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Introduction to solving SQL problems with MATCH_RECOGNIZE

About me…

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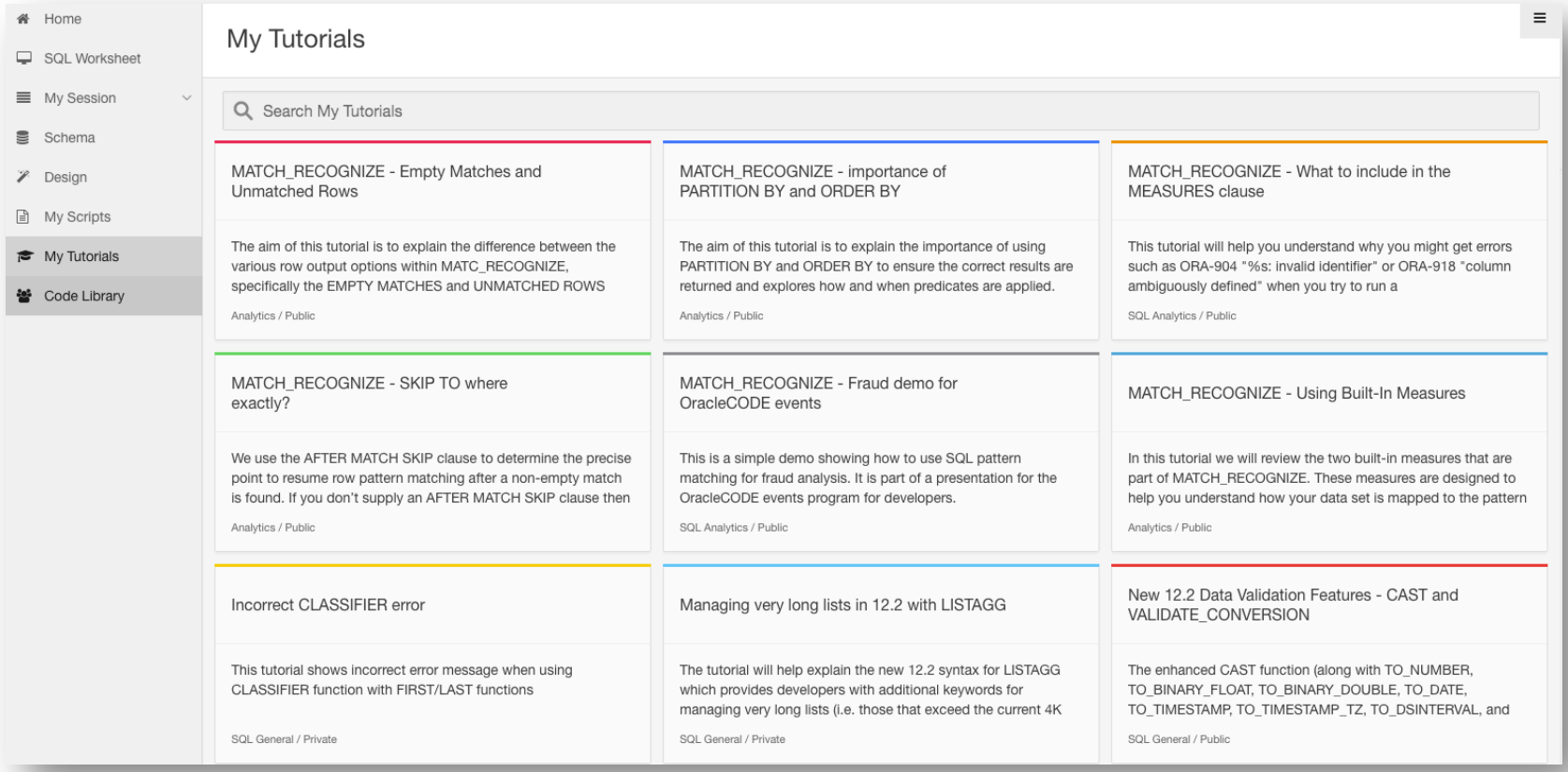
Agenda

1. What is MATCH_RECOGNIZE
2. Use Case 1: sessionization
3. Use Case 2: controlling string concatenation
4. Use Case 3: forming contiguous date ranges
5. Summary

Lots of tutorials on http://livesql.oracle.com



What is MATCH_RECOGNIZE

Pattern Recognition In Sequences of Rows

SQL - a new language for pattern matching

Provide native SQL language construct

With intuitive processing

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- New SQL construct MATCH_RECOGNIZE
  - Added as part of the ANSI-2016 SQL standard

With intuitive processing

Pattern Recognition In Sequences of Rows

SQL - a new language for pattern matching

Provide native SQL language construct

- New SQL construct MATCH_RECOGNIZE
  - Added as part of the ANSI-2016 SQL standard

With intuitive processing

- Four logical concepts:
  - Logically partition and order the data
  - Define pattern using regular expression and pattern variables
  - Regular expression is matched against a sequence of rows
  - Each pattern variable is defined using conditions on rows and aggregates

