Advances in Programming Languages

APL9: Using SQL from Java

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Topic: Domain-Specific vs. General-Purpose Languages

This is the first of three lectures on integrating domain-specific languages with general-purpose programming languages. In particular, SQL for database queries.

- Using SQL from Java
- Bridging Query and Programming Languages
- Heterogeneous Metaprogramming

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Preview

- SQL as a domain-specific language
- Injection of HTML, Javascript and SQL
- Frameworks for generating SQL code

SQL

SQL is a programming language, with a declarative part:

```
select isbn, title , price
from books
where price > 100.00
order by title
```

and an imperative part:

```
update books set price = 10.00 where price < 10.00
drop table sales
```

as well as numerous extensions, such as procedures and transactions.

SQL is a *domain-specific language*, rather than a general-purpose programming language.

Who Writes SQL?

SQL is one of the world's most widely used programming languages, but programs in SQL come from many sources. For example:

- Hand-written by a programmer
- Generated by some interactive visual tool
- Generated by an application to fetch an answer for a user
- Generated by one program to request information from another

Most SQL is written by programs, not directly by programmers.

The same is true of HTML, another domain-specific language.

Also XML, Postscript,...

SkyServer Demonstration

http://cas.sdss.org/dr7/en/
http://cas.sdss.org/dr7/en/sdss/telescope/telescope.asp
http://cas.sdss.org/dr7/en/tools/search/
http://cas.sdss.org/dr7/en/help/docs/realquery.asp

Sample Queries

```
-- Find some stars near a certain spot in the sky
SELECT top 10
 p.objId,
 p.run, p.rerun, p.camcol, p.field, p.obj,
 p.type, p.ra, p.dec
FROM PhotoTag p, fGetNearbyObjEq(40.433,0.449,3) n
WHERE n.objID=p.objID and p.type=3
```

Sample Queries

```
-- Make these a table with click-through links
SELECT TOP 10
 '<a target="INFO" href="http://cas.sdss.org/dr5/en/tools/chart/'+
 'navi.asp?ra=' + cast(p.ra as varchar(30)) + '&dec=' +
 cast(p.dec as varchar(30)) + '">' +
 cast(p.objId as varchar(30)) + '</a>' as objID,
 p.run, p.rerun, p.camcol, p.field, p.obj, p.type, p.ra, p.dec
FROM PhotoTag p, fGetNearbyObjEq(40.433,0.449,3) n
WHERE n.objID=p.objID and p.type=3
```

Sample Queries

```
-- Count those stars
select count(*) from star p

-- Planetary query
select 'Pluto&#39; FROM Planets<br><span style="color:white;"><i'
+'mg src="http://ian.stark.net/pluto.jpg">'
```

HTML Injection

The Pluto page is an example of *HTML injection*.

The SkyServer website appears to be serving an incorrect image.

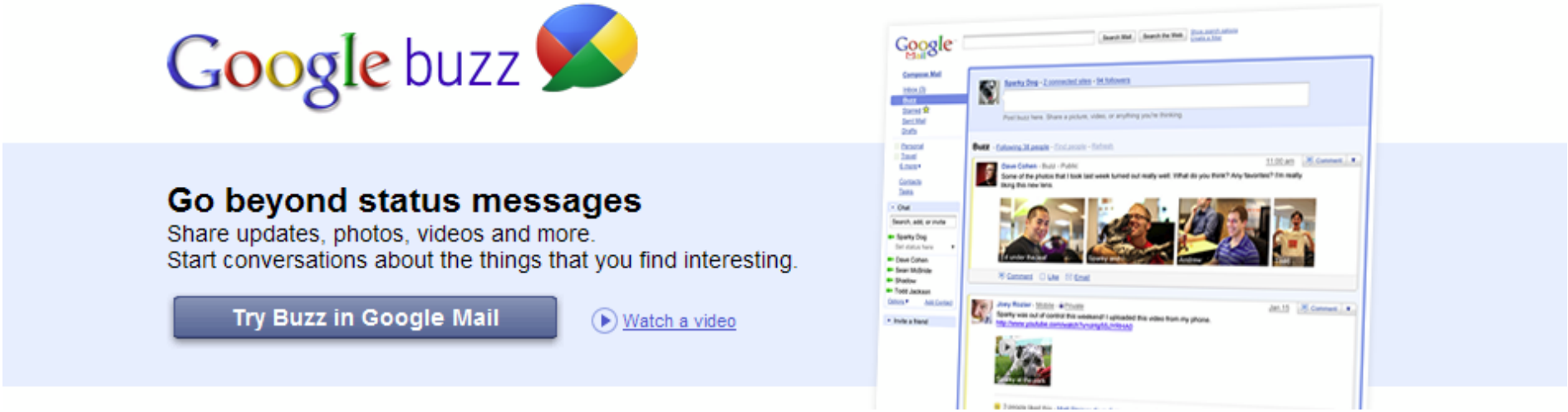
This is used in phishing attacks, and other fraud, where a web server can be cajoled into presenting novel material as its own.

For example, a suitably crafted URL may cause a bank's web server to present a page that requests account details and then sends them to an attacker's own site.

Similarly, a comment on a blog may contain code that when read in a web browser causes it to take some unexpected action.

This opportunity to inject HTML or Javascript can arise whenever a web site takes user input and uses that to generate pages. This is known loosely as *cross-site scripting* or *XSS*.

