Chapter 5: Advanced SQL

Database System Concepts, 6th Ed.

Database System Concepts

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Chapter 5: Advanced SQL

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JDBC and ODBC

- 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)
  - ODBC 1.0 (1992), ODBC 3.0 (1995), ODBC 3.8 (2009)
  - Orginally designed for C, now works with C++, C#, and Visual Basic
  - Other API's such as ADO.NET sit on top of ODBC
  - ODBC drivers exist for most DBMSs
- JDBC (Java Database Connectivity) works with Java
  - JDBC driver was a part of Java Development Kit (JDK) 1.1 (1997)
  - Since then, a part of Java Platform, Standard Edition (Java SE)
  - JDBC 4.2 (2013)

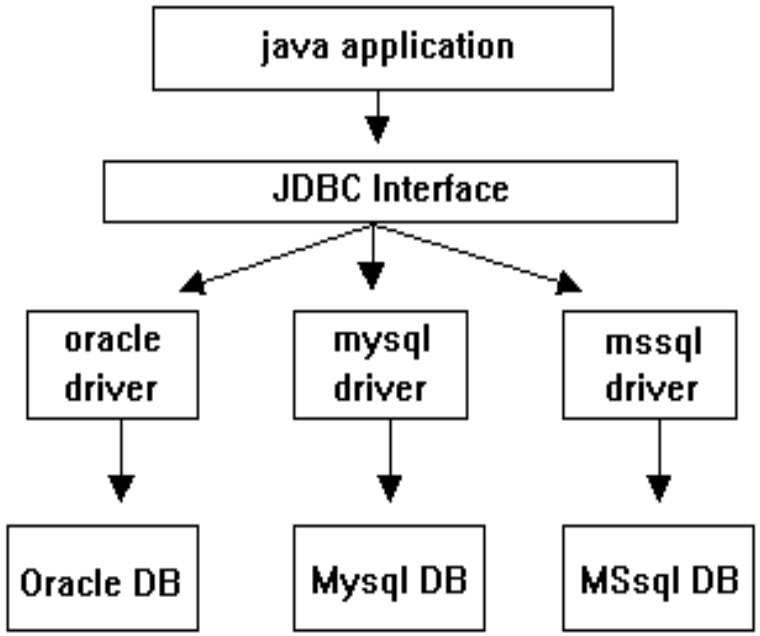
JDBC

- **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.
- JDBC 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

Overview

JDBC란 Java DataBase Connectivity의 약자로 데이터베이스에 연결 및 작업을 하기 위한 자바 표준 인터페이스이다.
자바는 DBMS의 종류에 상관없이 하나의 JDBC API를 사용해서 데이터베이스 작업을 처리할 수 있다.

1. JDBC의 구조



자바언어에서 데이터베이스 표준 인터페이스를 정의하고, 각 데이터베이스 회사들은 JDBC 인터페이스를 제공받아 자신들의 데이터베이스에 맞게 구현한후 드라이버를 제공한다. 개발자가 JDBC API를 사용할 경우 DBMS에 알맞은 JDBC드라이버만 있으면 어떤 데이터베이스라도 사용할 수 있게 된다.
JDBC 드라이버는 각 밴드사에서 jar파일로 제공된다.

```
1.  String driver="oracle.jdbc.driver.OracleDriver";
2.  String url="jdbc:oracle:thin:@localhost:1521:ORCL";
3.  String sql = "select no, name from member";
4.  Connection conn = null;
5.  PreparedStatement pstmt = null;
6.  ResultSet rs = null;
7.  try {
8.     // ① JDBC 드라이버 로딩
9.     Class.forName(driver);
10.    // ② 데이터베이스 connection
11.    conn=DriverManager.getConnection(url,"scott","tiger");
12.    // ③ 쿼리(sql)문장을 실행하기 위한 객체 생성
13.    pstmt=conn.prepareStatement(sql);
14.    // ④ 쿼리 실행
15.    rs=pstmt.executeQuery();
16.    // ⑤ 쿼리 실행의 결과값(int, ResultSet) 사용
17.    while(rs.next()){
18.     out.println("<h3>"+rs.getInt(1)+","+rs.getString(2)+"</h3>");
19.    }
20. }catch(Exception e){
21.   out.println("<h3>데이터 가져오기에 실패하였습니다.</h3>");
22.   e.printStackTrace();
23. }finally{
24.   // ⑥ 사용된 객체 종료
25.   try{rs.close();}catch(Exception e){}
26.   try{pstmt.close();}catch(Exception e){}
27.   try{conn.close();}catch(Exception e){}
28. }
```

JDBC Code

```
public static void JDBCexample(String userid, String passwd)
{
    try {
        Class.forName ("oracle.jdbc.driver.OracleDriver"); // JDBC driver loading
        Connection conn = DriverManager.getConnection(
                        "jdbc:oracle:thin:@db.yale.edu:2000:univdb", userid, passwd);
        Statement stmt = conn.createStatement();
        … Update code in the next page….
        … Query and fetch code in the next page…..
        stmt.close();
        conn.close();
    }
    catch (Exception e) {
        System.out.println("Exception : " + e);
    }
}
```