SQL MATCH_RECOGNIZE

"Declarative" pattern matching - 4 simple steps

1. Define the partitions/buckets and ordering needed to identify the 'stream of events' you are analyzing
   - Matching within a stream of events (ordered partition of data)

2. Define the pattern of events and pattern variables identifying the individual events within the pattern
   - Use framework of Perl regular expressions (conditions on rows)
   - Define matching using Boolean conditions on rows

```
Current time - INTERVAL '10' second) >= previous time
```

SQL MATCH_RECOGNIZE

"Declarative" pattern matching - 4 simple steps

3. Define measures: source data points, pattern data points and aggregates related to a pattern
   - MEASURES
     ```
     . . . Session_id
     . . . Number of events
     . . . Start time
     . . . End time
     . . . Duration
     ```
4. Determine how the output will be generated

Use Case 1: Sessionization

Use Case 1: Sessionization

Web Sessionization

Analyze online customer sessions by identifying each session within a series of clicks and then track user activity that typically involves multiple events

New SQL construct: **MATCH_RECOGNIZE**
Define patterns using regular expression syntax

Supports a wide range of use cases

Source Data Set: JSON Key-Value Pairs Log File

Store log file data as a JSON document

```
CREATE TABLE json_sessionization
(session_doc CLOB,
CONSTRAINT "VALID_JSON" CHECK
(session_doc IS JSON) ENABLE
```

```
SELECT
 TO_NUMBER(j.session_doc.time_id) as time_id,
 j.session_doc.user_id as user_id
FROM json_sessionization j;
```

```
1  [{
2  "time_id":"1",
3  "user_id":"Mary"
4  }
5  {
6  "time_id":"1",
7  "user_id":"Sam"
8  }
9  {
10 "time_id":"11",
11 "user_id":"Mary"
12 }
13 {
14 "time_id":"12",
15 "user_id":"Sam"
16 }
17 {
18 "time_id":"22",
19 "user_id":"Sam"
20 }
21 {
22 "time_id":"23",
23 "user_id":"Mary"
24 }
25 {
26 "time_id":"32",
27 "user_id":"Sam"
28 }
29 {
30 "time_id":"34",
31 "user_id":"Mary"
32 }
```

TIME_ID	USER ID
1	Mary
2	Sam
11	Mary
12	Sam
22	Sam
23	Mary
32	Sam
34	Mary
43	Sam
44	Mary
47	Sam
48	Sam
53	Mary
59	Sam
60	Sam
63	Mary
68	Sam

Use Case 1: Sessionization

Define a **session** as a sequence of one or more **events** within the same partition key **where** the inter-timestamp gap is less than a specified threshold

TIME_ID	USER ID
1	Mary
2	Sam
11	Mary
12	Sam
22	Sam
23	Mary
32	Sam
34	Mary
43	Sam
44	Mary
47	Sam
48	Sam
53	Mary
59	Sam
60	Sam
63	Mary
68	Sam

1. Number sessions per user

TIME_ID	USER ID	SESSION
1	Mary	1
11	Mary	1
23	Mary	2
34	Mary	3
44	Mary	3
53	Mary	3
63	Mary	3

2. Aggregate analysis to provide deeper insight

USER_ID	SESSION ID	START TIME	END TIME	NUM EVENTS	DURATION
Mary	1	1	11	2	10
Mary	2	23	23	1	0
Mary	3	34	63	4	29

Use Case 1: Sessionization

New syntax for discovering patterns using SQL:

MATCH_RECOGNIZE ( )

```
SELECT *
FROM . . . MATCH_RECOGNIZE
 (
      . . .
)
```

Defining PARTITION BY and ORDER BY Clauses

Find distinct user sessions in a weblog:

Step 1: define partitions/ buckets and ordering needed to identify the "stream of events"…

Set the PARTITION BY and ORDER BY clauses

```
SELECT *
FROM . . . MATCH_RECOGNIZE
(
      PARTITION BY user_id ORDER BY time_id


      . . .
)
```

Defining Pattern Statement

Step 2: define the pattern of events and pattern variables identifying the individual events within the pattern

Define the **pattern** – identify each “session”

```
SELECT *
FROM . . . MATCH_RECOGNIZE
(
      PARTITION BY user_id ORDER BY time_id

      PATTERN (b s+)

      . . .
)
```

Build Regular Expressions

- Concatenation: no operator
- Quantifiers:
  - * 0 or more matches
  - **+ 1 or more matches**
  - ? 0 or 1 match
  - {n} exactly n matches
  - {n,} n or more matches
  - {n, m} between n and m (inclusive) matches
  - {, m} between 0 an m (inclusive) matches
  - Reluctant quantifier – an additional ?

