Database-enabled web technology
DB Programming

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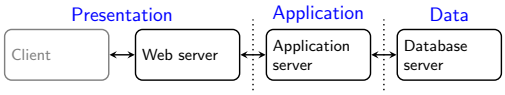
Previous weeks

- Introductions on
  - PHP
  - git
- A summary of DB design and SQL.
- An introduction to web programming,
  - Background: HTTP, CGI, networking, ...
  - Interacting with user in PHP: handling form input.

Today

- A short discussion of the N-tier software architecture.
- Stored procedures.
- Accessing databases from PHP using Pear DB library.
- Transactions.
- Triggers (a short introduction).

The multi-tier (or 3-tier) architecture



Presentation tier interacts with the user (e.g., ask the seat preference in an airline online check-in system).

Application tier implements the 'business logic' (e.g., check and reserve a seat, possibly using multiple queries and updates).

Data tier stores the data (e.g., retrieve and/or update the relevant data records).

In practice, division may not match the figure above. However separating presentation from application is always a good idea.

The N-tier architecture

- Sometimes application (business logic) tasks can be shifted towards the database (after all, the database design is based on the 'business logic').
- Often, the presentation and application tasks reside in a single application (e.g., your PHP code).
- Even if the system will not have another interface, separating presentation and the application tasks logically is a good idea.
- In typical web-based application development, the presentation tasks are shared between the client (web browser) and the server side programs (you PHP/HTML code).

Stored procedures

Stored procedures are general purpose programming procedures on a DBMS.

- Stored procedures support all typical general purpose programming constructs (variables, conditional execution, loops, ...)
- They are database objects, and stored in the database.

```
create procedure get_books()
begin
    select * from book;
end
```

```
call get_books;
```


Why (not) use stored procedures?

+ You put all your 'business logic' into one place.
+ They are (typically) faster than individual SQL queries.
+ They reduce the network usage.
+ They may provide convenient ways of access control, and may be useful to prevent some security problems.
– Syntax is incompatible between different DBMSes.
– Typically SPs are more difficult to debug.
– Puts a bigger burden on DBMS.

Note: The issue of stored procedures vs. inline SQL code may easily get into a heated discussion. Use when it makes sense.

Stored procedure implementations

- ANSI standard for stored procedure language is called SQL/PSM.
- Many vendors implemented their own languages, e.g., Oracle PL/SQL. Even if they do, the level standard compliance tends to be varied.
- Many DBMS systems support stored procedures written in more common languages as well: Java, C, perl, ..., even PHP (PostgreSQL).
- We will go through basics of SQL/PSM as implemented by MySQL (version 5+).

Stored procedures in MySQL

```
delimiter $$
create procedure get_books()
begin
    select * from book;
end $$
delimiter ;
```

- `call get_books();` calls the procedure.
- `show procedure status;` lists the stored procedures in the database.
- `show create procedure get_books();` lists the procedure code.
- `drop procedure get_books;` drops it.
- Change of `delimiter` is a trick to be able to use multiple statements with the default statement delimiter '`;`'.

SP variables

- You can use local variables in an stored procedure.
- You have to `declare` all local variables before the actual code starts. For examaple:

```
declare customer_id int;
```

- The keyword `set` is used for variable assignments.

```
set customer_id = 10;
```

- You can define or use so-called session variables which are accessible throughout the same database connection. Session variables start with a '`@`'.

```
set @update_status = 'success;
...
select @update_status;
```


SP arguments

- As expected, stored procedures can take arguments,

```
create procedure
    confirm_order(in cid int, out status varchar(10))
```

- The arguments are defined to be one of

in	arguments are read-only.
out	arguments are set inside the procedure, they do not have to be defined before.
inout	arguments are read, and modified by the stored procedure.

```
call confirm_order(10, @status);
select @status;
```


SP control structures

Stored procedures support basic control structures.