“Update DB” Code Details

- Update to database

```
try {
     stmt.executeUpdate(
    "insert into instructor values(’77987’, ’Kim’, ’Physics’, 98000)");
 }
catch (SQLException sqle)
 {
       System.out.println("Could not insert a tuple. " + sqle);
 }
```

"Query & Fetch" Code Details

- Execute query and fetch & print result

```
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));
  }
```

- Getting result fields:
  - **rset.getString("dept_name") and rset.getString(1) equivalent if dept_name is the first argument of select result.**

JDBC Prepared Statement

- PreparedStatement의 ?자리에 나중에 공급되는 value가 들어가는 mechanism

```
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();
```

- WARNING: always use prepared statements when taking an input from the user and adding it to a query
  - You better not create a query by concatenating strings!
  - " insert into instructor

    values(' " + ID + " ', ' " + name + " ', " + " ' + dept name + " ', " ' balance + ") "
  - What if name is "D'Souza"? ➔ single quotation mark will create a syntax error
  - The next slide shows an even-worse situation!

"Potentially Dangerous" SQL Injection in JDBC Prepared Statement

- 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 \ for a single quotation mark:
  "select * from instructor where name = 'X\' or \'Y\' = \'Y'
  - **Always use prepared statements, with user inputs as parameters**

JDBC Metadata Features

- Two types of JDBC Metadata
  - Meta data for a query
  - Meta data for the whole database

- ResultSetMetadata: meta data for query result

  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? ➔ useful for printing out the formatted table for query result!

JDBC Metadata Features (Cont)

- DatabaseMetadata: meta data for the database itself

```
DatabaseMetaData dbmd = conn.getMetaData();
ResultSet rs = dbmd.getColumns(null, “univdb”, “department”, “%”);
// Arguments to getColumns: Catalog, Schema-pattern, Table-pattern, 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? ➔ can be used for a database browser (or database GUI) that allows a user to navigate or examine tables

JDBC transaction control

- Updatable result sets
  - 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);
  - A group of transactions must then be committed or rolled back explicitly
    - conn.commit(); or
    - conn.rollback();
  - conn.setAutoCommit(true) turns on automatic commit.

JDBC Stored Procedures

- Calling statement interface for invoking SQL stored functions and procedures
  - CallableStatement cStmt1 = conn.prepareCall("{? = call some function(?)}");
  - CallableStatement cStmt2 = conn.prepareCall("{call some procedure(?,?)}");
  - Java program 내부에서 cStmt1와 cStmt2를 수행할수 있다

- Handling large object types without creating the large object in memory
  - 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).
  - Database에 있는 large object들을 Java program에서 partial access, update등이 가능하게 한다

ODBC

- Open Data Base Connectivity(ODBC) standard
  - Initially C language connection API to DBMS
  - 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

ODBC (Cont.)

- Each database system supporting ODBC provides a "ODBC 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.
- Opens database connection using SQLConnect() with parameters as below
  - connection handle,
  - the server to which to connect
  - the user identifier,
  - password
- Must also specify types of arguments:
  - SQL_NTS denotes previous argument is a null-terminated string.

ODBC Code (Cont.)

```
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);
    { …Code in the next page… }

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

ODBC Code (Cont.)

- Main body of program

```
char deptname[80];
float salary;
int lenOut1, lenOut2;
HSTMT stmt;
char * sqlquery = "select dept_name, sum (salary)
                   from instructor
                   group by dept_name";
SQLAllocStmt(conn, &stmt);
error = SQLExecDirect(stmt, sqlquery, SQL NTS);
if (error == SQL SUCCESS) {
    SQLBindCol (stmt, 1, SQL C CHAR, deptname , 80,   &lenOut1);
    SQLBindCol (stmt, 2, SQL C FLOAT, &salary, 0 ,    &lenOut2);
    while (SQLFetch(stmt) == SQL SUCCESS) {
        printf (" %s %g\n", deptname, salary);
    }
}
SQLFreeStmt(stmt, SQL DROP);
```

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.
  - 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 Prepared Statements

- **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
- 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

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.

- Transaction control: 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)}
  - A group of transactions can 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

- Database connection API for Visual Basic .NET and C# (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 first 2 attributes of result*/
}
rdr.Close();
conn.Close();
```

- Translated into ODBC calls
- Can also access non-relational data sources such as
  - OLE-DB
  - XML data
  - Entity framework

Embedded SQL

- The SQL standard defines embeddings of SQL in PLs 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.
- System R: ESQL into PL/I, Most DBMSs: ESQL/C
- **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 (eg., the Java embedding uses # SQL { . };)
- 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.

Updates Through Cursors in Embedded SQL

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

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

- To update tuple at the current location of cursor *c*