Define Pattern Variables…

Define the **pattern variables** – specify each variable listed in the pattern

a session is a sequence of one or more events within the same partition key where the inter-timestamp gap is less than a 10 seconds

```
SELECT *
FROM . . . MATCH_RECOGNIZE
(
      PARTITION BY user_id ORDER BY time_id



      PATTERN (b s+)
      DEFINE
        s as (time_id - prev(time_id)) <=10

      . . .
)
```

Listing Pattern Measures to be Computed

Step 3: define the measures: source data points, pattern data points and aggregates related to a pattern:

- MATCH_NUMBER()
- COUNT(): number of events
- FIRST: start time
- LAST: end time

```
SELECT *
FROM . . . MATCH_RECOGNIZE
(
      PARTITION BY user_id ORDER BY time_id
      MEASURES user_id,
               match_number() session_id,
               count(*) as no_of_events,
               first(b.time_id) start_time,
               last(s.time_id) end_time,
               last(s.time_id) - first(b.time_id) duration

      PATTERN (b s+)
      DEFINE
        s as (time_id - PREV(time_id)) <=10
      . . .
)
```

Defining Output Style: Summary vs. Detailed

Step 4: determine how the output will be generated

Output ONE ROW for each time we find a match to our pattern

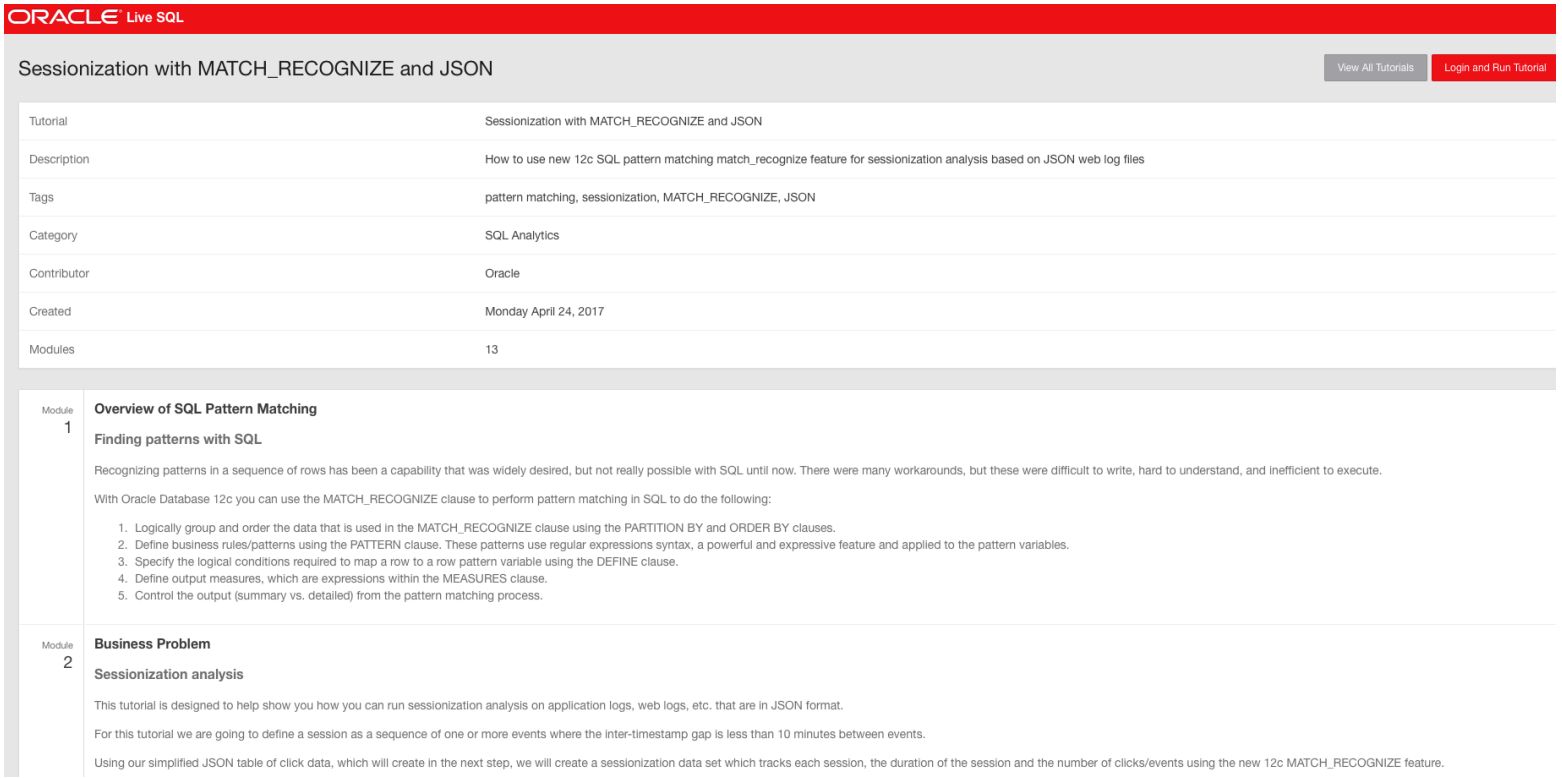
```
SELECT *
FROM . . . MATCH_RECOGNIZE
(
      PARTITION BY user_id ORDER BY time_id
      MEASURES user_id
               match_number() session_id,
               count(*) as no_of_events,
               first(time_id) start_time,
               last(s.time_id) end_time,
               last(time_id) - first(time_id) duration
      ONE ROW PER MATCH
      PATTERN (b s+)
      DEFINE
        s as (time_id - PREV(time_id)) <=10
      . . .
)
```

