Chapter 5: Advanced SQL

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Database System Concepts, 7th Ed.

Chapter 5: Advanced SQL

- Accessing SQL From a Programming Language
  - Embedded SQL
  - ODBC and JDBC
- Functions and Procedural Constructs
- Triggers
- Advanced Aggregation Features
- OLAP

Embedded SQL

- The SQL standard defines embeddings of SQL in a variety of programming languages such as C, Java, and Cobol.
- A language to which SQL queries are embedded is referred to as a **host language**, and the SQL structures permitted in the host language comprise *embedded* SQL.
- The basic form of these languages follows that of the System R embedding of SQL into PL/I.
- **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 { …. };)
- Main issues: exchange of parameters and results between the host language and SQL statements; sets vs. variables; get the execution status of the SQL statements; compile to host language;

Embedded SQL (Cont.)

- Example 1: Salary promotion:

  EXEC SQL update *instructor* set *salary* = *salary* * 1.05
  where *salary* < *:some_amount* END_EXEC

- Example 2: From within a host language, find the ID and name of students who have completed more than the number of credits stored in variable credit_amount.

Specify the query in SQL and declare a *cursor* for it

EXEC SQL

declare *c* **cursor for**
select *ID, name*
from *student*
where tot_cred > *:credit_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** :*si*, :*sn* END_EXEC

  Repeated calls to **fetch** get successive tuples in the query result

- A variable called SQLSTATE in the SQL communication area (SQLCA) gets set to '02000' to indicate no more data is available

- 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.

Embedded SQL (Cont.)

```
void getStudentInfo()
{
        int credit_amount;
        char sId[16];
        char sName[16];
        EXEC SQL declare c cursor select id, name from student where tot_cred> :credit_amount END EXEC;
        printf("Please input the credit amount: ");
        scanf("%d",&credit_amount);
        EXEC SQL open c END_EXEC;
        while (1)
        {
                EXEC SQL fetch c into :sId, :sName END_EXEC;
                if (!strcmp(SQLSTATE,"02000"))
                        break;
                printf("%s %s\n",sId,sName);
        }
        EXEC SQL close c END_EXEC;
}
```

Updates Through Cursors

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

  declare *c* **cursor for**
    select *
    from *instructor*
    where *dept_name* = 'Music'
  for update

- To update tuple at the current location of cursor *c,* usually when the application has complicated logic. For example, before an instructor is promoted, some specific information may be required, such as the number of courses he/she taught in the pervious years, the average grades of his/her classes, etc. After the specific conditions are met, the update can be executed as follows:

  update *instructor*
  set *salary* = *salary* + 100
  where current of *c*

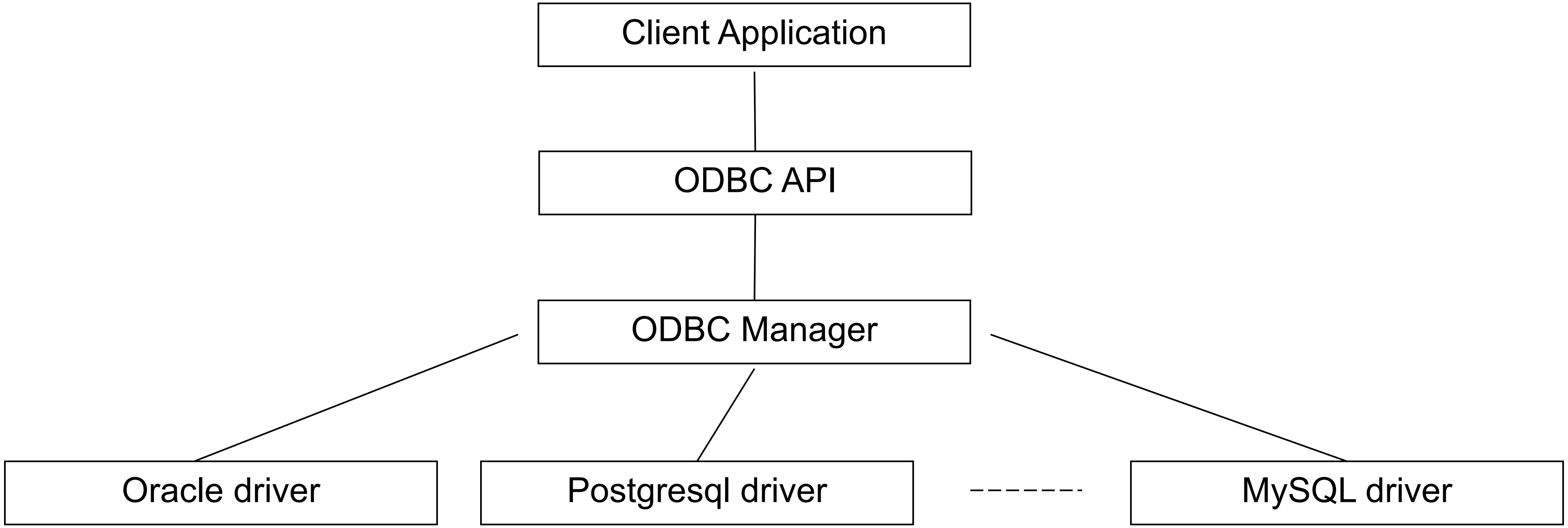
ODBC and JDBC

- 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
- 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

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, spreadsheets, etc. can use ODBC
- Was defined originally for Basic and C, versions available for many languages.