```
EXEC SQL
    update instructor
    set salary = salary + 100
    where current of c
```

SQLJ

- Alternative approach for combining SQL and Java
- JDBC에 비해서 Java Syntax에 가깝게 표현되는 방식

- SQLJ part 0: ANSI (1998), “Object Language Bindings (SQL/OLB)”, SQL—Part 10
- SQLJ part 1: ANSI (1999), "SQL Routines Using the Java"
- SQLJ part 2: ANSI (2000), "SQL Types Using the Java”

- *Object Language Bindings (SQL/OLB) :* ISO (2000), *SQL—Part 10*
- *SQL Routines and Types Using the Java (SQL/JRT)*: ISO (2002), *SQL—Part 13*

- *Only DBMSs by IBM, Oracle support SQLJ*
  - *Translator from SQLJ code to JCBC code*

SQLJ (cont'd)

- JDBC is overly dynamic, errors cannot be caught by compiler

  ➔ 그래서 JDBC program들은 Try … Catch.. 로 구성된다
- ESQL/C와 다른점: EXEC SQL 대신에 #sql, cursor대신에 iter
- 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();
```

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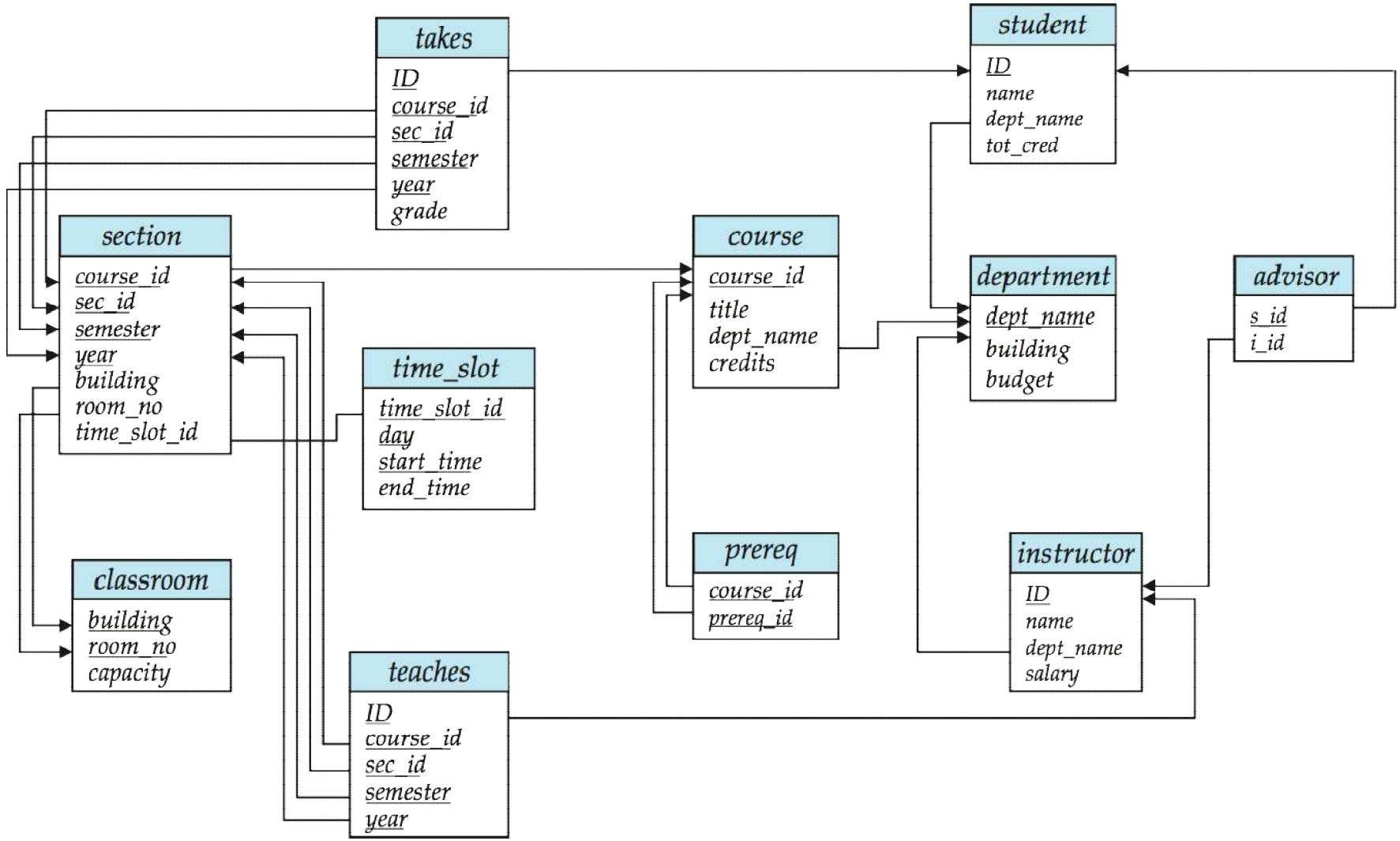
Procedural Extensions and Stored Procedures

- 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
- OOP의 method 개념을 support
- Object-oriented aspects of these features are covered in Chapter 22 (Object Based Databases)

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 DBMSs have proprietary procedural extensions to SQL that differ from SQL:1999.

Schema Diagram for University Database



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
```

- Calling a function within a query: Find the department name and budget of all departments with more that 12 instructors.

