高级SQL
Advanced SQL

李文根/Wengen Li
Email: lwengen@tongji.edu.cn
先进数据与机器智能系统实验室（ADMIS）
https://admis.tongji.edu.cn/main.htm

课程概要

- **Part 0: Overview**
  - Ch1: Introduction
- **Part 1 Relational Databases**
  - Ch2: Relational model
  - Ch3: Introduction to SQL
  - Ch4: Intermediate SQL
  - **Ch5: Advanced SQL**
- **Part 2 Database Design**
  - Ch6: Database design based on E-R model
  - Ch7: Relational database design
- **Part 3 Application Design & Development**
  - Ch8: Complex data types
  - Ch9: Application development
- **Part 4 Big data analytics**
  - Ch10: Big data
  - Ch11: Data analytics
- **Part 5 Data Storage & Indexing**
  - Ch12: Physical storage system
  - Ch13: Data storage structure
  - Ch14: Indexing
- **Part 6 Query Processing & Optimization**
  - Ch15: Query processing
  - Ch16: Query optimization
- **Part 7 Transaction Management**
  - Ch17: Transactions
  - Ch18: Concurrency control
  - Ch19: Recovery system
- **Part 8 Parallel & Distributed Database**
  - Ch20: Database system architecture
  - Ch21-23: Parallel & distributed storage, query processing & transaction processing
- **Part 9**
  - DB Platform: **OceanBase**, MongoDB, Neo4J

目录

- 编程访问SQL
- 函数和过程
- 触发器
- 递归查询
- 高级聚集特性

编程访问SQL

- API (application-program interface) for a program to interact with a database server
- **Application makes calls to**
  - Connect with the database server
  - Send SQL commands to the database server
  - Fetch tuples of result one-by-one into program variables
- **Various tools:**
  - Dynamic SQL
    - **ODBC** (Open Database Connectivity) works with C, C++, C#, and Visual Basic. Other API's such as ADO.NET sit on top of ODBC
    - **JDBC** (Java Database Connectivity) works with Java
  - Embedded SQL

JDBC (Java Database Connectivity)

- **JDBC**
  - a Java API for communicating with database systems supporting SQL
  - support a variety of features for querying and updating data, and for retrieving query results
  - support metadata retrieval, such as querying about relations present in the database and the names and types of relation attributes
- **Model for communicating with the database:**
  - Open a connection
  - Create a “Statement” object
  - Execute queries using the Statement object to send queries and fetch results
  - Exception mechanism to handle errors

JDBC Code


```
public static void JDBCexample(String dbid, String userid, String passwd){
    try {
            Class.forName ("oracle.jdbc.driver.OracleDriver");
            Connection conn = DriverManager.getConnection("jdbc:oracle:thin:@aura.bell-
labs.com:2000:bankdb", userid, passwd);
            Statement stmt = conn.createStatement();
            … Do Actual Work ….
            stmt.close();
            conn.close();
        }
    catch (SQLException sqle) {
            System.out.println("SQLException : " + sqle);
        }
}
```

JDBC Code (Cont.)

- **Update to database**

```
try { stmt.executeUpdate(  "insert into account values
                              ('A-9732', 'Perryridge', 1200)");
}
catch (SQLException sqle) {
    System.out.println("Could not insert tuple. " + sqle);
}
```

- **Execute query and fetch and print results**

```
ResultSet rset = stmt.executeQuery( "select branch_name, avg(balance)
            from account group by branch_name");
while (rset.next()) {
    System.out.println(
    rset.getString("branch_name") + "  " + rset.getFloat(2));
}
```

JDBC Code Details

- Getting result fields:

  rs.getString("branch_name") and *rs.getString(1)* are equivalent if branch_name is the first argument of select result.

- Dealing with Null values

  if (rs.wasNull())

  Systems.out.println("Got null value");

ODBC

- **Open DataBase Connectivity(ODBC) standard**
  - standard for application program to communicate with a database server
  - application program interface (API) to
    - open a connection with a database
    - send queries and updates
    - get back results
- Applications such as GUI, statistical analysis, and spreadsheets can use ODBC

ODBC (Cont.)

