Part X

Application Programming

Application Programming

1. Programming Language Connection

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2. JDBC

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7. Summary

Learning goals for today . . .

- Knowledge about concepts and interfaces for access on SQL-databases out of programming languages

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- Understanding of procedural interfaces on the example of JDBC
- Knowledge on embedded SQL and procedural SQL-extensions
- Basic knowledge on object-relational mapping

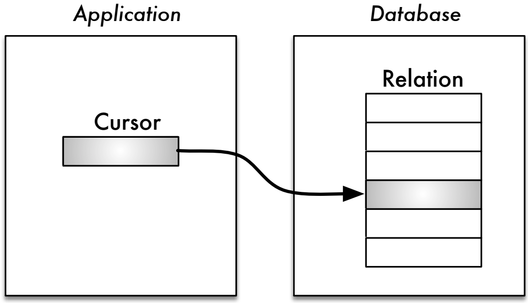
Programming Language Connection

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)

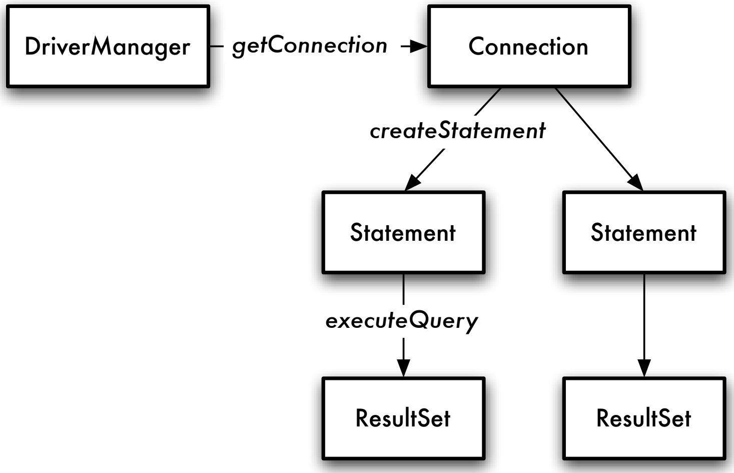


JDBC

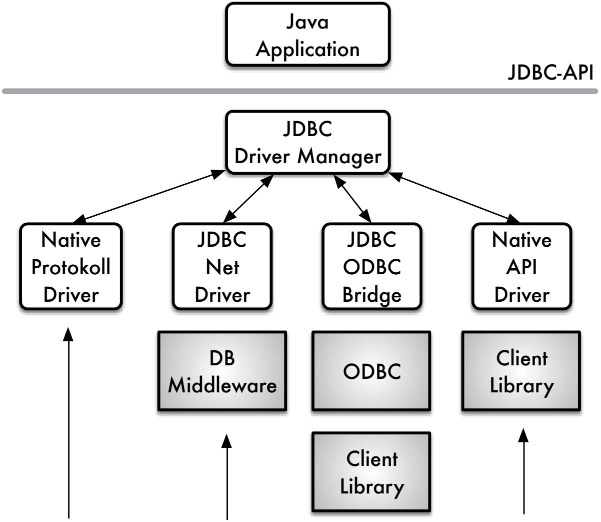
JDBC: Overview

- 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



JDBC: Driver Concept



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. Loding 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

```
Statement stmt = con.createStatement();
```

2. Execute statement

```
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)

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

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

   - with column index

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

   - with column name

   ```
   String wName = rSet.getString("Name");
   ```

JDBC: Exception Handling

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

```
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)

```
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()`

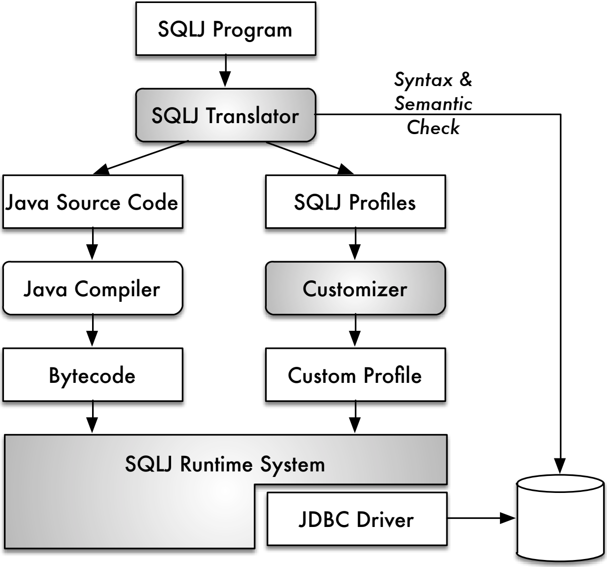
  Auto-Commit-Mode
  - Implicit commit after each statement
  - Transaction consists just out of one single statement
  - Switch mode with `setAutoCommit(boolean)`

SQLJ

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-Statements

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

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

- Example:

```
#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:

```
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

```
WineIter iter;
```

3. Execution of the statement

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

4. Navigation

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

Dynamic SQL

- SQL-Statements as during runtime constructed `Strings`