```
select dept_name, budget
from department
where dept_count (dept_name ) > 1
```

SQL Table Functions

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

```
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)
```

- Calling a table function:

```
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

SQL 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 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
```

- **For** loop

  Permits iteration over all results of a query

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

SQL 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

Functions/Procedures written in External PL

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

```
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'
```

Functions/Procedures written in External PL (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 allowed when efficiency is more important than security.

Security with External Language Routines

- To deal with security problems
  - Use **sandbox** techniques
    - A safe language like Java has the sandbox feature 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.

- Java Sand Box Model: Java Compiler가 신뢰성이 확보되지 않은 코드를 load할 때 항상 바이트 코드를 검사하여, 신용이 확인되지 않은 코드는 자바환경전체에 아무런 해약이 미치지 못하는 'Sand Box'에서 수행시켜 Local System에 대한 전면적인 접근을 금지하는 기법.

Chapter 5: Advanced SQL

- 5.1 Accessing SQL From a Programming Language
  - Dynamic SQL
    - JDBC and ODBC
  - Embedded SQL
- 5.2 Functions and Procedures
- 5.3 Triggers
- 5.4 Recursive Queries**
- 5.5 Advanced Aggregation Features**
- 5.6 OLAP**

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 were officially introduced to SQL standard in SQL:1999
- But triggers have been 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

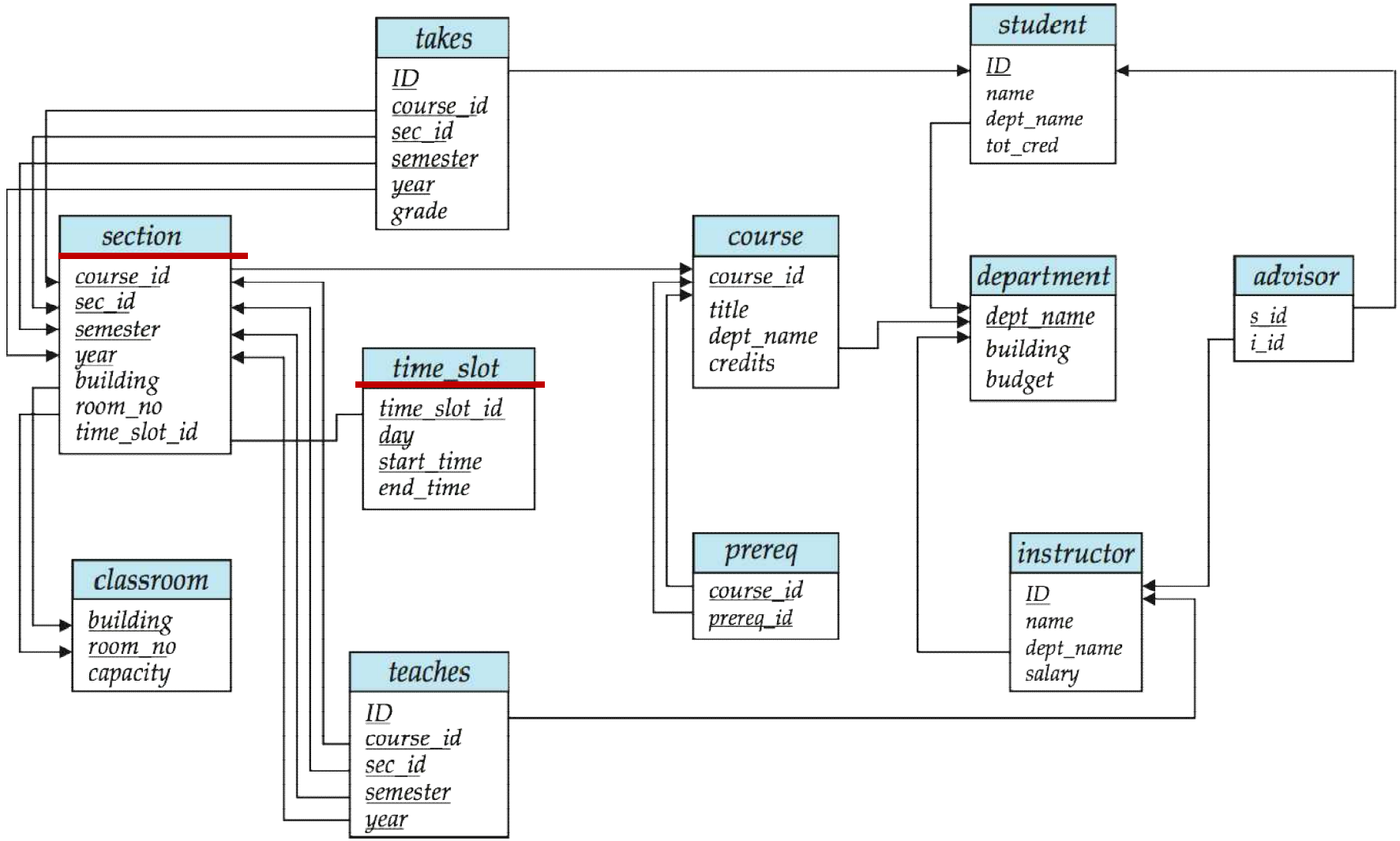
Trigger Example

- 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;
```

Schema Diagram for University Database



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 can be referenced before and after an update
  - **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

- **Keep tot_cred up-to-date when grade attribute is uptodated**

- **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

Alternativs to 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 in modern-day DBMS:
  - Built-in materialized view facilities to maintain summary data
  - 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