ODBC – Client Side Architecture



- Each database system supporting ODBC provides a "driver" library that must be linked with the client program.
- ODBC Manager determine to load which driver and connect to which server based on the data source name (DSN) configuration
- 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 – Driver and DSN Configuration

- Driver configuration example in odbcinst.ini:
  - [PostgreSQL]
  - Description=PostgreSQL driver for Mac
  - Driver=/usr/local/Cellar/psqlodbc/12.01.0000/lib/psqlodbcw.so
  - Setup=/usr/local/Cellar/psqlodbc/12.01.0000/lib/psqlodbcw.so
- DSN configuration example in odbc.ini
  - [Mike] //Data Source Name
  - Description=Mike
  - Driver=PostgreSQL
  - Database=mike
  - Servername=localhost
  - UserName=mike
  - Password=
  - Port=5432

ODBC – Prepare to Connect

- ODBC program first allocates an SQL environment, then a database connection handle.
- Opens database connection using SQLConnect(). Parameters for SQLConnect:
  - connection handle,
  - data source name
  - the user identifier,
  - password
- Must also specify types of arguments:
  - SQL_NTS denotes previous argument is a null-terminated string.

ODBC– Connect – Code Example

- int ODBCexample()

```
{
    RETCODE error;
    HENV    env;     /* environment */
    HDBC    conn;  /* database connection */
    SQLAllocEnv(&env);
    SQLAllocConnect(env, &conn);
    SQLConnect(conn, “Mike", SQL_NTS, "avi", SQL_NTS, "avipasswd",
      SQL_NTS);
    { …. Do actual work , usually use a statement handle to do the querey… }

    SQLDisconnect(conn);
    SQLFreeConnect(conn);
    SQLFreeEnv(env);
}
```

ODBC – Execute Stmt & Fetch Results

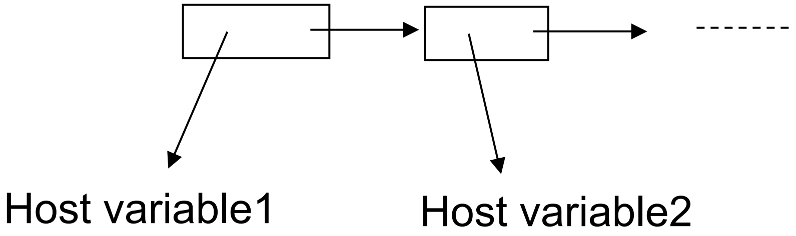
- After successful connection, program allocates a stmt handle, then sends SQL commands to database by using SQLExecDirect or SQLExecute
- After stmt execution, using SQLBindCol() to bind C language variables to attributes of the query result
  - Arguments to SQLBindCol()
    - ODBC stmt variable,
    - attribute position in query result,
    - The data type,
    - 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
  - When a tuple is fetched, its attribute values are automatically stored in corresponding C variables.
- Result tuples are fetched using SQLFetch() in a loop
- Good programming requires checking results of every function call for errors; we have omitted most checks for brevity.

ODBC - Statement Handle Internal

- Statement
- Metadata

- Value

- Host variables address:



ODBC – Stmt Execution Example

```
int getStudentInfo(HDBC conn)
{
        int creditAmount;
        char sId[24];
        char sName[24];
        int totalCredit;
        SQLLEN lenOut1,lenOut2,lenOut3;
        HSTMT stmt;
        RETCODE error;
        char sqlquery[1024], sCreditAmount[24];
        printf("Please input the credit amount: ");
        scanf("%d",&creditAmount);
        sprintf(sCreditAmount, "%d", creditAmount);
        strcpy(sqlquery,"select id, name, tot_cred from student where tot_cred>");
        strcat(sqlquery,sCreditAmount);  //Usually do not use strcat directly, use prepared stmt instead
        // to be continue
```

ODBC – Stmt Execution Example – Cont.

```
//follow the previous slide
SQLAllocStmt(conn, &stmt);
error = SQLExecDirect(stmt, (SQLCHAR *)sqlquery, SQL_NTS);
if (error == SQL_SUCCESS) {
        SQLBindCol(stmt, 1, SQL_C_CHAR, sId , 80, &lenOut1);
        SQLBindCol(stmt, 2, SQL_C_CHAR, sName , 80 , &lenOut2);
        SQLBindCol(stmt, 3, SQL_C_SLONG, &totalCredit , 0 , &lenOut3);
        while (SQLFetch(stmt) == SQL_SUCCESS) {
                printf (" %s %s %d\n", sId, sName, totalCredit);
        }
}
SQLFreeStmt(stmt, SQL_DROP);
return 0;
}
// end of getStudentInfo
```

Chance of SQL Injection - getStudentInfo version 2

```
int getStudentInfo(HDBC conn) {
        char sId[24];
        char sName[24];
        int totalCredit;
        SQLLEN lenOut1,lenOut2,lenOut3;
        HSTMT stmt;
        RETCODE error;
        char sqlquery[1024], sCreditAmount[1024];
        printf("Please input the credit amount: ");
        gets(sCreditAmount);  //dangerous
        strcpy(sqlquery,"select id, name, tot_cred from student where tot_cred>");
        strcat(sqlquery,sCreditAmount); //dangerous
        SQLAllocStmt(conn, &stmt);
        SQLExecDirect(stmt, (SQLCHAR *)sqlquery, SQL_NTS);
        ...........
```

- If user input is “3; update student set tot_cred=200 where ID = ‘19001’ ”, then the overall query will be “select id, name, tot_cred from student where tot_cred> 3; update student set tot_cred=200 where ID = ‘19001’ ”. The total credit of student with ID ‘19001’ will be updated to 200

ODBC Prepared Statements

- **Prepared Statement**
  - Can have placeholders when preparing: E.g. insert into account values(?,?,?)
  - Bind the host variables with those placeholders
  - Construct the complete statement with these information
  - Can repeatedly executed with different values for the placeholders
- To prepare a statement

```
SQLPrepare(stmt, <SQL String>);
```