- Each database system supporting ODBC provides a "driver" library that must be linked with the client program
- When client program makes an ODBC API call, the code in the library communicates with the server to carry out the requested action, and fetch results
- ODBC program first allocates an SQL environment, then a database connection handle

ODBC (Cont.)

- Opens database connection using SQLConnect(). Parameters for SQLConnect:
  - connection handle
  - the server to which to connect
  - the user identifier
  - password
- Must also specify types of arguments:
  - Constant (常数) SQL_NTS denotes that previous argument is a null-terminated string

ODBC Code

```
int ODBCexample(){
        RETCODE error;
        HENV    env;     /* environment */
        HDBC    conn;  /* database connection */
        SQLAllocEnv(&env);
        SQLAllocConnect(env, &conn);
        SQLConnect(conn, “db.yale.edu", SQL_NTS, "avi", SQL_NTS, "avipasswd", SQL_NTS);
        { …. Do actual work … }
        SQLDisconnect(conn);
        SQLFreeConnect(conn);
        SQLFreeEnv(env);
       }
```

ODBC Code (Cont.)

- Program sends SQL commands to the database by using SQLExecDirect
- Result tuples are fetched using SQLFetch()
- SQLBindCol() binds C language variables to attributes of the query result
  - When a tuple is fetched, its attribute values are automatically stored in corresponding C variables

ODBC Code (Cont.)

- **Arguments to SQLBindCol()**
  - ODBC stmt variable, attribute position in query result
  - The type conversion from SQL to C
  - The address of the variable
  - For variable-length types like character arrays
    - The maximum length of the variable
    - Location to store actual length when a tuple is fetched
    - Note: A negative value returned for the length field indicates null value
- Good programming requires checking results of every function call for errors; we have omitted most checks for brevity

ODBC Code (Cont.)

- **Main body of program**

```
char branchname[80];
float  balance;
int  lenOut1, lenOut2;
HSTMT   stmt;
SQLAllocStmt(conn, &stmt);
char * sqlquery = "select branch_name, sum (balance)
            from account group by branch_name";
error = SQLExecDirect(stmt, sqlquery, SQL_NTS);
if (error == SQL_SUCCESS) {
SQLBindCol(stmt, 1, SQL_C_CHAR, branchname, 80, &lenOut1);
   SQLBindCol(stmt, 2, SQL_C_FLOAT, &balance, 0, &lenOut2);
   while (SQLFetch(stmt) >= SQL_SUCCESS) {
          printf (" %s  %g\n", branchname, balance);
      }
}
SQLFreeStmt(stmt, SQL_DROP);
```

More ODBC Features

- **Prepared Statement**
  - SQL statement prepared: compiled at the database
  - Can have placeholders: E.g. insert into account values(?,?,?)
  - Repeatedly executed with actual values for the placeholders
- By default, each SQL statement is treated as a separate transaction that is committed automatically
  - Can turn off automatic commit on a connection
    - SQLSetConnectOption(conn, SQL_AUTOCOMMIT, 0)}
  - transactions must then be committed or rolled back explicitly by
    - SQLTransact(conn, SQL_COMMIT) or
    - SQLTransact(conn, SQL_ROLLBACK)

Embedded SQL

- The SQL standard defines embeddings of SQL in a variety of programming languages such as C, and Java
- A language to which SQL queries are embedded is referred to as a host language (宿主语言), and the SQL structures permitted in the host language comprise embedded SQL
- EXEC SQL statement is used to identify embedded SQL request to the preprocessor

EXEC SQL <embedded SQL statement > END_EXEC

Note: this varies by language (for example, the Java embedding uses # SQL { …. };)

Example Query

- Find the names and cities of customers with more than the variable amount dollars in some account
- Specify the query in SQL and declare a cursor for it

```
EXEC SQL
    declare c cursor for
    select depositor.customer_name, customer_city
    from depositor, customer, account
    where depositor.customer_name = customer.customer_name
            and depositor account_number = account.account_number
            and account.balance > :amount
END_EXEC
```

Embedded SQL (Cont.)

- The open statement causes the query to be evaluated

  EXEC SQL open c END_EXEC

- The fetch statement causes the values of one tuple in the query result to be placed on host language variables.