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Recursive View in SQL

- SQL:1999 permits recursive view definition
- Recursive views make it possible to write queries, such as transitive closure queries, that cannot be written without recursion or iteration.
- Example: find which courses are a prerequisite, whether directly or indirectly, for a specific course

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

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

Recursive View on a Relation

prereq relation

Course_id	Prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-347	CS-301
EE-181	PHY-101
CS-301	CS-201
CS-201	CS-101

Self_ join

prereq copy

Course_id	Prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-347	CS-301
EE-181	PHY-101
CS-301	CS-201
CS-201	CS-101

C_Prereq View

Course_id	Prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-347	CS-301
EE-181	PHY-101
CS-301	CS-201
CS-201	CS-101
CS-347	CS-201
CS-301	CS-101

Course_id	Prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-347	CS-301
EE-181	PHY-101
CS-301	CS-201
CS-201	CS-101
CS-347	CS-201
CS-301	CS-101

Self_ join

Course_id	Prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-347	CS-301
EE-181	PHY-101
CS-301	CS-201
CS-201	CS-101
CS-347	CS-201
CS-301	CS-101

Final C_Prereq View

Course_id	Prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-347	CS-301
EE-181	PHY-101
CS-301	CS-201
CS-201	CS-101
CS-347	CS-201
CS-301	CS-101
CS-347	CS-101

Non-Recursive Method for Transitive Closure Query

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

```
create function findAllPrereqs(cid varchar(8))
    -- Finds all courses that are prerequisite (directly or indirectly) for cid
returns table (course_id varchar(8))
    -- The relation prereq(course_id, prereq_id) specifies which course is
    -- directly a prerequisite for another course.
begin
    create temporary table c_prereq (course_id varchar(8));
        -- table c_prereq stores the set of courses to be returned
    create temporary table new_c_prereq (course_id varchar(8));
        -- table new_c_prereq contains courses found in the previous iteration
    create temporary table temp (course_id varchar(8));
        -- table temp is used to store intermediate results
    insert into new_c_prereq
        select prereq_id
        from prereq
        where course_id = cid;
    repeat
        insert into c_prereq
            select course_id
            from new_c_prereq;

        insert into temp
            (select prereq.course_id
                from new_c_prereq, prereq
                where new_c_prereq.course_id = prereq.prereq_id
            )
            except (
                select course_id
                from c_prereq
            );
        delete from new_c_prereq;
        insert into new_c_prereq
            select *
            from temp;
        delete from temp;

    until not exists (select * from new_c_prereq)
    end repeat;
    return table c_prereq;
end
```

Using procedural constructs SQL1999 such as repeat..until

Finding all prerequisites of a course

Computing transitive closure using iteration on a Relation

prereq relation

Course_id	Prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-347	CS-301
EE-181	PHY-101
CS-301	CS-201
CS-201	CS-101

Prerequisite courses of cs-347

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)

Fixed Point

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

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Ranking

- Ranking is done in conjunction with an order by specification.
- Suppose we have a relation ***student_grades(ID, GPA)***
- 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 can be done using basic SQL aggregation, but resultant query is 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 with **partition by** construct
- "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.
- 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*
- For a given constant *n*, 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*
- Examples of other window specifications:
  - **between rows unbounded preceding and current**
    - **Between**을 써서 지금까지의 모든 **row**들을 표현
  - **rows unbounded preceding**
    - 지금까지의 모든 **rows**
  - **range between** 10 **preceding and current row**
    - 현재 값과 현재 값 **– 10** 사이에 있는 값들을 표현
  - **range interval** 10 **day preceding**
    - **current row**를 안쓰고 지난 **10**일간을 표현

Windowing (Cont.)

- Can do windowing within partitions with partition by construct
- 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
```

➔ (*account_number, date_time, balance*) 생성

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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 quantity(*number)* of the *sales* relation
  - **Dimension attributes**
    - define the dimensions on which measure attributes (or aggregates thereof) are viewed
    - e.g., the 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
shirt	dark	large	6
shirt	pastel	small	4
shirt	pastel	medium	1
shirt	pastel	large	2
shirt	white	small	17
shirt	white	medium	1
shirt	white	large	10
pant	dark	small	14
pant	dark	medium	6
pant	dark	large	0
pant	pastel	small	1
pant	pastel	medium	0
pant	pastel	large	1
pant	white	small	3
pant	white	medium	0
pant	white	large	2

Dimension attributes

Measure attribute

Item_name 4가지
Color 3가지
Clothes_size 3가지
총 36 combinations
➔ 36 tuples

Plain Queries

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

Figure 5.23 Query result.

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
pants	dark	20
pants	pastel	2
pants	white	5

```
select item_name, sum(quantity)
from sales
group by item_name;
```

```
select item_name, color, sum(quantity)
from sales
group by item_name, color;
```

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

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

clothes_size **all**

item_name \ *color*	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