- if-then-else:

```
if x = 0 then
    set @status = 'x = 0';
elsif x <  10 then
    set @status = '0 < x < 10';
else
    set @status = 'x > 10';
end if;
```

- case

```
case x
    when 0 then set @status = 'x = 0';
    when 1 then set @status = 'x = 1';
    else        set @status = 'not 0 or 1';
end case;
```


SP loops

- while

```
while <condition> do
    ...
end while;
```

- repeat

```
repeat
...
until <condition>
end repeat;
```

- loop

```
<loop_label>: loop
    ...
    if <condition> then
        leave <loop_label>:
    end if;
end loop <loop_label>;
```


SP: cursors

- A cursor is a pointer to a row of a table, or a query result.
- Like local variables, you need to declare the cursor before using it:

```
declare cur cursor for select * from book;
```

- To start using it, you need to use the statement `open`.
- `fetch` reads the row, and moves the cursor to the next row,

```
fetch cur into isbn, author, title;
```

(assuming isbn, author and title are previously defined variables)

SP in MySQL an example

```
1  drop procedure if exists confirm_order;
2  delimiter $$
3  create procedure confirm_order(in cust_id int, out nitems int)
4  begin
5      declare isbn_tmp varchar(13) default null;
6      declare customer, quantity int;
7      declare more_rows bool default true;
8      declare cur cursor for
9          select cID, ISBN, qty from basket where cID = cust_id;
10     declare continue handler for not found set more_rows = false;
11     set nitems = 0;
12     open cur;
13     fetch cur into customer, isbn_tmp, quantity;
14     while more_rows do
15         set nitems = nitems + quantity;
16         insert into orders (cID, ISBN, qty, order_date, status)
17             values (customer, isbn_tmp, quantity, now(), 'N');
18         fetch cur into customer, isbn_tmp, quantity;
19     end while;
20 end $$
21 delimiter ;
```

```
call confirm_order(10, @nbooks);
select @nbooks;
```


Stored procedures: access control

- Stored procedures can be used to restrict direct access to database tables.
- The stored procedures are run with the database user who created them.
- The other users can execute a stored procedure even if they have no rights to access the tables used by the stored procedures.
- The rights are granted (and taken away) as in any other database object, using `grant` and `revoke` SQL statements.

Stored procedures: closing notes

- Similar to stored procedures, users can also define stored functions which act like standard SQL functions, such as `upper()` or `year()`.
- Stored procedures created, removed just like other database objects.
- SPs allow full procedural language constructs to be used with databases.
- SPs are just another tool available to software developer. Use them when it makes sense.

DB access from PHP using Pear DB

- There are multiple ways of connecting to databases, even multiple methods to connect to the same DBMS (For example, MySQL `mysql_` and `mysqli_` interfaces).
- We will follow a unified approach through Pear DB library.
- DB library allows a unified way to access different database management systems.
- A newer version, MDB2, with some improvements exists. We will stick to better-known and wide-spread DB library. You should consider MDB2 if it is available.

Pear DB: a first example

```
1  <?php
2      require_once('DB.php');
3      require_once('db-config.php');
4      $conn = DB::connect("mysql://$user:$pass@$host/$db");
5
6      $res = $conn->query('select * from book');
7
8      echo "<table border=\"1\">";
9      echo "<tr><th>ISBN</th><th>title</th></tr>";
10     while ($row = $res->fetchRow(DB_FETCHMODE_ASSOC)) {
11         echo "<tr><td>${row['ISBN']}</td>";
12         echo "<td>${row['title']}</td></tr>";
13     }
14     echo "</table>";
15     $conn->disconnect();
16 ?>
```


Pear DB: the DSN

phptype://user:pass@proto+host:port/db?opt=val&opt=val...

phptype	DB connection type (e.g., mysql, mysqli, odbc, sqlite, ...)
username	DB user name.
password	Password to connect to the DB
protocol	Connection protocol (e.g., tcp, unix, ...)
hostspec	Host name (or IP address)
port	Port number of the DB server
database	Name of the database
option=value	additional options for the DB connection