  EXEC SQL fetch c into :cn, :cc END_EXEC

  Repeated calls to fetch get successive tuples in the query result

- The close statement causes the database system to delete the temporary relation that holds the result of the query

  EXEC SQL close c END_EXEC

- Note: above details vary with language. For example, the Java embedding defines Java iterators to step through result tuples.

Updates Through Cursors

- Can update tuples fetched by cursor by declaring that the cursor is for update

```
declare c cursor for
    select *
    from account
    where branch_name = 'Perryridge'
    for update
```

- To update tuple at the current location of cursor c

```
update account
    set balance = balance + 100
    where current of c
```

Dynamic SQL

- Allows programs to construct and submit SQL queries at run time
- Example of the use of dynamic SQL within a C program.

  *char * sqlprog = "update account*
  *set balance = balance * 1.05*
  where account_number = ?"

  EXEC SQL prepare dynprog from :sqlprog;

  char account [10] = "A-101";

  EXEC SQL execute dynprog using :account;

- The dynamic SQL program contains a ?, which is a placeholder for a value that is provided when the SQL program is executed

目录

- 编程访问SQL
- 函数和过程
- 触发器
- 递归查询
- 高级聚集特性

Procedural Extensions and Stored Procedures

- **SQL provides a module language**
  - Permits definition of procedures in SQL, with if-then-else statements, for and while loops, etc.
- **Stored procedures**
  - can store procedures in the database
  - then execute them using the call statement
  - permit external applications to operate on the database without knowing about internal details

Functions and Procedures

- SQL:1999 supports functions and procedures
  - Functions/procedures can be written in SQL itself, or in an external programming language
  - Functions are particularly useful with specialized data types such as images and geometric objects
    - Example: functions to check if polygons overlap, or to compare images for similarity
  - Some database systems support table-valued functions, which can return a relation as a result
- SQL:1999 also supports a rich set of imperative constructs, including
  - loops, if-then-else, assignment
- Many databases have proprietary procedural extensions to SQL that differ from SQL:1999

SQL Functions

- Define a function that, given the name of a customer, returns the count of the number of accounts owned by the customer.

```
create function account_count (customer_name varchar(20)) returns integer
begin
    declare a_count integer;
    select count (* ) into a_count
    from depositor
    where depositor.customer_name = customer_name
    return a_count;
end
```

- Find the name and address of each customer that has more than one account

```
select customer_name, customer_street, customer_city
from customer
where account_count (customer_name ) > 1
```

Table Functions (表函数)

- SQL:2003 added functions that return a relation as a result
  - Example: Return all accounts owned by a given customer

```
create function accounts_of (customer_name char(20)
returns table ( account_number char(10),
                branch_name char(15)
                balance numeric(12,2))
return table
(select account_number, branch_name, balance
 from account A
 where exists (
    select *
    from depositor D
    where D.customer_name = accounts_of.customer_name
          and D.account_number = A.account_number ))
```

- Usage: select * from table (accounts_of (‘Smith’))

SQL Procedures

- The author_count function could instead be written as procedure:

create procedure *account_count_proc* (***in*** *customer_name varchar(20),* ***out*** *a_count integer)*
begin
    select *count(*)* ***into*** *a_count*
    from *depositor*
    where *depositor.customer_name =account_count_proc.customer_name*
end

- Procedures can be invoked either from an SQL procedure or from embedded SQL, using the call statement.

declare *a_count integer;*
call *account_count_proc('Smith', a_count);*

Procedures and functions can be invoked also from dynamic SQL

- SQL:1999 allows more than one function/procedure of the same name (called name overloading), as long as the numbers of arguments differ, or at least the types of the arguments differ

Procedural Constructs

- Compound statement: begin … end
  - May contain multiple SQL statements between begin and end
  - Local variables can be declared within a compound statements
- While and repeat statements:

```
declare n integer default 0;
while n < 10 do
    set n = n + 1
end while
repeat
    set n = n – 1
until n = 0
end repeat
```

Procedural Constructs (Cont.)

- **For loop**
  - Permits iteration over all results of a query
  - E.g., find total of all balances at the Perryridge branch

declare *n integer* ***default*** *0;*
for *r* ***as***
    select *balance* ***from*** *account*
    where *branch_name = 'Perryridge'*
do
    set *n = n + r.balance*
end for

Procedural Constructs (Cont.)