```
select item_name, color, sum(quantity)
from sales
group by cube(item_name, color)
```

이런 SQL Query의 도움을 받아서!!!!

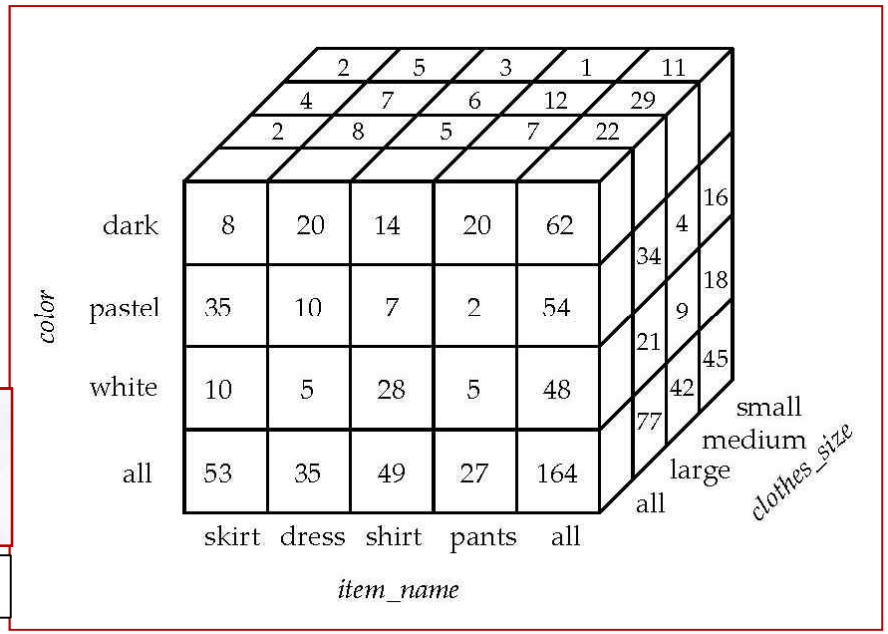
- The table above is an example of a **cross-tabulation** (**cross-tab**), also referred to as a **pivot-table**.
- The table is a very typical summary table or report table in real world office environments

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

```
select item_name, color, clothes_size, sum(quantity)
from sales
group by cube(item_name, color, clothes_size);
```

이런 SQL Query의 도움을 받아서!!!!



3D Data Cube of sales relation

OLAP Operations

- **Cube: union of groups of every subset combination of specified attributes**
- **Pivoting:** changing the dimensions used in a cross-tab
- **Slicing:** creating a cross-tab for fixed values only
  - Sometimes called **dicing**, particularly when values for multiple dimensions are fixed.
- **Rollup:**
  - **union of groups of every prefix combination of specified attributes**
  - 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

PIVOT operation in SQL

color attribute를 pivot으로 하고 sales relation을 재배치

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
shirt	dark	large	6
shirt	pastel	small	4
shirt	pastel	medium	1
shirt	pastel	large	2
shirt	white	small	17
shirt	white	medium	1
shirt	white	large	10
pant	dark	small	14
pant	dark	medium	6
pant	dark	large	0
pant	pastel	small	1
pant	pastel	medium	0
pant	pastel	large	1
pant	white	small	3
pant	white	medium	0
pant	white	large	2

```
select *
from sales
pivot (
      sum(quantity)
      for color in ('dark','pastel','white')
)
order by item_name;
```

⇨

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
pants	small	14	1	3
pants	medium	6	0	0
pants	large	0	1	2

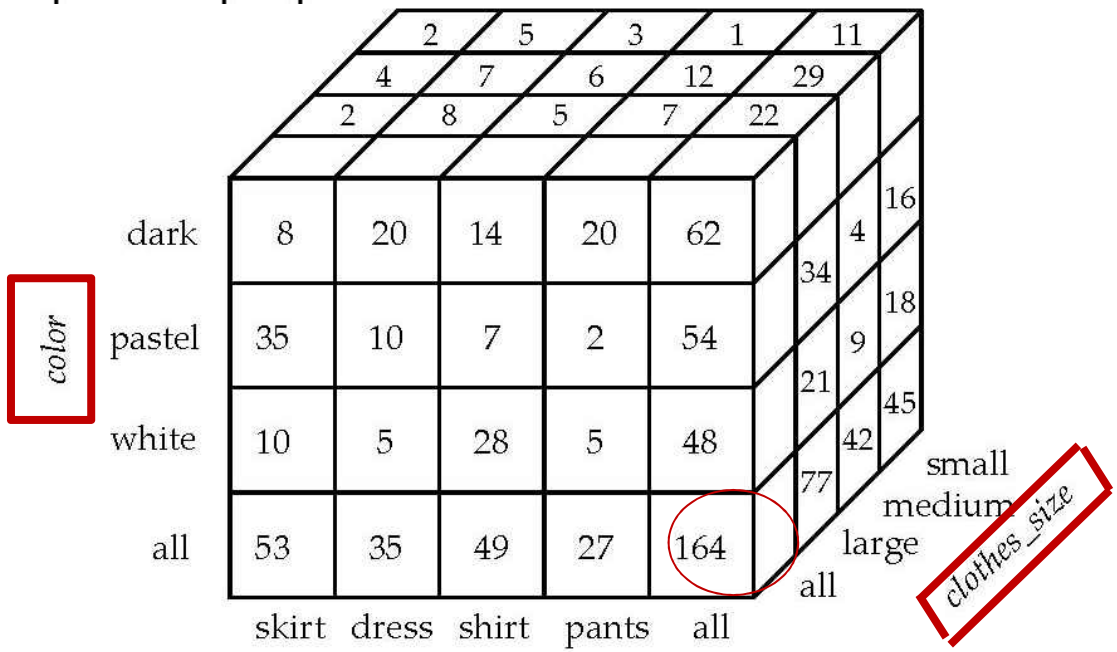
Data Cube

- 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

item_name	*color*	*clothes_size*	*quantity*
skirt	dark	small	2
skirt	dark	medium	5
skirt	dark	large	1

4 items, 3 colors, 3 sizes
need (4+1)X(3+1)X(3+1) =
80 cells in the data cube

Dimension attributes
Measure attribute