Google Buzz XSS Hack



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2010-02-16 Cross-site scripting injection attack publicly demonstrated

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http://www.theregister.co.uk/2010/02/16/google_buzz_security_bug/
http://ha.ckers.org/blog/20100216/google-buzz-security-flaw/

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2010-09-21 10am UK time

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SQL Injection

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```
select id, email, password
from users
where email = 'x' or 1=1 --'
```

which will return a complete list of users.

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where email = 'bob@example.com'
```

we might supply the perverse email address "x'; update users set email='bob@example.com' where email='admin@server' --" to get

```
select id, email, password
from users
where email = 'x'; update users set email = 'bob@example.com'
                                  where email = 'admin@server' --'
```

which will redirect all the administrator's email to Bob.

Dubious Licence Plate

Working with Query Languages

How then do we write programs to generate and manipulate queries?

A common approach is to use some standard framework or application programming interface (API). ODBC, the *Open Database Connectivity* specification, is a well-known framework for managed database access:

- At the back, an ODBC *driver* contains code for a specific database management system (DB2, Oracle, SQL Server, . . .).
- At the front, the programmer connects to a fixed procedural API
- In between, ODBC libraries translate between API and driver.

Particular programming languages and environments may place further layers on top of ODBC, or use similar mechanisms. For example: *JDBC* for Java and *ADO.NET* for the Microsoft .NET framework.

JDBC: Java Database Connectivity

JDBC is a Java library, in the java.sql.* and javax.sql.* packages, which provides access to read, write and modify tabular data.

Relational databases, with access via SQL, is the most common application; but JDBC can also operate on other data sources.

The connection to the database itself may be via a driver that bridges through ODBC, speaks a proprietary database protocol, or connects to some further networking component or application.

JDBC Bootup

```
import java.sql.*;    // Obtain the relevant classes

// Install a suitable driver
Class.forName("org.apache.derby.jdbc.EmbeddedDriver");

// Identify the database
String url = "jdbc:derby:Users";

// Prepare login information
String user = "bob"
String password = "secret"

// Open connection to database
Connection con = DriverManager.getConnection(url, user, password);
```

Sample JDBC

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

ResultSet rs = stmt.executeQuery("SELECT name, id, score FROM Users");

while (rs.next()) // Loop through each row returned by the query
{
  String n  = rs.getString("name");
  int i     = rs.getInt("id");
  float s   = rs.getFloat("score");
  System.out.println(n+i+s);
}
```

JDBC String Fiddling

```
float findScoreForUser(Connection con, String name) {

  Statement stmt = con.createStatement();

  String query =
    "SELECT id, score FROM Users WHERE name=" + name;

  ResultSet rs = stmt.executeQuery(query);

  float s = rs.getFloat("score");

  return s;
}
```

JDBC Prepared Strings

```
String findUsersInRange(Connection con, float low, float high) {

  String prequery =
    "SELECT id, name FROM Users WHERE ? < score AND score < ?";

  PreparedStatement stmt = con.prepareStatement(prequery);

  stmt.setFloat(1,low);    // Fill in the two
  stmt.setFloat(2,high);   // missing values

  rs = stmt.executeQuery(query); // Now run the completed query

  String answer = "";      // Start building our answer

  while (rs.next())        // Cycle through the query responses
  { answer = answer + rs.getInt("id") + ":" + rs.getString("name") + "\n"; }
  return answer;
}
```

That seems like hard work

These examples use the full generality of the ODBC framework:

- Arbitrary drivers . . .
- . . . possibly to proprietary data sources . . .
- . . . across the network . . .
- . . . with authentication and authorization . . .
- . . . ensuring consistency under multiple transactions.

Appropriate wrappers and frameworks can make things more straightforward in simpler situations.

However, the basic scheme of building queries as strings is ubiquitous.

Can I use something else instead?

There are several other approaches to database access:

- Frameworks like Java Hibernate preserve objects over time.
- Object Relational Mapping (ORM) translates between programming-language object structures and persistent database storage.
- An Object-Oriented Database Management System (OODBMS) works with objects instead of relations, tables and rows.
- Other systems like CouchDB, BigTable, and Cassandra store a variety of structured data for shared access.

These are sometimes known collectively as *NoSQL* architectures.

In general, these offer a different mix of features and performance to conventional relational database management systems (RDBMS).

So why would I want to use SQL anyway?

Sometimes, SQL is inevitable for non-technical reasons:

- External databases
- Legacy databases
- Existing code

Often, though, it's because of genuine advantages of relational databases:

- Complex queries joining multiple large datasets
- Efficient query optimization and execution
- Transactional consistency

SQL or not, though, any scheme which involves handing over complex queries to a specialized engine will encounter the issue of using one language from another.

Summary

SQL is a *domain-specific language* for programming queries over relational databases. Queries may be complex, with declarative and imperative components, and are often constructed by other programs rather than by hand.

Websites are vulnerable to *cross-site scripting* or *XSS* whenever they take user input and use it to generate pages. The analogous problem of *SQL injection* arises where free text input is used to construct structured queries.

Programs generating SQL code use frameworks like JDBC or ADO.NET; and these do construct queries using unstructured string manipulation. Using *prepared strings* begins to add back some structure.

SQL queries are programs in a structured high-level language, but we treat them as unstructured text.

Homework

Thursday's lecture will be about the LINQ framework on C#.

- Find an online tutorial about C#
- Read it.
- Post the URL, and your comments on the tutorial, to the blog

Background reading

To find out more about database access in Java and C#, start with these tutorials:

- Sun's JDBC tutorial
  http://java.sun.com/docs/books/tutorial/jdbc/index.html
- The *C# Station* ADO.NET tutorial
  http://www.csharp-station.com/Tutorials/AdoDotNet/Lesson01.aspx