- Conditional statements (if-then-else)
  - E.g. To find sum of balances for each of three categories of accounts (with balance <1000, >=1000 and <5000, >= 5000)

if r.balance < 1000
  then set l = l + r.balance
elseif r.balance < 5000
  then set m = m + r.balance
else set h = h + r.balance
end if

- Signaling of exception conditions, and declaring handlers for exceptions

declare out_of_stock condition
declare exit handler for out_of_stock
begin
…
.. signal out-of-stock
end

  - The handler here is exit -- causes enclosing begin...end to be exited
  - Other actions possible on exception

External Language Functions/Procedures

- SQL:1999 permits the use of functions and procedures written in other languages such as C or C++
- Declaring external language procedures and functions

create procedure *account_count_proc(****in*** *customer_name* ***varchar****(20),* ***out*** *count* ***integer****)*
language *C*
external name *' /usr/avi/bin/account_count_proc'*

create function *account_count(customer_name* ***varchar****(20))*
returns integer
language *C*
external name *'/usr/avi/bin/author_count'*

External Language Routines (Cont.)

- Benefits of external language functions/procedures:
  - more efficient for many operations, and more expressive power
- Drawbacks
  - Code to implement function may need to be loaded into database system and executed in the database system’s address space
    - risk of accidental corruption of database structures
    - security risk, allowing users access to unauthorized data
  - Direct execution in the database system’s space is used when efficiency is more important than security

Security with External Language Routines

- To deal with security problems
  - Use sandbox techniques
    - that is use a safe language like Java, which cannot be used to access/damage other parts of the database code
  - Or, run external language functions/procedures in a separate process, with no access to the database process' memory
    - Parameters and results communicated via inter-process communication
- Both have performance overheads
- Many database systems support both above approaches as well as direct executing in database system address space

目录

- 编程访问SQL
- 函数和过程
- 触发器
- 递归查询
- 高级聚集特性

Triggers (触发器)

- A trigger is a statement that is executed automatically by the system as a side effect of a modification to the database
- To design a trigger mechanism, we should:
  - specify the **conditions** under which the trigger is to be executed
  - specify the **actions** to be taken when the trigger executes
- The above model of triggers is referred to as the event-condition-action (ECA) model for triggers

Trigger Example

- Suppose that instead of allowing negative account balances, the bank deals with overdrafts (透支) by
  - setting the account balance to zero
  - creating a loan in the amount of the overdraft
  - giving this loan a loan number identical to the account number of the overdrawn account
- The **condition** for executing the trigger is an update (event) to the account relation that results in a negative balance value

Trigger Example in SQL:1999

```
create trigger overdraft_trigger after update on account
referencing new row as nrow
for each row
when nrow.balance <0
begin atomic
  insert into borrower
    (select customer_name, account_number
    from depositor
    where nrow.account_number =depositor.account_number);
  insert into loan values
    (nrow.account_number, nrow.branch_name, –nrow.balance);
  update account set balance = 0
    where account.account_number = nrow.account_number
end
```

Triggering Events and Actions in SQL

- Triggering event can be insert, delete or update
- Triggers on update can be restricted to specific attributes
  - E.g., after update of balance on account
- Values of attributes before and after an update can be referenced
  - referencing old row as: for deletes and updates
  - referencing new row as: for inserts and updates

Triggering Events and Actions in SQL

- Triggers can be activated before an event, which can serve as extra constraints

create trigger *setnull_trigger* ***before update on*** *r*
referencing new row as nrow
for each row
    when nrow.phone_number = ' '
    set nrow.phone_number = null

Statement Level Triggers

- Instead of executing a separate action for each affected row, a single action can be executed for all rows affected by a transaction
  - Use for each statement instead of for each row
  - Use referencing old table or referencing new table to refer to temporary tables (called transition tables) containing the affected rows
  - Can be more efficient when dealing with SQL statements that update a large number of rows

External World Actions

- We sometimes require external world actions to be triggered on a database update
  - E.g. re-ordering an item whose quantity in a warehouse has become small, or turning on an alarm light,
- Triggers cannot be used to directly implement external world actions, BUT
  - Triggers can be used to record actions-to-be-taken in a separate table
  - Have an external process that repeatedly scans the table, carries out external world actions and deletes action from table