```
select item_name, color, clothes_size, sum(quantity)
from sales
group by cube(item_name, color, clothes_size);
```

Cube operation in SQL: Union of group by's on every subset of the specified attributes

- *sales*(*item_name, color, clothes_size, quantity*)
- E.g. consider the query

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

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

{ (*item_name, color, clothes_size*), # 3 dimension attributes

(*item_name, color*), (*item_name, clothes_size*), (*color, clothes_size*), # 2 dimension attributes

(*item_name*), (*color*), (*clothes_size*), # 1 dimension attribute

( ) } # 0 dimension attribute where ( ) denotes an empty **group by** list.

- For each grouping, the result contains the null value for attributes not present in the grouping.
- The resulting cube relation will have 80 cells from 4 items, 3 colors, 3 sizes data
  - 4 items, 3 colors, 3 sizes need (4+1)X(3+1)X(3+1) = 80 cells in the data cube
- Union of **group by**'s on every subset of the specified attributes
- 위 SQL Query 결과물은 80

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

총 80 tuples

Original 36 tuples in sales relation

+

item_name, *color*, *clothes_size*, **sum**(*quantity*)
Item_name 4가지, Color 3가지, Clothes_size 3가지
총 36 combinations ➔ 36 tuples

skirt	dark	all	8
skirt	pastel	all	35
skirt	white	all	10
dress	dark	all	20
dress	pastel	all	10
dress	white	all	5
shirt	dark	all	14
shirt	pastel	all	7
shirt	White	all	28
pant	dark	all	20
pant	pastel	all	2
pant	white	all	5

Item_name, color, “all”, sum(quantity)
Item_name 4가지, Color 3가지, Clothes_size “all”
총 12 combinations ➔ 12 tuples

Item_name, “all”, *clothes_size*, sum(quantity)
Item_name 4가지, Color “all”, Clothes_size 3가지
총 12 combinations ➔ 12 tuples

“all”, color, *clothes_size*, sum(quantity)
Item_name “all”, Color 3가지, Clothes_size 3가지
총 12 combinations ➔ 9 tuples

Item_name, “all”, “all”, sum(quantity)
Item_name 4가지, Color “all”, Clothes_size “all”
총 12 combinations ➔ 4 tuples

skirt	all	all	53
dress	all	all	35
shirt	all	all	49
pant	all	all	27

“all”, color, “all”, sum(quantity)
Item_name “all”, Color 3가지, Clothes_size “all”
총 4 combinations ➔ 3 tuples

“all”, “all”, *clothes_size* , sum(quantity)
Item_name “all”, Color “all”, Clothes_size 3가지
총 4 combinations ➔ 3 tuples

“all”, “all”, “all”, sum(quantity)
Item_name “all”, Color “all”, Clothes_size “all”
총 1 combination ➔ 1 tuple

all	all	all	164

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

총 20 tuples

Item_name, color, “all”, sum(quantity)
Item_name 4가지, Color 3가지, Clothes_size “all”
총 12 combinations ➔ 12 tuples

Item_name, “all”, “all”, sum(quantity)
Item_name 4가지, Color “all”, Clothes_size “all”
총 12 combinations ➔ 4 tuples

“all”, color, “all”, sum(quantity)
Item_name “all”, Color 3가지, Clothes_size “all”
총 4 combinations ➔ 3 tuples

“all”, “all”, “all”, sum(quantity)
Item_name “all”, Color “all”, Clothes_size “all”
총 1 combination ➔ 1 tuple

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

Roll Up

Union on every prefix of specified attributes

- E.g., **select** *item_name*, *color*, *clothes_size*, **sum**(*quantity*)
  from *sales*
  group by rollup(*item_name, color, clothes_size*)

총 36+17=
53 tuples

- Generates union of 4 groupings of every prefix of specified attributes:

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

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
shirt	dark	large	6
shirt	pastel	small	4
shirt	pastel	medium	1
shirt	pastel	large	2
shirt	white	small	17
shirt	white	medium	1
shirt	white	large	10
pant	dark	small	14
pant	dark	medium	6
pant	dark	large	0
pant	pastel	small	1
pant	pastel	medium	0
pant	pastel	large	1
pant	white	small	3
pant	white	medium	0
pant	white	large	2

item_name, *color*, *clothes_size*, **sum**(*quantity*)
Item_name 4가지, Color 3가지, Clothes_size 3가지
총 36 combinations ➔ 36 tuples

+