Pear DB: connecting to a database

- `DB:connect()` takes a `DSN` argument and an optional set of `options`, and returns a connection handler if successful.
- `DSN` can be specified either as a string, or an array of the form

```
$dsn = array('phptype' => 'mysql',
             'hostspec' => 'localhost',
             ... )
```

- A second optional argument can be used to specify options like debug level, various portability options etc.

```
$options = array(
        'debug' => 0,
        'portability' => DB_PORTABILITY_LOWERCASE,
         ... )
```

- You can also set the options later using `setOption()`.

Error Handling

- The database operations do not always get executed successfully. You should check for errors.
- `PEAR::isError()` returns true if given DB object is an error.
- `getMessage()` can be used to get the error message.
- The same functions are usable on other DB objects, for example query result.

```
$db = DB::connect($dsn, $options);
if (PEAR::isError($db)) {
    die($db->getMessage());
}
```


Pear DB: query

- Pear DB supports a number of query functions. `query()` is the simplest form.
- `query()` returns a 'result handler'.
- `fetchRow()` can be used to process each row in a result.
- `numCols()`, and `numRows()` give the number of columns and rows returned for a query. `affectedRows()` gives the number of rows affected by an `insert` or `update`.

```
$q = "insert into book (ISBN, title)
                values ($isbn, $title)";
$res = $db->query($q);
if (PEAR::isError($res)) {
    echo "insert failed: $res->getMessage()";
} else {
    echo "$res->affectedRows() lines changed";
}
```


Input validation

- Not validating user input introduces bugs, and possible security problems!
- Consider the statement:
  `insert into book values ('$isbn', '$title').`
  where we take user input 'The Hitchhiker's Guide to the Galaxy'.
- The SQL statement, after PHP replaces the values will be:

```
insert into book values ('0330258648',
      'The Hitchhiker's Guide to the Galaxy')
```

- This is an invalid statement. We want
  `'The Hitchhiker\'s Guide to the Galaxy'`

This is also a security risk (to which we will return next week).

Input validation in Pear DB

- Pear DB provides functions for escaping strings depending on DBMS in use.
- `escapeSimple()` escapes the string values.
- `escapeSmart()` also converts numeric/boolean values if necessary (e.g., convert `true` to `1` if required by the DBMS).
- `quoteIdentifier()` quotes identifiers, for example table or column names. For example, if you are using a reserved word, or space in a column name.
- You should always escape user input in your SQL statements.

```
$q = "insert into book values ('"
     . $db->escapeSimple($isbn) . "', '",
     . $db->escapeSimple($title) . "')";
```


Pear DB prepare/execute

- For SQL statements that are used multiple times with different values, an alternative to `query()` is using `prepare()` and `execute()` functions.
- `prepare()` takes a query string with missing values:
  `$qh = $db->prepare('insert into book values(?,?)');`
- `execute()` takes the handle returned by `prepare()` and an array of values, and replaces the `?` with the values in the array:
  `$db->execute($qh, array($isbn, $title));`
- `prepare()`/`execute()` automatically escapes the input.
- If you do not want that for some reason, you can use '`!`' instead of '`?`'.
- If you want to pass contents of a file as is (e.g., image data), use '`&`' in `prepare()` and give the filename in `execute()`.

Consider a customer ordering a book in our bookshop example.

1. Customer finds the book s/he is interested in stock.
2. Customer orders the book: we add it to orders and discount it from the stock.

How about:

Customer 1	Customer 2
Finds the book in stock	
	Finds the book in stock
Orders the book	
	Orders the book

We want the operations 'check availability' and 'update stock/order' to be atomic.

Database transactoins

The solution to these problem by the databases are transactions.

