Part X

Application Programming
Application Programming

1. Programming Language Connection
2. JDBC
3. SQLJ
4. LINQ
5. Object-Relational Mapping
6. Procedural SQL-Extensions: SQL/PSM
Learning goals for today . . .

- Knowledge about concepts and interfaces for access on SQL-databases out of programming languages
- Understanding of procedural interfaces on the example of JDBC
- Knowledge on embedded SQL and procedural SQL-extensions
- Basic knowledge on object-relational mapping
Programming Language Connection

- **Coupling types:**
  - Procedural or CALL-interfaces (*call level interface*)
    - Examples: SQL/CLI, ODBC, JDBC, …
  - Embedding of a DB-language into programming languages
    - Static embedding: Precompiler-principle
      - SQL-Statements defined *at compile time*
    - Examples: Embedded SQL, SQLJ
    - Dynamic embedding:
      - construction of SQL-statements at runtime
  - **Language extensions** and new *language developments*
    - Examples: SQL/PSM, PL/SQL, Transact-SQL, PL/pgSQL
Cursor-Concept

- **Cursor**: iterator over list of tuples (query result)
JDBC: Overview

- Database access interface for Java
- Abstract, database neutral interface
- Comparable with ODBC
- Low-Level-API: direct usage of SQL
- Java-Package `java.sql`
  - `DriverManager`: Entrance point, loading of drivers
  - `Connection`: Database connection
  - `Statement`: Execution of statement with a connection
  - `ResultSet`: Manages results of a query, access on single columns
JDBC: Structure

DriverManager \( \xrightarrow{\text{getConnection}} \) Connection

\( \text{createStatement} \)

\( \text{executeQuery} \)

Statement -> ResultSet

Statement -> ResultSet
JDBC: Driver Concept

Java Application

JDBC-API

JDBC Driver Manager

Native Protokoll Driver

JDBC Net Driver

JDBC ODBC Bridge

Native API Driver

DB Middleware

ODBC

Client Library

Client Library

ODBC

Client Library

Native Protokoll Driver
JDBC: Sequence of Events

1. Establishing of a connection to the database
   - Specification of connection information
   - Selection and loading of the driver

2. Sending of a SQL-query
   - Definition of the statement
   - Assignment of parameters

3. Processing of the query results
   - Navigation over result relation
   - Access on columns
JDBC: Connection Establishment

1. Loading drivers

   Class.forName("com.company.DBDriver");

2. Establish connection

   String url = "jdbc:subprotocol:datasource";
   Connection con = DriverManager.getConnection(url, "scott", "tiger");

JDBC-URL specifies

- Data source / Database
- Connection mechanism (Protocol, Server and Port)
JDBC: Query Execution

1. Create statement
   ```java
   Statement stmt = con.createStatement();
   ```

2. Execute statement
   ```java
   String query = "select Name, Vintage from WINES";
   ResultSet rSet = stmt.executeQuery(query);
   ```

Class `java.sql.Statement`
- Execution of queries (**SELECT**) with `executeQuery`
- Execution of changing statements (**DELETE, INSERT, UPDATE**) with `executeUpdate`
JDBC: Result Processing

1. Navigation over result set (Cursor-Principle)

```java
while (rSet.next()) {
    // Processing of single tuples
    ...
}
```

2. Access of column values with `getType-methods`

- with column index

```java
String wName = rSet.getString(1);
```

- with column name

```java
String wName = rSet.getString("Name");
```
JDBC: Exception Handling

- Exception handling with **try-catch**-mechanism
- SQLException for all SQL- and DBMS-exceptions

```java
try {
    // call of JDBC-methods
    ...
}
catch (SQLException exc) {
    System.out.println("SQLException: " + exc.getMessage());
}
```
JDBC: Update Operations

- DDL- and DML-statements with `executeUpdate`
- Gives number of affected rows (for DML-statements)

```java
Statement stmt = con.createStatement();
int rows = stmt.executeUpdate(
    "update WINES set Price = Price * 1.1 " +
    "where Vintage < 2000");
```
JDBC: Transaction Management

- Methods of Connection
  - commit()
  - rollback()

Auto-Commit-Mode

- Implicit commit after each statement
- Transaction consists just out of one single statement
- Switch mode with setAutoCommit(\texttt{boolean})
SQLJ: Embedded SQL for Java

- Embedding of SQL-statements in Java source code
- Precompilation of the extended source codes onto real Java code with the translator `sqlj`
- Checking of the SQL-statements
  - Correct syntax
  - Accordance of the statements with the DB-scheme
  - Type compatibility of the for data transfer used variables
- Usage of JDBC-drivers
SQLJ: Principle

- **SQLJ Program**
- **SQLJ Translator**
- **Java Source Code**
  - Java Compiler
  - Bytecode
- **SQLJ Profiles**
  - Customizer
  - Custom Profile
- **SQLJ Runtime System**
  - JDBC Driver