Item_name, color, “all”, sum(quantity)
Item_name 4가지, Color 3가지, Clothes_size “all”
총 12 combinations ➔ 12 tuples

+

Item_name, “all”, “all”, sum(quantity)
Item_name 4가지, Color “all”, Clothes_size “all”
총 4 combinations ➔ 4 tuples

+

“all”, “all”, “all”, sum(quantity)
Item_name “all”, Color “all”, Clothes_size “all”
총 1 combination ➔ 1 tuple

Original 36 tuples

+

skirt	dark	all	8
skirt	pastel	all	35
skirt	white	all	10
dress	dark	all	20
dress	pastel	all	10
dress	white	all	5
shirt	dark	all	14
shirt	pastel	all	7
shirt	White	all	28
pant	dark	all	20
pant	pastel	all	2
pant	white	all	5
skirt	all	all	53
dress	all	all	35
shirt	all	all	49
pant	all	all	27
all	all	all	164

Roll Up (cont.)

- E.g., **select** *item_name*, *color*, **sum**(*quantity*)
  from *sales*
  group by rollup(*item_name, color*)
- Generates union of 3 groupings of every prefix of specified attributes:

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

총 17 tuples

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
shirt	dark	large	6
shirt	pastel	small	4
shirt	pastel	medium	1
shirt	pastel	large	2
shirt	white	small	17
shirt	white	medium	1
shirt	white	large	10
pant	dark	small	14
pant	dark	medium	6
pant	dark	large	0
pant	pastel	small	1
pant	pastel	medium	0
pant	pastel	large	1
pant	white	small	3
pant	white	medium	0
pant	white	large	2

Item_name, color, sum(quantity)
Item_name 4가지, Color 3가지, Clothes_size "all"
총 12 combinations ➔ 12 tuples

+

Item_name, "all", sum(quantity)
Item_name 4가지, Color "all", Clothes_size "all"
총 4 combinations ➔ 4 tuples

+

"all", "all", sum(quantity)
Item_name "all", Color "all", Clothes_size "all"
총 1 combination ➔ 1 tuple

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
skirt	all	53
dress	all	35
shirt	all	49
pant	all	27
all	all	164

Roll Up with Hierarchy

- E.g., suppose we have a table *itemcategory(category, item_name)* 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.c*

(category,	item_name)
wowenswear,	skirt
wowenswear,	dress
menswear,	pants
menswear,	pants

Item_name

category

Itemcategory hierarchy

womenswear	skirt	dark	8
womenswear	skirt	pastel	35
womenswear	skirt	white	10
womenswear	dress	dark	20
womenswear	dress	pastel	10
womenswear	dress	white	5
menswear	shirt	dark	14
menswear	shirt	pastel	7
menswear	shirt	White	28
menswear	pant	dark	20
menswear	pant	pastel	2
menswear	pant	white	5
womenswear	skirt	all	53
womenswear	dress	all	35
menswear	shirt	all	49
menswear	pant	all	27
	all	all	164

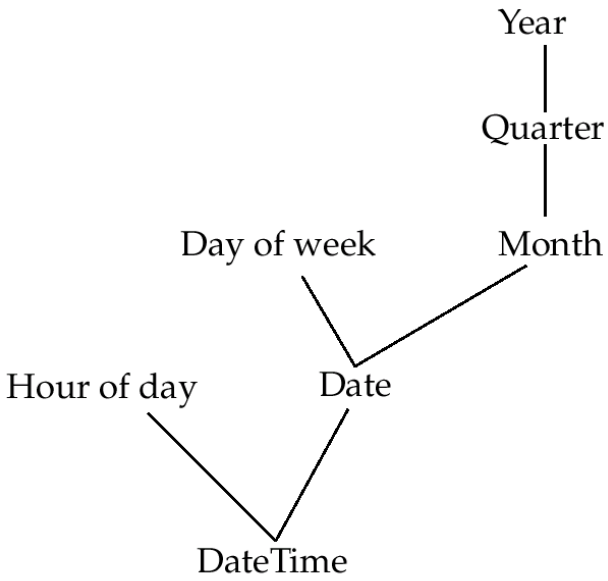
We can easily get this!

clothes_size: **all**

category	*item_name*	*color*				
		dark	pastel	white	total	
womenswear	skirt	8	8	35	53	
	dress	20	20	10	35	
	subtotal	28	28	45		88
menswear	pants	14	14	7	49	
	shirt	20	20	2	27	
	subtotal	34	34	9		76
total		62	62	54		164

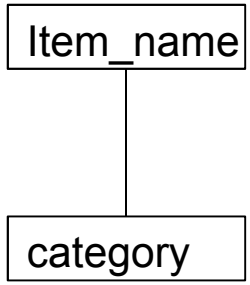
Hierarchies on Dimensions

- **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



c) Itemcategory hierarchy

참고자료

Relation with “null” to Cross-tab with “all”

- Relational representation of cross-tab (in next slide) 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)
```

- 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*)

Multiple rollups & cubes

- 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*), ( ) }

Figure 5.22: Result of SQL pivot operation on sales relation of Fig 5.16

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: Query Result

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

Figure 5.24: Query Result

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

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.

- Early OLAP systems precomputed *all* possible aggregates in order to provide online response
  - Space and time requirements for doing so can be very high
    - Cube operation needs 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*)
    - 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