- To bind parameters

```
SQLBindParameter(stmt, <parameter#>,
          … type information and value omitted for simplicity..)
```

- To execute the statement

```
retcode = SQLExecute( stmt);
```

- To avoid SQL injection security risk, do not create SQL strings directly using user input; instead use prepared statements to bind user inputs

Prepared Statements - getStudentInfo V3

```
int getStudentInfo(HDBC conn)
{
        int creditAmount;
        char sId[24];
        char sName[24];
        int totalCredit;
        SQLLEN lenOut1,lenOut2,lenOut3;
        HSTMT stmt;
        RETCODE error;
        char* sqlquery = "select id, name, tot_cred from student where tot_cred> ? ";
        printf("Please input the credit amount: ");
        scanf("%d",&creditAmount);
        SQLAllocStmt(conn, &stmt);
        SQLPrepare(stmt,(SQLCHAR* )sqlquery,SQL_NTS);
        SQLBindParameter(stmt,1,SQL_PARAM_INPUT, SQL_C_SLONG, SQL_INTEGER, 0,
0,(SQLPOINTER)&creditAmount, sizeof(int), NULL);  //safer way
        error = SQLExecute(stmt);
        ..........
```

More ODBC Features

- **Metadata features**
  - finding all the relations in the database and
  - finding the names and types of columns of a query result or a relation in the database.
- 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)

ODBC Conformance Levels

- Conformance levels specify subsets of the functionality defined by the standard.
  - Core
  - Level 1 requires support for metadata querying
  - Level 2 requires ability to send and retrieve arrays of parameter values and more detailed catalog information.
- SQL Call Level Interface (CLI) standard similar to ODBC interface, but with some minor differences.

ADO.NET

- API designed for Visual Basic .NET and C#, providing database access facilities similar to JDBC/ODBC
  - Partial example of ADO.NET code in C#

```
using System, System.Data, System.Data.SqlClient;
SqlConnection conn = new SqlConnection(
        “Data Source=<IPaddr>, Initial Catalog=<Catalog>”);
conn.Open();
SqlCommand cmd = new SqlCommand(“select * from students”,
                                        conn);
SqlDataReader rdr = cmd.ExecuteReader();
while(rdr.Read()) {
    Console.WriteLine(rdr[0], rdr[1]); /* Prints result attributes 1 & 2 */
}
rdr.Close(); conn.Close();
```

- Can also access non-relational data sources such as
  - OLE-DB, XML data, Entity framework

JDBC

- **JDBC** is a Java API for communicating with database systems supporting SQL.
- JDBC supports a variety of features for querying and updating data, and for retrieving query results.
- JDBC also supports 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:@db.yale.edu:2000:univdb", 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 instructor values('77987', 'Kim', 'Physics', 98000)");
} catch (SQLException sqle)
{
    System.out.println("Could not insert tuple. " + sqle);
}
```

- Execute query and fetch and print results

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

JDBC Code Details

- Getting result fields:
  - **rs.getString("dept_name") and rs.getString(1) equivalent if dept_name is the first argument of select result.**
- Dealing with Null values
  - **int a = rs.getInt("a");**

    if (rs.wasNull()) Systems.out.println("Got null value");

Prepared Statement

- PreparedStatement pStmt = conn.prepareStatement(
  "insert into instructor values(?,?,?,?)");
  pStmt.setString(1, "88877"); pStmt.setString(2, "Perry");
  pStmt.setString(3, "Finance"); pStmt.setInt(4, 125000);
  pStmt.executeUpdate();
  pStmt.setString(1, "88878");
  pStmt.executeUpdate();
- For queries, use pStmt.executeQuery(), which returns a ResultSet
- WARNING: always use prepared statements when taking an input from the user and adding it to a query
  - **NEVER create a query by concatenating strings which you get as inputs**
  - "insert into instructor values(' " + ID + " ', ' " + name + " ', " + " ' + dept name + " ', " ' balance + ")"
  - What if name is "D'Souza"?

SQL Injection

- Suppose query is constructed using
  - "select * from instructor where name = ’" + name + "’"
- Suppose the user, instead of entering a name, enters:
  - X’ or ’Y’ = ’Y
- then the resulting statement becomes:
  - "select * from instructor where name = ’" + "X’ or ’Y’ = ’Y" + "’"
  - which is:
    - select * from instructor where name = ’X’ or ’Y’ = ’Y’
  - User could have even used
    - X’; update instructor set salary = salary + 10000; --
- Prepared statement internally uses:
  "select * from instructor where name = ’X\’ or \’Y\’ = \’Y’
  - **Always use prepared statements, with user inputs as parameters**

Metadata Features

- ResultSet metadata
- E.g., after executing query to get a ResultSet rs:

```
ResultSetMetaData rsmd = rs.getMetaData();
for(int i = 1; i <= rsmd.getColumnCount(); i++) {
    System.out.println(rsmd.getColumnName(i));
    System.out.println(rsmd.getColumnTypeName(i));
}
```

- How is this useful?

Metadata (Cont)

- Database metadata
- DatabaseMetaData dbmd = conn.getMetaData();

```
ResultSet rs = dbmd.getColumns(null, "univdb", "department", "%");
// Arguments to getColumns: Catalog, Schema-pattern, Table-pattern,
// and Column-Pattern
// Returns: One row for each column; row has a number of attributes
// such as COLUMN_NAME, TYPE_NAME
while( rs.next()) {
    System.out.println(rs.getString("COLUMN_NAME"),
                       rs.getString("TYPE_NAME");
}
```

- And where is this useful?

Finding Primary Keys

```
DatabaseMetaData dmd = connection.getMetaData();