External World Actions

- E.g., suppose a warehouse has the following tables
  - inventory(item, level): How much of each item is in the warehouse
  - minlevel(item, level) : The minimum desired level
  - reorder(item, amount): What quantity should we re-order
  - orders(item, amount) : Orders to be placed

External World Actions (Cont.)

```
create trigger reorder_trigger after update of amount on inventory
referencing old row as orow, new row as nrow
for each row
   when nrow.level < = (select level
                                    from minlevel
                                      where minlevel.item = orow.item)
      and orow.level > (select level
                                 from minlevel
                                 where minlevel.item = orow.item)
begin
        insert into orders
                    (select item, amount
                     from reorder
                     where reorder.item = orow.item)
end
```

When Not to Use Triggers

- Triggers were used earlier for tasks such as
  - maintaining summary data (e.g., total salary of each department)
  - Replicating databases by recording changes to special relations and having a separate process that applies the changes over to a replica
- There are better ways of doing these now:
  - Databases today provide built in materialized view facilities to maintain summary data
  - Databases provide built-in support for replication
- Encapsulation facilities can be used instead of triggers in many cases
  - Define methods to update fields
  - Carry out actions as part of the update methods instead of through a trigger

目录

- 编程访问SQL
- 函数和过程
- 触发器
- 递归查询
- 高级聚集特性

Recursion (递归) in SQL

- SQL:1999 permits recursive view definition
  - E.g., find all employee-manager pairs, where the employee reports to the manager directly or indirectly (that is manager's manager, manager's manager's manager, etc.)

```
with recursive empl (employee_name, manager_name ) as (
   select employee_name, manager_name
   from  manager     /*a base query */
  union
   select manager.employee_name, empl.manager_name
   from   manager, empl       /*a recursive query*/
   where manager.manager_name = empl.employe_name)
select *
from empl
```

Note: This example view **empl** is called the transitive closure (传递闭包) of the manager relation

The Power of Recursion

- Recursive views make it possible to write queries, such as transitive closure queries, that cannot be written without recursion or iteration.
  - Intuition: Without recursion, a non-recursive non-iterative program can perform only a fixed number of joins of manager with itself
    - This can give only a fixed number of levels of managers
    - Given a program we can construct a database with a greater number of levels of managers on which the program will not work

The Power of Recursion

- **Computing transitive closure**
  - The next slide shows a manager relation
  - Each step of the iterative process constructs an extended version of empl from its recursive definition.
  - The final result is called the fixed point of the recursive view definition.
- Recursive views are required to be monotonic. That is, if we add tuples to manger the view contains all of the tuples it contained before, plus possibly more

Example of Fixed-Point Computation

employee_name	*manager_name*
Alon	Barinsky
Barinsky	Estovar
Corbin	Duarte
Duarte	Jones
Estovar	Jones
Jones	Klinger
Rensal	Klinger

Iteration number	*Tuples in empl*
0	
1	(Duarte), (Estovar)
2	(Duarte), (Estovar), (Barinsky), (Corbin)
3	(Duarte), (Estovar), (Barinsky), (Corbin), (Alon)
4	(Duarte), (Estovar), (Barinsky), (Corbin), (Alon)

目录

Advanced SQL Features

TONGJI UNIVERSITY

- Create a table with the same schema as an existing table:

  create table *temp_account* ***like*** *account*

- SQL:2003 allows subqueries to occur anywhere a value is required provided the subquery returns only one value. This applies to updates as well
- SQL:2003 allows subqueries in the from clause to access attributes of other relations in the from clause using the lateral construct:

```
select C.customer_name, num_accounts
from customer C,
     lateral (select count(*)
                  from account A
                  where A.customer_name = C.customer_name )
          as this_customer (num_accounts )
```

Advanced SQL Features (Cont.)

TONGJI UNIVERSITY

- Merge construct allows batch processing of updates
  - E.g., relation funds_received (account_number, amount) has a batch of deposits to be added to the proper account in the account relation

```
merge into account as A
    using (select *
        from funds_received) as F
   on (A.account_number = F.account_number )
   when matched then
     update set balance = balance + F.amount
```