ways:
 - **Reduced Memory Usage:** By processing the data in a pipelined manner, the function only needs to store a small amount of data in memory at a time, reducing the memory footprint and improving performance.
 - **Faster Data Retrieval:** Pipelined functions can return data to the caller as soon as it is available, rather than waiting for the entire result set to be generated. This can significantly improve data retrieval times, especially for large datasets.
 - **Improved Scalability:** Pipelined functions can handle large datasets more efficiently, making them more scalable and suitable for big data applications.
3. **How it Works:** In the `get_sales_data` function, we use a cursor to iterate over the orders table, filtering the data based on the specified month and year. For each row, we use the `PIPE ROW` statement to return a single record to the caller, allowing the data to be processed in a streaming fashion.
4. **Caller Perspective:** From the caller's perspective, the pipelined function returns a table of records that can be processed using a cursor or a loop. The caller can process the data as it is returned, without having to wait for the entire result set to be generated.