// Arguments below are:  Catalog, Schema, and Table
// The value “”  for Catalog/Schema indicates current catalog/schema
//  The value null indicates all catalogs/schemas
ResultSet rs = dmd.getPrimaryKeys(“”, “”, tableName);

while(rs.next()){
    // KEY_SEQ indicates the position of the attribute in
    // the primary key, which is required if a primary key has multiple
    // attributes
    System.out.println(rs.getString(“KEY_SEQ”),
                                    rs.getString("COLUMN_NAME");
}
```

Transaction Control in JDBC

- By default, each SQL statement is treated as a separate transaction that is committed automatically
  - bad idea for transactions with multiple updates
- Can turn off automatic commit on a connection
  - conn.setAutoCommit(false);
- Transactions must then be committed or rolled back explicitly
  - conn.commit();   or
  - conn.rollback();
- conn.setAutoCommit(true) turns on automatic commit.

Other JDBC Features

- Calling functions and procedures
  - CallableStatement cStmt1 = conn.prepareCall("{? = call some function(?)}");
  - CallableStatement cStmt2 = conn.prepareCall("{call some procedure(?,?)}");
- Handling large object types
  - getBlob() and getClob() that are similar to the getString() method, but return objects of type Blob and Clob, respectively
  - get data from these objects by getBytes()
  - associate an open stream with Java Blob or Clob object to update large objects
    - blob.setBlob(int parameterIndex, InputStream inputStream).

SQLJ

- JDBC is overly dynamic, errors cannot be caught by compiler
- SQLJ: embedded SQL in Java
  - ```
    #sql iterator deptInfoIter ( String dept name, int avgSal);
    deptInfoIter iter = null;
    #sql iter = { select dept_name, avg(salary) from instructor
                  group by dept name };
    while (iter.next()) {
        String deptName = iter.dept_name();
        int avgSal = iter.avgSal();
        System.out.println(deptName + " " + avgSal);
    }
    iter.close();
    ```
    ```

Procedural Constructs in SQL

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
  - separate the business logic and user interface logic
  - decrease back and forth of command and data over the network
  - compile and recompile of the procedure before execution, highly increase the efficiency of the application

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 department, returns the count of the number of instructors in that department.

  create function *dept_count* (*dept_name* **varchar**(20))
  returns integer
  begin
      declare *d_count* **integer;**
      select count (*) **into** *d_count*
      from *instructor*
      where *instructor.dept_name* = *dept_name*
      return *d_count;*
  end

- Find the department name and budget of all departments with more than 12 instructors.

  select *dept_name, budget*
  from *department*
  where *dept_*count (*dept_name*) > 12

Table Functions

- SQL:2003 added functions that return a relation as a result
- Example: Return all instructors of one department

create function *instructors_of* (*dept_name* **char**(20))
    returns table (*ID* **varchar**(5),
        name **varchar**(20),
        dept_name **varchar**(20),
        salary **numeric**(8,2))
return table
    (**select** *ID, name, dept_name, salary*
     from *instructor*
     where *instructor.dept_name = instructors_of.dept_name*)

- Usage

    select *
    from table (*instructors_of* (‘Music’))

SQL Procedures

- The *dept_count* function could instead be written as procedure:

```
create procedure dept_count_proc (in dept_name varchar(20),
                                  out d_count integer)
begin
  select count(*) into d_count
  from instructor
  where instructor.dept_name = dept_count_proc.dept_name
end
```

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

```
declare d_count integer;
call dept_count_proc( 'Physics', d_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 number of arguments differ, or at least the types of the arguments differ

Stored Procedure Example (pgSQL)

- Find the number of students with tot_cred greater than some amount. Create a procedure with one "in" parameter creditAmount and one "inout" parameter numOfStudent

```
CREATE OR REPLACE PROCEDURE findNumOfStudent(creditAmount in INT,
numOfStudent inout INT)
LANGUAGE plpgsql
AS $$
BEGIN
  select count(*) into numOfStudent from student where tot_cred >
creditAmount;
END;
$$;
```

Stored Procedure Example (pgSQL) - Cont.

- Call from another procedure

```
CREATE OR REPLACE PROCEDURE callExample(cAmount in INT)
LANGUAGE plpgsql
AS $$
DECLARE
      noStudent INT := 0;
BEGIN
      call findNumOfStudent(cAmount,noStudent);
      RAISE NOTICE '%', noStudent;      //output to screen
END;
$$;
```

Procedural Constructs

- Warning: most database systems implement their own variant of the standard syntax below
  - read your system manual to see what works on your system
- Compound statement: **begin ... end**,
  - May contain multiple SQL statements between **begin** and **end**.
  - Local variables can be declared within a compound statement
- **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, like cursor
  - Example:

```
declare n  integer default 0;
for r  as
      select budget from department
       where dept_name = 'Music'
do
      set n = n + r.budget
end for
```

Procedural Constructs (cont.)

- Conditional statements (**if-then-else**)
  SQL:1999 also supports a **case** statement similar to C case statement
- Example procedure: registers student after ensuring classroom capacity is not exceeded
  - Returns 0 on success and -1 if capacity is exceeded
  - See book for details
- Signaling of exception conditions, and declaring handlers for exceptions

  declare *out_of_classroom_seats* **condition**
  declare exit handler for *out_of_classroom_seats*
  begin
  …
  .. **signal** *out_of_classroom_seats*
  end

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

Procedural Constructs (PG example)

- Find number of students whose tot_cred is greater then some number and who have at least one advisor
- Can do with one SQL query. Illustrate cursor and loop here in a function

```
CREATE OR REPLACE FUNCTION findStudentsWithAdvisor(credAmount Integer)
  RETURNS Integer
LANGUAGE plpgsql
AS $$
DECLARE
   num Integer DEFAULT 0;
   numOfAdvisor Integer DEFAULT 0;
   sId char(12) DEFAULT '';
   curStudent CURSOR (cAmount Integer)
      FOR SELECT ID
      FROM student
      WHERE tot_cred > cAmount;
BEGIN
-- to be continued
```

Procedural Constructs (PG example, Cont.)