Pattern Output Options

Controlling the output

- Which rows to return
  - ONE ROW PER MATCH
  - ALL ROWS PER MATCH
  - ALL ROWS PER MATCH WITH UNMATCHED ROWS
- After match SKIP option :
  - SKIP PAST LAST ROW
  - SKIP TO NEXT ROW
  - SKIP TO <VARIABLE>
  - SKIP TO FIRST(<VARIABLE>)
  - SKIP TO LAST (<VARIABLE>)

Live demonstration – Sessionization Tutorial



https://livesql.oracle.com/apex/livesql/file/tutorial_EWB8G5JBSHAGM9FB2GL4V5CAQ.html

Use Case 2: Controlling String Concatenation

Employee Data Set

Transform EMP table to . . .

DEPTNO	EMPNO	ENAME	JOB	MGR	HIREDATE	SAL	COMM
10	7782	CLARK	MANAGER	7839	09-JUN-81	2450	-
10	7839	KING	PRESIDENT	-	17-NOV-81	5000	-
10	7934	MILLER	CLERK	7782	23-JAN-82	1300	-
20	7369	SMITH	CLERK	7902	17-DEC-80	800	-
20	7566	JONES	MANAGER	7839	02-APR-81	2975	-
20	7788	SCOTT	ANALYST	7566	19-APR-87	3000	-
20	7876	ADAMS	CLERK	7788	23-MAY-87	1100	-
20	7902	FORD	ANALYST	7566	03-DEC-81	3000	-
30	7499	ALLEN	SALESMAN	7698	20-FEB-81	1600	300
30	7521	WARD	SALESMAN	7698	22-FEB-81	1250	500
30	7654	MARTIN	SALESMAN	7698	28-SEP-81	1250	1400
30	7698	BLAKE	MANAGER	7839	01-MAY-81	2850	-
30	7844	TURNER	SALESMAN	7698	08-SEP-81	1500	0
30	7900	JAMES	CLERK	7698	03-DEC-81	950	-

Table listing employees in each Dept.

DEPTNO	NAMELIST
10	CLARK;KING
10	MILLER
20	SMITH;JONES
20	SCOTT;ADAMS
20	FORD
30	ALLEN;WARD
30	MARTIN;BLAKE
30	TURNER;JAMES

Partitioning and Ordering the source data

```
SELECT *
FROM scott.emp
MATCH_RECOGNIZE(
     PARTITION BY deptno ORDER BY empno
```

Create PATTERN Statement and DEFINE Pattern Variables

Add PATTERN statement and DEFINE pattern variables

```
SELECT *
FROM scott.emp
MATCH_RECOGNIZE(
    PARTITION BY deptno ORDER BY empno
    PATTERN (s b*)
    DEFINE
     b AS LENGTHB(S.ename) +
     SUM(LENGTHB(CONCAT(B.ename, ';'))
     + LENGTHB(';') < = 15
```

List Measures to be Calculated

Use built-in measure MATCH_NUMBER() to return a grouping ID

```
SELECT *
FROM scott.emp
MATCH_RECOGNIZE(
     PARTITION BY deptno ORDER BY empno
     MEASURES match_number() AS mno


     PATTERN (S B*)
     DEFINE
      B AS LENGTHB(S.ename) +
      SUM(LENGTHB(CONCAT(B.ename, ';')))
      + LENGTHB(';') < = 15
```

Define Type of Output: Detailed vs. Summary

Return detailed report – returns one row for each successful match of pattern

```
SELECT *
FROM scott.emp
MATCH_RECOGNIZE(
     PARTITION BY deptno ORDER BY empno
     MEASURES match_number() AS mno
     ALL ROWS PER MATCH

     PATTERN (S B*)
     DEFINE
      B AS LENGTHB(S.ename) +
      SUM(LENGTHB(CONCAT(B.ename, ';'))) 
      + LENGTHB(';') < = 15
```

Define Where To Resume Searching

Using default SKIP TO… behaviour to control where to start searching for next pattern

```
SELECT *
FROM scott.emp
MATCH_RECOGNIZE(
     PARTITION BY deptno ORDER BY empno
     MEASURES match_number() AS mno
     ALL ROWS PER MATCH
     AFTER MATCH SKIP PAST LAST ROW
     PATTERN (S B*)
     DEFINE
      B AS LENGTHB(S.ename) +
      SUM(LENGTHB(CONCAT(B.ename, ';')))
      + LENGTHB(';') < = 15
```

SKIP TO - basic syntax

- **AFTER MATCH SKIP TO NEXT ROW**
  - Resume pattern matching at the row after the first row of the current match.
- **AFTER MATCH SKIP PAST LAST ROW** [DEFAULT]
  - Resume pattern matching at the next row after the last row of the current match.
- **AFTER MATCH SKIP TO FIRST** *pattern_variable*
  - Resume pattern matching at the first row that is mapped to the pattern variable.
- **AFTER MATCH SKIP TO LAST** *pattern_variable*
  - Resume pattern matching at the last row that is mapped to the pattern variable.
- **AFTER MATCH SKIP TO** *pattern_variable*
  - The same as AFTER MATCH SKIP TO LAST pattern_variable.