```
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;
```

LINQ

Language Integrated Query (LINQ)

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

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

- Own language constructs (since C# 3.0)

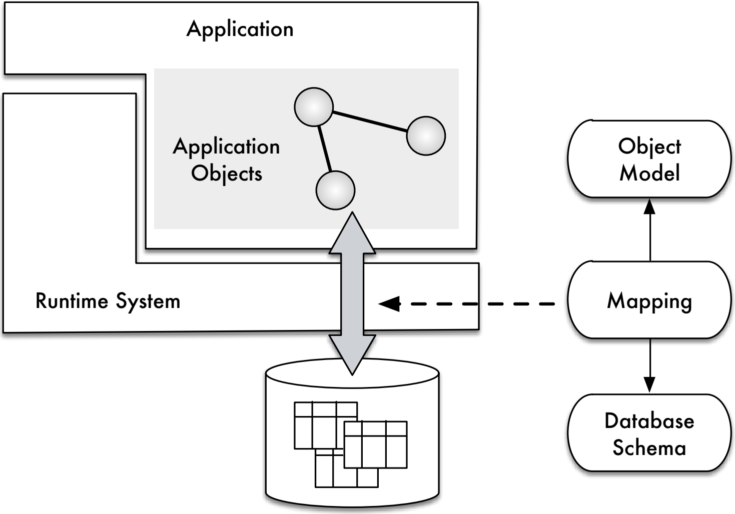
```
IEnumerable<op> res = from w in wines
   where w.Color = "Red"
   select new { w.Name };
```

Object-Relational Mapping

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. . .

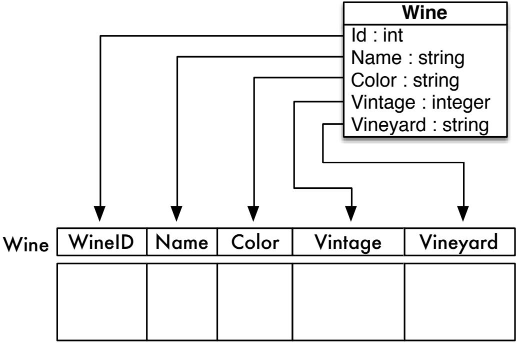
Object-Relational Mapping: Principle



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

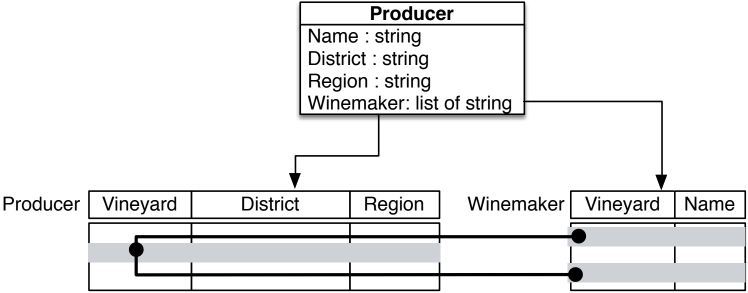
Classes and Tables: Example



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

Hibernate

- Java-framework for object-relational mapping
- Idea: Mapping of Java-objects to tuples of a relational database
- Principle: Java-class + mapping rule$\leadsto$ 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)

Hibernate: Example

```
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>
```

Hibernate: Object Creation

```
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();
}
```

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

```
Query query =
   session.createQuery("from Wine where Color = ’Red’");
Iterator iter = query.iterate();
while (iter.hasNext()) {
   Wine wine = (Wine) iter.next();
   ...
}
```

Procedural SQL-Extensions: SQL/PSM

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

```
declare Price float;
declare Name varchar(50);
declare Set int default 0;
```

SQL/PSM: Flow Control

- Assignment

```
set var = 42;
```

- Conditional branching

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

SQL/PSM: Flow Control/2

- Loops

```
loop <Statement> end loop;
while <Condition> do
   <Statement> end while;
repeat <Statement>
   until <Condition> end repeat;
```

SQL/PSM: Flow Control /3

- Loops with cursor

```
for LoopVariable as CursorName cursor for
   CursorDeclaration
do
   Statement
end for;
```

SQL/PSM: Flow Control

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

for w as WineCurs cursor for
   select Name from WINES where Vineyard = ’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)

```
signal <ConditionName>;
```

- Declaration of exceptions

```
declare missing_vineyard condition;
declare invalid_region
   condition for sqlstate value ’40123’;
```

SQL/PSM: Exception Handling/2

- 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

```
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
```

SQL/PSM: Functions /2

- Call inside of a query

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

- usage outside of queries

```
set wine_taste = taste(12);
```

SQL/PSM: Procedures

- Procedure definition

```
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 Vineyard = prod
   do
      -- see example of slide 10-44
   end for;
end; end;
```

SQL/PSM: Procedures /2

- Usage via **call**-statement

```
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**)

Summary

Control Questions

- What concepts exist that can access SQL-databases?

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- 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