```
 -- Open the cursor
  OPEN curStudent(credAmount);
  LOOP
    -- fetch row
    FETCH curStudent INTO sId;
    -- exit when no more row to fetch
    EXIT WHEN NOT FOUND;
    -- just for example, simple logic below, can have much complicated logic
    select count(*) into numOfAdvisor from advisor where s_id = sId;
    -- if have advisor, num++
    IF numOfAdvisor > 0 THEN
      num := num + 1;
    END IF;
  END LOOP;
  -- Close the cursor
  CLOSE curStudent;
  RETURN num;
END; $$
```

Stored Procedure Example (Transfer Fund)

```
CREATE OR REPLACE PROCEDURE transfer_funds(source_account_id INT, destination_account_id INT, amount DECIMAL)
LANGUAGE plpgsql
AS $$
BEGIN
   -- Check if source account has enough funds
   IF (SELECT balance FROM accounts WHERE id = source_account_id) < amount THEN
   RAISE EXCEPTION 'Insufficient funds’;
   END IF;
   -- Deduct amount from source account
   UPDATE accounts SET balance = balance - amount WHERE id = source_account_id;
   -- Add amount to destination account
   UPDATE accounts SET balance = balance + amount WHERE id = destination_account_id;
   -- Record the transaction
   INSERT INTO transfers (source_id, destination_id, amount, transaction_date) VALUES (source_account_id, destination_account_id, amount,
CURRENT_TIMESTAMP);
   -- If everything is successful, commit the transaction
   COMMIT;
EXCEPTION
   WHEN OTHERS THEN
      ROLLBACK;
      RAISE;
END;
$$;
```

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 dept_count_proc(in dept_name varchar(20),
                                 out count integer)
language C
external name ’ /usr/avi/bin/dept_count_proc’

create function dept_count(dept_name varchar(20))
returns integer
language C
external name ‘/usr/avi/bin/dept_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
  - There are alternatives, which give good security at the cost of potentially worse performance.
  - 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.

Triggers

Triggers

- 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 must:
  - Specify the conditions under which the trigger is to be executed.
  - Specify the actions to be taken when the trigger executes.
- Triggers introduced to SQL standard in SQL:1999, but supported even earlier using non-standard syntax by most databases.

  - Syntax illustrated here may not work exactly on your database system; check the system manuals

Trigger Example

- E.g. *time_slot_id* is not a primary key of *timeslot,* so we cannot create a foreign key constraint from *section* to *timeslot.*
- Alternative: use triggers on *section* and *timeslot* to enforce integrity constraints

```
create trigger timeslot_check1 after insert on section
referencing new row as nrow
for each row
when (nrow.time_slot_id not in (
            select time_slot_id
            from time_slot)) /* time_slot_id not present in time_slot */
begin
    rollback
end;
```

Trigger Example Cont.

```
create trigger timeslot_check2 after delete on timeslot
    referencing old row as orow
    for each row
    when (orow.time_slot_id not in (
                select time_slot_id
                from time_slot)
                /* last tuple for time slot id deleted from time slot */
            and orow.time_slot_id in (
                select time_slot_id
                from section)) /* and time_slot_id still referenced from section*/
    begin
        rollback
    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** *takes* **on** *grade*
- 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
- Triggers can be activated before an event, which can serve as extra constraints. E.g. convert blank grades to null.

```
create trigger setnull_trigger before update of takes
referencing new row as nrow
for each row
when (nrow.grade = ' ')
 begin atomic
        set nrow.grade = null;
 end;
```

Trigger to Maintain credits_earned value

```
create trigger credits_earned after update of takes on (grade)
referencing new row as nrow
referencing old row as orow
for each row
when nrow.grade <> ’F’ and nrow.grade is not null
    and (orow.grade = ’F’ or orow.grade is null)
begin atomic
     update student
     set tot_cred= tot_cred +
           (select credits
            from course
            where course.course_id= nrow.course_id)
     where student.id = nrow.id;
end;
```

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

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 (called **change** or **delta** 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

When Not To Use Triggers

- Risk of unintended execution of triggers, for example, when
  - loading data from a backup copy
  - replicating updates at a remote site
  - Trigger execution can be disabled before such actions.
- Other risks with triggers:
  - Error leading to failure of critical transactions that set off the trigger
  - Cascading execution

Recursive Queries

Recursion in SQL

- SQL:1999 permits recursive view definition
- Example: find which courses are a prerequisite, whether directly or indirectly, for a specific course

```
with recursive rec_prereq(course_id, prereq_id) as (
        select course_id, prereq_id
        from prereq
    union
        select rec_prereq.course_id, prereq.prereq_id,
        from rec_rereq, prereq
        where rec_prereq.prereq_id = prereq.course_id
    )
select ∗
from rec_prereq;
```

This example view, *rec_prereq,* is called the *transitive closure* of the *prereq* relation

Note: 1st printing of 6th ed erroneously used c_prereq in place of rec_prereq in some places

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 *prereq* with itself
    - This can give only a fixed number of levels of managers
    - Given a fixed non-recursive query, we can construct a database with a greater number of levels of prerequisites on which the query will not work
    - Alternative: write a procedure to iterate as many times as required
      - See procedure *findAllPrereqs* in book

The Power of Recursion

- Computing transitive closure using iteration, adding successive tuples to *rec_prereq*
  - The next slide shows a *prereq* relation
  - Each step of the iterative process constructs an extended version of *rec_prereq* 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 *prereq* the view *rec_prereq* contains all of the tuples it contained before, plus possibly more