Final Output from MATCH_RECOGNIZE

DEPTNO	EMPNO	MNO	ENAME	JOB	MGR	HIREDATE	SAL	COMM
10	7782	1	CLARK	MANAGER	7839	09-JUN-81	2450	-
10	7839	1	KING	PRESIDENT	-	17-NOV-81	5000	-
10	7934	2	MILLER	CLERK	7782	23-JAN-82	1300	-
20	7369	1	SMITH	CLERK	7902	17-DEC-80	800	-
20	7566	1	JONES	MANAGER	7839	02-APR-81	2975	-
20	7788	2	SCOTT	ANALYST	7566	19-APR-87	3000	-
20	7876	2	ADAMS	CLERK	7788	23-MAY-87	1100	-
20	7902	3	FORD	ANALYST	7566	03-DEC-81	3000	-
30	7499	1	ALLEN	SALESMAN	7698	20-FEB-81	1600	300
30	7521	1	WARD	SALESMAN	7698	22-FEB-81	1250	500
30	7654	2	MARTIN	SALESMAN	7698	28-SEP-81	1250	1400
30	7698	2	BLAKE	MANAGER	7839	01-MAY-81	2850	-
30	7844	3	TURNER	SALESMAN	7698	08-SEP-81	1500	0
30	7900	3	JAMES	CLERK	7698	03-DEC-81	950	-

Final Output from MATCH_RECOGNIZE

Output from MATCH_NUMBER part of final grouping within LISTAGG

DEPTNO	EMPNO	MNO	ENAME	JOB	MGR	HIREDATE	SAL	COMM
10	7782	1	CLARK	MANAGER	7839	09-JUN-81	2450	-
10	7839	1	KING	PRESIDENT	-	17-NOV-81	5000	-
10	7934	2	MILLER	CLERK	7782	23-JAN-82	1300	-
20	7369	1	SMITH	CLERK	7902	17-DEC-80	800	-
20	7566	1	JONES	MANAGER	7839	02-APR-81	2975	-
20	7788	2	SCOTT	ANALYST	7566	19-APR-87	3000	-
20	7876	2	ADAMS	CLERK	7788	23-MAY-87	1100	-
20	7902	3	FORD	ANALYST	7566	03-DEC-81	3000	-
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30	7698	2	BLAKE	MANAGER	7839	01-MAY-81	2850	-
30	7844	3	TURNER	SALESMAN	7698	08-SEP-81	1500	0
30	7900	3	JAMES	CLERK	7698	03-DEC-81	950	-

Controlling String Concatenation

LISTAGG - returns list of concatenated strings arranged as groups within each DEPTNO

DEPTNO	NAMELIST	F
10	CLARK;KING	
10	MILLER	
20	SMITH;JONES	
20	SCOTT;ADAMS	
20	FORD	
30	ALLEN;WARD	
30	MARTIN;BLAKE	
30	TURNER;JAMES	

```
SELECT
  deptno,
  LISTAGG(ename, ';')
    WITHIN GROUP (ORDER BY empno) AS namelist,
FROM emp_mr
 GROUP BY deptno, mno;
```