*Syntax & Semantic Check*
SQLJ-Statements

- Identification with `#sql` declaration
- Class definition for iterators
- SQL-statements: Queries, DML- and DDL-statements

```sql
#sql { SQL-statement };
```

Example:

```sql
#sql { insert into PRODUCER (Vineyard, Region) values ('Wairau Hills', 'Marlborough') };```
Host-Variables

- Variables of a host-language (here Java) that can occur in SQL-statements
- Usage: Exchange of data between the host-language and SQL
- Identification with ":variable"
- Example:

```java
String name;
int wineID = 4711;
#sql { select Name into :name
    from WINES where WineID = :wineID }
System.out.println("Wine = " + name);
```
Iterators

1. Declaration of the iterator

```sql
public iterator WineIter(String Name, String Vineyard, int Vintage);
```

2. Definition of the iterator object

```java
WineIter iter;
```

3. Execution of the statement

```sql
iter = { select Name, Vineyard, Vintage from WINES };
```

4. Navigation

```java
while (iter.next()) {
    System.out.println(iter.Name() + " " +
                         iter.Vineyard() + " " + iter.Vintage());
}
```
Dynamic SQL

- SQL-Statements as during runtime constructed Strings

```sql
exec sql begin declare section;
    QueryString char(256) varying;
exec sql end declare section;
exec sql declare QueryObjekt statement;
QueryString =
    'delete from WINES where WineID = 4711';
...
exec sql prepare QueryObjekt from :QueryString;
exec sql execute QueryObjekt;
```
Language Integrated Query (LINQ)

- Embedding of a DB-language (SQL) into a programming language (C#)
- Specialized class methods

```csharp
IEnumerable<string> res = wines
    .Where(w => w.Color = "Red")
    .Select(w => new { w.Name });
```

- Own language constructs (since C# 3.0)

```csharp
IEnumerable<op> res = from w in wines
    where w.Color = "Red"
    select new { w.Name };
```
Object-Relational Mapping

- Use of
  - Relational back ends (SQL-DBMS)
  - Object-relational applications, applications servers, middle ware, ...

- Implementation of "'business logic'" in form of objects (customer, order, process, ...)  
  - e.g., as Java Bean, CORBA-object

- Requires: Mapping class ↔ relation

- Aspects:
  - Conceptual mapping
  - Runtime support

- Technologies/Products: JDO, Hibernate, ADO.NET Entity Framework...
Object-Relational Mapping: Principle
Classes and Tables

- **OO**: Class defines properties of objects (intention) + covers set of all objects (extension)
- **RM**: Relation covers all tuples, relational scheme describes structure
- **Obvious**: class = table
- **But**: normalization decomposes relations!
  - 1 class = 1 table
  - 1 class = \( n \) tables
  - \( n \) classes = 1 table
Classes and Tables: Example

Wine
- **Id**: int
- **Name**: string
- **Color**: string
- **Vintage**: integer
- **Vineyard**: string

<table>
<thead>
<tr>
<th>Wine</th>
<th>WineID</th>
<th>Name</th>
<th>Color</th>
<th>Vintage</th>
<th>Vineyard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Relations

- **Embedded foreign key** in the relation of the class, i.e. the identifier of the associated object is saved as foreign key in additional columns.

- **Foreign key tables**: the relation instance is represented as tuple with the keys of the involved objects.

- Mapping of the relating classes on a **single table**: violation of the normal form.

- **Concrete**
  - 1:1-Relation: embedded foreign keys
  - 1:n-Relation: embedded foreign keys of foreign key tables
  - Relations with attributes: Foreign key tables
  - m:n-Relations: Foreign key tables
  - Three- and more valued relations: Foreign key tables
Relations /2

Producer
Name: string
District: string
Region: string
Winemaker: list of string

Producer
Vineyard
District
Region
Winemaker
Vineyard
Name

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Database Concepts
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Hibernate

- Java-framework for object-relational mapping
- Idea: Mapping of Java-objects to tuples of a relational database
- Principle: Java-class + mapping rule $\rightarrow$ SQL-table
- No explicit SQL-statements required!
- Support of the navigation over relations (automatic loading of the referenced objects)
- Queries on some languages (HQL resp. QBC/QBE)
public class Wine {
    private int id;
    private String name;
    private String color;
    private int vintage;
    private String vineyard;

    public void setName(String n) { name = n; }
    public String getName() { return name; }
    public void setColor(String c) { color = c; }
    public String getColor() { return color; }
    public void setVintage(int v) { vintage = v; }
    public int getVintage() { return vintage; }
    ...
}

Hibernate: Example /2

- Declaration of the mapping in a XML-Mapping-File
- Mapping rule is interpreted during runtime