Example of Fixed-Point Computation

course_id	*prereq_id*
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-319	CS-101
CS-347	CS-101
EE-181	PHY-101

Iteration Number	Tuples in cl
0	
1	(CS-301)
2	(CS-301), (CS-201)
3	(CS-301), (CS-201)
4	(CS-301), (CS-201), (CS-101)
5	(CS-301), (CS-201), (CS-101)

Advanced Aggregation Features

Ranking

- Ranking is done in conjunction with an order by specification.
- Suppose we are given a relation
  student_grades(ID, GPA)
  giving the grade-point average of each student
- Find the rank of each student.

```
select ID, rank() over (order by GPA desc) as s_rank
 from student_grades
```

- An extra **order by** clause is needed to get them in sorted order

```
select ID, rank() over (order by GPA desc) as s_rank
 from student_grades
 order by s_rank
```

- Ranking may leave gaps: e.g. if 2 students have the same top GPA, both have rank 1, and the next rank is 3
  - **dense_rank** does not leave gaps, so next dense rank would be 2

Ranking

- Ranking can be done using basic SQL aggregation, but resultant query is very inefficient

```
select ID, (1 + (select count(*)
                 from student_grades B
                 where B.GPA > A.GPA)) as s_rank
from student_grades A
order by s_rank;
```

Ranking (Cont.)

- Ranking can be done within partition of the data.
- "Find the rank of students within each department."

```
select ID, dept_name,
        rank () over (partition by dept_name order by GPA desc)
                as dept_rank
 from dept_grades
 order by dept_name, dept_rank;
```

- Multiple **rank** clauses can occur in a single **select** clause.
- Ranking is done *after* applying **group by** clause/aggregation
- Can be used to find top-n results
  - More general than the **limit** *n* clause supported by many databases, since it allows top-n within each partition

Ranking (Cont.)

- Other ranking functions:
  - **percent_rank** (within partition, if partitioning is done)
  - **cume_dist** (cumulative distribution)
    - fraction of tuples with preceding values
  - **row_number** (non-deterministic in presence of duplicates)
- SQL:1999 permits the user to specify **nulls first** or **nulls last**

select *ID*,
    rank ( ) **over** (**order by** *GPA* **desc nulls last**) **as** *s_rank*
from *student_grades*

Ranking (Cont.)

- For a given constant *n*, the ranking the function *ntile*(*n*) takes the tuples in each partition in the specified order, and divides them into *n* buckets with equal numbers of tuples.
- E.g.,

  select *ID*, **ntile**(4) **over** (**order by** *GPA* **desc**) **as** *quartile*
  from *student_grades;*

Windowing

- Used to smooth out random variations.
- E.g., **moving average**: "Given sales values for each date, calculate for each date the average of the sales on that day, the previous day, and the next day"
- **Window specification** in SQL:
  - Given relation *sales(date, value)*

    select *date*, ***sum***(*value*) **over**
        (**order by** *date* **between rows** 1 **preceding and** 1 **following**)
    from *sales*

Windowing

- Examples of other window specifications:
  - **between rows unbounded preceding and current**
  - **rows unbounded preceding**
  - **range between** 10 **preceding and current row**
    - All rows with values between current row value –10 to current value
  - **range interval** 10 **day preceding**
    - Not including current row

Windowing (Cont.)

- Can do windowing within partitions
- E.g., Given a relation *transaction* (*account_number, date_time, value*), where value is positive for a deposit and negative for a withdrawal
  - "Find total balance of each account after each transaction on the account"

```
select account_number, date_time,
    sum (value) over
            (partition by account_number
            order by date_time
            rows unbounded preceding)
   as balance
from transaction
order by account_number, date_time
```

OLAP**

Data Analysis and OLAP

- **Online Analytical Processing (OLAP)**
  - Interactive analysis of data, allowing data to be summarized and viewed in different ways in an online fashion (with negligible delay)
- Data that can be modeled as dimension attributes and measure attributes are called **multidimensional data**.
  - **Measure attributes**
    - measure some value
    - can be aggregated upon
    - e.g., the attribute *number* of the *sales* relation
  - **Dimension attributes**
    - define the dimensions on which measure attributes (or aggregates thereof) are viewed
    - e.g., attributes *item_name, color,* and *size* of the *sales* relation

Example sales relation

item_name	*color*	*clothes_size*	*quantity*
skirt	dark	small	2
skirt	dark	medium	5
skirt	dark	large	1
skirt	pastel	small	11
skirt	pastel	medium	9
skirt	pastel	large	15
skirt	white	small	2
skirt	white	medium	5
skirt	white	large	3
dress	dark	small	2
dress	dark	medium	6
dress	dark	large	12
dress	pastel	small	4
dress	pastel	medium	3
dress	pastel	large	3
dress	white	small	2
dress	white	medium	3
dress	white	large	0
shirt	dark	small	2
shirt	dark	medium	6
…	…	…	…
…	…		…

