Advances in Programming Languages

APL9: Domain-Specific Languages

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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
- LINQ: .NET Language Integrated Query
- Language integration in F#

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 as a way to communicate with another

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

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

SkyServer Demonstration

http://cas.sdss.org/dr6/en/
http://cas.sdss.org/dr6/en/sdss/telescope/telescope.asp
http://cas.sdss.org/dr6/en/tools/search/

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 own web server to present a page that requests account details and then sends them to an attacker's own site.

The opportunity to inject HTML and even Javascript can arise whenever a web site takes user input and uses that to generate pages. It is even possible to use web search engines to locate vulnerable sites.

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```
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from users
where email = 'x' or 1=1 −−'
```

which will return a complete list of users.

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

which will send the administrator's email to Bob.

Example: Security Advisory

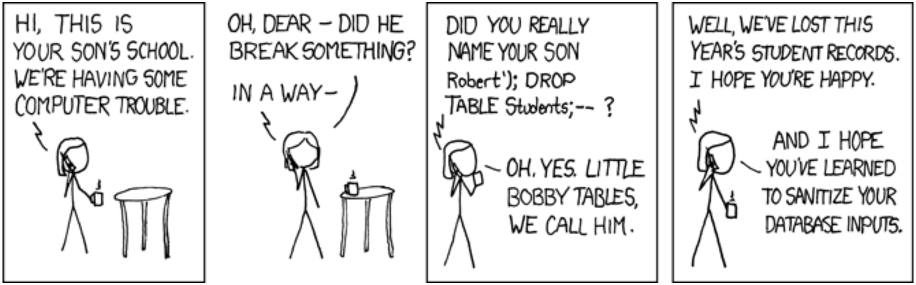
Secunia Advisory	SA28883
Release Date	2008-02-12
Critical	Moderately critical
Impact	Manipulation of data, exposure of sensitive information
Where	From remote
Solution Status	Unpatched
Software	Rapid Recipe 1.x (component for Joomla!)

Description

Input passed to the category_id parameter . . . and user_id. . . in the Joomla! installation's index.php script . . . is not properly sanitised before being used in SQL queries. This can be exploited to manipulate SQL queries by injecting arbitrary SQL code.
Successful exploitation allows e.g. retrieving administrator usernames and password hashes, . . .

`http://secunia.com/advisories/28883/`

XKCD on SQL Injection


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

`http://xkcd.com/327` *or* `http://bobbytables.com`

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, core ODBC libraries translate between the API and the driver.

Particular programming languages and environments may place further layers on top of ODBC, or have alternative 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

```
float 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;
}
```

Homework

Have a look at these two tutorials on database access in Java and C#.

- 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`

You don't need to work through every detail, but the key is to see how these languages provide control of SQL.

Summary

- SQL is a domain-specific programming language.
- This makes it excellent for abstraction and expressiveness in its domain.
- Treating SQL programs as strings ignores all of this.
- Lots of programs write other SQL programs, by concatenation.
- That can create problems, most notoriously security holes.
- Standard frameworks may plug some holes, but that's about it.

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