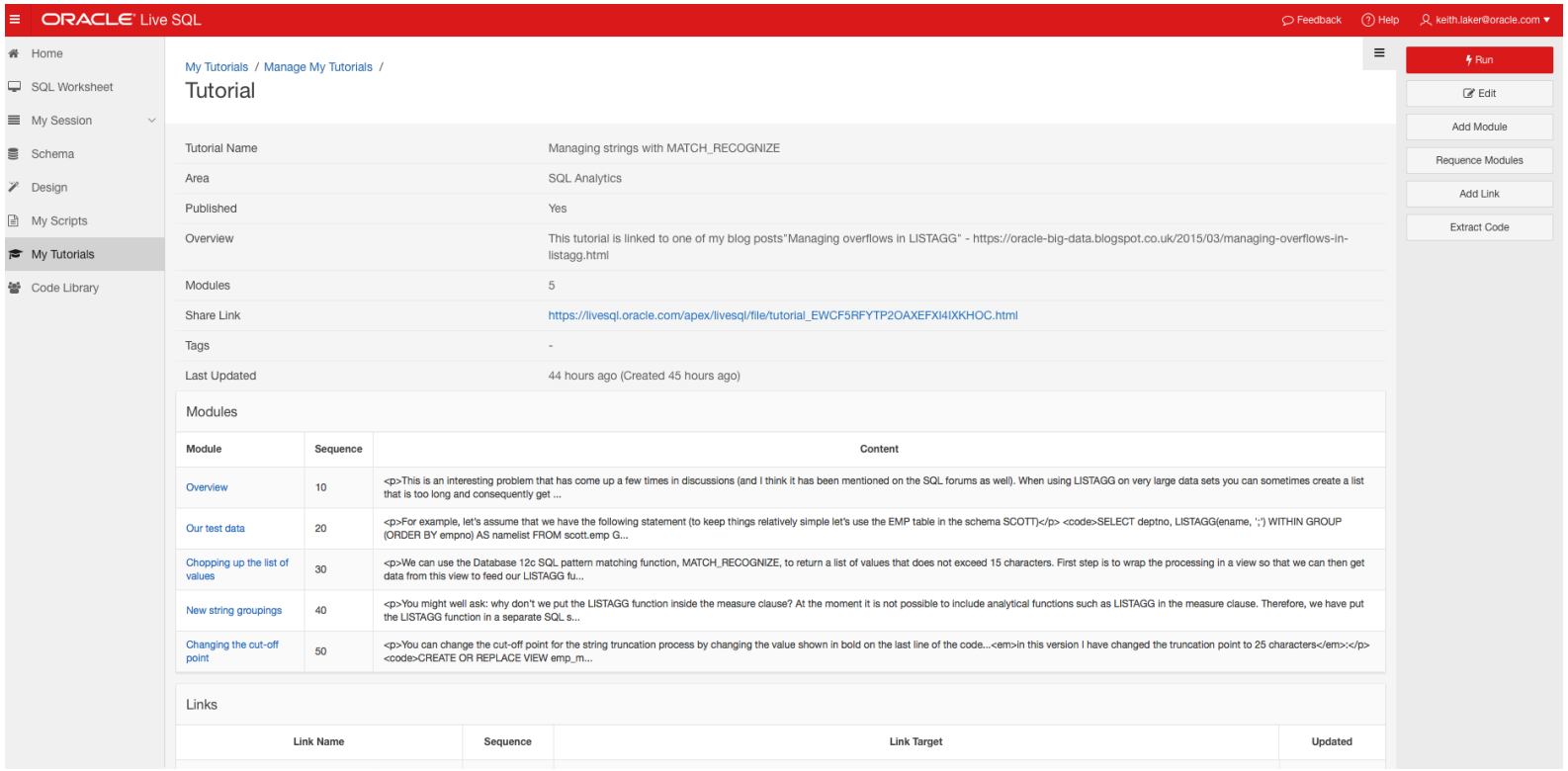
Controlling String Concatenation

LISTAGG - returns list of concatenated strings arranged as groups within each DEPTNO

DEPTNO	NAMELIST	HOW_LONG
10	CLARK;KING	10
10	MILLER	6
20	SMITH;JONES	11
20	SCOTT;ADAMS	11
20	FORD	4
30	ALLEN;WARD	10
30	MARTIN;BLAKE	12
30	TURNER;JAMES	12

```
SELECT
  deptno,
  LISTAGG(ename, ';')
    WITHIN GROUP (ORDER BY empno) AS namelist,
  LENGTH(LISTAGG(ename, ';')
    WITHIN GROUP (ORDER BY empno)) AS how_long
 FROM emp_mr
 GROUP BY deptno, mno;
```

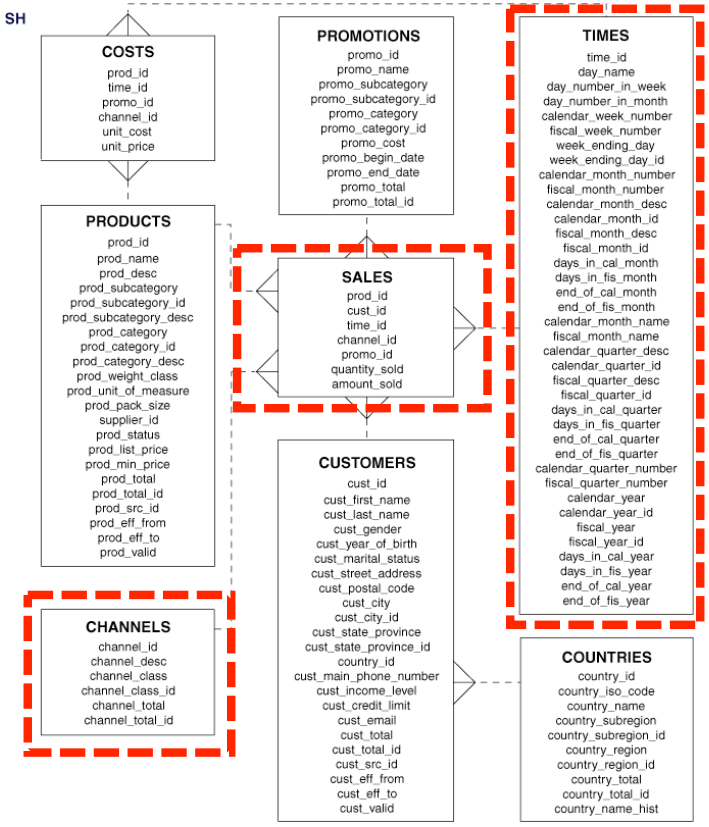
Live Demonstration – MATCH_RECOGNIZE and LISTAGG



https://livesql.oracle.com/apex/livesql/file/tutorial_EWCF5RFYTP2OAXEFXI4IXKHOC.html