Cross Tabulation of *sales* by *item_name* and *color*

clothes_size **all**

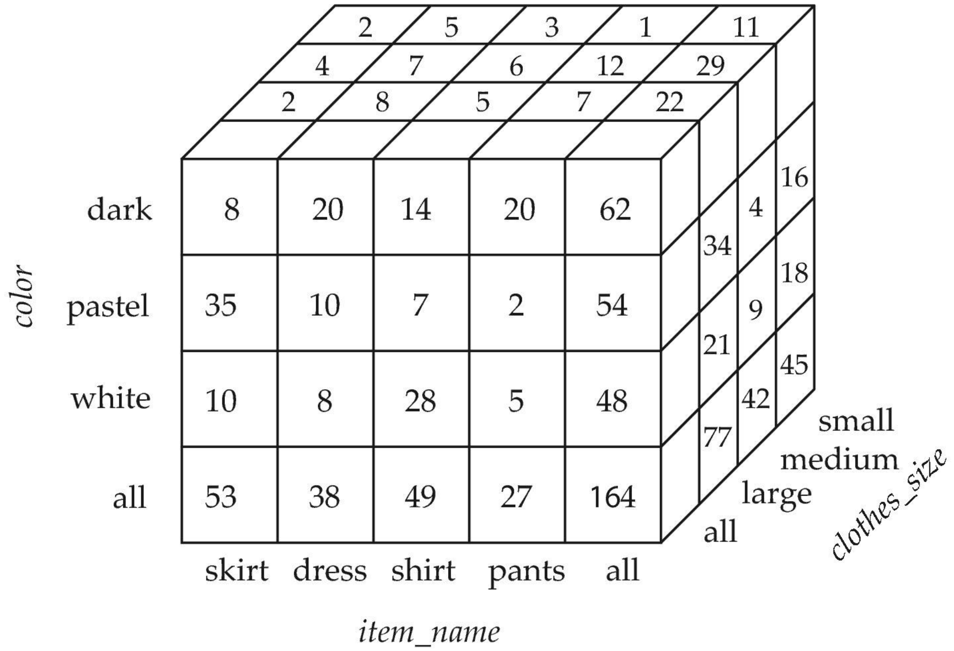
color

item_name	dark	pastel	white	total
skirt	8	35	10	53
dress	20	10	5	35
shirt	14	7	28	49
pants	20	2	5	27
total	62	54	48	164

- The table above is an example of a **cross-tabulation** (**cross-tab**), also referred to as a **pivot-table**.
  - Values for one of the dimension attributes form the row headers
  - Values for another dimension attribute form the column headers
  - Other dimension attributes are listed on top
  - Values in individual cells are (aggregates of) the values of the dimension attributes that specify the cell.

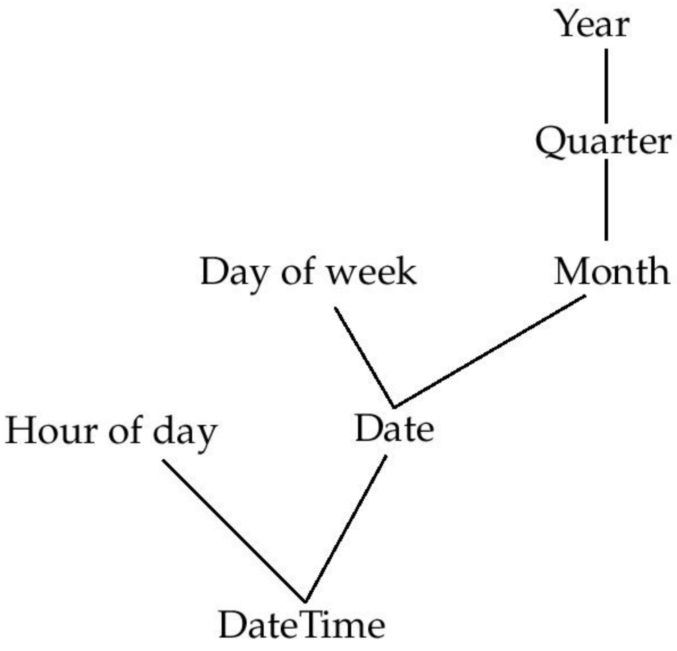
Data Cube

- A **data cube** is a multidimensional generalization of a cross-tab
- Can have *n* dimensions; we show 3 below
- Cross-tabs can be used as views on a data cube

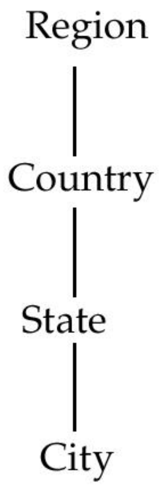


Hierarchies on Dimensions

- **Hierarchy** on dimension attributes: lets dimensions to be viewed at different levels of detail
  - E.g., the dimension DateTime can be used to aggregate by hour of day, date, day of week, month, quarter or year



a) Time Hierarchy



b) Location Hierarchy

Cross Tabulation With Hierarchy

- Cross-tabs can be easily extended to deal with hierarchies
  - Can drill down or roll up on a hierarchy

clothes_size: **all**

category	*item_name*	*color*: dark	pastel	white	total	
womenswear	skirt	8	8	10	53	
	dress	20	20	5	35	
	subtotal	28	28	15		88
menswear	pants	14	14	28	49	
	shirt	20	20	5	27	
	subtotal	34	34	33		76
total		62	62	48		164

Relational Representation of Cross-tabs

- Cross-tabs can be represented as relations
  - We use the value **all** is used to represent aggregates.
  - The SQL standard actually uses null values in place of **all** despite confusion with regular null values.

item_name	*color*	*clothes_size*	*quantity*
skirt	dark	all	8
skirt	pastel	all	35
skirt	white	all	10
skirt	all	all	53
dress	dark	all	20
dress	pastel	all	10
dress	white	all	5
dress	all	all	35
shirt	dark	all	14
shirt	pastel	all	7
shirt	White	all	28
shirt	all	all	49
pant	dark	all	20
pant	pastel	all	2
pant	white	all	5
pant	all	all	27
all	dark	all	62
all	pastel	all	54
all	white	all	48
all	all	all	164

Extended Aggregation to Support OLAP

- The **cube** operation computes union of **group by**’s on every subset of the specified attributes
- Example relation for this section
  sales(*item_name, color, clothes_size, quantity*)
- E.g. consider the query

  select *item_name, color, size,* **sum**(*number*)
  from *sales*
  group by cube(*item_name, color, size*)

  This computes the union of eight different groupings of the *sales* relation:

  { (*item_name, color, size*), (*item_name, color*),
  (*item_name, size*), (*color, size*),
  (*item_name*), (*color*),
  (*size*), ( ) }

  where ( ) denotes an empty **group by** list.
- For each grouping, the result contains the null value for attributes not present in the grouping.