```
<hibernate-mapping>
  <class name="Wine" table="WINES">
    <id name="id">
      <generator class="native"/>
    </id>
    <property name="name"/>
    <property name="color"/>
    <property name="vintage" column="vintage"/>
    <property name="vineyard"/>
  </class>
</hibernate-mapping>
```
Transaction tx = null;

Wine wine = new Wine();
wine.setName("Pinot Noir");
wine.setColor("Red");
wine.setVintage(1999);
wine.setVineyard("Helena");

try {
    tx = session.beginTransaction();
    session.save(wine);
    tx.commit();
} catch (HibernateException exc) {
    if (tx != null) tx.rollback();
}

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Database Concepts
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Hibernate: Queries

- Queries with Hibernate’s query language HQL
- Formulation on the *conceptual* scheme (Java-classes)
- Select-clause not required (results are always objects)
- Example

```java
Query query = 
    session.createQuery("from Wine where Color = 'Red'");
Iterator iter = query.iterate();
while (iter.hasNext()) {
    Wine wine = (Wine) iter.next();
    ...
}
```
SQL/PSM: The Standard

- SQL-Standard for procedural extensions
- PSM: Persistent Stored Modules
  - Stored modules of procedures and functions
  - Single routines
  - Integration of external routines (implemented in C, Java, ...)
  - Syntactic constructs for loops, conditions etc.
  - Basis for method implementation for object-relational concepts
Advantages of Stored Procedures

- Proved structuring tool for larger applications
- Specification of functions and procedures done in the database language; thus only depending on DBMS
- Optimization by DBMS possible
- Execution of the procedures completely under control of the DBMS
- Central control of the procedures allows a redundancy-free representation of relevant aspects of the application functionality
- Concepts and mechanisms of the right assignment of the DBMS can be extended on procedures
- Procedures can be used for integrity protection (e.g., as action part of triggers)
SQL/PSM: Variable Declaration

- Declare variables before consumption
- Specification of identifier and data type
- Optional with initial value

```sql
declare Price float;
declare Name varchar(50);
declare Set int default 0;
```
SQL/PSM: Flow Control

- Assignment

```sql
set var = 42;
```

- Conditional branching

```sql
if <Condition> then <Statement>
[ else <Statement> ] end if;
```
Loops

```sql
loop <Statement> end loop;
while <Condition> do
    <Statement> end while;
repeat <Statement>
    until <Condition> end repeat;
```
Loops with cursor

```sql
for LoopVariable as CursorName cursor for 
  CursorDeclaration 
do
  Statement
end for;
```
SQL/PSM: Flow Control

```sql
declare wlist varchar(500) default ' ';
declare pos integer default 0;

for w as WineCurs cursor for
    select Name from WINES where Vintage = 'Helena'
do
    if pos > 0 then
        set wlist = wlist || ', ' || w.Name;
    else
        set wlist = w.Name;
    end if;
    set pos = pos + 1;
end for;
```
**SQL/PSM: Exception Handling**

- Triggering of an exception (Condition)
  
  ```sql
  signal <ConditionName>;
  ```

- Declaration of exceptions
  
  ```sql
  declare missing_vineyard condition;
  declare invalid_region
  condition for sqlstate value '40123';
  ```
Exception handling

begin
    declare exit handler for ConditionName
    begin
        -- statements for exception handling
    end
    -- statements that can trigger exceptions
end
SQL/PSM: Functions

- Function definition

```sql
create function taste (rz int)
    returns varchar(20)
begin
    return case
       when rz <= 9 then 'Dry'
       when rz > 9 and rz <= 18 then 'Medium-Dry'
       when rz > 18 and rz <= 45 then 'Smooth'
       else 'Sweet'
    end
end
end
```
SQL/PSM: Functions /2

- Call inside of a query

```sql
select Name, Vineyard, taste(residualSugar)
from WINES
where Color = 'Red' and taste(residualSugar) = 'Dry'
```

- usage outside of queries

```sql
set wine_taste = taste(12);
```
**SQL/PSM: Procedures**

- **Procedure definition**

```sql
create procedure winelist (in prod varchar(30),
                          out wlist varchar(500))
begin
    declare pos integer default 0;

    for w as WineCurs cursor for
    select Name from WINES where Vintage = prod
    do
        -- see example of slide 10-38
        end for;
end; end;
```
**SQL/PSM: Procedures /2**

- **Usage via call-statement**

```sql
declare wlist varchar(500);
call winelist ('Helena', wlist);
```
SQL/PSM: Access Characteristics

- Properties of procedures that affect query execution and optimization
  - **deterministic**: Routine gives same results for same parameters
  - **no sql**: Routine contains no SQL-statements
  - **contains sql**: Routine contains SQL-statements (standard for SQL-routines)
  - **reads sql data**: Routine executes SQL-queries (select-statements)
  - **modifies sql data**: Routine that contains DML-statements (insert, update, delete)
Control Questions

- What concepts exist that can access SQL-databases?
- What are advantages and disadvantages of call-level-interfaces such as JDBC in comparison with embedding of SQL?
- How can application objects be mapped to SQL-tables? What tasks are therefore required?
Summary

- Connection between SQL and imperative languages
- Call-level-interfaces vs. embedded SQL
- Object relational mapping
- SQL/PSM: imperative extension of SQL → implementation of functions and procedures