Use Case 3: Building Contiguous Date Ranges

Data Set



Return result set showing:

1) Start date of contiguous range
2) End of date of contiguous range
3) Number of days in contiguous range

Define SELECT statement for source data

```
SELECT start_day, end_day, count_day
FROM
 (SELECT
  DISTINCT s.time_id AS day_id,
  t.calendar_year AS cal_yr
 FROM sh.sales s, sh.times t
 WHERE channel_id = 4 AND t.time_id= s.time_id)
```

Partitioning and Ordering the source data

```
SELECT start_day, end_day, count_day
FROM
(SELECT
 DISTINCT s.time_id AS day_id,
 t.calendar_year AS cal_yr
FROM sh.sales s, sh.times t
WHERE channel_id = 4 AND t.time_id= s.time_id)
MATCH_RECOGNIZE(
  PARTITION BY cal_yr ORDER BY day_id
```

Create PATTERN Statement and DEFINE Pattern Variables

Add PATTERN statement – *includes ALWAYS TRUE variable* - DEFINE pattern variables

```
SELECT start_day, end_day, count_day
FROM
(SELECT
 DISTINCT s.time_id AS day_id,
 t.calendar_year AS cal_yr
FROM sh.sales s, sh.times t
WHERE channel_id = 4 AND t.time_id= s.time_id)
MATCH_RECOGNIZE(
  PARTITION BY cal_yr ORDER BY day_id
```

```
   PATTERN (strt a+)
   DEFINE a AS day_id = PREV(day_id)+1);
```

List Measures to be Calculated

Use new functions FIRST and LAST to return values from start and end of pattern

```
SELECT start_day, end_day, count_day
FROM
(SELECT
 DISTINCT s.time_id AS day_id,
 t.calendar_year AS cal_yr
FROM sh.sales s, sh.times t
WHERE channel_id = 4 AND t.time_id= s.time_id)
MATCH_RECOGNIZE(
  PARTITION BY cal_yr ORDER BY day_id
  MEASURES
    FIRST(strt.day_id) AS start_day,
    LAST(a.day_id) AS end_day,
    COUNT(day_id) AS count_day
  PATTERN (strt a+)
  DEFINE a AS day_id = PREV(day_id)+1);
```

Define Type of Output: Detailed vs. Summary

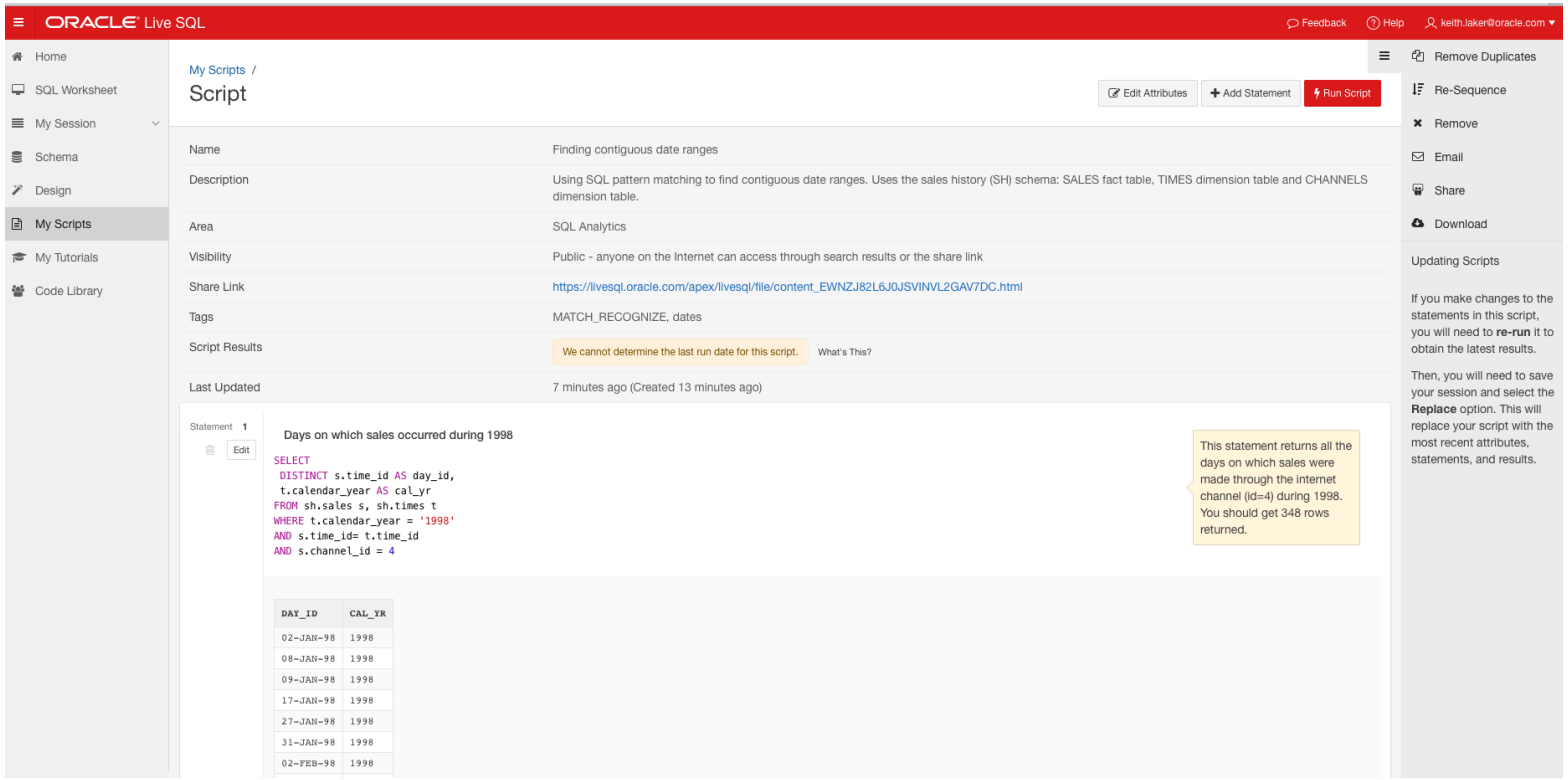
Return summary report – returns one row for each successful match of pattern

```
SELECT start_day, end_day, count_day
FROM
(SELECT
 DISTINCT s.time_id AS day_id,
 t.calendar_year AS cal_yr
FROM sh.sales s, sh.times t
WHERE channel_id = 4 AND t.time_id= s.time_id)
MATCH_RECOGNIZE(
  PARTITION BY cal_yr ORDER BY day_id
  MEASURES
    FIRST(strt.day_id) AS start_day,
    LAST(a.day_id) AS end_day,
    COUNT(day_id) AS count_day
  ONE ROW PER MATCH
  PATTERN (strt a+)
  DEFINE a AS day_id = PREV(day_id)+1);
```