Online Analytical Processing Operations

- Relational representation of cross-tab that we saw earlier, but with *null* in place of **all**, can be computed by

  select *item_name*, *color*, **sum**(*number*)
  from *sales*
  group by cube(*item_name, color*)

- The function **grouping()** can be applied on an attribute
  - Returns 1 if the value is a null value representing all, and returns 0 in all other cases.

select *item_name, color, size*, **sum**(*number*),
    grouping(*item_name*) **as** *item_name_flag*,
    grouping(*color*) **as** *color_flag*,
    grouping(*size*) **as** *size_flag*,
from *sales*
group by cube(*item_name, color, size*)

Online Analytical Processing Operations

- Can use the function **decode()** in the **select** clause to replace such nulls by a value such as **all**
  - E.g., replace *item_name* in first query by
    decode(**grouping**(item_*name*), 1, ‘all’, *item_name*)

Extended Aggregation (Cont.)

- The **rollup** construct generates union on every prefix of specified list of attributes
- E.g.,

    select *item_name*, *color*, *size*, **sum**(*number*)
    from *sales*
    group by rollup(*item_name, color, size*)

  Generates union of four groupings:

    { (*item_name, color, size*), (*item_name, color*), (*item_name*), ( ) }

- Rollup can be used to generate aggregates at multiple levels of a hierarchy.
- E.g., suppose table *itemcategory*(*item_name, category*) gives the category of each item. Then

    select *category, item_name*, **sum**(*number*)
    from *sales, itemcategory*
    where *sales.item_name = itemcategory.item_name*
    group by rollup(*category, item_name*)

  would give a hierarchical summary by *item_name* and by *category.*

Extended Aggregation (Cont.)

- Multiple rollups and cubes can be used in a single group by clause
  - Each generates set of group by lists, cross product of sets gives overall set of group by lists
- E.g.,

  select *item_name, color, size*, **sum**(*number*)
  from *sales*
  group by rollup(*item_name*), **rollup**(*color, size*)

  generates the groupings

  {item_name, ()} X {(color, size), (color), ()}

  = { (*item_name, color, size*), (*item_name, color*), (*item_name*), (*color, size*), (*color*), ( ) }

Online Analytical Processing Operations

- **Pivoting:** changing the dimensions used in a cross-tab is called
- **Slicing:** creating a cross-tab for fixed values only
  - Sometimes called **dicing**, particularly when values for multiple dimensions are fixed.
- **Rollup:** moving from finer-granularity data to a coarser granularity
- **Drill down:** The opposite operation - that of moving from coarser-granularity data to finer-granularity data

OLAP Implementation

- The earliest OLAP systems used multidimensional arrays in memory to store data cubes, and are referred to as **multidimensional OLAP (MOLAP)** systems.
- OLAP implementations using only relational database features are called **relational OLAP (ROLAP)** systems
- Hybrid systems, which store some summaries in memory and store the base data and other summaries in a relational database, are called **hybrid OLAP (HOLAP)** systems.

OLAP Implementation (Cont.)

- Early OLAP systems precomputed *all* possible aggregates in order to provide online response
  - Space and time requirements for doing so can be very high
    - 2^n combinations of **group by**
  - It suffices to precompute some aggregates, and compute others on demand from one of the precomputed aggregates
    - Can compute aggregate on (*item_name, color*) from an aggregate on (*item_name, color, size*)
      - For all but a few “non-decomposable” aggregates such as *median*
      - is cheaper than computing it from scratch
- Several optimizations available for computing multiple aggregates
  - Can compute aggregate on (*item_name, color*) from an aggregate on (*item_name, color, size*)
  - Can compute aggregates on (*item_name, color, size*), (*item_name, color*) and (*item_name*) using a single sorting of the base data

End of Chapter

Exercises in the book : 6, 15

Additional:

1）写一个嵌入SQL/ODBC程序或Stored Procedure，保存一位同学的一门选课信息，需检查不能有冲突的上课时间；所有先修课必须通过；教室容量必须够。如果以上条件不满足则失败

Figure 5.22

item_name	*clothes_size*	*dark*	*pastel*	*white*
skirt	small	2	11	2
skirt	medium	5	9	5
skirt	large	1	15	3
dress	small	2	4	2
dress	medium	6	3	3
dress	large	12	3	0
shirt	small	2	4	17
shirt	medium	6	1	1
shirt	large	6	2	10
pant	small	14	1	3
pant	medium	6	0	0
pant	large	0	1	2

Figure 5.23

item_name	*quantity*
skirt	53
dress	35
shirt	49
pant	27

Figure 5.24

item_name	*color*	*quantity*
skirt	dark	8
skirt	pastel	35
skirt	white	10
dress	dark	20
dress	pastel	10
dress	white	5
shirt	dark	14
shirt	pastel	7
shirt	white	28
pant	dark	20
pant	pastel	2
pant	white	5

Another Recursion Example

- Given relation
  manager(*employee_name, manager_name*)
- 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
    union
        select manager.employee_name, empl.manager_name
        from   manager, empl
        where manager.manager_name = empl.employe_name)
select *
from   empl
```

This example view, *empl,* is the *transitive closure* of the *manager* relation

Merge statement (now in Chapter 24)

- Merge construct allows batch processing of updates.
- Example: relation *funds_received* (*account_number, amount*) has 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*