A. Transactions are atomic: either all parts are executed or none.
C. Transactions are required to preserve consistency when run alone.
I. The DBMS executes transactions such that they appear to run in isolation.
D. The effects of the transactions are required to be durable: after transaction is finished, the effect persists even in case of system failures.

These properties are often called the ACID properties.

Transactions in SQL

- The statement `start transaction` starts a transaction.
- The transaction ends with either `commit` or `rollback`.
- If some hardware/network failure caused transaction to be interrupted, the system rolls back by default.
- Normally every SQL DDL or DML statements is committed automatically.

```
set autocommit = 0;
start transaction;
select isbn into @isbn from book
    where title='The Left Hand of Darkness';
select qty from stock where isbn = @isbn;
-- rollback here if qty < 1;
update stock set qty= qty - 1 where isbn = @isbn;
commit;
```

MySQL Note: transactions are available in some storage engines.

Transaction isolation levels

Transaction isolation levels can be set using
`set transaction isolation level <level>` command.
Where `<level>` is one of:

SERIALIZABLE transactions execute in complete isolation. DBMS may run multiple transactions concurrently only if they do not interfere with the others.

REPEATABLE READ is similar to serializable, but inserts are allowed in the range the transaction may be reading. The same query should return the same values during the transaction (except so-called 'phantom reads').

READ COMMITTED The transaction does not read the uncommitted data, but two queries may return different results during the transaction.

READ UNCOMMITTED 'Dirty reads' are allowed. The data transaction reads may be rolled back.

Transactions in PHP / Pear DB

```
$db->autoCommit(false);
$db->query(...);
...
if (some condition) {
 $db->rollback()
} else {
 $db->commit();
}
```

Notes:

- The above sets isolation level to DBMS default.
- Other interfaces provide similar functions for using transactions.
- You cannot maintain transactions over different connections.

Triggers

- Triggers are a piece of conditional code that is run on DBMS when a certain event happens on a certain table.
- Triggers are similar to stored procedures, except they are not called by user code, but executed automatically.
- Triggers can be used for doing arbitrary check in case a certain event occurs.
- Triggers can be used to duplicate data.
- Triggers can be used simulate check constraints.
- Trigger syntax and support varies among different DBMSes.

Triggers in SQL

```
create trigger <trigger_name> <when> <action>
    on <table>
    for each row
begin
    /* trigger body */
end
```

- `<action>` is either `insert`, `update` or `delete`.
- `<when>` is either `before` or `after`
- If `for each line` is specified, the trigger is run for each line. Otherwise, it is run once.
- Trigger body is similar to stored procedures. Within the trigger body the new values is accessible through the variable `new` and previous value is accessible through the variable `old`.
- The trigger can be removed using `drop trigger <trigger_name>`.

Trigger example (MySQL)

```
1  drop trigger if exists test;
2  delimiter $$
3  create trigger test before insert on book
4      for each row
5  begin
6      declare msg varchar(255);
7      if new.year > year(now()) then
8          set msg = concat('Invalid year in book table: ',
9                           cast(new.year as char));
10         signal sqlstate '45000' set message_text = msg;
11     end if;
12 end $$
13 delimiter ;
```

Note: this works only in MySQL 5.5+

Summary

Stored Procedures or stored functions allow general-purpose procedural programming on the DBMS side.

PHP DB access There are many ways to access databases from PHP, but Pear DB (or it's successor MDB2) provide a uniform way to access multiple databases.

DB transactions ensure that a set of successive SQL statements are executed in an atomic manner without external influences.

Triggers are like stored procedures. However, they are executed when a specified event happens.

Further reading and next week

Further reading

- On stored procedures, transactions and triggers:
  - Any good DB book will have further info
  - MySQL manual for MySQL specifics.
  - Other online sources
- On PHP Pear DB:
  - Pear DB manual at `http://pear.php.net/manual/en/package.database.db.php`
  - Many other online sources and tutorials are available.

Next week: back to web server programming . . .

- Session management.
- Security (some).