Finding Contiguous Date Ranges…

START_DAY	END_DAY	COUNT_DAY
01-JAN-98	28-FEB-98	59
02-MAR-98	06-MAR-98	5
08-MAR-98	01-APR-98	25
04-APR-98	06-APR-98	3
08-APR-98	11-APR-98	4
13-APR-98	18-APR-98	6
22-APR-98	06-MAY-98	15
08-MAY-98	12-MAY-98	5
14-MAY-98	24-MAY-98	11
26-MAY-98	06-JUN-98	12
08-JUN-98	11-JUN-98	4
13-JUN-98	18-JUN-98	6

Live demonstration – Finding Contiguous Date Ranges



https://livesql.oracle.com/apex/livesql/file/content_EWNZJ82L6J0JSVINVL2GAV7DC.html


Summary

Typical Pattern Matching LOB Use Cases

	Input Data	Pattern	Result
Sessionization	Weblogs	continuous clicks by same user	Generate reports on number of distinct sessions, average page views per session, etc
Fraud	Credit card transactions	two transactions in different locations within a short period of time	Find cases in which a credit card may have been used fraudulently since a physical person cannot be in two places at once
In-game purchases	Games logs	events leading up to an in-game purchase	Detect common sequences of event that results in an in-game purchase
Fraud (mobiles)	CDR logs	SIM card being used in multiple handsets	Flag individual SIM cards being used by multiple handsets within a specified time period
Stock market analysis	Ticker logs	Track possible fraudulent linked patterns of behavior	Track known patterns of behavior such as head and shoulders, triangles, channels and wedges

Typical Pattern Matching LOB Use Cases

	Input Data	Pattern	Result
Auditing/ Compliance	Application logs	Analyze changes to secure customer data	Find instances where operator has made suspect modifications to secure client data
Money laundering	Transaction logs	Search for small transfers within a time window following by large transfer within “x” days of last small transfer	Detect suspicious money transfer pattern for an account and report account, date of first small transfer, date of last large transfer
Call service quality	CDR logs	Search for dropped/ reconnected calls	Identify how many times calls were restarted in a session, total effective call duration and total interrupted duration

Summary – You Can Now….

- Construct a MATCH_RECOGNIZE statement
- Build search criteria using pattern variables
- Organize your data correctly to discover the pattern
- Control the type of data returned: summary vs. detailed
- Understand the power and value of SQL pattern matching

- **Go and use MATCH-RECOGNIZE to your advantage!**

Where To Get More Information

- Analytical SQL Home Page on OTN with links to:
  - Training + Oracle By Example
  - Podcasts for pattern matching
  - Whitepapers
  - Sample scripts and simple tutorials for pattern matching on liveSQL
- Data Warehouse and SQL Analytics blog
  - http://oracle-big-data.blogspot.co.uk/